Space India 2.0

Commerce, Policy, Security and Governance Perspectives

Rajeswari Pillai Rajagopalan
Narayan Prasad (Eds.)

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FOREWORD

In the modern history of humankind's forays into the field of exploration and uses of outer space, India's space endeavours have occupied a special place due to the richness and the quality of their contributions. With few rivals in sheer mystery, space continues to capture the imagination of our younger generation, presenting an inexhaustible potential for exploration, discovery and diverse uses that modern society demands. What has been established with certainty through the past decades of space endeavours, of the world in general and of India in particular, is its multidimensional role and relevance—from international diplomacy for peace to applications that touch the daily lives of large populations across the world.

As is true with any modern tool, space technology can serve as an instrument in enhancing human welfare, forewarning against disasters, and expanding the horizons of human knowledge. It can also be used to mitigate the devastating consequences of conflicts, wars and deprivation that threaten human survival.

Space governance has thus become a major concern for the international community in recent decades, amidst new threats such as the growth and evolution of terrorism. The number of stakeholders in outer space has also increased considerably, and a key role is now being played by private entities in an environment which is becoming congested and heavily contested in some parts. Today, more nations are actively participating in space activities by building and operating space systems. Informed debates on issues relevant to space governance assume high priority both at national and international levels.

By its fundamental nature, space inspires a global perspective, and reveals a viewpoint that extends to a universal dimension. Indeed, space endeavours of diverse nations have global implications. The ancient Indian thought and traditions reflect such a broader and universal outlook, as they explored the principles of human development and mysteries of origins, existence and destiny of the universe by dwelling deeper into human consciousness. India's current progress is also extending to the outer world, addressing the quality of life of a billion-plus population. India stands at a cusp to establish harmony of inner and outer lives; this may yet prove to be its major contribution to global development.

A hallmark of India's space programme has been international cooperation. Some of the finest expressions of this paradigm can be seen from the beginnings of the programme, such as the dedication of Thumba Equatorial Rocket Launching Station to the United Nations and the assistance to an international community of scientists in the study of upper-atmospheric phenomena. Transcending ideological barriers, India's cooperation has also flowered into different hues, including joint space missions, data sharing, capacity building in space applications, and policy coordination. Of great relevance is how this can be evolved in the future as a vibrant instrument of new advances in space activities, including human space flight, space commerce, actions against climate change, and international peace and security.

Over the decades, challenges of space activities have grown manifold. This is a time when the world is seeing the emergence of NewSpace as a revolution in space industry, with private industries leading the way in applying the foundation elements established by space agencies as commercial value propositions. Disruptive business models are being built and there are distinct signs of growing potential for the overall size of the space economy to grow multi-fold. Policy elements relevant to space commerce and the private sector's role in the future is extremely relevant for the growth of India's space endeavours.

Security applications of space, on one hand, and ensuring secure environment using space, on the other, are no longer a matter of choice for spacefaring states like India. Several initiatives at the international level need to be coordinated and harmonised with India's national interests, as the country emerges as an economic power and seeks to strengthen its relations with other states in an interdependent world. Examining the various aspects of this dimension is extremely important, both to develop holistic perspectives and to generate required capacities in India.

The Observer Research Foundation's (ORF) initiative is commendable for creating a platform for discourse. As it involves both national and international experts on these extremely relevant issues, this volume of well-researched articles provides highly relevant analyses in the context of future developments in the field of space.

Indeed, such interaction at the international level is not new to the Indian space programme. From the outset, with Dr. Vikram Sarabhai, the leadership of the Indian Space Research Organisation (ISRO) has pursued interaction with the finest minds in science, government, and industry. Such fruitful interactions have generated valuable contributions not only for India but also for the global community in terms of a vast array of societal applications of space technology, cost-effective approaches, and enriching collaborative endeavours such as Chandrayaan.

This book gives insights by providing a glimpse into the past, while it connects with the present and delivers perspectives on the future dimensions of India's space programme. The chapters cover a broad range– Commercial & NewSpace, Space Policy, Space Security, International Cooperation, and Space Sustainability & Global Governance—and they deliver educated suggestions and opinions to policymakers of the country to review their strategies on these issues. Understanding expert opinions in these areas shall bestow the emerging managers of the space programme with holistic insights. This work is a unique collection of thoughts and analyses on matters relevant to space policy and governance, a good account of accomplishments, and thought-provoking puzzles on future possibilities. The authors are national and international experts in different disciplines, both veteran and young scholars, and thus will be an invaluable resource for policymakers, academic researchers, and the public at large. This work can also be a concrete step for continuing discourse on varied subjects or issues of importance, which demand an interactive and evolutionary approach to progress on policy. While there could be some differences in the positions taken by writers with reference to the views of some stakeholders in policymaking, the academic yet non-formal nature of the content in this book will hopefully create enough spaces for reflecting on a cohesive and harmonious framework of policy and its continued dynamism in a field where India can make significant contributions to national and global developments.

K Kasturirangan

Raman Research Institute
3 January 2017

INTRODUCTION

Rajeswari Pillai Rajagopalan and Narayan Prasad

India's space programme is more than five decades old and the country today has come to be acknowledged as an established space power. India began its space journey in 1963 with the launch of a sounding rocket (Nike-Apache) supplied by NASA, a sodium vapour payload by France, with a range clearance provided by a Russian helicopter. From these humble beginnings, India in the 1980s would then develop its renowned Indian Remote Sensing (IRS) and Indian National Satellite System (INSAT) satellites series. The INSAT communication satellites have been operating in the entire Asia Pacific region, offering services including television broadcasting, weather forecasting, disaster warning, and search and rescue missions. The IRS satellites comprise the largest State-operated civilian constellation in the world and use state-of-the-art cameras for images of the Earth in multiple resolutions, bands, and swaths. They provide services nationally and to a large number of customers across the globe. Indeed, even as interplanetary missions were not part of the original vision and mandate of the ISRO, they have since matured to become an important area of focus of the programme. Given that India was faced with multiple social and developmental challenges, New Delhi, during the development stages of both satellites and launch vehicle technologies, had maintained focus on societal applications. However, with the changing dynamics of regional security, the Indian political and scientific leadership set their mind on the importance of space technology in the context of development but also national security.

Even as India has journeyed for close to sixty years in this domain, there are several requirements that need to be addressed for India to maximise its gains and the potential of its strong capacity to build satellites and launch vehicles. We believe there are several strategies, both short-term and long-term, that may be employed by policymakers to expand the utilisation of space assets and increasing the overall size of the country's space economy.

This book addresses many of these prevalent policy issues and suggests measures to address them from the varied perspectives of space commerce, space policy, space security, global governance, and international cooperation. It contains 26 chapters that deal with the different aspects of India's space programme, grouped in five sections, and seek to provide insights to policymakers in the country.

The first section is on space commerce, and it opens with two chapters authored by Narayan Prasad outlining first, the need for expansion of India's space industry to achieve a global footprint and second, an overview of India's space economy and the role of traditional and NewSpace industry in India. A chapter by Prof. KR Sridhara Murthi follows, arguing for the need to undertake policy regulations for greater commercialisation of India's space programme and tap into the burgeoning emerging space markets. Neha Satak, Madhukara Putty and Prasad Bhat, in their chapter explore the possibility of using satellites for digitally connecting more than a billion people in bridging the digital divide that has both social and economic implications. Arup Dasgupta then describes in his chapter the potential benefits of using geospatial data for both government initiatives and businesses, which have so far been fairly limited. He makes a strong case for public-private partnerships in order to meet the growing demand, which has been previously met by the government alone. Narayan Prasad, in chapter six, argues for the holistic development of India's space ecosystem, with the establishment of a space start-up incubator as a preliminary step which can be expanded to aid NewSpace companies in contributing to India's space economy growth story. Chapter seven by Rohan Ganapathy, Arun Radhakrishnan and Yashas Karanam, on electric propulsion and launch vehicles, explores the possibilities of adapting electric propulsion for in-space navigation which would also create the spin-off benefit of lowering the cost of launches.

Section two, in five chapters, details various aspects of India's space policy. Chapter eight by Kumar Abhijeet makes the case for legislative requirements for elevating the private sector as a major actor in India's space story. Ashok GV and Riddhi D'Souza review India's SATCOM policy and norms with a view to both increasing private sector participation and creating a public-private partnership that will enhance India's space programme. Ranjana Kaul examines India's geospatial policy and articulates the need for the government to fill the gaps in a balanced and nuanced manner. Chapter eleven, authored by Malay Adhikari, analyses the case of the legal backbone establishment as the Polar Satellite Launch Vehicle (PSLV) private sector-ISRO partnership matures. He argues that given PSLV's track record as a platform, this joint venture could possibly be the first step towards privatisation. Vidya Sagar Reddy's chapter on space as an instrument of foreign policy outlines several historical instances of India's international partnerships with the US, Russia and France. Reddy advocates for India to use space as a tool in furthering its foreign policy objectives.

Section three comprises three chapters focusing on the different aspects of India's space security needs and requirements, both in the institutional and policy realm. Ajey Lele in chapter thirteen details India's space journey, from an apprehensive beginner to ardent operator, especially in the security domain. In chapter fourteen, Moriba Jah discusses the significance of space situational awareness in the context of the growing number of natural hazards and man-made challenges confronting outer space environment. Rajeswari Pillai Rajagopalan in chapter fifteen makes the case for an Indian military space policy. Even as India remains wedded to the idea of peaceful uses of outer space, developments in the space domain both within the region and globally have driven India to confront the new realities and adapt in terms of both policy and institutions.

Section four on international cooperation focuses on India's major space partners. In chapter 16, Prof. Jacques Blamont examines India's almost six-decade-old space cooperation with France and identifies future areas of partnership between the two nations. Victoria Samson in chapter seventeen describes India's space cooperation with the US dating back to the early 1960s when NASA supplied India with the first sounding rocket Nike-Apache. She details the journey that the two civil space organisations have gone through and highlights major recent initiatives, including the NISAR satellite. Chapter eighteen, authored by Vladimir Korovkin, documents the Russian-Indian space cooperation and its future. He suggests cooperation in the areas of deep space exploration, space tourism, as well as jointly building infrastructure for operation of small satellites. Deganit

Paikowsky and Daniel Barok in chapter nineteen examine India and Israel's collaboration, barely three decades old but strong. In chapter twenty, Kazuto Suzuki details India-Japan space cooperation, which has so far been rather limited in scope but carries significant potential to grow, given the broader convergence in their political and strategic goals. Jason Held looks at India-Australian space relationship which, like the India-Japan one, is still at its exploratory stage. He examines the future potential in the context of the growing India-Australia strategic partnership.

Section five contains five chapters detailing India's approach to space sustainability and collective governance of outer space. MYS Prasad provides an overview of the major Indian efforts at tracking space debris, including ISRO's Space Debris Tracking Systems. Daniel Porras in his chapter examines the relatively new area of space mining operations in the context of both the US and global legal regimes. The chapter then goes on to analyse the regulations that could be put in place to fulfil the goals espoused by the Space Competitiveness Act. Charles Stotler studies Article VI in the context of space security and sustainability. The chapter deals with the complexities of new actors in outer space including non-state players and the implications of these for the sustainability of outer space. Yasushi Horikawa details the global governance mechanisms such as the UN Committee on the Peaceful Uses of Outer Space (COPUOS) in the context of both space sustainability and the larger strategic cooperation between India and Japan. The last chapter on India and global governance by Rajeswari Pillai Rajagopalan articulates the need for India to take on a more pro-active approach both within the UN COPUOS as well as in fora such as the Conference on Disarmament (CD), though the CD has remained stagnant for more than two decades. Given India's strong sentiment that the CD is the key body for all multilateral negotiations on international security issues, New Delhi should take the lead in injecting political imagination to revive the CD as an effective platform in developing an effective outer space regime.

We hope this volume adds to the slowly evolving debate on India's space policy and ambitions as it highlights some of the key challenges and opportunities that are facing India in this realm.

I

SPACE COMMERCE

1

Space 2.0 India: Leapfrogging Indian Space Commerce

Narayan Prasad

Space is expensive, space is unrelenting and space is extremely challenging to have a system perform efficiently. A sector where engineering and management of missions are extremely complex due to the unrelenting environment and a 'fly right or forget' evolution of missions. Today, this conventional wisdom is being challenged with the walls for investments and the approach to engineering and management of space missions being redefined to embrace risk and mobilise disruptive and derivative technologies in a $300-billion industry.

Space 1.0

Space as a high-technology sector kicked off with government-backed investments with official institutions in the military and civilian realm developing core competence over decades of engineering. Space as an industrial complex is one that has grown with this competence being transferred to or encouraged to develop novel technologies in the industry, which enables the private sector to then diversify its offerings as well as expand its market reach. This process of initial capacity-building in the industry can be deemed as Space 1.0, where the objective is to enable the trickling down of technology, processes, patents, which have been developed by taxpayer-funded research and development to an entrepreneurial foundation which can commercialise and spin-off.

Space 1.0 is a process of handholding the industry to reach a tipping point where there is a credible, reliable technology delivery capability established, while the government may further support this capacity-building by buybacks of products and services for its own missions. Space 1.0 is a phenomenon that has been going on in India over the past four decades where the technology competence developed by the Indian Space Research Organisation (ISRO) is being transferred to Small and Medium-Scale Enterprises (SMEs), with encouragement from ISRO to buy back this competence converting the SME as a vendor in its missions.

Today, the Indian space programme stands with a strong vendor base of 500 suppliers for its space transportation, spacecraft development and ground operations functions. With the increased demand for space-based services in the country, ISRO is now envisioning greater involvement of the Indian industry in the production of satellites and launch vehicles. To this end, the formation of a consortium of industries with ISRO for the development of the Polar Satellite Launch Vehicle (PSLV) has been initiated, while ISRO has also invited Indian industry to express interest in systems Assembly, Integration and Testing (AIT) of standard ISRO satellites.

Space 1.5

The encouragement that the industry is finding as a move further in the steps of capacity building can be deemed as Space 1.5. This exercise in technology/knowledge transfer provides the industry with the complete know-how in end-to-end development of space and launch systems. Although the entire technology will be that of ISRO, such a move will provide a foundation to build core competence in the industry which, at the same time, can be potentially used to diversify the offering from a user base perspective or a technology perspective. From a user base perspective for such systems, the immediate requirements from a medium-term perspective (five to seven years) may well arrive from defence users who have tremendously increased their utilisation of space-based capabilities for security purposes. Moreover, this will provide the Indian industry with the ability to design and develop advanced new-generation systems, which in the longer term (10 to 15 years) may well match or feature themselves as state-of-the-art systems in the world.

The emergence of Space 1.5 models in space transportation as well as satellite manufacturing in the upstream hardware realisation plans of

ISRO is essentially a response to the increased demand for space-based services in the country both on the government as well as the private industry side. Recently, 170 projects spanning over 60 central ministries/departments have been identified in the areas of natural resources management, energy & infrastructure, disaster & early warning, communication & navigation, e-governance & geospatial governance, societal services, and support to flagship programmes for potential utilisation of space technology-based tools. This largely ties with the conviction of the government to use space-based technology to create more transparent, efficient and scalable approaches to delivering services in government-to-customer (G2C), government-to-business (G2B), and government-to-government (G2G) interactions.

India has also experienced a stark rise in commercial services such as Direct-To-Home (DTH) with an annual percentage growth of 25.73 percent during the period from December 2010 to December 2015, which indicates a strong demand from the commercial space services segment to which ISRO is acting as a provider. Therefore, the rising demand from both the government as well as the private sector is gathering tremendous momentum and has led to the comprehensive roadmap ahead with 71 satellites to be built by 2021 and a target to increase the launch frequency of rockets to 12-18 annually. Therefore, Space 1.5 is mainly a volume-driven phenomenon and different industry-government engagement models may emerge in each vertical of both upstream and downstream services with the primary goal of achieving this volume within the timeframe.

It is important to note that this nature of Space 1.5 will drive the use of much of the existing infrastructure that is already created by the government for further capacity building in the industry. The nature of capacity building will be more of a handover of activities to the private sector under the supervision of the space agency to ensure quality and reliability, which on one end will add a dimension of transfer of know-how to the industry, while the industry need not make substantial capital investments in setting up similar infrastructure for production. Space 1.5 in India is likely to take a more consortium approach of a number of vendors/SMEs since there is clearly no large space sector players in the private sector of the country which can take on the risk of such a project.

This void, in some sense, may be also due to the fact that the country only gained independence in an era where aerospace technology in the international scene had already modernised against the backdrop of world wars.

Post-independence, the sanctions against the country hindered growth and maturity of the foundation technology and know-how while the space sector enjoyed much more international collaboration and therefore leapfrogging in the development of the foundation technology. From an industry evolution perspective, the likes of Boeing and Lockheed Martin in the US could take on the functions of Space 1.5 in a more rigorous manner with larger functions due to the sheer size of their organisations with a sound heritage and financials which was built up over decades of expertise in the aerospace sector even before satellites or rockets were around.

Therefore, on the space transportation front, India might see an evolution of a Public-Private Partnership (PPP) model as a part of Space 1.5 that is quite unique in the international market and does not align with the likes of other models such as Ariane Space. The important difference in this PPP model against the ones already in the market is that the PPP model India is evolving is one that may be completely dedicated to achieving volumes for meeting local and international demand for reliable launch vehicles such as Polar Satellite Launch Vehicle (PSLV) and, eventually, Geostationary Satellite Launch Vehicle (GSLV). The function of development of new launch vehicles and making them operational will still lie entirely in the government realm. This is one key difference in the PPP model that is likely to evolve in India against that of Ariane Space or United Launch Alliance, where the PPP models have also expanded to develop new launch systems in addition to achieving volumes and serving national and international markets under the PPP umbrella.

Similarly, on the spacecraft development front, ISRO is fostering a capacity-building programme with the industry by engaging a vendor to be involved in the realisation of two satellites which shall provide the industry with an end-to-end spacecraft AIT know-how while operating under the supervision of ISRO Satellite Centre. This again can be ticked off as a Space 1.5 step for the industry to gain experience in AIT functions which have been the function of the space agency for the past five decades. This will enable ISRO to use the private sector to meet the burgeoning demand which dictates about 10-12 satellites be flown every year for at least the next five years instead of substantially increasing its manpower base and infrastructure. Therefore, this step of capacity building on the spacecraft side is an important step of transferring the technology, project and quality management know-how to the industry for an end-to-end spacecraft. It is likely that this step will lead to the industry developing the spacecraft bus based on the type of mission while ISRO shall focus on the development of new technologies for the spacecraft/mission payload itself and integrate with the bus delivered by the industry. This is a model that is quite different from developed spacefaring nations such as the US, Canada, and EU, where end-to-end contracts are given to a single vendor, which again has been possible via a more historically evolved government-industry from the headstart in the 1900s.

Much of the liberalisation of the space activities in major spacefaring countries has been based on providing encouragement to the private industry for capturing the rising demand for services on the downstream. The entry of the private sector has driven the year-on-year growth of the space sector based on services where today almost two-thirds of the $300 billion that runs in the space industry is captured by services. Therefore, active promotion of involvement of the industry in downstream activities is a crucial step in increasing the overall size of the space economy. For example, tele-education via satellites for the first time via the Satellite Instructional Television Experiment (SITE) by ISRO is one of the biggest successes in vetting a use case for satellite-based communications services. With the technology maturing (on both the consumer electronics segment as well as the satellite segment) from the time of SITE, the applications of satellite-based television have not only served in societal development but have also largely evolved as a commercial television services platform for service providers to broadcast news, advertisement, and entertainment. This demand, driven by the active engagement of the private sector in the downstream, has therefore provided the impetus for increased demand in terms of transponders.

While DTH is just one example, India has a large potential to evolve such services via the private sector which can already be witnessed in the year-on-year growth of services such as DTH in other downstream activities, given the fact that India operates one of the largest fleets of Earth Observation satellites capable of both in optical and radar as well as has its own regional navigation system. Therefore, the premise of Space 2.0 in India is to harmonise the relationship between the public and private sectors to evolve a space economy that not only drives societal development effectively but will go beyond to establish commercial service offerings that are scalable, creating more revenues for the country.

Space 2.0

The only way to break the conventional wisdom which says space is expensive, space is inaccessible, and space is only for large companies, is by closing the walls between engineering and business, which forms the foundation of Space 2.0. It is important to note that this approach to developing such a narrative is not exclusive to the conventional space agency developed technologies or missions. Indeed, to a large extent it is based on technology foundation developed by taxpayer-funded research. While conventional space agency approach is more inward-looking towards achieving targets based on national priorities, Space 2.0 is more outward-looking with an intention to be globally disruptive in terms of offering a space product or service.

The global NewSpace phenomenon is one that is fledging on this trend where space entrepreneurs are funded by private capital to achieve a product or a service that has the potential to disrupt the barrier to access to space (in upstream) or offer a service at a price that potentially opens doors to addition of a large base of new consumers (on the downstream).

To understand this phenomenon a bit more, Figure 1 provides an illustration of what NewSpace companies are attempting to do. Traditional space agencies have a budget that is driven by a political will which, in turn, depends on geopolitical scenarios, where any steep rise in budgetary allocation has to be driven by a national will which has mostly occurred due to international competition. Therefore, typically space agencies may, at best, have had linear growth post the Cold-War era. This also applies to India (Figure 2) where the budget increase has also witnessed a similar trend for investments in the space sector. Where NewSpace is trying to find value is in engineering their offering that enables a disruptive business model that will go in one step to what can be achieved in a typical space agency approach only with many folds of investment/timeline against that done by these private actors.

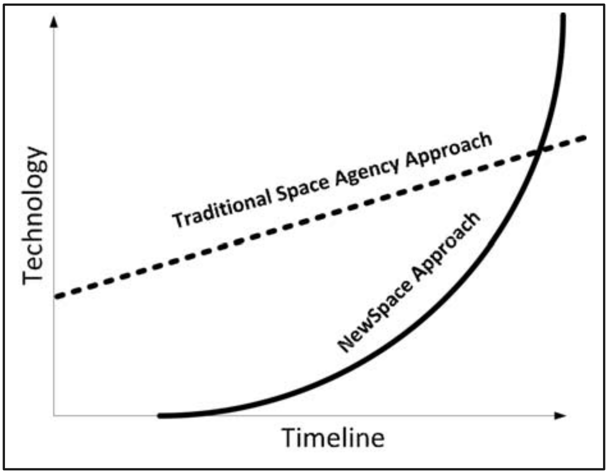

Figure 1 - Expected growth of NewSpace vs Traditional Space Agency

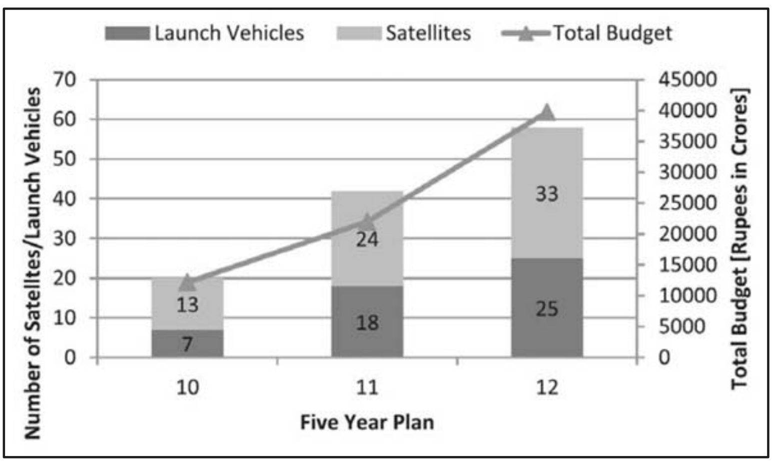

Figure 2 – India's space budget over past three Five-Year Plans

A prominent example in the current trends for such an effort is that of SpaceX which is now trying to achieve a Reusable Launch Vehicle (RLV) which the company expects to lower the cost of access to space by at least 30 percent while still being able to launch over a dozen launches a year. The approach taken by SpaceX is based on a business model that intends to disrupt the cost of access to space while achieving it by developing a disruptive technology that will create a barrier for its competition to match in the short or medium term of five to seven years. It is important to note that SpaceX's efforts are not completely independent or isolated from that of NASA. NASA provided much of the technology for engines for the company under a technology transfer programme to understand the foundation of building rockets. NASA also rescued SpaceX from going bankrupt by awarding its first launch contract.Where SpaceX has also possibly benefited in making its design for an RLV is in learning from the mistakes of the shuttle programme.

The key question is how this approach—where the financial risk is initially borne by private investments—which benefited from an active public-private partnership in learning about the foundation technologies to create a product that would otherwise take many folds more of investments in both time and money to achieve in a traditional space exploration approach? The answer lies in the approach to risk management in decision-making as well as the management matrix itself which are inherently different for a public institution that is held accountable for spending tax money against that of a private actor. The approach is therefore taken to management and realisation of such large-scale projects seems to change dramatically by NewSpace players where the priority in getting a product or service going is to get the most value for money, while a conventional space agency approach would be to prioritise decision-making on reducing risk.

The very reason that private capital backs NewSpace is that these investors are ready to play with a risk vs reward quotient against a given opportunity in a much vigorous fashion that may be impossible to substantiate for a taxpayer-funded agency. In funding NewSpace entrepreneurs, private capital is risking returns while a conventional space agency will have no room for such risks. This is one reason why a government-backed space agency would rather support a private actor who is willing to risk. One should also underscore the realities of a possible bubble in NewSpace in a sector that has already witnessed such a bubble being burst.

The understanding of these dynamics of institutional voids and organisational pressures by space programme managers, bureaucrats, policymakers, can help shape the creation of a Space 2.0 ecosystem in India. These typically are unchartered waters in India since the industry or the start-up ecosystem in the space sector has still not entered into delivering any large-scale end-to-end space-based service or product. In the formation of a Space 2.0 ecosystem in India, it is imperative to understand the key differences in these realms and any policies shall have to augur with the viewpoint of what is best for the nation.

Space 2.0 India

Space 2.0 in India is a vision to develop an ecosystem that will encourage and enable SMEs as well as NewSpace entrepreneurs to take the next leap forward in the country to develop end-to-end products and services that are globally scalable. It is that stage where enterprises and start-ups in the country shall be able to leapfrog based on the five decades of experience and expertise gathered in space with offerings that complement the efforts of ISRO. It is empowering small businesses to scale their offering of products and services to integrate into the global space supply chain and compete internationally in the $300-billion industry.

There are several important developments that need to move ahead as India builds up to this sort of ecosystem. On the already established SME landscape in space, India needs to witness the Space 1.5 step of some of the SMEs or the large business houses in the country making stronger commitments to investment in the space sector in gaining sophisticated end-to-end system level knowledge. This will also need encouragement from ISRO to guide these first movers towards sustainable growth. There is a strong possibility of this occurrence since there is an inherent national demand that is driving the need for production of over a dozen rockets or satellites a year.

From a start-up perspective, there is a need for mechanisms to evolve to engage with start-up entrepreneurs who would want to build products and services with a vision to scale it to solve some of the major problems of the society such as global connectivity, clean energy, decision intelligence, among others. In order to build a sustainable private capital investment scenario, transparent and timeline oriented policies must be brought forth for both upstream and downstream products and services in at least the well-established areas of communications and broadcasting, remote sensing, navigation and timing.

Space 2.0 is not just integrating products and services into the global space supply chain but also enabling opportunities for global collaborations that may not just be academic or technological, but will go further in solving the problems of financing and regulatory frameworks, working with networks investors and space lawyers around the world. Space 2.0 will also see the spill-over of technology products and services from government being a primary end-customer to a more market force driven B2B/B2C dynamic, which shall provide space entrepreneurs to scale offerings in the local markets as demand increases while potentially planning to expand their footprints to other markets.

An exampleof Space 2.0 effort is that of Astrome Technologies, a start-up based in Bangalore trying to solve the problem of providing connectivity to the 70 percent of the country's population who live in semi-urban and rural India via satellite-based internet. This has the potential to enable the country to leapfrog in achieving the vision of Digital India and can be extended to the regional grouping, SAARC, or other developing countries.

It is important to understand that the foundation and practice of establishing a fair and transparent space legislation and regulatory system can provide leeway to achieve a critical mass of linkages between upstream and downstream activities that can potentially expand the space economy of the country to many folds to what it is today. This can also serve in setting precedents for a future that may behold larger initiatives such as space mining, space tourism, and space solar power.

Developing an ecosystem that will support the rise of Space 2.0 in the country has the potential to make space the next big technological leap in the country after information technology and bio-technology. The words of Dr. A. P. J. Abdul Kalam, the former president of India, may yet prove omniscient: "The future generations will look at the Earth, the Moon and the Mars as a single economic and strategic entity." A Space 2.0 India revolution awaits.

2

Traditional Space and NewSpace Industry in India: Current Outlook and Perspectives for the Future

Narayan Prasad

The Indian space programme is one of the world's fastest growing (Figure 1). Backed by investments for over five decades now, India is moving towards increasing its capacity and capabilities of using space technology products and services not only for societal applications but also to support commercial space activities and pursue diplomatic and security objectives. Thus there is an inherent potential to exploit the technological prowess developed in the country for homegrown enterprises to expand products and services for the domestic market as well as participate in the $300-billion global space industry.

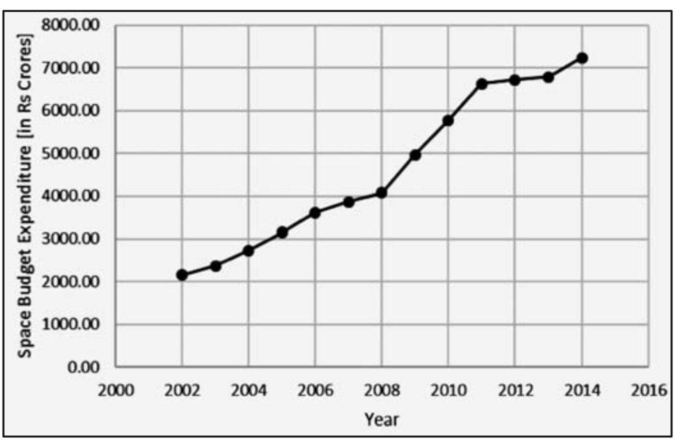

Figure 1 - Evolution of India's Space Budget[1]

1. Traditional Space in India

In order to understand the business ecosystem and the aspirations of Indian space industry for expansion, it is important to acknowledge the strengths and weaknesses of traditional business models in the space sector. Today, India has a large Small-Medium-Enterprises (SMEs) base that caters within the traditional space agency-driven model. The phenomenon of encouraging the development of India's private sector in the space domain began in the 1970s when the Indian Space Research Organisation (ISRO) started handholding entrepreneurs in technology transfer initiatives with the safety net of buybacks to ensure business survivability.[2] Fast forward four decades, today there are new initiatives being taken to encourage the complete development of end-to-end systems in both launch vehicles[3] and satellites[4] by the private industry.

Figure 2 provides an overview of a SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) for the traditional space approach. What traditional space approach tries to do is to increasingly offload work that is considered to be routine to the industry as an initiative in capacity building to achieve volumes that might not be possible without a significant increase in the infrastructure and manpower within a space agency. This is no doubt a significant step in helping the Indian industry to further mature and be able to perform Assembly, Integration and Testing (AIT) of both rockets and satellites. However, the current measures are more top-down in nature, and mostly based on capacity building via development of industry in upstream.

Figure 2 - SWOT Analysis of Traditional Space in India

This step will elevate vendors in the space programme to the next level, working alongside the space agency to be able to deliver back complete end-to-end systems. However, this current form of capacity building where a partnership is envisioned to perform AIT-related aspects (in both launch vehicles and satellites) is an extremely elementary one since the know-how transferred in this process is mostly at the system level of integration and does not entail capacity building to design, develop and complete end-to-end systems independently.

Although this is definitely a jump up for the industry in acquiring the know-how on AIT aspects, the roadmap for the traditional vendors to get to a level of being able to design, develop and manufacture end-to-end launch vehicles or satellites is not on the horizon until the current initiatives attain fruition and begin to show signs of sustainability. Therefore, this track is more a top-down model that enables the industry over long gestation periods to systematically develop capacity and primarily feeds on taxpayer funding to execute projects.

This model of industry engagement is not exclusive to India. Most traditional space business models work on this framework where the industry is funded largely by the government to deliver end-to-end systems. However, what is different between advanced spacefaring nations and India in terms of current models is the level of capacity builtup in the private industry. As a country, India is one of the most successful nations to have developed the capacity to deliver payloads to space or to develop satellites for services or to interplanetary missions. However, there is a stark gap in the capacity builtup in the private industry where the industry is mostly involved as tier-based vendors and presently there is no single industry vendor who has the capacity to deliver end-to-end systems. This creates bottleneck effects in the possible expansion of industry to the global supply chain, especially from an export perspective.

However, traditional space approach has a strong edge of having room for building upon proven and reliable technology and handholding from the space agency. Policymakers should look to draw a long-term roadmap in creating an environment of multiple industry players or industry consortiums having the ability to deliver end-to-end systems so that there is room for competition in the national ecosystem.

The current outlook for traditional space approach in India is positive with the initiatives of stepping of industry participation in launch vehicles and satellites. From a market perspective, the present outlook makes it certain that traditional space suppliers will be limited to upstream capacity building and will not be able to participate in completely commercial frameworks in the downstream.

The traditional space industry ecosystem will definitely benefit from long-term perspective planning by policymakers. Building a long-term perspective plan where the industry is enabled to participate in a complete commercial model where end-to-end systems shall be delivered can help in not only meeting the growing requirements in volumes nationally but also in integrating the Indian industry base globally.

2. NewSpace in India

NewSpace is a worldwide phenomenon of entrepreneurs developing products, and service enterprises focusing on space and are using private funding in their initial developments. While there is no internationally accepted technical definition of 'NewSpace', principally, the ethos of the movement has been to challenge the traditional ways of space exploration that are widely considered as too expensive, time-consuming, and lacking in room for inventive risk-taking. Companies that fit in the bracket of NewSpace include the likes of SpaceX, OneWeb, and Planet Labs, which are primarily funded by private capital to build products and services that challenge the cost to either access to space itself or access to services based out of assets in space.

NewSpace has gone on to attract successful global entrepreneurs to either kick-off ventures of their own or to support start-ups. Examples of such global entrepreneurs include the likes of Richard Branson kicking off Virgin Galactic, Jeff Bezos starting up Blue Origin, and Larry Page backing Planetary Resources.[5] One can argue that NewSpace kicked off where traditional space enterprises were stifling with the cost for creating more assets in space in areas such as developing cheaper rockets with greater launch cadence and developing satellite constellations that can enable greater and faster coverage to now many of them diversifying into space tourism and mining of space resources.

While this phenomenon has largely been orchestrated for the past decade and a half with leadership from the US, with the revolution in small satellites and the cost to access to space being reduced substantially, there are 10,000 NewSpace enterprises expected to kick-off around the world in the next 10 years.[6] Even if this may be an estimate that is ten times over what is realisable, having some 1,000 NewSpace companies in the next 10 years can well change the very nature of space exploration and exploitation. The key question here from a NewSpace perspective that needs to be asked is this: Will India have, if not a dominant, at least a relevant global NewSpace footprint or will it be a closed self-serving ecosystem?

NewSpace has inspired several Indian entrepreneurs to form companies that can inspire a whole new generation of fellow Indians to dream of businesses based on space products and services. The ecosystem is very recent with start-ups in a mix of both upstream and downstream offerings such as Team Indus, Earth2Orbit, Astrome Technologies, Bellatrix Aerospace, and SatSure. The spread of these companies include dreams of landing a rover on the Moon,[7] developing space-based internet service,[8] developing a private launch vehicle,[9] and using space data to change the face of how space-based technology can be used to provide forecast and insights to important basic sectors such as agriculture.[10]

Figure 3 provides an overview of a SWOT analysis for NewSpace in India. The key question is how different these start-ups are from those 500-odd small and medium-size enterprises (SMEs) that serve ISRO. The answer lies in the rather simple fact that these companies are the ones that plan to build either end-to-end systems or services for the first time in the country. Their business model is more diversified, with the possibility of either serving (private businesses or consumers themselves) customers themselves directly. Another strong distinction from the traditional business models that exist so far in the country is their vision to focus on the possibility of exporting their offerings.

It is important to understand that enabling NewSpace in India will have an effect not only on young start-ups with but it also gives an opportunity for the already built-up SMEs to expand their business. NewSpace in this sense is not a phenomenon but more of a framework that can act as an enabler to expand capacity and capability for the industry to offer end-to-end products and services.

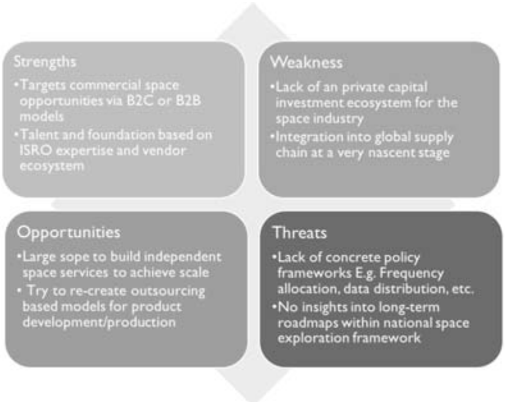

Figure 3 - SWOT Analysis of NewSpace in India

NewSpace India will look to feed on successes such as the most cost-effective and the only first-time success mission to Mars as a brand-building exercise and shall try to translate it into international business for homegrown industries as a recognition of producing world-class products and services. Therefore, NewSpace offers the potential for diversification of customer base for Indian industry in the space sector at the global level.

The government of India has actively floated several key initiatives such as 'Make in India' and 'Digital India', in which the space industry has a key role to play in achieving the goals. With the backbone technology know-how foundation in place, mainly by the efforts of ISRO and its vendor base, there is immense scope for NewSpace enterprises to leverage these cluster-based externalities such as technologies, infrastructure and manpower to build space-based services.

The investments needed for NewSpace commercial enterprises are extremely large since the target is to build end-to-end products and services models. Therefore, one of the major challenges will remain to convince private capital investors to buy into the business models. This exercise is also challenging due to the fact that there is no long-term framework within the national goals for NewSpace in India alongside concrete policy frameworks.

However, there is immense scope for effecting change in the commercial space landscape and achieving economies of scale in space-based services if NewSpace is enabled. Parallels can be drawn to the rise of the IT industry which enabled the creation of an environment that today is one of the pillars of export activity in the country.

3. Need for a Cluster Mapping & Competitiveness Study

A comprehensive mapping of the Indian space industry ecosystem (Figure 4) will help managers, policymakers from both India and abroad, to take advantage of the opportunities available in the country including the talent pool, inherent growing market requirements within, and the already established capacity to deliver highly reliable technology products and services.

3.1. Benefits for Indian Industry

- Successes such as the most cost-effective and the only first-time success mission to Mars must act as a brand-building exercise and should translate to international business for homegrown industries as a recognition of producing world-class products and services. Therefore, cluster development is an important exercise in the diversification of customer base for Indian SMEs and greater integration of Indian vendors into the global supply chain.
- With the backbone technology know-how foundation in place, mainly by the efforts of the ISRO, there is immense scope for these technologies to trickle down to domestic industry via focused initiatives to encourage cluster externalities. These can be in the form of spin-ins or spinoffs, which can emerge as innovative business models for products and services for these new offerings for both India's market and allied ones.
- Effective cluster mapping and positioning to achieve collaborative partnerships between Indian and international firms can lead to SMEs in the country to learn from international partners to work with new standards (e.g., European Cooperation for Space Standardization). Such an exercise can spread the capacity within the industry to replicate

the success achieved in the auto-industry within the country.

- One of the critical needs in the current landscape for the SMEs in the country is the need to access capital to achieve a larger scale in capabilities and capacity.[11] Provided that India has a very niche and nascent investment ecosystem for a sector such as space, the clustering exercise can help Indian SMEs to attract attention for possible FDI, Mergers & Acquisitions (M&A) or Joint Ventures (JV) with international partners that will bring mutual benefit.

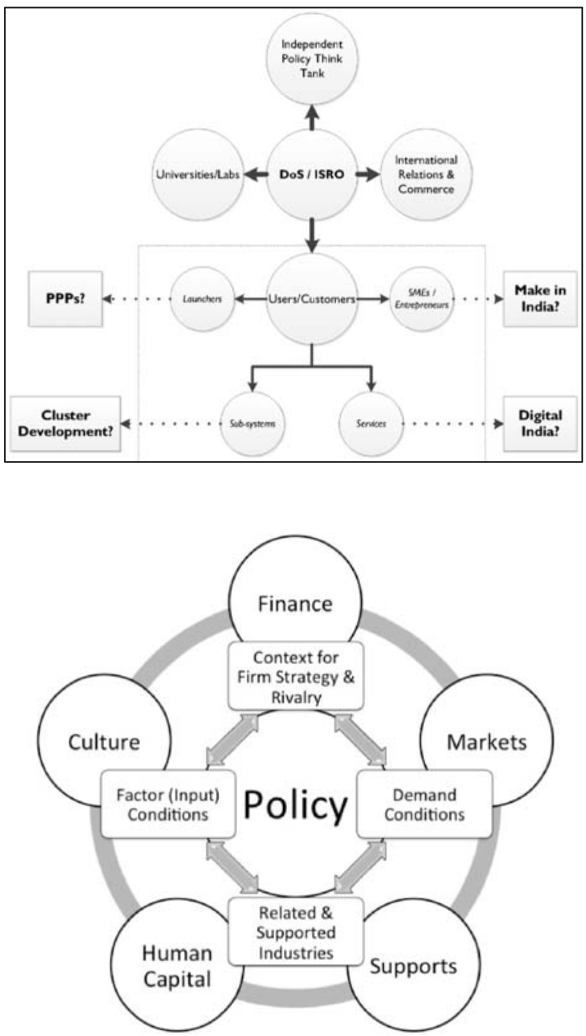

Figure 4—Need for Cluster Mapping & Competitiveness Study

- The government of India has actively floated several key initiatives such as 'Make in India' and 'Digital India', in which the space industry has a key role to play in achieving the goals set out under these missions. Therefore, a cluster-based network study can help policymakers to gain key insights to actively align policy decisions to further encourage the inclusive growth of the Indian industry and academia.

3.2. Perspectives for Global Players to Invest in Indian Space Industry

- With India recently permitting 100-percent FDI in the space sector,[12] there is an opportunity for international firms to gain a market entry into India by positioning their offerings independently or by integrating their marker strategies via partnerships (via JVs, M&As or SPVs) with Indian SMEs to realise end-to-end upstream and downstream systems offerings.
- Take advantage of the local market conditions (e.g.,talent pool, low labour costs, engineering services backbone, and others) to replicate the cost-competitive IP creation and co-creation in the country that has been a construct that global firms have already used successfully in technology sectors such as aerospace and IT.
- The space industry is a niche sector with several global pockets for vendors for specialised products and services. Knowledge of the local industry cluster of a market such as India can potentially help consolidate their supply chain and mitigate some of the inherent supplier risks and well as solve single-vendor problems for global firms.
- There is a difference in the route to innovation pursued by firms in developed countries and emerging economies. Innovations in emerging economies tend to not involve major technological breakthroughs but take a more novel and innovative combination of existing knowledge and technologies to solve pressing local problems by using new processes and business models. This makes a case for international firms to utilise India as a hub for 'reverse innovation' before 'trickling up' to either allied markets in emerging economies or developed countries themselves.

- For example, General Electric's ultra low-cost ultrasound and ECG machines, were led by development teams in India, initially for use in these countries, but with inputs from local and foreign subsidiaries.[13]

- Based on the long-term strategy, global firms can typically benefit by exploiting India as a foundation for improvising growth strategy under competitive pressures by developing expansion plans as a part of larger global strategy, increasing speed to market, improving service levels, business process redesign, adopting an industry practice, testing differentiation strategy, access to new markets, enhancing system redundancy.

4. Conclusion and Recommendations

The current outlook for traditional space approach in India is positive with the initiatives of stepping of industry participation in launch vehicles and satellites. NewSpace start-ups in India plan to either build end-to-end systems or services for the first time in the country with diversified business models bringing the possibility of either serving (private businesses or consumers themselves) customers themselves directly including possible export-oriented models.

The current ecosystem can be further fostered by developing mechanisms of continuous tracking and monitoring to provide a strong foundation in enabling business from a policy framework perspective. To this end, there is scope for initiating the 'State of the Space Industry', which can draw a lot of inspiration from similar practices in the international space industry to provide the outside world an overview of the current Indian capabilities in ISRO and in the industry. This can help showcase to foreign companies the relevance of working with their Indian counterparts.

There are several other broad ways of promoting growth that need to be considered with measures to promote Indian space industry. These include the following:

- Confederation of Indian Industry (CII) awards for Indian companies to be given at the Bangalore Space Expo in different categories such as 'Best SME', 'Best space spin-off', 'Best space start-up', among others.

- Starting a space directory of companies, capabilities, and others, which is easily accessible to anyone in the international markets so that it can promote ease of doing business by increasing networks.
- Promoting Indian industry to participate with ISRO in the largest space conference in the world – the International Astronautical Congress (IAC).

Finally, it is important to understand that traditional space and NewSpace may be different approaches but they both aim to expand the country's space economy.

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3

A Review of India's Commercial Space Efforts

K. R. Sridhara Murthi

Commercial Space Activities: A Wider Perspective

Commercial Space efforts the world over have evolved on the foundations of government expenditures, particularly on military space programmes that created technological muscle in an industry used for spinning off commercial products and services. It was the deregulation drive for telecommunications that created, for the first time, a major opportunity for a competition-driven commercial space industry. This industry thrived on an enterprising private sector with the support of government policies. Integration of space infrastructure into the larger telecommunication industry, which is globally worth US $5 trillion annually, has enabled the creation of a large value chain for space telecommunication services. Comparatively, the size of the entire space economy, including all government budgets and commercial revenues, is US $330 billion annually. A revolutionary space-based capability, seen in the more recent past, had been the phenomenal growth of positioning and navigation services. Extension of satellite services in positioning and telecommunication to the mobile environments and the provision of direct consumer services through satellites are the twin opportunities that offer a great potential for expanding the markets, especially in emerging economies around the globe. It is in these markets that infrastructure is yet to fully develop to serve the underserved populations, and there are opportunities for manifesting several downstream value-building activities using space technology. Particularly for India, the consumption propensity of a strong middle-class population and the preferences of youth-dominated demography offer unique opportunities for market development.

There are, however, many challenges unique to space technologies. These include limited access to technologies, huge risks, and excessive government interventions. It is no secret that today's dominant space industrial companies evolved and grew due to the huge military expenditure during the Cold War era. Industry consolidation over the decades, the technology-transfer constraints and the dual-use nature of space systems had led to concentrated markets and islands of capabilities on a global landscape. The metamorphosis came in the post-Cold War era, with the privatisation of intergovernmental systems, such as Intelsat and Inmarsat, and the segmentation of space activities to facilitate orientation towards free markets for space-based services, on the one hand, and tighter controls on dual-use technologies, on the other. The growth rate of commercial space had invariably been influenced and preceded by the policy drives in major markets, such as the United States. Until now, transformations in global space commerce had remained more policy driven than market driven. Therefore, when it comes to the review of India's commercial space, the seminal role of policy dimensions cannot be undermined.

India's Space Industry

The historical backdrop of industrial setting in India and the objectives for the origins of Indian space endeavours, which were non-military unlike those of advanced economies, did not facilitate India's early entry into commercial space efforts. The priority for the Indian Space Programme, in its initial decades, was to achieve self-reliance and to develop a robust national industry to support the government-funded national programme, which had been conceived and executed by the Indian Space Research Organisation (ISRO). Further, the existence of well-developed national space industrial capabilities in key segments of space activities is a strength to rely upon for sustaining and growing commercial space efforts. ISRO's forward-looking and well-thought strategies helped in building India's space industry. As a result, India's space industry is now extensive, though not fully integrated.

Indeed, the quest for industry partners for ISRO's space projects began as early as when the developments of India's maiden satellite launch vehicle, SLV-3, and the first Indian satellite, Aryabhata, were taken up in the early 1970s. Pioneering policies for technology transfer and industry development introduced in the mid-1970s resulted in multifarious initiatives, such as the creation of space divisions in industry, production of several components of space systems, building of specialised test equipment and ground facilities by the industry, and support for innovative space applications. The range of manufacturing and service rendering capabilities of the Indian space industry is illustrated in Fig. 1. The opportunities for space industry growth as well as policy renewal needs are illustrated in Fig. 2.

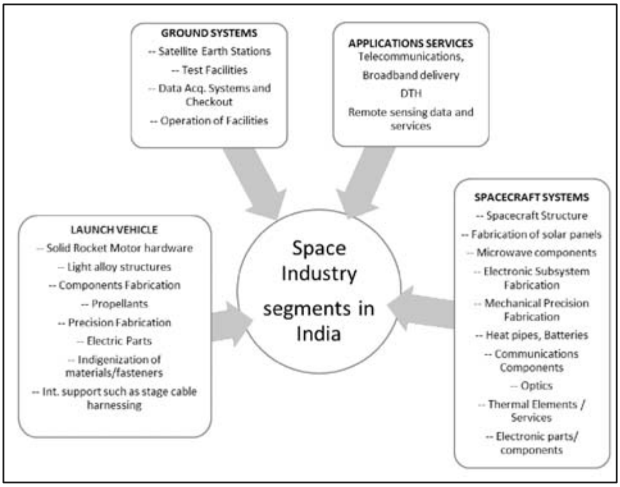

Fig 1. Indian Space Industry Capabilities

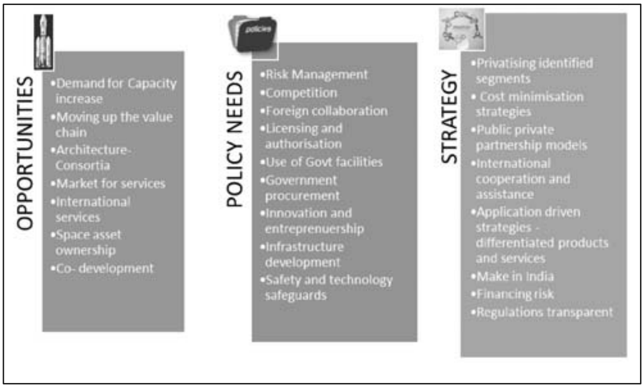

Fig 2. Indian Space Industry: Opportunities and Policy Needs

Leading Commercial Space Activities: ISRO's Corporate Front

It was ISRO's technology-transfer and industry-cooperation programme that sowed the seeds for India's commercial space initiatives. During visioning exercises for the 1990s, the idea for formation of a corporate front for ISRO was mooted, to assist in the management of the rapidly expanding ISRO's industry interface activities for its operational era. The concept for Antrix Corporation as a marketing arm of ISRO was concretised from the above idea. Considering the international dimensions of space activities, including the nature of space industry and commerce, authorities realised, even during that time, that Indian space industry should be globally relevant and should not lose sight of international opportunities and developing competitive strengths.

Antrix was incorporated in September 1992, as a private limited company, and was wholly owned by the Government of India, with the objective of promoting and commercially exploiting the space products developed by ISRO. It was initially intended that Antrix would undertake technical consultancy services and manage technology transfer activities of ISRO, to assist the Indian space industry. Since its inception in 1992 and until mid-2011, Antrix was managed by a board chaired by the Chairman of ISRO and the Secretary of the Department of Space. The members of the Board included key leaders of ISRO's centres, responsible for satellites, launch vehicles and applications, and a few eminent leaders of the industry in the private sector. The integration at board level with top-level ISRO management is a key factor that ensured ISRO's support to this company and allowed it to rely on ISRO's infrastructure (both the facilities and expert technical human resources) in executing customers' programmes. Due to the capital-intensive nature of space investments, high risks and the long gestation for returns on investments, it was initially planned that Antrix would not own expensive facilities or a large workforce, as found in many other public-sector enterprises, and would instead leverage the capacity created in Indian industries and in ISRO. Antrix, thus, aimed to set a new trend by adopting a very lean and efficient structure in terms of human resources. One of the priorities set by top leadership of ISRO, soon after Antrix began its operations, was that Antrix should play an enabling role for the growth of India's space commerce using synergistic interactions with the space industry instead of doing everything by itself or reinventing the wheel.

Because of the wide diversity in ISRO's activities and capabilities, the business portfolio of Antrix, too, was spread into many areas including: (i) provision of spacecraft systems, subsystems and components; (ii) remote-sensing services; (iii) satellite communications transponder leasing services; (iv) launch services; (v) mission-support services; (vi) ground systems; (vii) spacecraft-testing services; (viii) training and consultancy services.

Global Marketing of IRS data

Taking advantage of the contemporary features in ISRO's fleet of remote-sensing satellites, Antrix began to market Indian Remote Sensing (IRS) Satellite data at very competitive costs. By establishing an alliance with one of the global leaders for marketing, Antrix began to provide data and downlinks in the US and other markets around the globe. This cooperation brought about a synergy of complementary capabilities available from Antrix and its US collaborator, Earth Observation Satellite (EOSAT) Company (later known as Space Imaging LLC.), resulting in a visible market impact. Over time, an international network of 20 ground stations were promoted in countries, such as the US, Germany, Russia, China, Australia, UAE, Kazakhstan, Saudi Arabia, Thailand, Myanmar and Algeria, with the capability to directly access data from IRS satellites. Sustaining this segment of business had become a challenge over the years, in view of shrinking capacity due to increased domestic demands and increased competition. Nevertheless, it still presents an opportunity for the Indian industry to enter the business of satellite-based remote sensing, provided initiatives for support are forthcoming from the government. There have been continuous advances in this field of technology in India by way of ISRO's programs, which can provide sustaining inputs for the commercial industry. Another major opportunity lies in creating an environment for the growth of the downstream industry, so that value addition by this segment in India can be maximised. One of the issues is access to high-quality images from space. Advances in information technology, especially for real-time processing and for analytics involving large volumes of data, growth of mobile communications and precise location capabilities have transformed the very structure of value-adding industry by spawning a variety of services related to information and governance. Diversification towards mass markets and service focus are important drivers that the policy should address.

Commercial Launch Services

Commercial launch services for small and medium satellites with the well-proven Polar Satellite Launch Vehicle (PSLV) is a success that should be maintained. Notwithstanding the barriers of the launch market environment, Antrix successfully found international customers for launching small satellites from a score of countries including Germany, Korea, Belgium, Argentina, Indonesia, Israel and Italy on India's PSLV, both in piggy back and primary payload modes. As of end-November 2016, a total of 79 satellites from international customers were launched into orbit successfully by PSLV. PSLV has established a record of reliable flights, regular turnaround and flexibility for accommodating different types of orbits. Based on domestic and other commercial demands, in the future, ISRO is planning to launch 12 to 18 PSLVs per year.[1] Moreover, there could also be demand for at least three to four Geosynchronous Satellite Launch Vehicles (GSLVs) annually, and commercial opportunities will increase once the GSLV Mark III version is operational. This means much more than just doubling the present capacity in the industry; the entire supply chain in space industry can benefit in addition to opportunities for new entrepreneurships.

It is also pertinent to note that the world's launch services industry is not fully governed by market principles. There are concerns regarding technology safeguards and political considerations for trade in this area. The phases of development of launch capabilities across the globe are also uneven and have often given rise to conflicting interests among established players and new entrants. Such factors and balance of interests made negotiations for a Commercial Space Launch Agreement between the US and India difficult. Even recently, there have been reports[2] that the US launch vehicle companies, including those working on a new generation of vehicles designed for dedicated Small Sat launches, have argued against easier access to the PSLV. Therefore, viability for a sustainable private launch services industry in India is highly uncertain in the foreseeable future. If at all it is possible, only a public–private partnership model can be attempted, in which ISRO can farm out certain aspects of the launch vehicle manufacture and launch services business through long-term arrangements for risk sharing. Another major challenge that Indian launch services activities have to confront in the future is the disruptive cost trends triggered by developments in reusable vehicle technologies by private initiatives in the US. India's investment strategies in space launch vehicles must consider seriously this changing trend in technology trajectory.

Marketing Telecommunication Satellites: Antrix–Astrium Alliance

Due to its modest launch vehicle capabilities in terms of launch mass, ISRO focused on development of relatively smaller satellites and has achieved heritage and proficiency in the same. Based on this niche capability, Antrix collaborated with EADS Astrium of Europe to jointly manufacture and supply communications satellites to global markets based on Indian satellite technology. This alliance has won two satellite contracts from prestigious European customers. ISRO-designed spacecraft platform, integrated with payloads from Astrium, were delivered to the customer. This alliance demonstrated effective industrial teaming of two different cultures for a common high-technology project. These types of models are very useful for Antrix, and for the Indian space industry in general, to enhance their global presence. Depending on the scope of collaboration, such alliances could also be considered for fulfilling offset obligations.

Satcom Policy and Its Objectives

India's satellite communications policy (1999) came into effect in the backdrop of worldwide trends for satellite communication services by the private sector. The purpose[3] of this policy was to build national capability in satellite communications through a healthy and thriving industry and through sustained use of India's space capabilities. Another declared objective was to encourage and promote privatisation of satellite communications by attracting private-sector investments in space industry, as well as foreign investments. This policy also purported to make available

Indian National Satellite System (INSAT) capacity to service providers in private sector for socially relevant applications. A set of norms, guidelines and procedures for implementation[4] of this policy was approved by the Government of India in 2000.

In pursuance of this policy and the implementation processes that were evolved by ISRO/Department of Space in compliance with the decisions made by INSAT Coordination Committee, Antrix was mandated to market and manage the contracts for lease of capacity from INSATs or GSATs to Indian service providers. In case of short supply of capacity from INSAT, Antrix would lease from a foreign satellite operator to meet the demands of service providers in India, until capacity from Indian satellites was available. The service providers in all such cases were allowed to participate during discussions with foreign vendors (unless the capacity demanded was too small) while Antrix endeavoured to obtain the best bargains. Notwithstanding the relatively lower prices of satellite bandwidths as compared to other regions of the world, this procedure of canalising was a limitation according to the industry, and the latter demanded to replace it with an open-skies policy. The government needs to weigh the interests of a robust service industry, imperatives of autonomy in a critical infrastructure area, and a sound regulatory system ensuring national security. However, open-skies policy by itself need not conflict with these diverse goals. Moreover, putting all types of satellites in a single basket, extending the security argument and denying market opportunities will be neither convenient nor profitable to the space industry. Therefore, classifying satellites based on their capabilities is one viable approach. No one can deny that security is the prime concern of current times, for both the government and businesses. In the context of security, it is necessary to consider satellite as an element (albeit a critical one) in a complex network of infrastructure. The policy issue is also intertwined with considerations of international environment, which is characterised by restrictions on technology flows, quasi-permanent occupation of geostationary slots and limited nature of orbit-spectrum resources.

The time is now ripe to debate and review the policy statement of 1999, which aimed to promote privatisation of satellite communications by encouraging private-sector investments in space industry and by attracting foreign investments. Having established a large services market satellite TV and telecommunications, Indian space industry could be interested in making investments for owning and operating satellite assets. A serious dialogue is crucial between the industry and the government, on aspects of risk management, incentives and technological support. Since such evolution in Indian space industry is also possible through international collaboration, suitable clarity on regulatory and policy aspects is important.

By way of lessons learnt, a brief mention of Antrix–Devas Agreement is in order. Under this agreement, the broader aim was to establish nationwide direct satellite to mobile phone connectivity for multimedia applications, for the first time in the country, using a small satellite. The agreement was only for leasing capacity from satellite, which needed to prove a risky new antenna technology, to a service-providing enterprise. The service-providing enterprise, too, undertook the risk of developing a compatible ground segment. It was clearly stated that it was the service provider's responsibility to obtain necessary service-related authorisations, including relevant frequency authorisations, payment of relevant spectrum fees operating licenses from concerned administrative authorities. Yet, there were misleading accusations and some inappropriate actions for cancellation, which brought about unsavoury legal consequences. Although such risk-sharing agreements between ISRO and industry is not new, in cases where unforeseen and rapid changes in techno-market conditions transform the value perceptions, the risk for controversy is higher.

There is a growing emphasis on opening markets for satellite services. At the same time, the industry segment relating to satellite infrastructure and launching activities are heavily regulated internationally and are influenced by the export control policies of different nations, which supply parts and components for space systems worldwide. While some of the impediments for accessing markets and production factors need to be overcome through political dialogue and international cooperation, a sound business strategy is also very important for overcoming already existing competition from global industries. Strategy for Indian industries' foray into space segment ownership and operations, thus, need to be evolved through policy drivers formulated through the engagement of stakeholders.

Future Market Perspectives

The Continuing trend for deregulated industry in information and communication services in the context of a growing Indian economy, whose GDP is projected to attain a level of US $86 trillion by 2050, presents an unprecedented opportunity for a competition-driven growth for space-based services. The present-day capability of space systems to directly service individuals and homes (as in case of PNT or DTH or broad band delivery applications) enables a paradigm shift of these services towards mass markets, which has immense further potential to expand user base and diversify applications. This potential is well positioned by India's demographic advantage in the coming few decades, because by the year 2050, there will be an expected 800 million working-age population. Further, the trends of economic development will also generate a huge and consuming middle-income group population. This augurs well for the expansion of a variety of information and communications services that can be supported through new generations of space systems, such as High-throughput satellites and constellations of agile, low-cost, high-performance remote-sensing spacecraft designed for providing on-demand services. Several applications including GIS-based decision support, positioning and location-based services, homeland security, disaster management, wide-band connectivity to remote rural areas and mobile multimedia services represent significant untapped potentials. Even for established services such as direct TV broadcast to home, there had been demands for satellite capacity that exceeded the supply, over the past several years. Aforementioned applications will generate continuing demand for space systems and opportunities for international collaborations.

The trend of private-sector initiatives, in the US and elsewhere, to reduce launch costs through reusable systems and through other innovations are going to influence the developments in India as well, where demands will be up for enhancing launch capacities and lowering the cost of launches. New public-funded programs are likely in many areas, such as some segments of human space flights, planetary exploration through orbiters/ landers and rovers, insitu operations on planetary surfaces or asteroids, resource exploration on the moon and other celestial bodies, and participation in space tourism. These will generate additional work in the space industry and opportunities for entrepreneurship. Even with the yet-to-develop ecosystem for space entrepreneurship, the progress and entrepreneurial initiatives of Team Indus, Astrome Technologies, Bellatrix Aerospace, Dhruva Space, Earth2Orbit, etc., are highly pioneering, and such initiatives require greater support and encouragement.

Technology Trends

Miniaturisation of space components and systems enabled by increased use of solid-state power devices, new generation sensor devices, exponential growth in processing and data storage capabilities, enhancement of weight efficiency of energy storage and conversion, and process innovations such as concurrent engineering have greatly influenced reduction of launch and spacecraft costs. "New Space" era has also brought many disruptive concepts, such as miniaturised high-performance spacecraft, inflatable structures, large-scale clustering and constellations, greater autonomy in spacecraft, smart concepts in power, bandwidth and payload management, intelligent and robotic structures, and architectural integration in space and ground networks. While future developments in technology in the longer range will be directed towards increasing human presence in space, for creation of habitations, in situ operations and resource exploration, there will also be demands for technological developments for overcoming the challenges being brought about by the new trends in space as well as tackling global crises, such as climate change, terrorism, conflicts and uneven development. Space systems can be an important component of new generation systems needed for monitoring our planet's health and natural resources on a continuous and long-term basis using networks of sensors far denser than the current ones. In this field, integration of space technologies and space-based applications with new tools/technologies, such as big data analytics and Internet of Things, can be expected. Advances will also be demanded for making space operations safer and more secure. This, in turn, will create an imperative of better Space Situational Awareness through global cooperation and pursuit of new steps for active debris removal or on-orbit repair missions. For India, through the next few decades, practical applications of space for better weather predictions and extreme-weather monitoring, applications in democratising information and towards empowerment, education and optimum use of natural resources and enhancing national security are greater priorities than esoteric pursuits of space endeavours. Convergence of space technologies with many terrestrial technologies, involving a 'spin-in' process, had begun to reduce the costs, and novel approaches are being experimented in the building of space systems. While India will continuously enhance its space transport capabilities, it can be expected that some intermediate steps will be pursued for cost reduction before large-scale reusability is attempted. Developments in air breathing engine technologies and semi-cryogenic stages will be advancements in this direction. Space rendezvous, docking and on-orbit robotic operations will also need to be tested. In summary, technology trajectories are complex to predict in view of interactions among multiple disciplines, which the space activities and future applications are likely to involve. For India, continued investment by the government is crucial if the country aspires to play a globally significant role in diplomacy, socio-economic advances and international security.

Policy Implications

The preceding discussion clearly indicates that India's commercial space developments cannot be seen in isolation and must be viewed holistically, keeping in mind the multidimensional objectives that the National Space Policy will demand, besides imperatives of emerging international environment both in terms of the commercial and strategic aspects of the space domain. Major long-term policy implications for space commerce, given the potentials of India's economic developmental aspirations, can be perceived as follows:

Target-Oriented Policies: Indian space-based service industry should be targeted to reach a level of US $40–50 billion by 2050. This is not unrealistic if economic development is sustained to predicted levels. In terms of market values, this represents an eight-to ten-fold increase over the next three decades. A robust infrastructure should be enabled by both government expenditure and private investments or through public–private partnerships.

Industry Architecture: Recognising dimensions of space as a global activity, policies should enable and incentivise a balance of competitiveness and sustainability. There will be both hierarchy, e.g. a prime contractor and associated supply chain, and segment-wise specialisations based on value chain, e.g. infrastructure and services. A clear-cut policy is needed on collaborations. For security applications, the architecture and roles of space industry and their interface with government-owned facilities and regulation should differ.

National Space Ecosystem: India's space industry should be modelled as an important part of the larger ecosystem, addressing space assets manufacturing, private ownership of space assets, national level space services and global market access.[5] Indian space industry needs to orient for a quantum jump in technological growth and adopt organisational models that will ensure economic efficiency and enable a vibrant private sector.

International Coordination: The government needs to provide assistance to the space industry for safe and secure use of their assets in space, for Space Situation Awareness, and for an appropriate engagement with the industry to facilitate internationally coordinated resources such as orbit-spectrum coordination.

Governance and Regulation: The structures for governance for national space and commercial activities should recognise new stakeholders and, accordingly, involve them in ensuring proper governance of space activities as well as the commercial sector. Regulatory system should be renewed to ensure independence, transparency and adequate coverage.

Concluding Remarks

In pursuit of the government-funded space programme over the past five decades, ISRO has made some remarkable achievements, including autonomous access to space and making and operating state-of-the-art satellites that became the mainstay for television, telecommunication and the image-applications industry, with a multibillion-dollar domestic market. Opportunities are opening up to expand commercial space role of the Indian industry, though the challenges that confront these opportunities are daunting, and they demand a well-crafted strategy of engagement between government and industry, with a long-term perspective. The world has witnessed mainly policy driven forays in commercial space activities and, more recently, a new breed of entrepreneurship in the western world, challenging the traditional concepts and approaches. The potentials for space commerce must be tapped by promoting an overall ecosystem for space activities, which should serve to advance robust national space capacities, innovation in technologies and applications in commercial and non-commercial domains. There is also an urgent need for renewing policy and regulatory systems for incentivising the growth of India's space industry.

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Exploring the Potential of Satellite Connectivity for Digital India

Neha Satak, Madhukara Putty, Prasad H L Bhat

Very many individuals with myopic vision questioned the relevance of space activities in a newly independent nation which was finding it difficult to feed its population. But the vision of the leaders was very clear: if Indians were to play a meaningful role in the community of nations, they must be second to none in the application of advanced technologies to their real-life problems.

- A P J Abdul Kalam in his autobiography, Wings of Fire

Introduction

India is a country at the cusp of a major transformation. Since early 2000, the Indian internet user base has virtually exploded. It took 20 years to have the first 100 million users online, but the next 100 million users will come in less than three years.[1] To cater to this meteoric rise in demand, it is imperative to look beyond the traditional modes of internet delivery, and as this chapter argues, space-based solutions are necessary.

India: A Country on a Launchpad

Through a series of economic reforms that began in the early 1990s, India was made open for international players in a move that resulted in a rapid and sustained expansion of the economy. Between 1991 and 2015, the Gross Domestic Product (GDP) of the country rose from a modest $200 billion to $2 trillion.[2] This impressive growth was chiefly driven by the flourishing

Information Technology (IT) and Information Technology enabled Services (ITeS), as well as a growing industrial sector. Currently, India's export of software and allied services account for about two-thirds of the $120-130-billion global market.[3] Today, India is also home to research and development centres of many of the major technology companies.

Buoyed by the success of IT and ITeS, Indians are moving out of their comfort zones and embracing entrepreneurship. As of January 2016, India had more than 19,000 technology-enabled start-ups, of which about 5,000 were started in 2015 alone.[4] E-commerce companies have greatly increased the choice of products for the consumers and allowed sellers to reach out to a large number of customers. By bringing in the rural markets to the mainstream, the e-commerce ecosystem has the potential to integrate rural and urban economies. A large number of start-ups working on the Internet of Things (IoT) are trying to hook up sensors and generate a data deluge. Cashing in on the rising awareness about the electronic payments are financial technology companies building digital wallets that enable the seamless flow of money among various stakeholders.

Government's 'Digital India' programme envisions to "transform India into a digitally empowered society and knowledge economy". The government intends to achieve this by focusing on three vision areas, namely: 1) Digital Infrastructure as a Core Utility to Every Citizen; 2) Governance and Services on Demand; and 3) Digital Empowerment of Citizens.[5]

In a nutshell, both the government and the private sectors are working together to take India to the next level. However, for India to take off from the launchpad, internet connectivity is the fuel—connectivity not just in cities but reaching the end points of the country.

India in Space

India has been an active player in space and has always utilised space for improving the quality of life of its people. It is one of the few countries in the world that have the capability to develop indigenous technologies to carry out space missions.[6] In 2014 the country joined an elite club by successfully launching a Mars Orbiter in its very first attempt and at a relatively lower cost. After its establishment in 1969, the Indian Space

Research Organisation (ISRO) has developed significant expertise in building satellites for various applications including remote sensing, communication, weather forecasting, and national security. India's indigenous launch vehicles, the Polar Satellite Launch Vehicle (PSLV) and the Geo-Synchronous Launch Vehicle (GSLV) have earned a name for their reliability in the global launch services market. As of September 2016, PSLV had successfully placed 121 satellites into low earth orbit, of which, 79 are from countries other than India.[7] Every year, updates provided by 'eyes in the space' have helped save thousands of lives in times of extreme weather events like a cyclone. Remote sensing data provided by ISRO satellites are helping researchers across the country to understand the impact of climate change on the local environment.[8] There also have been efforts to leverage satellite communication technologies for making quality education and healthcare available to people living in the remotest villages.[9] However, satellites can play a much bigger role in India's ambition to transform itself into a country empowered by digital technologies.

Sustained efforts of global space organisations to build capability in space has created the required talent and companies across the globe, including in India, that are capable of taking private space to its version 2.0. ISRO is encouraging private industry to transform themselves from manufacturer of parts to becoming full satellite integrators and manufacturers. There is enough expertise in India and globally to create multiples of these organisations and serve the needs of the growing satellite industry. In light of this development, several companies including start-ups have ambitious plans to build viable and sustainable businesses solving real problems.

Taking the Internet to the Villages

India faces various hurdles as it aims to transform itself into a technologically developed nation. With an estimated 462 million internet users online, India has the second largest internet user base after China. But, with more than 65 percent of the population without access to internet connectivity, India's task is difficult.[10] Internet penetration in the US, for example, is at 88.5 percent; Japan is at 91.1 percent, and China, 52.2 percent. However, what stands out for India is the rate of growth. Between 2015 and 2016, the number of internet users in India increased by 30.5 percent—a growth that is unheard of in any other country in the world in the same period. The high growth rate can largely be attributed to the fact that more than half of India's population is below 25 years of age. Further, the growth is not limited to the number of users; the demand for data, especially over mobile phones, is also growing at a much faster rate all over the world. By 2020, monthly global mobile data traffic is expected to reach 30.6 exabytes from 3.7 exabytes in 2015.[11]

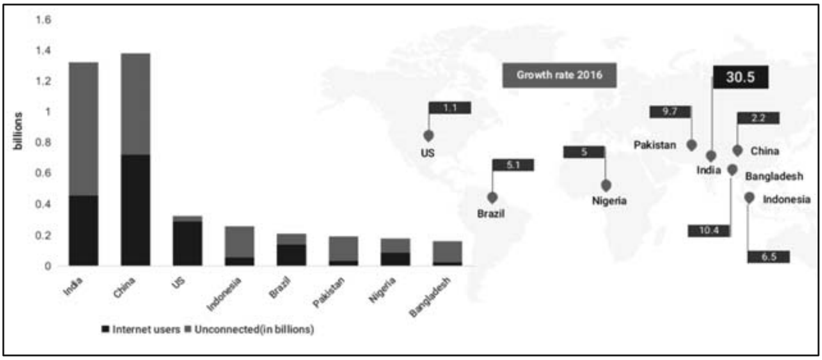

Figure: Internet's growing demand

The internet user growth so far has been skewed towards urban areas even though majority of the population resides in rural areas. The main reason for this disparity is low population density in rural areas which makes it difficult for traditional internet solutions to recover the cost. However, there has been a growing demand for internet in urban and rural areas alike. By 2018, India is expected to have more than 500 million internet users, and about half of them will come from rural areas.[12]

Recognising the socio-economic dividends of broadband internet, in 2011, the Indian government rolled out an ambitious project to connect 250,000 village *panchayats* with optical fibres. The project, initially called National Optical Fiber Network, and later renamed Bharat-Net 2015, is expected to facilitate transition to e-commerce, e-Banking, e-Governance, e-Education, and Tele-medicine. At the time of writing this chapter, the project had reached 15,624 village panchayats.[13]

All the major internet service providers in India are also making large investments into expanding their existing infrastructure to get ready for the expected growth. Bharti Airtel, for instance, is committed to expanding its mobile broadband coverage to all Indian towns and 750,000 villages.[14]

Reliance Jio, a relatively new player into the country's telecom market, has made large investments to create fibre optic-based 4G infrastructure to provide telecom internet service across India. However, their coverage capacity is strongly linked to the population density of a region.

Limitations of Optical Fibres

Optical fibre, along with wireless infrastructure mounted on towers, form the core of ground infrastructure required to provide broadband connectivity. In fact, there are long cables on the ocean bed connecting continents and transmitting large volumes of data at very high speeds. Similar fibres, laid underground, are also used to deliver broadband internet to homes and businesses in cities and towns. Optical fibres, though reliable, turn out to be expensive when they are used to connect regions of low population densities. It costs about $3,000 to lay optical fibre for a length of one kilometer. Thus, if there are not enough consumers, recovering capital costs becomes a challenge. Since a significant portion of the Indian population that is yet to come online lives in semi-urban and rural areas, it may not be economical to lay optical fibres in some of those regions. Also, developing ground infrastructure is an incremental process—it is not possible to provide connectivity to a village unless its surrounding areas are already connected. Therefore, providing high-bandwidth internet to such a large, widely distributed population creates a need to look beyond the ground infrastructure. Space technology may yet have all the answers.

Beaming Internet from Space

Satellite internet provides an economical solution to most of the challenges faced by ground infrastructure. Optical fibres bring in higher capacity in a concentrated fashion, while space-based technologies are effective at distributing capacity over a large area. Calculations show that the cost to cover one sq km from space varies between $1.5 and $6, which is negligible as compared to $3,000 to $30,000 required by ground infrastructure to cover the same area. Moreover, accessing space-based internet is as simple as getting DTH television services—all a consumer needs is an antenna on the rooftop, and a set top box inside the house.

Satellite infrastructure also complements the ground internet network. Areas where ground infrastructure is difficult and cost-intensive to penetrate, satellite infrastructure can easily cover. Moreover, it also frees ground infrastructure from the burden of being incremental as telecom towers with satellite as backbone can now be deployed in new areas without worrying about surrounding infrastructure. Owing to the minimal surrounding infrastructure required when telecom towers uses satellite as backbone, it expedites the return on investment for ground infrastructure.

In countries like India, satellite infrastructure can also reduce congestion in already overloaded networks, and thus improve the quality of service provided by mobile networks. They can be integrated into 5G systems, and help take advanced IoT applications to regions that are beyond the reach of terrestrial networks. Satellite systems are universal, too—in fact no other broadband technology promises quality coverage in urban, semi-urban, remote and mountainous regions. It can also provide internet on oceans and islands, and even to those in the sky.[15]

In addition to these, trends on the space technology front imply that the time is right for making high-bandwidth internet from space a reality. Because of significant improvements in rocket technology, the launch costs have come down over the last few decades. For instance, with India's Geosynchronous Satellite Launch Vehicle (GSLV - 3) the cost of launching a kilogram of material to space is expected to be just a third of the cost with the PSLV launcher. This is highly encouraging news for this industry.

For these reasons, even the International Telecommunication Union/ UNESCO Broadband Commission for Broadband Development, makes the following observation in its report *The State of the Broadband 2016.*[16]

"Satellite systems should be given full consideration as solutions for next-generation broadband network deployments in rural and remote areas, as well as in diverse environments and deployment scenarios."

In simple terms, terrestrial technologies are commercially viable in the densely populated urban areas, while satellite internet provides a better business case for sparsely populated regions.

A Framework for Beaming Internet from Space

In principle, just a few High Throughput Satellites (HTS) are sufficient to cover a country as vast as India and provide high-bandwidth, high-speed, reliable internet. These high-throughput satellites can be placed in Low Earth Orbit (LEO), Middle Earth Orbit (MEO), and Geosynchronous Earth Orbit (GEO) orbit. The lower orbits have substantially lower latency than the higher orbits but they require a higher number of satellites to cover the same area. Lower latencies are absolutely necessary for good-quality internet. Since satellites LEO and MEO are moving constantly with respect to ground, they take turns to serve specific regions on Earth. Some ground infrastructure, called 'ground nodes', are required to connect to the servers on Earth.

A constellation of about 150 satellites will be sufficient to cover most of the developing countries whose internet demand is growing rapidly. From a business perspective, these countries represent a huge opportunity which can be tapped by satellite internet as it offers higher penetration rates. This is the plan for Astrome, a start-up incubated at the Indian Institute of Science (IISc), Bangalore.[17] Astrome's HTS, which act as 'floating routers', will orbit the earth in LEO at about 1,400 km from the Earth's surface. With this in place, it is possible to provide a bandwidth of 50 megabytes per second to home users, and 400 megabytes per second to business users, for both downloads and uploads. Since bandwidth depends only on the satellite, the location of the user does not matter—for a given cost, consumers in either a big town or a tiny Himalayan hamlet will get the same bandwidth.

Pervasive Internet: What can it enable?

Access to broadband is a "vital enabler of economic growth, social inclusion and environmental protection".[18] By improving connectivity, a reliable broadband coverage has the potential to transform a country. A World Bank study estimates that a 10-percent increase in broadband connectivity in a country can increase its GDP by 1.38 percent.[19] In the case of India, research has shown that 100-percent internet connectivity by 2020 can add an extra $1 trillion to its GDP.[20] These economic benefits are accrued from dramatic changes in the way people connect with each other, the government, and businesses. With the advent of pervasive internet, as promised by the proliferation of satellite internet technologies, one can expect dramatic transformations in the way some of the essential services are delivered. At the same time, internet also opens up a plethora of opportunities for start-ups to develop technology-enabled products and services that cater to various sections of people.

1. Catalysing business: With quality internet, people living even in far flung areas can also avail banking services through their mobile phones, and benefit from the financial security that comes with it. In fact, in 2015 alone, mobile internet contributed $3.1 trillion to global GDP, and lifted millions out of poverty.[21] In India, in 2013, the internet economy contributed $60 billion or 2.7 percent of the country's GDP, and by 2020, the contribution is expected to reach four percent.[22]

Internet is fast becoming a critical resource for Indians. A rural entrepreneur from Gujarat, for example, has improved his wood block painting business by promoting his products on a Facebook page. An enterprising farmer from Sangli, Maharashtra, once rallied 25,000 farmers on Facebook to stop the crashing of turmeric prices in the local market. A Bangalore-based mobile phone store has managed to reach out to customers in far-off states like Assam and Jammu & Kashmir through its association with e-commerce companies. In urban localities, tens of millions of users are making transactions on consumer-to-consumer portals. By 2018, around 8 million market-place websites are expected to be using the internet to connect to customers online, and the internet economy is expected to create 1.5 to 2 million jobs.[23] With 160 million active users every month, India is the largest market for WhatsApp, and many of these users get on WhatsApp to sell their goods to customers who they will otherwise not have access to.[24]

The Indian government is also making a strong push towards building a digital economy by encouraging cashless transactions. The direct electronic transfer of subsidies to the bank accounts of millions and millions of citizens is just an example for how state-of-the-art technologies can help reduce corruption and improve governance. Recently, the government also released the Unified Payment Interface (UPI), a payment system that facilitates seamless fund transfer between two bank accounts.[25] The app does not require bank account details and sending money is claimed to be as simple as sending a text message. The government has also released Aadhar Payment App, an application which enables merchants to receive payments from customers who do not have a mobile phone, but have the

Aadhar number. This app uses fingerprints for authentication, and requires a decent internet connection.[26] With satellite internet, this revolutionary app can be made usable in every nook and corner of the country. Apart from these apps, the government has also introduced RuPay, a debit card which comes with lesser transaction costs as compared to other cards in the market.[27]

The Indian entrepreneurial ecosystem is also cashing in on the opportunity by coming out with various fund transfer apps, each with its own flavour.

2. Education: In absolute numbers, Indian higher education system is the third largest in the world, next only to the US and China. However, only a few educational institutions of higher learning are equipped with infrastructure for delivering quality education. The IITs, which are known globally for their quality training, cater only to less than ten thousand students.

High-speed broadband internet can take learning materials even to those who cannot attend these elite institutions. Scores of students and professionals learn new skills through popular educational websites like MIT Open Courseware, and online platforms like edX which connect learners to the best universities in the world. The National Program on Technology Enhanced Learning (NPTEL), a joint initiative of the IITs and the IISc, is creating hundreds of Massive Open Online Courses (MOOC) to which students can enrol and get certified in various subjects.[28] Free and Open Software in Education (FOSSEE), part of the National Mission on Education through Information and Communication Technology (ICT), Ministry of Human Resources and Development, is enabling students to improve their computational skills by learning new free and open source tools online.[29] The reach of such relevant and ambitious programmes is hindered by the absence of internet in many of the smaller towns and villages in the country. Satellite internet can go a long way in taking these initiatives to the doorstep of every learner in the country.

3. Healthcare: Like education and finance, healthcare is a basic service that must be easily available to every citizen of the country. However, a single statistic puts India's healthcare system in perspective: only two percent of the country's doctors cater to the rural areas, which are home to 68 percent of the total population. Public health centres are understaffed, and often, are too distant to be visited by many villagers. With the availability of satellite internet, specialist doctors can remotely monitor patients and help in early diagnosis of various medical conditions. The availability of such preventive healthcare facilities can also have a positive effect on the finances of rural households.

4. Smart Cities: Cities around the globe are becoming hubs of economic activity. They occupy two percent of the total land area, accommodate more than half of the world's population, account for 70 percent of global GDP, consume 60 percent of global energy consumption, emit 70 percent of greenhouse gases, and produce 70 percent of total waste.[30] Obviously, managing cities is becoming a challenge to all governments. The Indian context gets more complicated because of the wide economic disparity among the urban middle class and the urban poor. The government's Smart Cities Mission aims to leverage state-of-the-art technology to improve the quality of life in the country's crowded cities. The smart cities, among other things, are thought to be brimming with sensors that constantly monitor water and electricity supply, air pollution levels at designated areas, and flag concerned officials automatically. These sensors require internet connectivity to communicate among themselves and to the central server that transforms raw sensor data into actionable insights. Though urban areas are covered by optical fibres, satellite internet can be used as a backup when the primary network breaks down in case of an emergency.

5. Smart Agriculture: Agriculture, the sector which employs about half of India's workforce, provides plenty of opportunities for technological intervention at various stages. Sensors that can measure moisture content in the soil can ensure that the crops are grown at the right moisture level, and can also help save water in large quantities. Video surveillance systems can help farmers monitor their agricultural lands electronically.

India is second largest in the world in terms of farm output. Yet it also loses a significant proportion of its produce to waste, due to poor storage and transportation facilities. Technology solutions can be developed to centrally monitor storage facilities scattered across the country. Tracking of vehicles that transport agricultural produce can also go a long way in improving the overall logistics of the agriculture sector. A pervasive internet can enable these interventions in a sector that forms the backbone of the rural economy.

What Needs to be Done?

The proliferation of broadband has helped improve the quality of life of people across the globe. Mobile phones, with their astounding penetration rates, are becoming the most popular mode of accessing the internet. The need of the hour is to make high-bandwidth, broadband internet universally available in India. Experience has shown that "value is shifting away from connectivity towards a portfolio of mobile-enabled services".[31] Thus, governments and private entities should create applications that are tailored to the needs of different sections of people. Also, various stakeholders should come together to increase awareness about the utility of broadband by conducting awareness campaigns, training programmes, and developing and hosting content in local languages. This could be a particularly challenging task in India because of the country's inherent cultural and linguistic diversity. A number of start-ups have already risen up to this challenge by creating visual apps and content in local languages.

Internet connectivity is not a game changer by itself. What it provides is the basic infrastructure for developing technology solutions that solve real issues faced by a large number of people. At the same time, it opens a great opportunity for entrepreneurs to develop solutions to serious challenges in critical sectors like financial services, education, healthcare, and agriculture. Without such specific solutions, the power of the internet as an enabler of socio-economic change is not fully realised.

Some changes are needed at the policy level, too. ISRO has laid a strong foundation for the Indian space programme. It is high time that the government drafted policies to enable the private sector to build on ISRO's pioneering work, and build products and services not only for India but for the entire world. The country's experience in other sectors, especially in telecommunications, has only shown that private sector participation ultimately results in better services to the consumer. In the case of space, private players may well relieve ISRO of creating routine infrastructure and let the organisation focus more on challenging space missions.

Conclusion

Robust economic growth over the last few decades, increased investments into R&D, and proactive policies have helped India to embark on a journey of technological transformation. As the country prepares itself for the road ahead, it should first address the wide disparity in the availability of technology to its citizens. Making high-bandwidth, broadband internet available to everyone is one of the best ways to make technology more democratic. However, ground infrastructure may not be the best choice for some of the rural and remote areas of the country.

This chapter argues that the time is ripe for leveraging satellite internet, a technology that is unparalleled in its reach and reliability. Pervasive internet, delivered from space, has the potential to transform the way basic services like banking, education, and healthcare are delivered to citizens of the country. Of course, for a country that has a tradition of utilising space technology for social good and progress, beaming internet from space could well be the next obvious step.

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5

Unlocking the Potential of Geospatial Data

Arup Dasgupta

Introduction

For the planned development of a vast country like India, timely and accurate information on various natural resources is vital. Such information can be used for the optimum management of these scarce resources. The spectacular advances in space science and technology in general, and geospatial techniques like remote sensing, Geographical Information Systems (GIS) and Global Positioning System (GPS), in particular, have emerged as reliable and powerful means to this end.

India's tryst with geospatial technology is not new. India boasts institutions like the Survey of India, the Geological Survey of India (GSI), the Forest Survey of India (FSI) and the Departments of Land Records in different states, which have been around for at least a century. These organisations have been updating their systems with new technologies, though not perhaps as efficiently as is desirable.

Some of the points of inflection which mark the induction of new and disruptive geospatial technologies can be outlined. The Pre-investment Survey of Forest Resources conducted by the government in collaboration with ITC in the 1960s was the first time an aircraft was used for remote sensing. From this followed the establishment in 1966 of the Indian Photo-interpretation Institute (IPI), now known as the Indian Institute of Remote Sensing (IRS). The next milestone was in 1969 when the first United Nations conference on the exploration and peaceful uses of Outer Space

(UNISPACE) was held in Vienna. Dr. Vikram Sarabhai noted in his report to the conference the importance of remote sensing for developing countries like India. He said:

> "When we came to Vienna, we thought that the areas of most immediate practical application would be communications, meteorology and navigation, in that order. But one of the most striking things to emerge has been appreciation of the great potentiality of remote sensing devices, capable of providing large-scale practical benefits. One of the group discussions considered the cost effectiveness of these techniques, and it was pointed out that there is a high cost benefit ratio, which, for example, in cartography, can be as much as 18:1. The time has come to interest meteorologists, hydrologists, surveyors, agricultural specialists and other groups in such programmes. The Chairman of the thematic session summarised the consensus that aircraft could initially be used because of their comparatively low cost. There is need, to begin with, to understand problems of interpretation. Remote sensing cannot replace man on ground, but can direct man's efforts on ground to be more efficient."[1]

Remote Sensing in India: A Brief History

The Indian foray into remote sensing from space began in 1975 with the country's participation in the analysis of data obtained by the Landsat satellite the same year, and the setting up of the National Remote Sensing Agency and its Landsat Data Reception Station. The launch of INSAT 1A and 1B in 1982-83 with a Very High Resolution Radiometer onboard for meteorological applications was the next step. In 1988, India entered the age of operational land remote sensing from space with the launch of IRS-1A carrying 70m and 35m-resolution CCD cameras. The IRS programme went international in 1994 with the signing of an agreement with EOSAT, the company which operates the Landsat satellites, to market IRS data globally. Indian users also got access, albeit controlled, to the metre and sub-metre resolution data from the private satellite operators. In1999, the Indian Space Research Organisation (ISRO) launched Oceansat-1 as its first satellite to observe marine phenomena in optical and microwave wavelengths. RISAT carrying a Synthetic Aperture Radar was launched in 2012. With this, ISRO achieved the capability of imaging land and sea from wavelengths that extended from the optical to the infrared to microwave, an achievement not many other countries have managed.

Programme Evolution

The two departments which played key roles in the evolution of geospatial technologies in India are the Departments of Space (DOS) and the Department of Science and Technology (DST). The two have always worked in sync to introduce and promote new technologies. The IRS programme was conceptualised and launched in 1981. Simultaneously, the then Chairman of ISRO, Prof. Satish Dhawan coordinated with the then Secretary of Science and Technology, Prof. M. G. K. Menon, to launch a programme called the National Natural Resources Management System (NNRMS) that would prepare Indian scientific departments to use the data from IRS. NNRMS was established in 1983 by the Planning Commission and had the participation of all government departments and ministries. One of its activities was the assessment of the forest cover of India in 1984. Using Landsat data, the DOS released a figure of 17 percent, a far cry from the 33 percent claimed by the FSI. There was a hue and cry, and the number was ultimately revised upward after much discussion, but the 33 percent claim was put to rest. The outcome was that the FSI began to use remote sensing to periodically assess the forest cover of India. The NNRMS programme resulted in many new initiatives, such as the mapping of potential groundwater zones, wastelands, grasslands, water bodies and coastal zones, to name a few.

All these efforts were in the nature of inventories and soon the question began to be asked: What next? The question was sought to be answered with a programme called the Integrated Mission for Sustainable Development started in 1986, which sought to use remote sensing to plan for better management of land and water. This programme and another one on Scientific Source Finding for the Drinking Water Mission in 1985 brought out an important fact – that remote sensing by itself was not enough. It needed information from many other sources, and planning activity had to take into account the aspirations and expectations of the people, who were to be the ultimate beneficiaries of the programmes. There was, at this juncture, a standoff between the remote sensing purists who refused to countenance any other data source or data management system, and the planners who needed tools to evolve decision support alternatives. This laid the ground for the entry of GIS.

Experimentation with GIS began almost in conjunction with IRS, and by 1989 GIS had found its way into the DOS, the DST, the Survey of India, the FSI and other major departments. Two major projects under the NNRMS, the Natural Resources Data Management System of the DST and the National Resources Information System of the DOS spearheaded these efforts. Survey of India set up its Digital Mapping Centre and Modern Mapping Centre to cater to the upcoming requirement of digital base maps for GIS. A major exercise to define a Digital Vector Data Standard was undertaken, as well as a national Spatial Data Exchange standard for vector and raster data.

Meanwhile, Global Navigation Satellite Systems began to revolutionise position location and the use of GPS for precise location, survey and mapping became common. The removal of selective availability gave a great fillip to these activities. ISRO worked with Airports Authority of India to establish the GPS Aided Geo-Augmented Navigation (GAGAN), a space based augmentation system for aircraft navigation using GPS. A regional navigation system, Navigation with Indian Constellation (NAVIC) has also been established recently to provide an exclusive positioning and navigation system for India under its own control.

Expansion and Growth

The growth of these activities also saw a parallel expansion in Indian industry. Many multinational corporations (MNCs) began to tie up with Indian firms to market their geospatial products in India. The IT industry, which expanded in the 1990s, also began to address the geospatial market. The DOS also actively promoted the growth of geospatial entrepreneurs and many professionals took voluntary retirement from its ranks to open geospatial service companies and even manufacturing units for image analysis systems. Large mapping projects were also outsourced by the government which encouraged the growth of this service sector. A large part of this growth was also the result of Defence requirements, and many companies had special units which catered exclusively to the needs of the Army, Navy and Air Force.

As can be seen from this rather concise history, geospatial activities in India are almost wholly government driven. The private sector has a role to play in supporting these activities. However, use of geospatial technologies by and for private industry is rather limited. There are a few examples like Hindustan Lever which uses geospatial technologies for Supply Chain Management, Hindustan Construction Co., which used it to manage its mega urban project Lavasa, and Reliance Power and Reliance Communications.

Current Status

Today, investment in major government projects which use geospatial technology is growing at a compound annual growth rate of 30 percent. Programmes like the Restructured Accelerated Power Development and Reforms Programme (RAPDRP); the National Land Records Modernisation Programme (NLRMP) and the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) together have an investment of nearly INR 5,000 million. Most of the work related to geospatial and IT is outsourced to private industry. These numbers do require a leap of faith because work has been slow, but it is picking up. The interesting fact about these programmes is the way geospatial technology is being incorporated into their systems.

If the initial phase consisted of managing geospatial data by way of mapping and listing inventories, the current phase is one of managing data geospatially by making geospatial systems an integral part of the IT infrastructure of the programmes. Thus the GIS component of RAPDRP is a part of its overall IT strategy to make power distribution efficient and reduce losses. Similarly, the geospatial component of the NLRMP seeks ways to use the technology to rapidly map land holdings and update all the Records of Rights and make these available through an IT infrastructure. The process of updating land records is well established and the geospatial and IT components have been woven into this process. The JNNURM is, however, a different story. While it does recognise the importance of geospatial technology for mapping and updating maps at regular intervals, it seems to have restricted the usage to determining taxes and building permissions alone. Little wonder then, that of the 63 cities initially picked up for the mission, not one has effectively integrated geospatial systems into its IT infrastructure. However, this too will change with geospatial activities picking up.

Other major sectors of significant geospatial activity are Defence and Homeland Security. The Directorate General of Information Systems of the Ministry of Defence has a major programme for inducting geospatial systems into its Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) activities. The National Technical Research Organisation (NTRO) is similarly inducting the latest technologies into its activities for Homeland Security. Both these sectors provide huge opportunities for the Indian geospatial industry.

Future Directions

As a promoter of remote sensing and satellite communications, the DOS has been in constant touch with ministries. At a recent interaction it zeroed in on about 160 projects across 58 ministries/departments in the areas of Natural Resources Management, Energy and Infrastructure, Disaster and Early Warning, Communications and Navigation, e-Governance and Geo-spatial Governance and Societal Services.

These 160 projects encompass applications across varied domains: Earth Observation and Geospatial (97 projects), Communications and Navigation (30), Technology Development (10), Meteorology (6), Asset mapping and Mobile applications (8) and others (9). Some of these projects will also render support to flagship programmes of the government such as the Atal Mission for Rejuvenation and Urban Transformation (AMRUT), the Smart Cities project, the Pradhan Mantri Awas Yojna (PMAY), the Clean Ganga project, the Pradhan Mantri Krishi Sinchai Yojana (PMSKY), the Digital India project, among others.

Space Applications Supporting Flagship Programmes of the Government

Atal Mission for Rejuvenation and Urban Transformation (AMRUT)

The objectives of AMRUT are as follows: (a) to ensure that every urban household has access to a tap with assured supply of water and a sewerage connection; (b) to increase the amenity value of cities by developing greenery and well maintained open spaces (e.g. parks); and (c) to reduce pollution by encouraging a switch to public transport and improving facilities for non-motorised transport (e.g. walking and cycling).

A large scale geospatial database on a scale of at least 1:4,000 is essential for a city level master plan, as well as for spatial planning and implementation of the utilities planned under AMRUT. The programme covers 500 cities with populations of 100,000 and above, covering all states and union territories (UTs). AMRUT Cities GIS Database Design Standards document has been prepared by ISRO and the Ministry of Urban Development (MoUD) along with state town planning departments. Urban and Regional Development Plans Formulation and Implementation (URDPFI) guidelines have also been released.

The work involves preparation of base data (five base layers and 28 urban land use layers) on a scale of 1:4,000 for 500 towns and cities to enable formulation of a master plan for urban transformation.

The preparation of the AMRUT Cities GIS database is scheduled to be completed in two years, with 100 cites being completed every six months. The database will be hosted on the Bhuvan Geo-platform and provided to the concerned urban local body over the Cloud for the preparation of the master plan and Infrastructure plans. GIS tools have been developed on Bhuvan in open source for the preparation of the master plans.

Already, about 3,500 town planning personnel are being trained in how to using the Bhuvan GIS tools to prepare the master plan.

Smart Cities

The large-scale GIS database prepared under AMRUT will also be used for smart cities. Selected smart cites will be taken up on priority basis to complete the GIS based Master Plan preparation.

Pradhan Mantri Awas Yojana – Housing for All (Urban)

This mission will be implemented from 2015 to 2022 and will provide central assistance to urban local bodies and other implementing agencies through states and union territories for *in-situ* rehabilitation of existing slum dwellers using land as a resource through private participation. There will be credit linked subsidy for beneficiary-led individual house construction and enhancement. ISRO is working with Ministry of Housing and Urban Poverty Alleviation (MoHUPA) for effective monitoring of the progress of construction through mobile based geo-tagging of beneficiaries' houses.

National Mission for Clean Ganga

The key to rejuvenation of the river Ganga is a shift in the approach towards rivers, and the formulation of a multi-pronged action plan using cutting edge technologies like space technologies for effective monitoring and improvement of water quality.

ISRO and the National Mission for Clean Ganga (NMCG) have identified the need for utilising aerospace and other cutting-edge technologies for effective planning and monitoring of the activities taken up to clean the river. They have also agreed on a long term partnership utilising geospatial and crowd-sourcing technologies for water quality monitoring, development of a mobile application to enable community participation in monitoring, customising the Bhuvan geo-portal for visualisation, and developing web-based applications for river water quality monitoring.

The Bhuvan Ganga Portal is an exclusive web portal deployed in ISRO's Bhuvan geo-portal with all geospatial layers related to the river Ganga. It will be used as a tool to support decision making and planning for the Clean Ganga Mission. Information on total suspended sediments and turbidity for the 600 km stretch from Kannauj to Kanpur is being generated on a monthly basis using satellite data. The Bhuvan mobile app is a user-friendly android based application to enable the public to collect and report information on various pollution sources that affect the water quality of the Ganga. This app provides a platform for crowd sourcing to monitor pollution in the Ganga and thus enables decision makers to prioritise interventions.

Integrated Watershed Management Project (IWMP)

IWMP will ensure optimal soil and water conservation and assured crop irrigation through water resources harvesting, which helps to improve crops and provide sustainable livelihoods to the people residing in the watershed area. De-silting of tanks and other watershed activities that provide employment under the Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) programme are also being evaluated using satellite data. Presently, the IWMP is being carried out by ISRO in collaboration with the Ministry of Rural Development, to monitor and evaluate about 52,000 micro-watersheds in 10 states and 50 identified districts across the country.

Accelerated Irrigation Benefit Programme (AIBP)

A customised application software module on web-GIS, namely AIBP-Bhuvan, has been developed by ISRO and deployed for on-line monitoring of AIBP projects by the Ministry of Water Resources and internalised in the Central Water Commission (CWC) through capacity building. The CWC carries out online monitoring of 150 projects biannually covering pre- and post- monsoon seasons. It involves generating an inventory of existing irrigation infrastructure using high resolution satellite data and comparing it with the planned irrigation infrastructure to make an assessment of the critical gaps and additional irrigation potential created. These are used to reconcile the irrigation potential reported by state governments and for a critical review of the projects for further funding by CWC.

Other Major Space Applications

Programme on Horticulture Assessment and Management

Considering the importance of horticulture in food and nutrient security, and its export potential and economic benefits, a satellite technology based programme has been launched for the assessment and inventory of horticultural crops. It is being used to assess site-suitability for introduction and expansion of plantation and inputs for crop intensification in regions which are underutilised. The programme, called 'Coordinated Programme on Horticulture Assessment and Management using geo-informatics (CHAMAN)', will be carried out in different phases. Presently, the pilot phase includes seven crops – banana, mango, citrus, potato, onion, tomato and chilli, covering180 districts in 11 states. The programme will also pave the way for geospatial applications for infrastructure planning to minimise losses, as fruits and vegetables are perishable in nature.

Space-Based Information Support for Decentralised Planning

The state-wise natural resource database for the entire country on a scale of 1:10,000 is nearing completion. A Bhuvan panchayat portal has been developed for facilitating mapping of assets (281), planning of activities (29) and monitoring of schemes (71) at the panchayat level. It helps Panchayati Raj Institutions (PRIs) to track the progress of work undertaken by citizens under various schemes. Citizens in general and three tiers of PRIs in particular –the gram panchayat, the block panchayat and the district panchayat, are the users of the portal. The Ministry of Panchayati Raj plans to establish Satellite Communications Group (SATCOM) centres in every block (around 7,000 of them) for capacity building of PRIs and stakeholders.

Applications for Socio-economic Development and Benefits for the Common People

The Ministry of Tribal Affairs runs a programme identifying existing and potential water collection spots, which could be developed for fish culture using labour generated under the MNREGA. This scheme is for 168 tribal dominated districts (covering less than 25 percent of the tribal population) in 24 states/UTs. The work involves repeated satellite mapping and creation of a GIS database to identify potential fish breeding ponds. In order to use these satellite based maps, capacity building of state level officials has been carried out in Odisha, West Bengal, the North-East, Gujarat and Jharkhand.

Conservation of Heritage Sites

The conservation of world heritage sites – ancient monuments and archaeological sites – is of national importance, and also helps in development and promotion of tourism, one of the major engines of economic growth. A systematic database of heritage sites, and site management plans generated using space technology, will help to take informed decisions on the conservation, preservation and monitoring activities of heritage sites. Space based technology tools are also being planned to map and identify the vulnerability of each monument and prepare plans to track and mitigate damage caused to them by environmental or weather changes.

As a pilot project, inventory and site management plans have been completed for 516 heritage sites in Karnataka and uploaded on Bhuvan after validation. A proposal for similar inventory and site management plan for about 3,600 other heritage sites across the country has been cleared by the Ministry of Culture.

ISRO has developed a mobile application using a GAGAN dongle to collect the geo-coordinates of heritage sites in order to demarcate the zones around them – the 'protected' area of the monument itself, the 'prohibited' area, up to a radius of 100 metres of the monument within which fresh construction is disallowed and the 'regulated' area, up to a radius of 300 metres, within which any new construction requires a licence from the Archaeological Survey of India. The database of these coordinates will be integrated with the application portal of the National Monument Authority to determine whether a plot on which fresh construction is requested is within the protected, prohibited, or regulated zones, or totally outside them.

Automated Warnings at Unmanned Level Crossings Using SATCOM and Navigation Services

Pilot studies to install automatic warnings at unmanned level crossings have been carried out using GAGAN, Rail-Navigator tools, Mobile Satellite Services (MSS) based tracking systems and Bhuvan. The idea is to create a geospatial database containing the locations (the geographical coordinates) of unmanned level crossings and have GAGAN enabled devices mounted on train engines. A train mounted with such a device will know the location of unmanned level crossings and the train's hooter will automatically be activated when the train approaches an unmanned crossing.

Enabling Paperless Tickets for the Mumbai Suburban Railway through Geo-fencing

Western Railway has launched a mobile application for paperless ticketing on the Mumbai suburban railway, as a pilot project. ISRO has facilitated

Geo-fencing for the mobile app, using which a prospective commuter can book his ticket using his mobile, if his location is between 30 metres and 2 km of the outer tracks of the suburban lines. This service currently covers 35 stations on the 123 km long Churchgate–Dahanu section.

Geo-spatial Inventory of Post Offices

Web-based and mobile applications have been developed for geo-tagging of post offices along with the services offered by them. The geospatial database enables identification of the gap areas and planning for new post offices/services. Pilot studies on geo-database of post offices for the Mysore and Nanjangud divisions have been completed. Citizen-centric applications have been developed to locate the nearest post office with the desired services and the shortest possible route to the post office using a pocket Bhuvan. Geospatial database has also been initiated for mapping postmen's beats.

Data Connectivity for Rural India

ISRO has fast-tracked the realisation and launch of the GSAT-11 communication satellite. GSAT-11 is an advanced communication satellite with Ku and Ka Band communication payload, capable of providing up to 10 Gbps throughput. With such capacity, this satellite is expected to provide high bandwidth data connectivity for rural India as envisaged under Digital India. The satellite is targeted for launch in 2017.

Android Applications for Monitoring Rural Development Programmes

Space technology support is envisaged towards:

- Geo-tagging and time stamping of stages of development to evaluate the progress of projects
- Identifying of areas for taking up activities enabling work generation

The Ministry of Rural Development is implementing a number of programmes such as the Pradhan Mantri Gram Sadak Yojna (PMGSY), the MNREGA, the Indira Awas Yojna (IAY) and the IWMP, in rural areas through state governments to reduce poverty, generate employment, build rural infrastructure, develop habitat and provide basic minimum services.

Rural employment guarantee projects span a variety of activities ranging from earthworks to establishment of plantations, which can alter the land cover status. Activities such as renovation, setting up anganwadis, providing rural drinking water, creating fisheries, improving food grain production and sanitation may not register any land cover change, but an android application has been developed which will be useful in capturing these activities through good quality geo-tagged photographs of the sites which can be uploaded to a server through a wireless or wired network.

Bhuvan already has in place an initial version of an application for monitoring progress of housing activities, using Android technology along with direct wireless network based upload capacity. The Andhra Pradesh government's State Housing Corporation has used the app successfully for operational monitoring and evaluation of building activity, and on the basis of its data provided approvals of final fund allocation, in a much shorter period than the process usually takes.

Monitoring the construction of rural roads is not easy. It has to be done at specific times across different stages to ensure it will have all weather connectivity. It requires huge investments, too. Roads selected may be existing oft-used roads between habitations. The Android application created for monitoring should have the capacity to record the stages of road construction at regular intervals, with enough benchmarks, and cover the entire process of building. Since road construction has stages corresponding to the preparation of a construction site, with different materials having to be laid, field recording has to cover all these stages in all key locations for comprehensive understanding. Construction of culverts also has stages and these too need to be recorded accordingly.

With the advent of higher resolution satellite data, it may be possible in the future to identify individual structures as they are built. The app devised could also have a 'citizen module' for people to upload requests for permission to construct houses, with the pre-construction status of the land selected clearly captured. The Bhuvan interface has been designed and developed, for specific use of space technology to facilitate evaluation and monitoring of key rural development activities like road building and house building.

Weaknesses and Threats

As with everything in India, geospatial systems and applications offer a huge opportunity but also face hurdles. The biggest hurdle is that of data sharing followed by data policies and lack of trained human resources.

Data Sharing

Indians tend to be very data secretive. As a result, the same data is collected over and over again by different departments, and often by different teams from the same department. As mentioned earlier, two major projects, NRDMS and NRIS attempted to create structured geo-databases on the basis of the Indian administrative structure. From this it was a short step to creating a Spatial Data Infrastructure which could be shared by different departments and provide data for academia and industry as well. This effort, originally called the National Geospatial Data Infrastructure and later renamed the National Spatial Data Infrastructure (NSDI), was launched in 2001 by DOS and DST. After several meetings, the task group on NSDI submitted its report in 2006. On 02 June 2006, the Cabinet approved the creation of NSDI and constituted a National Spatial Data Committee and an executive committee with a secretariat to assist the two committees. An NSDI geo-portal was established on 22 December 2008. However, the providing of information about the data held by different departments to this geo-portal is still incomplete. Meanwhile individual portals have been set up by different departments and states. NRSC has its own platform on Bhuvan, while Survey of India and NIC have their own portals. Portals of the Census of India and GSI are also available. As a way out of this resistance to data sharing, NSDI promoted state portals, so that the states could retain control over their data. Other useful efforts of the NSDI such as the establishment of core metadata standards, Geography Mark-up Language (GML) schemas and thematic standards have gone unnoticed.

Notwithstanding the poor progress of NSDI, a new project, the National GIS (NGIS), was promoted by the erstwhile Planning Commission to replicate the work of the NSDI and in addition, provide development support services for states (DSSS) for different departments of the government. NGIS was to have been implemented by the DST. Ultimately, the Digital India Programme took over these efforts, saying:

"Various government services can be offered in a better way by proper use of GIS technology in e-governance applications. National Geospatial Information System (NGIS) is being implemented to integrate geo-spatial data available with a number of organisations such as Survey of India, National Informatics Centre (NIC), NRSA and Ministry of Earth Sciences (MoES) to develop a GIS platform for e-Governance applications.

"This GIS platform will be leveraged as a service for the benefit of various mission mode projects and other e-governance initiatives. NGIS can also be leveraged for monitoring the physical progress of projects, disaster management and specialised needs of public safety agencies".

While this is a good move, no mention was made at all of the new National Centre of Geo-informatics (NCOG) that had been set up as an independent business division of Medialab Asia, and its relationship with other simultaneous efforts. Looking at the stated objectives of NCOG, the confusion deepens. It positions itself as a 'one of a kind GIS Platform' to support 'sharing and collaboration of GIS data, location based analytics and DSS for Central and state government departments'. This sounds suspiciously like the same reasons put forward for setting up NSDI and NGIS. NCOG also takes on itself everything from geospatial resources, applications and solutions to human resources development, collaboration with public and private agencies and R&D.

Clearly, there is enough confusion at the level of the government itself as to who is doing what in the matter of geospatial applications. This highlights the problem of moving ahead with geospatially enabled governance in India. Without any meaningful discussion among themselves, government departments have moved ahead creating their own versions of Spatial Data Infrastructure leading to waste of taxpayers' money in half-baked initiatives and duplication of data.

The main drawback, as has been pointed out, is the unwillingness to share data. But confusion could have been avoided by making sharing mandatory. For example, the R-APDRP and JNNURM will require base data which could be supplied by the NSDI through the state portals. This would require a standardisation of the data at the structural level as well as at the thematic level. NSDI has standardised on GML for the structure and this schema could be adopted. Thematic standards have been prepared from time to time by different projects. These need to be vetted and adopted as national standards to ensure semantic interoperability.

Data Policies

The key feature of geospatial data is geo-referencing. It encompasses maps, imagery and point information generated by GPS as well as by other means of data acquisition. The right to generate data is wholly with the government. Space data is generated and distributed by the DOS alone and topographic data is the responsibility of Survey of India. Aerial surveys, including those using Unmanned Aerial Vehicles (UAVs), are regulated by the Director General of Civil Aviation (DGCA) the Ministries of Defence and Home Affairs, and are subject to stringent controls. Because of the spatially referenced context, such data is considered to be strategic, and therefore its generation and access is controlled by the state. This control is by way of established policies.

The Map Policy regulates access to maps created by the Survey of India. The Open Series of Maps (OSM), available to general users, is subject to several licences. Maps of coastal and international boundaries are secret in the OSM series. No height data is included in the OSM series. Third party value addition to OSM maps becomes the intellectual property of the Survey of India. A new Map Policy is in the process of being released which will reduce, but not remove, these restrictions.

Remote sensing is controlled by three policies. Aerial survey and UAV policies have been mentioned earlier. The DOS has a Space Remote Sensing Policy that regulates access to data having resolution better than one metre. Data better than one metre resolution, such as Cartosat 2A and 2B data and foreign panchromatic data is subject to screening. The group of government users who are eligible to use such data without further clearance are spelt out in detail. This was an area of ambiguity in the earlier policy and created problems for many projects like R-APDRP, which were being executed by PSUs.

Antrix, which handles access of foreign entities to IRS data, can also enter into agreements with foreign data suppliers for marketing their data in India, in addition to NRSC. But NRSC continues to be the sole data distributor and in practice, is a single point choking off data supply. Private users need a government certificate stating that the data is for development purposes in India only before getting access to sub metre data from all satellites. For those without such a certificate, the request is referred to a High Resolution Data Committee for approval.

These policies effectively control and regulate the use of Indian data by Indian users, but are ineffective in controlling their legal or illegal use by foreign entities. Indian map data is available off the shelf abroad and even on the Internet. High resolution data on India from foreign remote sensing satellites is also available on the Internet on payment, and free on applications like Google Maps. Stereo imaging data from foreign satellites can be used in a standard digital photogrammetry workstation to obtain accurate height information, which can be superimposed on the Open Series maps. GPS is now available commercially on mobile phones and car navigation systems, thus enabling 10m or even sharper accuracy in positioning.

Meanwhile, the Ministry of Home Affairs has come out with a draft Geospatial Information Regulation Bill 2016 which is so restrictive that it could, if adopted, actually hinder the adoption of geospatial technologies by the government, industry and academia. A new Geospatial Data Policy 2016 has also been announced by the DST which is much more enabling, but the problem is that a Bill will always override a policy. There is need to ensure that the proposed geospatial data policy is realistic and addresses the needs of bonafide Indian users in the government, industry, education and NGO sectors. It is necessary to revisit the several separate policies and evolve a unified geodata policy which will satisfy development and civilian applications, while at the same time taking care of national security concerns.

Capacity Building

There are various institutions in India that offer post-graduate courses in Geomatics or more specifically, Remote Sensing and GIS. A shared problem is that students who take these courses do not find suitable placement. At the same time, industry bemoans that it is not able to get trained people. To understand, consider the definition of Geographic Information Science by the University Consortium of GIS:

"Geographic Information Science (G I Science) is the basic research field that seeks to redefine geographic concepts and their use in the context of geographic information systems. G I Science also examines the impact of GIS on individuals and society, and the influences of society on GIS. G I Science re-examines some of the most fundamental themes in traditional spatially oriented fields such as geography, cartography, and geodesy, while incorporating more recent developments in cognitive and information science. It also overlaps with and draws from more specialised research fields such as computer science, statistics, mathematics, and psychology, and contributes to progress in those fields. It supports research in political science and anthropology, and draws on those fields in studies of geographic information and society."

Industry considers geospatial technologies related to IT and recruits people with IT backgrounds for it. Unfortunately, India's education system is such that these graduates know little about geography beyond their Class X 'Social Studies'. Institutions are more perceptive and select students with backgrounds in the kind of subjects mentioned in the definition of G I Science, but they may not be as well versed in computer applications programming.

What is needed therefore is not separate courses, but G I Science electives in existing courses in computer science, statistics, mathematics, geography, physics, life sciences, engineering and management. Administrators in the government and industry need to go through such courses as well during their induction training. State academies for administrative training need to hold refresher courses from time to time to update their staff capacities. A beginning has been made in introducing geospatial subjects in school curricula by the Central Board of Secondary Education. This needs to spread to all other Boards as well so that the importance of geospatial applications and technology is understood and it becomes a career option for students entering college.

People as Sensors

The relaxation of restrictions and the creation of a geospatially enabled population will also help to promote Volunteered Geographic Information (VGI). For a country of India's size and diversity, the acquisition of data is a major task. VGI can provide a cost-effective solution. The operationalisation of NSDI should include processes to enable VGI and its vetting and ingesting into the relevant databases. The government lays stress on government-to-citizen interfaces through IT enabled services. This should include geospatial information to enable citizens to understand and perhaps even participate in the decisions that impact their lives and living spaces.

Private-Public Partnership

The government is also keen on Private-Public Partnerships (PPPs). However, their scope is rarely defined in concrete terms and is usually reduced to contract services. If geospatial enablement is to take off, industry involvement has to move beyond supply of hardware and software. For example, in JNNURM, the problem is that of an urban planning mindset which is tied to 'building permissions' and 'tax collection'. Very few metropolitan cities have planning departments and those that do are staffed at best by eight to 10 planners under an engineer, all of whom are busy with building permissions, rather than planning, because they are short of personnel, under-budgeted and lack modern geospatial tools like GIS.

The need is for 80 to 100 planners for a large city and their domains of expertise should cover the various sectors of planning as well as economics and architecture. Needless to say, they also need to be able to handle modern geospatial technology in their planning processes. This technology goes much beyond a simple GIS and encompasses new data acquisition systems, Enterprise Resource Planning (ERP) and modelling. This is an area where PPP in its truest sense can really take off.

While JNNURM provides the entry of geospatial technologies into urban management through its stress on the use of GIS for efficient tax collection and rational building permissions, geospatial professionals with domain knowledge should use this opportunity as the thin edge of the wedge to push into city and town planning technologies which recognise and account for social, cultural and economic factors along with engineering considerations. JNNURM is the start of the Smart City and a city becomes smart when it provides a sustainable enabling environment to its population.

Today, geospatial technologies are adopting new technologies and processes. Cloud, Big Data, Internet of Things, Deep Learning are the latest tools which are already in use in the business environment. Early adopters have shown that these can be very useful in the geospatial domain too. This is another area for PPP.

The Geospatial Trajectory

Overall, the trajectory of India in the geospatial space is highly promising. However, considerable efforts are needed to realise these promises. So far, India has been enterprising and has worked around obstacles; after all, the Indian ethos is one of compromise and improvisation. With new projects on the horizon and the urgent need for development, geospatial systems have become a necessity. The government, industry and academia need to pull together to achieve goals set for the next five years.

Endnotes

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6

Developing a Space Start-up Incubator to Build a NewSpace Ecosystem in India

Narayan Prasad

The development of India's space industry started in the 1970s with the Indian Space Research Organisation (ISRO) helping entrepreneurs kick-off Small and Medium Scale Enterprises (SMEs) by providing technology and buy-back opportunities, while encouraging spin-offs.[1] Today the landscape of the Indian industry that serves ISRO includes about 500 of these SMEs.[2]

With the increase in demand for space-based services in the country—it is projected that 70 operational satellites will be needed in the country in the next few years[3] —the ISRO is increasing its engagement with the space industry for the production of both satellites and launch vehicles. Industry consortiums are being floated for the production of the Polar Satellite Launch Vehicle (PSLV)[4] and the Indian Regional Navigation Satellite System (INRSS) satellites.[5] This brings a unique opportunity for the Indian industry ecosystem to build up, for the first time, systemic capacity to deliver end-to-end space systems in the country.

This development in the traditional space industry is based on a two-pronged approach. One, to transition to a state where the industry can achieve the required volumes of satellites and launch vehicles under ISRO supervision while allowing ISRO to focus completely on novel technology development over a longer period; and second, to serve as boon to the

'Make in India' initiative. This is a welcome step in further maturing the capacity of the Indian industry while it has both supervision and customer in the form of the ISRO.

The effect of such increased trust in Indian industry by ISRO shall provide it further confidence to invest in infrastructure that can deliver ISRO's needs. The satellite AIT industry consortium has already accounted for commitments worth INR 100-150 crore in investments[6] to set up facilities that can support the operations required. In the current growth trajectory, Indian industry, under ISRO supervision, will be equipped to deliver rockets and satellites by 2020.

While these developments are encouraging, India is also now seeing a growing NewSpace phenomenon. Backed by private investors, Team Indus, for example, is the first Indian private company to sign a launch contract with ISRO.[7] Bangalore-based space start-up Astrome Technologies, meanwhile, intends to launch 150 satellites into space by 2020,[8] providing high-speed affordable internet to remote locations in the world. Astrome's technology and the use of satellite for internet can provide a significant boost for the government's aim to connect 244,729 Gram Panchayats (GPs) across the country. Currently, the government is pursuing the National Optical Fibre Network (NOFN) plan of connecting the GPs through optical fibre cable (OFC). According to recent media reports, OFC in 76,728 GPs and optical fibre in 64,599 GPs have been laid,[9] which allows significant room for satellites to contribute to the Digital India initiative.

Similarly, NewSpace is also having an effect on the downstream ecosystem. Companies such as SatSure are building analytics engines based on satellite and complimentary sensor data to help decision-making[10] by governments, insurance and re-insurance companies, banks, pesticide and seed companies, and commodity trading firms. These are exciting developments in the space industry of India.

Why encourage NewSpace in India?

In order to understand the possible growth trajectories for traditional and NewSpace to exploit their full potential in developing a scalable space economy in the country, it is important to understand the key underlying differences between the traditional and NewSpace approaches.

- **Customer Landscape** – Traditional space industry approach largely depends on taxpayer-funded requirements within the national demand framework administered by a space agency. This is a process that several countries have pursued in upgrading their industry capacity. NewSpace tries to build up B2B and B2C models which can scale both nationally and internationally without heavily leaning towards traditional space industry approaches for the majority of the business to stay afloat.
- **Technology Landscape** – NewSpace companies try to use novel approaches such as design using Commercial-Off-The-Shelf (COTS) components while trying to reduce the cost of the overall system. Meanwhile, traditional space companies are dictated by legacy space agency-based approaches. The idea is also to use the approach of fail-fast and iterate quickly to constantly scale. However, this also increases the risk of failure.
- **Product/Service Development Landscape** – Traditional space industry in India has typically been providing services of manufacturing according to the final integrator (ISRO) requirements at Tier-2/Tier-3 levels with the initial technology and know-how itself being mostly borrowed from ISRO. Therefore, the traditional space industry will tend to gain more traction by working towards establishing a larger share in manufacturing and assembly of the systems as required by the customer (ISRO) as demand surges. This is the case with the industry-led Assembly, Integration and Testing (AIT) of satellites and launch vehicles. NewSpace companies such as Astrome are developing a completely end-to-end service where the enterprise has complete control on the design, development, fabrication and market delivery of the space system which shall provide the service.
- **Financing Landscape** – The traditional space approaches are based on Small and Medium Enterprises (SMEs) that have serviced the space agency with requirements growing systematically to upgrade capacity as the demand grows within the space agency. The scope of investment for such upgrades are based on performance- and asset-based guarantees with institutional investments limited to banks. NewSpace brings a high-risk, high-return scenario where traditional institutional financing such as banks are not an option that rather attracts venture capital.

- **Growth Landscape –** Since traditional space industry approaches mostly depends on the space agency/national requirements mandated funds as a primary customer, the ability to scale business limits to large orders moved to industry. NewSpace, due to its diversified business model approach with possible scaling to international markets, brings a high-growth potential. It should be noted that there are a large number of failures associated with the start-up nature of NewSpace as well.
- **Exit Landscape** – Traditional space industry approach has exit scenarios that are mostly via Mergers & Acquisitions (M&As) due to a spike in increased demand within the space agency/national requirements with interest from larger corporations to take over such opportunities. NewSpace brings with it the possibility of Mergers & Acquisitions (M&As) in consolidation and positive liquidation events for investors and entrepreneurs. A mature ecosystem is necessary for such exit scenarios.

From an Indian context, the argument is not Traditional vs NewSpace for India; rather, it is one about supporting the development of the space economy of the country by systematically enabling both these approaches to increase their capacity to deliver systems and services. Both these approaches have the potential to scale the capacity in the Indian industry which is yet to achieve maturity in the ability to design, develop, deliver a complete end-to-end space system or a space-based service.

Creating a NewSpace Ecosystem in India

NewSpace holds the potential for creating a multiplier effect on the space economy unlike the circulation of tax money that normally happens within traditional space industry approaches. The country's policymakers must support NewSpace to further catalyse the multiplier effect while steps are being taken in parallel to upgrade the capacity of the traditional space industry.

The creation of a NewSpace ecosystem in India will be key in creating complementarity with traditional space enterprises. One of the key steps towards this step is the possible creation of a NewSpace start-up ecosystem via a dedicated space incubator in the country. Given the current presence of the Department of Space (DoS)/ISRO and its centres in the delivery aspects of both upstream and downstream of the space ecosystem, the participation of DoS/ISRO will be key to the creation of such an ecosystem in India. This will help NewSpace start-ups in both the development and deployment of their products/services on the basis of the requirements of the country, most of which are currently being serviced by DoS/ISRO.

For a national space programme, investment in business incubation activities bears multiple fruits as shown in Figure 1.[11] Space agencies such as the European Space Agency (ESA) have been championing the need for entrepreneurship by supporting innovation and economic development. ESA created an annual fund called the 'Open Sky Technology Fund' of €100 million for supporting start-ups that make use of ESA's technology. The fund is managed by a VC firm called Triangle Ventures. The ESA Business Incubator Centre (BIC) programme has succeeded in creating around 50 viable companies and serves as a good model for space agencies to encourage entrepreneurship.[12] India can learn from the success of these incubation programmes in its efforts to creating a vibrant space industry ecosystem.

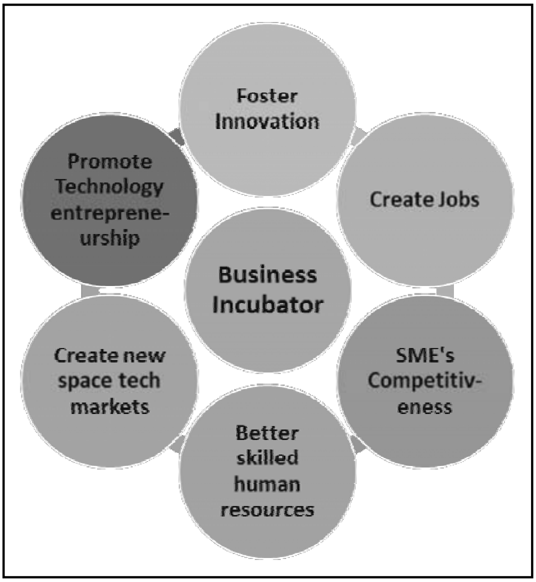

Figure 1- Business Incubator Benefits

Vision for a NewSpace Start-up Incubator in India

'Making Indian NewSpace second to none in the realm of space applications for the benefit of man & society.'

The foundation of developing a vibrant NewSpace ecosystem in India lies in developing an internationally reputed space start-up incubator programme that enables kicking-off a new wave of NewSpace start-ups in the country, which can scale nationally and internationally with Indian space technology products/services.

Incubation Structure

Given the nature of the space ecosystem in India, we believe that the participation of the ISRO/DoS shall be extremely important to the success of the incubator. ISRO/DoS can be critical in providing the basis for spin-offs, request for technology while there is room for them to also act as users/facilitators to other government departments.

Figure 2 gives an overview of the organisational structure of the space start-up incubator. The Federal-State structure of the country and the autonomy of organisations (user agencies) leave plenty of room for the possible participation of States as catalysts in the incubator. While DoS/ISRO can provide for technology licensing, access to facilities, consultancy and act as pilot for the selected start-up product/service, States can offer a broad range of services under the incubator such as the seed money, volunteering as a first user via a pilot phase deployment of a particular service, office space/utilities in exchange for incubating within the jurisdiction of the State.

This will provide a two-pronged support to the start-ups in the incubator, where the start-ups will get a secured kick-off. In exchange for the support by ISRO/DoS, Antrix Corporation can hold upto five-percent equity in the start-ups. Similarly, in exchange for support from States, the State government via a relevant authority can hold five-percent equity. This will ensure that the incubation services provided by these stakeholders can be monetised as the start-up goes from ideation stage towards deployment of the product/service.

The dynamic of the involvement of the State and DoS can also ensure that priority can be given to accelerating the development of start-ups based on the local cluster/ISRO centre. For example, an incubator based in Bangalore can essentially benefit out of the presence of local centres of ISRO such as ISRO Satellite Centre (ISAC), Laboratory for Electro-Optics Systems (LEOS), and others. This development model shall allow to spring several incubators around different ISRO centres and will provide a possible cluster effect in ecosystem as start-ups will take advantage of local expertise available at the local ISRO centres.

The seed-pilot approach will ensure that the start-ups will not suffocate due to lack of availability of capital and can still ensure organic growth. Moreover, this approach ensures that there is a trust-platform built for a possible super-Angel or Venture Capitalist (VC) to review the start-up after their ideation phase and participate in their first round of major investments.

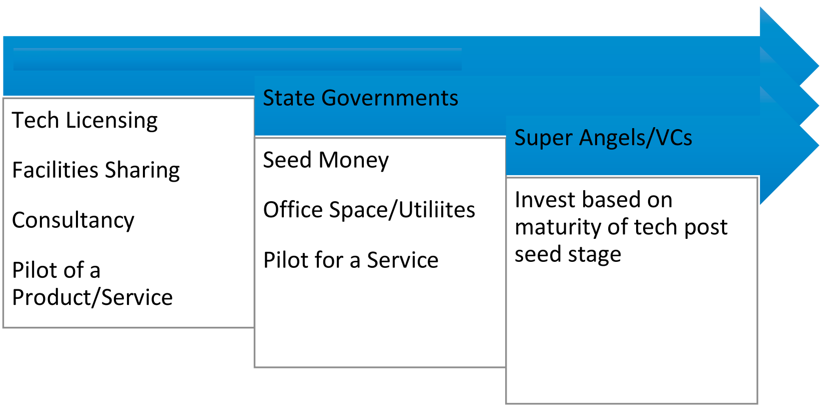

Figure 2 - Organisational Structure for Space Start-up Incubator from Seed to Series A Funding

Incubation Tracks

The incubation tracks for NewSpace in India can be divided into Solicited and Unsolicited tracks as shown in Figure 3. The Solicited track shall consist of focussed efforts on acceleration of spin-off of ISRO technologies by start-ups, push for 'Make in India' in space alongside possible request for technologies from ISRO. The unsolicited tracks shall keep the door open for entrepreneurs to build independent new products/services based on local/international market requirements that they foresee.

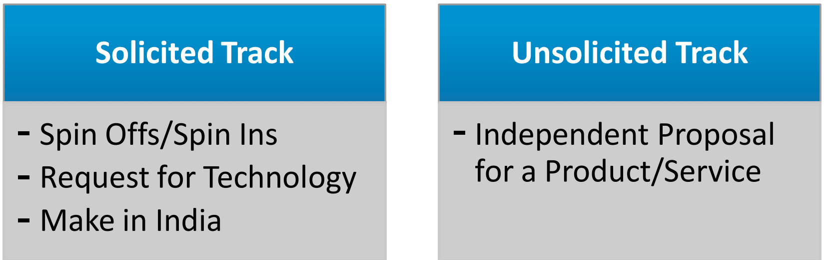

Figure 3 - Tracks for Seeking Start-up Proposals

Spin-off technologies are the commercial services or products derived from existing space technologies that are currently being used by ISRO for its space missions. For instance, the silica aerogel manufactured indigenously by the scientists of Vikram Sarabhai Space Centre (VSSC), ISRO originally for the purpose of insulating the surface of its rockets,[13] can be exploited commercially through use in clothing and insulation in extreme cold climates and marketed both domestically and internationally. A non-commercial use is in providing protective clothing for Indian Army personnel posted at harshly cold locations such as the Siachen. Being a research organisation, ISRO is not built for productionisation and therefore spinning-off a technology into a commercially viable product would be best accomplished by innovation hubs that are start-ups.

Spin-in technologies are those that can be adopted for use by ISRO in its space missions and which are developed from existing non-space technologies. For instance, data analytics platforms are already being built around satellite image data by companies domestic and international, such as the Bengaluru-based SatSure and the Dutch Skylab Analytics that cater to the insurance and agro markets. Components of this big data and multi-sensor data processing capability can be adopted for use by ISRO for real-time processing and interpretation of data from its imaging satellites, given its growing imaging satellite fleet in the near future.[14]

The 'Make in India' initiative should witness great success in the space sector if start-ups are encouraged to cater to the manufacturing requirements of ISRO. The adoption of an open source policy by the government of India in 2015 was a certain step towards propelling the country from being a 'purchaser' to an 'innovator' which can be greatly assisted by the innovation potential of start-ups.

Specific Technology Requirements by ISRO can be in the form of technologies or software or processes. Given the latest efforts towards privatisation of satellite Assembly, Integration and Testing (AIT)[15] and also the privatisation of PSLV, there will be a need for innovation in the traditional approach for a faster turn-around time and higher cost savings. The processes need to be modified or re-drafted to facilitate an assembly line scenario.

Selection and Screening of Start-ups

The approach from incubation to exit is mapped in Figure 4. The selection of start-ups shall be done by the efforts of an in-house analyst team a special that is made of analysts who understand the technical and business potential while the screening of the start-ups after selection is done by a review committee that shall interview the founders. The review committee itself can be comprised of stakeholders from ISRO/DoS, the State representatives, and an institutional investor.

While the call for taking up spin-offs/request for technology would depend on the listing provided by the Department of Space, the Make in India and unsolicited proposal submission shall remain open through the year for founders. The selection and screening will happen on a quarterly basis. The final selection will be made on the basis of demonstrated ability to create space products/services or commercialise a spin-off technology.

Incubation Process of Selected Start-ups

Selected start-ups will shall get 30 months of access to ISRO/DoS facilities, consultancy and the local government perks of seed money, office and utilities, among others. The most critical aspect of the selection would be that either or both ISRO/State agree to act as beta-testers of the product or service, depending on what they are. ISRO can also coordinate with other government departments on the question of who can use the solutions. All selected proposals will have ability to scale nationwide (other States) and possibly in the international market as well.

A 30-month incubation period should provide enough runway for the start-ups in the fold to create a product or service to go from its ideation phase to a Minimum Viable Product (MVP), in the process creating a roadmap for scaling the MVP into a fully blown product or service with further financing. The limited time should also ensure a commercial approach to the development of the product or service. Following this period, the start-up shall be liable to pay for any further use of facilities and consulting, either by ISRO or the States.

The incubated start-ups will also receive legal support for registration of the company, equity distribution, the patenting of its technology or service, awareness on legal dispute resolution mechanisms, and other requirements.

National and International Collaborations

In addition to providing the start-up companies access to other government departments and ministries for testing of technology and service, the start-up incubator team can further facilitate collaborations with national and international research bodies. The Defence Research and Development Organization (DRDO) Labs, the Indian state-owned aerospace and defence companies *Bharat Electronics Limited* (*BEL*) and *Hindustan Aeronautics Limited* (HAL) are all excellent potential collaborators that can share their facilities and even technology know-how with technology start-up incubators. International Space Agencies such as European Space Agency (ESA), the National Aeronautics and Space Administration (NASA), Japan Aerospace Exploration Agency (JAXA), Russian Federal Space Agency (RFSA or Roscosmos) should also be interested in collaborations given the high innovation potential of India courtesy its younger demographic and large number of engineering graduates.

Internationally acclaimed universities involved in space research with an entrepreneurial perspective such as the International Space University (ISU) based in Toulouse in France—which also happens to be the European Space industry hub—and the Skolkovo Foundation in Moscow can also be approached for collaborations. All these not only can involve joint development of technology or services, but also enable the national or international collaborator to act as a testbed for the technology or service developed by the incubatee.

The incubator team would also provide the necessary legal consulting services and administrative assistance in all collaborations.

Post-Incubation

The incubation process would ensure start-ups that do not perform and cannot sustain to fold the idea, while the start-ups that do create value continue on to scale. The pilot deployment with ISRO/States shall give the start-ups a credible footing to stage expansion of the product or service into the national and international markets.

For example, if a start-up chooses to provide agriculture or crop analytics and does a pilot at a district level of a State: Based on the success of the Pilot, the State can scale the service to its entire jurisdiction, in the process benefiting its local farm community. Based on this success, the start-up shall be able to approach other States and scale nationwide. An example from the product side would be to test a particular technology such as an electric propellant-based thruster via the support of ISRO to deploy it on its spacecraft. Based on its performance in space, the start-up can claim heritage and market the product internationally to the larger space industry. In case of spin-in and special technology request areas under the solicited track, ISRO will also offer buyback guarantees to the incubatees.

One of the extremely important phenomenon in the creation of an ecosystem is the Merger and Acquisition (M&A) landscape. India so far has not seen a strong M&A landscape in consolidation of industry in the space sector. Creating a NewSpace ecosystem provides a great opportunity to complement the development of the traditional space sector by creating this M&A landscape as start-ups which create value can be acquired or acquihired. It should be also noted that there is substantial scope for successful space-based services to grow to a scale towards creating larger public value via Initial Public Offerings (IPO).

Conclusion

India has created a strong foundation in space technology by investing into creating a self-sustaining space exploration ecosystem for the last five decades. There is a need to carry a comprehensive outlook towards the globalisation of this foundation. While there are several positive developments in the expansion of the traditional space industry—such as the newly envisioned, ISRO-supported Joint Ventures with the domestic industry in producing satellites and launch vehicles—there is significant opportunity to explore the NewSpace phenomenon in the country.

Going forward, the debate in India should not be *Traditional vs NewSpace;* rather, about facilitating the development of the space economy of the country by systematically enabling both these approaches to increase their capacity to deliver systems and services. Both these approaches have the potential to scale the capacity in the Indian industry which is still immature in the ability to design, develop, deliver a complete end-to-end space system or a space-based service.

Supporting and nurturing a NewSpace ecosystem in India with the support of DoS/ISRO is a step towards creating public-money independent space products and services, which in turn provides a long-term horizon in the accelerated capture of a larger market share of the $300-billion global space market.

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7

Electric Propulsion & Launch Vehicles: An Indian Perspective

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Introduction

November 21, 1963 marks the first milestone in India's space odyssey as the country launched its first rocket from Thumba. This launch represented India's future ambitions in outer space. Today India is a full-fledged spacefaring country, with the Indian Space Research Organisation (ISRO) conducting missions to the Moon and Mars.

India's space programme has grown tremendously since its humble beginnings during the 1960s. It is now on par with other space leaders such as the United States, Russia, Europe, Japan and China. This growth has been possible even with a minimum budget of $1.2 billion, while the US spends almost 33 times more.

Today, outer space is no longer limited to just research and development but has become an integral part of everyone's life. The steady advances by the space industry and new trends in manufacturing have driven down the costs and enhanced innovation. The space industry is now on the cusp of rapid expansion both in terms of capabilities and services, even as experts deem that the industry is nearing saturation after years of successive growth. The penetration of smartphones and Internet of Things (IoT)—which leverage data derived from satellite-augmented services—are two key drivers of this growth.

India is also witnessing the development of its commercial space industry particularly by NewSpace entrepreneurs. For example, the Indian start-up, Astrome Technologies, promises to provide internet connectivity in India using their fleet of 120 high-throughput microsatellites. India's first private satellite manufacturing company, Dhruva Space, also plans to operate constellations of satellites.

This global surge in demand for satellite services requires more satellites on orbit. However, the existing launch costs are prohibitive for these businesses to succeed. By adapting new modes of satellite propulsion, the overall mass of the satellites can be reduced, thus bringing down the cost of launches.

Electric Propulsion

An electrically powered spacecraft uses electrical energy to change its velocity. These systems work by electrically expelling propellant (reaction mass) at high speed. Electric thrusters typically consume less propellant as they have a higher exhaust speed (operates at a higher specific impulse) than chemical rockets. The use of electric propulsion has been on the rise in the last few decades.

In the early 1980s, satellite manufacturers began implementing arc jets and resistojets, early forms of electric propulsion, for north-south station keeping.

Using more efficient electric propulsion allowed satellite manufacturers to either increase payload mass or extend satellite life while maintaining the same launch mass. Gradually, newer electric propulsion technologies such as gridded ion engines and hall thrusters were introduced and electric propulsion began to carry more of the propulsion load for commercial spacecraft.

In 2010, when an Advanced Extremely High Frequency satellite experienced an anomaly with its main propulsion system, it used onboard high-power Hall thruster to complete its orbit raising manoeuvres. This was the first in-flight demonstration of a high-powered (4.5 kW) hall thruster. This event paved the way for more widespread adaptation of electric propulsion for orbit raising of satellites.

The twin Boeing 702SP spacecraft introduced in 2012 uses xenon-ion thrusters for both station-keeping and orbit raising manoeuvres. Weighing a combined 4,100 kg (9,000 lb.) and offering between 3-7 kW of power each, the all-electric 702SPs are half the weight of equivalent chemical-propulsion satellites. This has prompted other operators to also adopt electric propulsion. Eutelsat recorded a 20-percent reduction in its capital expenditure per year due to early adoption of electric propulsion. A global leading rocket and spacecraft propulsion company, Safran, predicts that the future of satellite industry will be all-electric.

However, the industry has been generally slow in adopting electric propulsion due to the relative complexity of designing and developing the technology. At the same time, satellite companies such as Airbus and Boeing have stated that the long-term benefits of adopting an all-electric satellite fleet are significant.

Advances in Electric Propulsion

Research on electric propulsion at academia, industry and government space agencies is focused on developing low-cost, high-efficiency thrusters. In India, the Centre for Nano Science and Engineering (CeNSE) at the Indian Institute of Science (IISc) in collaboration with Research Center Imarat (RCI), Hyderabad has developed nano single firing solid propellant thrusters that can address the manoeuvrability issues of small class satellites. With support from ISRO, a private company in India has made significant progress in electric propulsion through the development of Microwave Electrothermal Thruster and specialised thrusters for nano-satellites. The company is also developing other electric propulsion systems in collaboration with the IISc.

Some of the major international private players in the field of electric propulsion include Safran of France, Alta of Italy and Busek of the US. NIIMash, Fakel Design Bureau and Keldysh Space Center of Russia are long-term players in the domain of chemical and electric propulsion. Russia has pioneered Hall Effect thruster technology while National Aeronautics and Space Administration (NASA) has evolved gridded ion thruster technology. ISRO is currently working towards the development of Stationary Plasma Thrusters with support from Fakel Design Bureau and Keldysh Space Centre to realise all-electric Indian satellites.

This variety of thrusters offering various advantages should be adopted by the industry also for orbit raising, orbital maintenance and station keeping of satellites. According to Northern Sky Research forecast, 50 percent of global orders for electric propulsion systems have originated from Asian operators. Asia is expected to account for a high market share of full electric propulsion or hybrid system procurements. This will include established regional players with multi-satellite fleets as well as emerging companies, such as Aniara. This is critical for India as the adoption and maturity of electric propulsion is critical in capturing a hold in this expanding market.

Electric Propulsion: India's Perspective

Although research and testing of variants of electric propulsion systems have been performed for several decades, this technology has not been widely employed on due to the unavailability of sufficient electrical power onboard a spacecraft. However, constantly increasing levels of electrical power on new developed spacecraft allows electric propulsion technologies to be a serious competitor to chemical propulsion. The use of EP for different types of missions is already a common practice internationally.

Electric propulsion can be put to use for a variety of Earth-bound applications such as Earth observation, navigation and communications satellites in geostationary orbit, as well as small satellite constellations. Future applications include space tugs, human spaceflight, and inter-planetary space exploration missions. The missions to Mars will most likely use electric propulsion with NASA's Science Mission Directorate working on In-Space Propulsion Technology. NASA is also developing NASA Evolutionary Xenon Thruster (NEXT) gridded ion thrusters and Hall Effect Electric Propulsion (HEP) and Mars Ascent Vehicle (MAV). All these developments indicate that electric propulsion will soon become the core of in-space propulsion.

India must also take steps towards developing advanced electric propulsion technologies. Research institutions and organisations as well as private companies need to invest in developing different types of electric propulsion systems. The European model of promoting research in the area of electric propulsion could be adopted to encourage research on electric propulsion in India. As part of Horizon 2020 Space Work Programme, the European Commission has funded a programme called Electric Propulsion Innovation & Competitiveness (EPIC). This programme is aimed at providing a clear, integrated roadmap and a master plan for its coordination and implementation to increase the Technology Readiness Level (TRL) of electric propulsion technologies.

The main activities of this initiative include the collection and consolidation of requirements for future electric propulsion thrusters from across the world, survey of available European electric propulsion technologies and their TRLs, funding of grants and to come up with a fully detailed master plan to coordinate all the activities for the whole duration of the project. Such a model could be employed in India to advance technology development in research and educational institutions, and private companies.

Today, advances in technology have allowed micro satellite clusters to replace larger satellites for many commercial applications. Driven by this innovation, companies such as Google, Facebook and SpaceX are launching thousands of nano-satellites for internet applications, thus unveiling large market opportunities in this area. However, operation of constellations of nano-satellites is not yet efficient as there is no propulsion technology developed for these small satellites.

The life of a nano-satellite is just about two years owing to the fact that no propulsion system is currently in place that can maintain the satellite's orbit. This factor severely restricts mobility in space, resulting in increased launches that only add to the costs. Advances taking place in the electric propulsion technology are aimed towards addressing this limitation and extending the life of nano-satellites. This will allow manufacturers to set up nano-satellite constellations that will provide full capability to their organisations while dramatically reducing the cost of operations and maintenance of satellite constellations.

Electric Propulsion of Nano-satellites

With advancing technology, smaller satellites are becoming capable of performing more complex tasks. Nano-satellites are revolutionising the satellite industry by replacing conventional satellites. According to the Space

Works' 2014 Projection, it was estimated that between 140 and 143 nano/micro satellites across all sectors would be launched globally in 2014; 158 nano/microsatellites were actually launched. This represented an increase of nearly 72 percent compared to 2013.

The major forces driving this market are price reduction, increasing demand, investments from the Silicon Valley, better mission launches and continual decrease in average satellite mass. The significance of Nano and Microsatellites has increased due to increase in number of application areas such as academic training, scientific research, earth observation, remote sensing, among others. The increase in use of these satellites across a range of commercial applications in all regions of the world has been noted as one of the major factors behind the continuing increase in Nano and Microsatellite market size.

In India, Prime Minister Narendra Modi has called for a complete digitisation of the services within the country, starting from banking to governance and medicine. Such an extent of digitisation requires an infrastructure to build up from the grassroots level and fulfil the inclusive promise of a digital India. The only way to cater to such massive task is to meet the demand for bringing Internet connectivity to the masses, and this is a difficult task considering the exorbitant prices for laying cables.

This is where the application of space comes into the picture, and where the use of satellites shines. To begin with, the connectivity by using satellites is around $3-6 compared to the $3000 for a given area by laying cables and cellular towers. The task of digitisation is unenviable in a country like India where there are only 375 million internet users in a population of 1.2 billion. The dream of digitisation then will only become a reality when the nation is completely connected. This calls for a huge demand in setting up the satellite infrastructure that can cater to the billion-plus users.

This opens up a huge market potential for the use of Nano-size thrusters in enabling Nano-satellites to reach full functionality in terms of deployment. This is crucial in formation flying or constellations as Nano-satellites require an on board propulsion system to maintain formation, this is one of the reasons why current research in Electric Propulsion is critical as it is the only technology which can be adopted for Nano-satellite propulsion with the main reason being the incumbent small size of the satellite curtails the addition of extra mass in the form of propellant. In most cases, Nano-satellite constellations are deployed in the higher earth orbit of 650 km to negate the effect of atmospheric drag. While it has greater orbital life than the nano-satellites deployed in Low Earth Orbit, the mobility of satellite flying is extremely limited.

With companies like Astrome, SpaceX and OneWeb all planning to deploy constellations for Nano-satellites, it is critical that the technology readiness level of Nano-satellite thrusters reaches full maturity in time for the deployment of such constellations else the constellations would fail.

In India, a Private R&D company is currently developing ultra-low power Nano-Satellite thrusters that can be used for multiple-firing operations, pushing the technology envelope on the execution of precise constellations and orbital insertions for nano and small satellites.

A revolution in bridging the gap between today and tomorrow requires a lot of satellites, and there is a huge deficit in meeting launch requirements of these satellites.

ISRO's proven reliability with the PSLV, coupled with its low cost advantage has lured international clients into its forte. Considering India's requirements, India presently has about 34 satellites dedicated towards its own use. Despite this, India still leases foreign transponders which are secured at an astronomically high amount of money. This has called for a demand of 70-74 satellites in the near future.

This has led to ISRO working round the clock in providing launch capabilities towards the demand of fulfilling launch orders. As a result, the wait times for the launch vehicle and the satellite development is often very high. The other inhibiting factor in accommodating more clients is the inability of the industry to churn out more PSLVs to meet the global demands on time. This has led to ISRO taking up the initiative to completely privatise the operations and construction of the PSLV by the year 2020. This is a bold step in the right direction towards recognising the importance of opening up the space programme to the global platform and meeting the increasing demands posed by the global launch vehicle market.

What can be applied here is ISRO being a scientific organisation, can follow the western model of the launch space where government-owned space agencies engage in R&D while launch services are contracted to private companies with minimal supervision. This model can be seen in the US launch segment where NASA has distributed all the launch contracts towards private players such as ULA and SpaceX while being completely involved in R&D work. A similar model is adopted in the European space segment where most of the launch contracts are taken up by Arianespace. This distributed model of administration acts a catalyst in bringing about greater innovation within the industry.

The PSLV then, is an example of a Public-Private corporation with vendors that include Godrej & Boyce, L&T, Centum Electronics, Data Patterns, HAL, among others, supplying 80 percent of the components which are strictly scrutinised by ISRO. At the present rate of one satellite launch per month, ISRO still faces a huge backlog in the net satellites launched. Though ISRO plans to increase the capability to 1.5 – 2 satellites a month, this is still a far cry from what needs to be achieved to position itself as one of the major launch service providers in the world.

Table: Comparison of Launch Costs

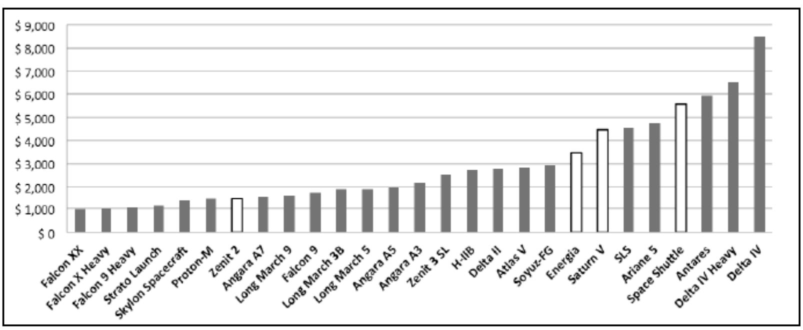
Launch vehicle	Country	Mass to LEO *(in tons)*	Mass to SSO *(in tons)*	Mass to GTO *(in tons)*	Estimated Price *(million USD)*
Atlas V	US	8.1 - 18.8	6.5 - 15	3.4 – 8.9	110-230
Delta IV	US	9.4 – 28.7	6.7 – 23.5	3 – 14.2	164-400
Falcon 9	US	13.1	-	4.9	61.2
Falcon Heavy	US	54	-	22.2	90
Antares	US	3.5 – 7	2.1 – 3.4	-	80-85
Ariane 5	ESA	20	-	10	165-220
Long March	China	25	-	14	-
GSLV`	India	5	-	2.5	36
GSLV LVM III	India	8	-	4	60
Proton	Russia	22.8	-	6.3	65
Soyuz 2	Russia	8.2	4.9	3.25	50
H - II	Japan	10-16.5	3.6 – 4.4	4 – 6	90-112.5
PSLV	India	3.8	1.8	1.4	15
Electron	US	-	0.15	-	4.9
Vega	Italy	1.5	1.4	-	42

For India to remain competitive, there should be an array of launch vehicles which cater to the respective weight segments of different classes of satellites. However, today India has only the PSLV (1.75 tons to SSO) and the GSLV Mark-III (4 tons to GTO). This necessitates the development of a launch vehicle for the small and heavy classes of satellites. This void is best filled by emerging private space companies that seek to emulate the western model of privatisation of launch services.

This list is dominated by heavy launch vehicles such as Ariane 5, Delta IV, Falcon 9 and Long March 5, with smaller ones still in development. ISRO's PSLV and GSLV find themselves to be an attractive proposition as their price undercuts the rest of the competition by a huge margin. It is clear that India needs to develop heavy launch vehicles to cater to the needs of the entire market. In the above depiction, a lacuna can be seen in the micro/small satellite launch segment as there are only few launch vehicles that are dedicated towards the purpose of launching small satellites in large numbers. There are a few emerging players in this regard, such as Rocket Lab, Inter Orbital Systems, Vega which at present is developing the electron rocket for launching small satellites at an affordable cost. India needs to utilise this lacuna in the small segment to tap into the future growth as the trends clearly show that the number of small satellites is on a rise.

Consider a scenario involving a satellite constellation service provider planning to launch its own constellation of 30 microsatellites over two years. The best way to execute this as per the plans of the satellite operator would be to launch the satellites in a series of batches. Deployment of this constellation by the use of a heavy launch vehicle is not always the best option as it would lead to indefinite wait times in securing and launching the satellite flock, often delaying the time the entire constellation would be fully operational. One major advantage of using a small satellite launch vehicle is that it is cheaper to secure the launch contract as the entire rocket can be bought specifically for per say a given satellite company allowing for faster deployment of the entire constellation. This is often not the case in using larger launch vehicle as the costs usually runs north of a few hundred million dollars and raising that large amount of investment only for launch capability is often a risky venture in the case of an uneventful launch.

Just as the growing trend towards smaller satellites highlights the necessity towards the need for a dedicated small satellite launcher, many countries are contemplating the process of converting their existing ballistic missile arsenal into satellite launch vehicles to cope with the present demand. This sounds like a genuinely good idea but it is not without issues. The technical drawbacks of this involve re-engineering the missile so that the upper stages can be converted for placing a satellite into precision orbit. This conversion often escalates the launch costs to an even higher level than what is presently offered by the launch services. The second aspect is often linked to technology itself—ask an owner of an old car and they would highlight the difficulty in procuring compatible spare parts. Similarly, the advancement of technology would pose a great risk in procuring supplies in maintaining a fleet of missile converted rockets. The advantages of present technology and manufacturing methods such as additive 3D printing and CNC machines make the development of a new launcher a cheaper and a more viable option than the proposition of converting old missiles. The drawbacks are not limited to technology alone but the socio-economic aspects of churning out a fleet of missiles at a time when tensions are running high: the technology can be military in application, forcing hostilities between countries. This is what happened in the moments after China conducted the Anti-Sat test opening speculations on the dangers of Missile-converted launchers.



Cost Comparison of foreign rockets
Source: AIAA 2013 Report

The competitiveness of the PSLV has forced the international consortium specifically the US to impose restrictions on the PSLV. As India is yet to sign the CSLA (Commercial space Launch Agreement), this agreement raises the launch costs of the PSLV, thus making the pricing in line with the commercial launch market. According to think-tanks, India may never sign the CSLA as the country already enjoys a ready list of orders from other countries. This is also augmented by the fact that the recent missions of the PSLV also included a US-based satellite from a company called SkyBox Imaging.

The Emergence of a Space Ecosystem in India

Experts within the space industry have often asked the question on whether a company like SpaceX will be seen in India. This question is relevant more today than ever before in the context of a paradigm shift in the way India's space programme is transitioning towards the public-private model. A private company must then emerge in the launch segment by indigenously developing its own launch vehicle, with ISRO as the mentor. It is also to be noted that a new private entity in India cannot shoulder the entire responsibility of independently developing a new launch platform from scratch. This is mainly attributed to the substantially long time of development, huge funding requirements, and riding the risk for the first time. After the bold decision towards privatisation of the PSLV, ISRO must take the next leap forward by handholding private entities which are looking towards developing an indigenous launch vehicle on its own. This would create a ripple effect within the space industry where it would result in spin-offs arising from the various technologies that are incorporated in a given launch vehicle.

Though India has garnered a good name in the space industry in recent days, it is noteworthy that only three percent of the total number of launches that took place between 2004-2013 happened from Indian soil and only three percent of the total satellites were manufactured in India. This is a clear indication that there is still a long way to go for India to become a prominent player in the space industry. The US, Russia, Europe and China dominate the list by making significant contributions in satellite manufacturing and launch services. This was possible only because these countries nurtured a space ecosystem that could sustain itself and promote a major contribution to the space industry from private companies. A similar approach is recommended for developing a good space ecosystem in India.

India has a small space ecosystem supplying to ISRO. When more and more launch service providers, satellite manufacturers and satellite service providers emerge from the private sector, catering to customers across the globe, a strong self-sustaining ecosystem will emerge. This will affect India in many ways. A good ecosystem will attract many foreign companies to set up units in India and local companies to expand their businesses into the space sector. Emerging companies in launch segment and satellite manufacturing and services segment will create additional employment in their respective industries. Indirectly, more employment will be created in sub-system manufacturers, part suppliers, system developers, consulting services providers, marketing agencies, and in many other levels. As the number of satellites manufactured and launched from India increases, it will promote construction and launch activities, tourism (frequent visits from clients), and development of allied technologies in the country (such as development of 3D printing technology, carbon composites technology). Creation of highly skilled employment and knowledge and technology spill-overs will elevate the standards of all sectors of Indian industry. The net result of all these benefits is that 'Make in India' initiative will flourish. India will slowly emerge as a hub for research and technology development.

A good example of how a launch service provider can affect the space ecosystem and economy of a country can be seen from the impact the Rocket Lab is creating in New Zealand. Analogous to how ISRO brought about a space ecosystem in India, Rocket Lab is indirectly pushing towards the development of a new space ecosystem in New Zealand. A study on the economic impact of Rocket Lab in New Zealand estimates that Rocket Labs alone can add a value of up to US$1.5 billion directly and indirectly over the next 20 years.

The call for a clear definition of space policy

For the private companies to boldly venture into the launch segment, there must a clear definition of a framework, policy and regulations in this domain. The government along with ISRO has recognised the importance of this and is now coming up with a clear roadmap for private companies geared towards the launch segment in India. This call for policy greatly encourages growth in the space sector considering that the number of foreign companies which are coming towards India due to the government's policy of 100 percent FDI in Space. A clear-cut policy in

Indian Space would lay down the roadmap for the better governance of Space and would ensure transparency in tailoring for the various vendors within the space industry. Thus, a space policy would act as a catalyst in providing functions that allow India to shoulder with other spacefaring countries such as the US, UK and China. Such an initiative would not only drive confidence within the industry but would bring it up to an entirely new level. A similar debate on the necessity of a space driven policy by the US space industry has prompted the US parliament to pass the SPACE (Spurring Private Aerospace Competitiveness and Entrepreneurship) Act of 2015 to promote greater private participation in developing the commercial space industry and spurring spin-offs that address the needs and requirements of the industry by allowing for a better private investment into such ventures.

A case in point is a company whose inception has captured the attention of enthusiasts and aspiring geeks around the world—the Space Exploration Technologies or SpaceX. SpaceX is one of the main launch vendors in the global market and these days their ambitious plans to colonise Mars in the coming few years is making headlines the world over. How SpaceX came to be during a time when NASA was the only undisputed king of the US launch segment shows just how much the times have changed. SpaceX started in the summer of 2002 and after long years of development, three consecutive failures of their Falcon launcher nearly left the company in shambles, but the ecosystem of trust and support built around had managed the company to rise out of this time and the success of the fourth and final rocket turned the tides in their favour. This led to the acceptance by NASA to award them with launch contracts for the progress ships towards the ISS, and the rest is history.

SpaceX today is at the forefront of the competition by proving success with their reusable launch vehicles. 'Reusability' is now the catchphrase of the space industry as the major players try to perfect their own models in this sphere. India has taken up Reusability seriously and the recent tests by ISRO on its own Reusable Launch Vehicle reinforces this intent.

Just as how the success of SpaceX turned out to be the success model that space programmes around the world seek to emulate, none of this would not have been possible if the initial investors of the company did not see the launch failures as setbacks but rather bitter medicine that was administered so that unforeseen problems are ironed out to set off an enterprise which has a long-term vision towards the future. Such a story would never come up in India until investors learn to let go of the age-old mantra on investments seeking short-term returns but rather focus on the long-term commitments where the returns are guaranteed in the long run.

The story of SpaceX is however only one side of the coin; flip the coin and the dark side to this picture comes into play. The fall of Firefly is a lesson to all budding launch service providers about how the challenges are not only in the realm of technology but are also spread to the political and financial spheres. New companies must carefully asses such landscapes and carefully lay their roadmap.

The world famous management Guru Peter Drucker wrote in his famous book, 'The Effective Executive':

> *"There is no inherent reason why medicines should taste horrible — but effective ones usually do. Similarly, there is no inherent reason why decisions should be distasteful — but most effective ones are."*

It is not just enough that new space companies are built. There is a need for an ecosystem where the companies compete and this would lead to a transformative effect where India is not just the country where jobs are outsourced to but a hub from where advanced technology is sourced the world all over. Such an ecosystem in India can be maintained only if there is a definite institutional framework and policy that encourages and stimulates innovation and research on a broader scale.

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II

SPACE POLICY

8

Privatisation of Space in India and the Need for A Law

Kumar Abhijeet

Introduction

In the era of commercial use of outer space, private enterprise participation has been significantly increasing. This escalation is largely because of global cuts in governmental space budgets and the possibility of implementingrelatively cheaper space activities through private sector involvement. Growing interest of private entities in space has generated much discourse about the need for laws. Does participation of private entities demand that laws be passed to cover their activities? Generally, any law is needed to address the interest of stakeholders underlying the subject of legislation. A space activity,although territorial in origin, actually operates or is intended to operate in the global commons. Thus for any space activity, the international community is the first and foremost stakeholder. The second stakeholder is the State itself, which undertakes a particular space activity because unlike in other branches of international law, for space, States bear liability for private actors as well. And the third is the private enterprise, if indeed a state intends to include them in its space programme.

In India, the private sector has shown remarkable interest in space activities. Media reports (*Business Standard*, 13 June, 2016) suggest that by 2020, India's first private rocket will be set for launch. Yet another media report (*The Indian Express*, 4 December, 2016) suggests Team Indus aspires to tie up with the Indian Space Research Organisation (ISRO) to plant the Indian flag on the Moon in 2018. There is no doubt that India has had a robust history in space, and its future holds plenty of promise, too. For the last five decades space activities in India has been purely governmental in nature and thus there has been no need for a unique law. Increasing private sector participation today necessitates immediate attention on the need for a law. This paper explains the need for a law in the light of private sector participation, addressing the concerns of all the three stakeholders in space.

Requirements of the International Community

States were the sole participants during the initial days of space exploration. Soon, it was anticipated that private entities might also participate in the future. The Negotiation and drafting history (1962) on the Outer Space Treaty reveals that the then Soviet Union was in favour of giving monopoly to governments for all space activities. The United States, on the other hand, was already then making plans for privately operated telecommunications.[1]A compromise was reached, which is manifested in the wordings of Article VI of the OST:[2]

"States bear international responsibility for national activities in outer space…, whether such activities are carried on by the governmental agencies or non-governmental body corporate by the State concerned. The activities of non-governmental bodies corporate shall require authorization and continuing supervision by the State concerned."[3]

Thus Article VI of the OST imposes international responsibility upon States not only for the governmental activities in outer space but even for non- governmental activities in outer space. It considers both of their space activities alike, referring to them as 'national activity'. States bear international responsibility to ensure that their national activity are carried out in accordance with the provisions of the OST. For any activity in outer space undertaken by a private enterprise—for example, operation and control of a satellite or any other space objects, launching of space objects, among others—the concerned State bears international responsibility. Since the responsibility also includes that of ensuring compliance with the OST, it is important to know what are the provisions imposed by the OST on both freedoms and limitations of space activity.

i. Freedom in Outer Space

Article 1 of the Outer Space Treaty (OST) grants three kinds of freedoms in outer space, namely: (i) freedom of exploration and use of outer space including the Moon and other celestial bodies;[4] (ii) freedom of access to all areas of celestial bodies;[5]and (iii) freedom of scientific investigation in outer space including the moon and other celestial bodies.[6]

Hobe (2009) has commented that 'freedom' here connotes that any entity is free to explore or find out possible use of outer space without any permission from any other state.[7] A state is free to take any space activity(s) including economic activities and even profit from these activities.[8] This freedom is not restricted to the government but also available to non-governmental entities and individuals via Article VI[9] of the OST.

The freedom in outer space, including the Moon and other celestial bodies, is not *absolute*. There are limitations set by Article 1 and some express limitations outside Article 1 of the OST. Paragraph 1 of Article 1 provides that the freedom shall be exercised for the "benefit and interests of all countries" and continues later that it shall be the "province of mankind". It reminds the States that outer space is not under the jurisdiction of specific States and therefore an activity carried out in outer space and on celestial bodies may not be undertaken for the sole advantage of States.[10] The freedom is to be exercised in a non-discriminatory manner, on the basis of equality.

The limitations stated outside Article 1, meanwhile, include the non-appropriation principle,[11]the applicability of international law and the UN Charter,[12] limited military use,[13] international responsibility for national activities,[14] and avoidance of harmful contamination in outer space.[15]These are discussed in turn in the following sections.

ii. Non-appropriation principle

The freedom of exploration and use of outer space is subject to the non-appropriation principle. "The exploration and use of outer space…is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means."[16] The 'non-appropriation' principle is the fundamental rule regulating the exploration and use of outer space that aims to protect outer space from the possibility of conflict driven by territorial or colonisation-driven ambition.[17] It prohibits sovereign or territorial claims in outer space. No amount of the use or occupation of outer space will ever suffice to justify a claim of ownership rights over the whole or any part of outer space, including the Moon and other celestial bodies.[18]

iii. Space Exploration in accordance with international law

Article III of the OST widens the ambit of legal prescription to space activities and makes international law, including the Charter of the United Nations, applicable to them. Judge Lachs has expressed that "the obligation to confirm with the Charter of the United Nations implies not only the application of provisions of international law as defined by it but also all those that have grown as a result of the further development of the United Nations and subjected to a new and more up-to-date interpretation."[19] Thus, new principles set out by the treaties become applicable to space activities with the development of international law.[20] In addition to the OST, India has signed and ratified the Rescue Agreement, the Liability Convention, and the Registration Convention. Therefore, all national space activities must be in accordance with the four space treaties, the international law in general, and the UN Charter in particular.

iv. Peaceful Use of Outer Space

Article IV of the Outer Space Treaty strives to limit the use of space for peaceful purposes. It prohibits placing of nuclear weapons or weapons of mass destruction in the orbit of Earth.[21] The establishment of military bases, installations and fortifications is forbidding, as are the testing of any type of weapons and the conduct of military manoeuvres on celestial bodies. The Moon and other celestial bodies are to be used exclusively for peaceful purposes.

v. Liability for damage caused by space objects

It is the responsibility of States to ensure that their national activities are carried out in conformity with the OST.[22] A failure to diligently discharge this responsibility will make the State liable for damages caused by the space object. The 'launching state' bears international liability to compensate for damage caused by its space object.[23]

vi. Avoidance of harmful contamination

Article IX of the OST may be considered the basis for environmental protection of outer space and its preservation for peaceful use. Activities in outer space are considered highly hazardous, possessing the risk of harm to both terrestrial and outer space environment. States must "conduct exploration of outer space, including the Moon and other celestial bodies, in such a way so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, [to] adopt appropriate measures for this purpose." With respect to private entities participation in space activities, States must ensure that their activities do not create debris or if in remote possibility debris is created, they must have adequate debris remediation measures in place.

Article 51 of the Constitution of India mandates to foster respect for international law and treaty obligations. At present, space activities in India are regulated through a few policy documents and rules that are grossly inadequate to regulate entry of private players in space in light of the country's international obligations.[24] Thus, effective means of implementing international obligations must be in the priority agenda for India's space legislation. It must be ensured that private entities do take responsibility for compliance with international treaties, the failure of which may cause liability for India.

Domestic Requirements

i. Authorisation of space activities

The international obligations laid down by the Outer Space Treaty do not bind private enterprises.[25] Indeed, private entities reap the benefits of space, whereas all obligations vest with the States. In this respect,the OST itself provides for a framework determining how to bind private entities.[26] "The activities of non-governmental entities in outer space…shall require authorization and continuing supervision by the appropriate State Party to the Treaty."[27]Analysts have commented that since sentence 2 of the OST exclusively deals with the activities of non-governmental entities, therefore Article VI sentence 2 is the starting point for discussions on the privatisation of space activities.[28]

However, Article VI prescribes neither the contents of authorisation nor the manner of authorisation. It is left rather to the discretion of the State to decide the contents of authorisation. It is clear from sentence 1 of the OST that compliance is an inherent requirement for authorisation. Second, since space activities are inherently dangerous,the safety and security of a nation is of paramount importance. Other issues like environmental safeguards[29] and financial and technological capacities of the private entity are important factors for authorisation. Liability for damages caused by space objects[30] and registration of space objects[31] are other important international obligations set forth by the OST.

ii. Continuing Supervision

It is important that conditions of authorisation—i.e., compliance with international obligations, safety and security—are complied with not only at the time of seeking authorisation but throughout the operation of that space activity. It is for this reason that Article VI of the OST, in addition to authorisation of non-governmental activities,also demands continuing supervision. Existing national space legislations of various countries suggest that States fulfill this obligation by imposing a duty upon private actors to furnish the concerned government agency with periodic information. Any change in the initial conditions of the authorisation issued to the entity must be communicated to the authorising body. States reserve the right of search, seizure, inspection of documents and facilities related to the space activities of these private actors. Failure to comply with any of the authorisation conditions may invite sanctions from the State in the form of suspension, termination, or cancellation of authorisation,as well as possible monetary fines and imprisonment.

iii. Liability for damage caused by space objects

A launching State is internationally liable for damages caused by its space object.[32] A State that launches or procures the launching or from whose territory or facility an object is launched qualifies as a launching State.[33] The rationale for imposing liability on the launching state for damage inflicted on other State parties is the interest of the international community in securing a reliable state liability regime to respond to these ultra-hazardous activities.[34]

The combined effect of Article VI and Article VII of the OST is that States are both internationally *responsible* and *liable* for damages towards other State parties and their nationals for their national space activities.[35] This obligation extends to assuming liability for private operations for which a State is responsible under Article VI.[36] The Liability Convention[37] elaborates further the rules and procedures for damages caused by space objects. It prescribes a two-fold liability regime: A launching State is absolutely liable for damages caused by space object on earth or in air space,[38] whereas for damages caused in outer space, liability is on-fault based.[39] In view of the immense risk posed by the ultra-hazardous space technology, a victim-oriented approach has been taken prescribing non-fault based, absolute or objective liability.[40] In case of two or more States jointly launching a space object, their liability is joint and several.[41]

Thus, 'public liability for private activities'[42] is a strong incentive for States to legislate. "If States are internationally responsible for private space activities, they have a vital interest in regulating such activities and in making sure that norms of international space law are respected by private space actors – as far as possible".[43] It must not be misconstrued that by merely enacting a legislation, States can escape liability for damage caused by private entities.[44] Rather, liability always vests with the launching State – "once a launching State, forever a launching."[45] However, by way of legislation a State can prescribe a mechanism for recourse.[46] It can reserve its right to seek indemnification should a State be required to pay on behalf of its private entities. Should the State seek absolute indemnification or put a cap, this will depend upon the space policy of a State towards private entities. State practices suggest that many States[47] put a limit on the liability of private players beyond which the State itself bears the liability. It serves as an incentive for private players,though to avail this benefit it is expected that private entities exercise due diligence. Further, since damages are oriented to the future, "unlimited in quantum and territory",[48] it is in the interest of States as well as private enterprise that mandatory third-party insurance is undertaken.[49]

iv. Registration of Space Objects

Jurisdiction and control of space objects is determined by the registration of space objects.[50] The Cologne Commentary on Space Law has commented that 'jurisdiction' means the legislation and enforcement of laws and rules in relation to persons and objects and 'control' means the exclusive right and the actual possibility to supervise the activities of a space object, and if applicable the space object".[51] "Ownership of objects launched into outer space, including, objects landed or constructed on a celestial body, and of their component parts is not affected by their presence in outer space or on a celestial body or by their return to the Earth."[52]

The implied requirement of maintaining a national register of space objects provided for in Article VIII of the OST has been expressly stated in the Registration Convention. A launching state must maintain a national registry of objects launched into outer space and must inform the UN Secretary General of the establishment of such registry.[53] Further, it must furnish the UN Secretary General, as soon as practicable, the information in a prescribed manner concerning the space object carried on the national registry.[54]

Thus, despite a space activity being undertaken by a private entity, the respective launching State has yet another obligation to register its space objects. This is in the interest of State. If the private entity is found violating its authorisation conditions, a State need not do anything extra to take over jurisdiction and control.[55] By virtue of the registration of space objects, States already exercise jurisdiction and control of all space objects launched under their registry. It might appear that the private entities are in a disadvantageous position but it is rather a win-win situation for both of them. A State will overtake control of a space object only for non-compliance of authorisation conditions, which means a private entity must throughout the operation of its authorised activity strictly adhere to these conditions. To avoid arbitrary State action it is important that legislation prescribes authorisation conditions in clear, unambiguous terms, ensuring transparency and predictability in establishing 'rule of law'. The registration of space objects shall also serve as an enabling tool in ensuring 'continuing supervision'.

In the era of commercialisation, it is likely that there may be on orbit sale-purchase/ transfer of space objects. An inter-State sale-purchase/ transfer of space object might be problematic, as it is clear that UN treaties do not allow the transfer of a launching State's obligations. It is essential that national space legislation prescribes conditions of sale-purchase/transfer and, in case of inter-State sale-transfer, an Inter-State agreement shall be needed wherein the transferee State agrees to take all responsibility for such space object and in case of any liability arising from the sale/transfer, the transferee State agrees to indemnify the transferor State.[56]

Article VI of the OST, widely seen as the basis of national space legislation, only demands authorisation of space activities that could be achieved by any other means, not necessarily through legislation. But as discussed earlier, the obligations flowing from international treaties are highly complicated that it is desirable for States to enact their national space legislations. In view of the ongoing privatisation of space activities, the international space law in particular on many counts requires domestic implementation by means of national laws.[57] Realising the importance of national space legislation, India is working on its draft legislation.[58] As reported in the *Deccan Herald,*[59]the inter-ministerial body is currently reviewing the draft legislation. Once the review is complete, the draft legislation will be placed in the public domain.[60]

Concerns of Non-governmental Entities

Space activities are increasingly becoming diversified and more profit-oriented, relying mainly on contributions from the industrial sector.[61] Since non-governmental entities are the direct beneficiaries of this legislation, they are prominent stakeholders in national space legislation. National space legislation must address their needs and requirements as well.[62] A potential investor will expect the rules to be transparent and reliable, which shall in turn enable them to weigh the risks and resilience factors before entering into this business that not only entails huge risks but is also costly.[63] 'State Practice' suggests that this has been generally achieved through implementing rules and decrees. In addition to National Space Legislation, implementing rules and decrees will be required to fill the gaps between theoretical law and practical necessity. This sets up the immediate future task for the nations, which are in the process of drafting their respective national space legislations.

Legislation should also prescribe an inherent mechanism for their growth and self-reliance. A study of national space legislations of spacefaring nations could show the path in this regard. Some legislations prescribe limited liability of private enterprise towards third-party damages, whereas others provide for reduced administrative fee/waiver of insurance conditions for certain activities, which could serve as a model for drafters. The United States and Australia are considered to have the most developed legal systems for space activities. Until 1984, before the US Commercial Launch Act put a cap on the liability, private enterprisesdid not get motivation to engage in space activities because they had to bear unlimited absolute liability for damages.[64] They argued that unlimited absolute liability would either cause them to perish or would dissuade them from starting up their business unless an appropriate ceiling was put.[65] On the lines of US, subsequently the 1998 Australian Space Activities Act limited the liability of Australian national private enterprise. The Explanatory Memorandum[66] to the Australia's Space Activities Bill stated, "imposition on launch operators of unlimited liability is neither commercially tenable nor desirable from a competitive standpoint." Besides limited liability space regulations in Australia may prescribe for different administrative fee for approved scientific or educational organisations.[67]

A similar approach has been experienced with national space legislation in Europe, including in France, one of the world's most important spacefaring nations. A special feature of the French Law on Space Operations is the possibility of a state guarantee, often considered to be as public subsidy.[68] The State owns the responsibility for damages exceeding the insurance amounts.[69] Where the operator provides some other form of financial guarantee, insurance can be avoided.[70] Further, while the French government has reserved the right to make claims for indemnification by the operator in cases where it has paid international liability, the "Government will not make a claim for indemnification if the damage was caused by a space object used as a part of an operation authorized according to the Act and resulting from acts targeting governmental interest".[71] A similar approach has been witnessed in the Austrian national space legislation wherein if a space activity serves science, education and research the insurance amount may be lowered to the extent of complete waiver depending upon the risk involved and the financial capacity of the operator.[72] Even the South African Space Affairs Act has a residual clause where the liability of licensee for damage may be limited or excluded.[73]

Initially, private enterprises in the United Kingdom used to self-bear unlimited liability but beginning in 1 October 2015,[74] the UK has also put a limit on their liability. The latest in the trend comes from Japan. As reported in the *Yomiuri Shimbun,*[75] Japan has passed outer space-related bills designed to support space activity by business enterprises and other entities. Through the outer space activities law, "the government authorizes and stands surety for rocket launches by the private sector." The government will share responsibility for compensating damage on behalf of private enterprise.[76] This indicates that the march of national space legislation across the world is towards shared public-private liability. A limited liability is expected to "prove effective in making it easier for private enterprises to take up the challenge of outer space development, which involves enormous risks."[77]

Issues of technology transfer; financing and protection of intellectual property rights are of paramount importance for space commerce.[78] The US Space Code could be a good study in this aspect. "The role of law is not merely to regulate rights and obligations of subjects, it also provides norms and institutional mechanism to promote the policy goals of the community."[79] Thus, intended legislation should serve as an enabling factor and not as an impediment for the growth of private enterprise. India is also aspiring to develop its commercial launch industry.[80] Undoubtedly, the experience of launching countries shows that if a viable space industry is to emerge in India, significant governmental support will be needed not only during the initial phase,[81] but also in latter phases, so long they undertake space activities.

Conclusion

Articles VI, VII and VIII of the OST establish the primary basis for national space legislation. At present, there exists a wide gap between the international requirements and the domestic legal instruments to implement these obligations. Having successfully demonstrated five decades of space capabilities, India now needs to formalise and define the institutional legal mechanism for its space activities. Being a party to existing international space treaties, India has realised that for promoting private sector participation it is essential to have space legislation. It is expected that India's national space legislation will take care of international obligations as well domestic requirements, and at the same time, serve as an enabler of space commerce facilitating private enterprise. State practices suggest that space legislation provides inbuilt mechanism for necessary governmental support for the growth of the private sector.

Since private space activities are significantly going to increase, national space legislation is just a beginning step. Depending on the particular kind of activity—say, commercial launch, remote sensing, satellite communications, satellite navigation, geo-spatial data usage and others—further theme-based, specific laws will be needed. This shows that there is ample scope for developing a robust legal regime for commercial space activities in India, as has been shown by the United States. Private enterprise is going to give second impetus to space activities in India and, accordingly, laws must develop. National space legislation is the immediate need of the hour if India is to aspire for the 2018 public-private partnership mission to the Moon, and its first privately built rocket launch in 2020.

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9

SATCOM Policy: Bridging the Present and the Future

Ashok G.V. and Riddhi D'Souza

Introduction

The world is breaking free of the shackles to its imagination and is looking towards space, not just as means to satisfy its existential curiosity, but to achieve resource security and bridge people and nations. With the United States government announcing its support to private enterprises mining space objects[1] and the government of Luxembourg setting up a fund to enable such activities,[2] space is no longer the exclusive forte of governments alone. These instances reveal an increasing synergy and cooperation between governments and the private sector. Thus, space, which was once the forte of governments, now represents an opportunity as well as a responsibility for the private sector. A partnership between these stakeholders is inevitable and perhaps even desirable to drive innovation and overcome challenges associated with leveraging and exploring space.

India, being sixth[3] in the list of the world's spacefaring nations, is not far behind. The Indian Space Research Organisation (ISRO) has demonstrated its capacity for deep-space activity through its Mars mission. Moreover, the recent achievements of the Polar Satellite Launch Vehicle (PSLV) and Geosynchronous Launch Vehicle (GSLV) have established that the Indian space programme is not cheap, but in fact, cost competitive and effective. ISRO is already thinking of models to engage with the private sector for the operation of the PSLV.[4] Seen in conjunction with the initiative to engage the private sector for satellite integration activities,[5] there is no doubt that ISRO is driven by a forward-thinking vision designed to encourage and support the private sector's aspirations to be part of India's space story. While the development of a private space sector in India represents one part of the reason to actively engage the private sector, there is a more fundamental need to address grassroots demand for communication and broadcasting services.

As of 31 June 2016, India recorded close to 159.76 million broadband subscribers[6] and over a billion mobile phone subscribers.[7] The demand for pay-TV alone is projected to hit US$18 billion.[8] Consequently, the Indian market represents huge opportunities for satellite-based communication services. However, less than 50 percent of commercial satellite capacity in India is served today by Indian satellites, with the majority being provided by foreign satellite operators such as SES, Intelsat and AsiaSat that sub-lease capacity to ISRO.[9] In fact, there are now seven foreign satellite operators, including one high-throughput satellite operator (Thaicom), that provide bandwidth commercially, the vast majority indirectly through ISRO.[10] This situation is the result of a disparity between the lack of capacity available from ISRO and the strong growth in demand in recent years, driven by DTH TV broadcasting.[11] It is thus anticipated that the revenue potential for foreign suppliers of communication satellites should remain in the hundreds of millions of dollars over the next 10 years, despite continuous improvement of domestic capabilities at ISRO.[12]

Furthermore, initiatives like the Digital India programme, slated to be worth US$20 billion[13] along with the proposed Goods and Services Tax Network, which is an online platform for management and compliance of India's proposed singular indirect tax regime, is likely to lead to a huge surge in the market for internet connectivity. Under the circumstances, one can reasonably assume that India will be the most sought after destination for both domestic and foreign satellite service providers. Presently, India has inherent advantages over other countries due to the availability of skilled workforce, a stable and business-friendly government, positive investor climate, and low cost of operations[14] besides representing an enormous market opportunity.

Indian companies like Ananth Technologies Limited[15] and Astrome[16] are already developing satellite systems to meet this demand and they are driven by both vision and capability that is on par with the best in the world. Especially with upcoming space start-ups, what makes the Indian private sector exceptional is also their commitment to national interests and their respect and appreciation for the Indian space programme. If this potent combination of talent and vision among the private space enterprises in India is integrated with the government-authored space programme, India can consolidate its position as one of the most powerful spacefaring nations in the world and indigenise its SATCOM and Broadcasting infrastructure. However, to give flight to the aspirations of the private space sector in India, a critical area of need is to put in place an enabling space policy.

The present Indian space policy is summarised by the following:

- Framework for Satellite Communication in India ('SATCOM Policy');
- The Norms, Guidelines and Procedures for implementation of the Policy framework for satellite communications in India ('SATCOM Norms');
- Remote Sensing Data Policy, 2011 ('RSDP');
- Technology Transfer Policy ('TTP')

To India's credit, the sum total of the above policies not only acknowledgesthe existence of a private space sector in India, but numerous provisions are made to enable a private space economy by creating a framework for authorising and launch of satellites, for leveraging the data generated by remote sensing satellites and also for commercially exploiting technologies developed by the Indian space programme. With a Foreign Direct Investment Regime allowing for 100-percent FDI in the establishment and operation of satellites,[17] one would assume that India would have attracted a significant portion of the global investments in the space sector. Yet, with all its technical prowess and skilled labour, India's private sector has not matured beyond a vibrant vendor ecosystem for the nation's space programme.

This chapter examines the role of the SATCOM Policy and Norms in addressing this predicament and offers a solution-based narrative that is forward-thinking in vision and collaborative in approach. After all, if the policy and the norms are suitably reviewed and addressed, it not only can significantly encourage the private space sector in India but also become the foundation for a strong government-private sector partnership that will help India achieve its aspirations in space.

The private sector's engagement with the Indian government are broadly classified into two categories: 1) Where the government is the customer for technologies and services developed by private space enterprises; and 2) Where the government is the enabler for private space enterprises to do business and become commercially viable. Parallel to this classification, this chapter recognises that India's space policy must also achieve the difficult balancing act of:

a) Ensuring compliance of international obligations;
b) Preservation of national security and the legacy of the Indian space programme;
c) Promoting national interests; and
d) Enabling the aspirations of the private space sector in India.

Understanding SATCOM Policy and Norms

India's SATCOM policy ('Policy') and SATCOM norms ('Norms'), covers that area of policy where the government is mostly the facilitator or the enabler of commercial space activities. The SATCOM Policy, read with the Norms, addresses three principal subjects:

1. Allocation and utilisation of INSAT Capacity
2. Establishment and Operation of Indian Satellite Systems
3. Use of Foreign Satellites for SATCOM Services

INSAT Capacity

The Policy authorises capacity on the INSAT satellite systems to be leased to non-government (Indian and foreign) parties as well as for Indian parties to provide services including TV through Indian Satellites. At the outset, quota allotted for the Department of Telecommunications, Doordarshan and All India Radio for the use of INSAT Capacity is untouched. Clause 2.5.2, read with Clause 2.6.2 of the Norms specifies that a certain percentage of INSAT capacity will be earmarked for lawfully authorised non-governmental users to provide telecommunication services including broadcasting or any other service so authorised by the Department of Space.

The provisions of Clause 2.6 vest discretion in the Department of Space to oversee and manage the commercial activities of Department of Space/INSAT or any corporate structure meant for operating INSAT System. Where the demand exceeds the capacity, the DOS/INSAT is required to evolve transparent procedures for allocating the capacity which could either be in the form of auction, good faith negotiations, first-come first-served, or any other equitable mechanism. The Norms also envisages an INSAT Coordination Committee to formulate suitable policies for the use of the INSAT System.

Establishment and Operation of Indian Satellite Systems

For the purpose of authorising launches and operation of satellite systems, the Norms contemplates a Committee for Authorising the Establishment and Operation of Indian Satellite Systems ('CAISS') that will review applications seeking Authorisation from the Department of Space to own and operate an India Registered Satellite System (including the Spacecraft Control Centre) as well as for setting up a Space Station.

The CAISS draws its composition from the following departments and ministries of the Government of India:

- Department of Space
- Ministry of Information and Broadcasting
- Ministry of Home Affairs
- Ministry of Defence
- Ministry of Industry
- Wireless Advisor to the Government of India

As per Section 3.6.1., only an Indian Registered Company may be allowed to establish and operate an Indian Satellite System. However, Foreign Direct Investment (FDI) of up to 100 percent through the approval route is allowed in the Applicant Company.

Besides the insistence on Indian Applicants, the Applicant must be able to demonstrate, technical and financial credentials to undertake the construction, launch and operation of the proposed satellite systems within the time scales contained in its business plan.[18] Furthermore, the ground unit, i.e., the Satellite Control Centre (SCC), must be situated in India.[19] The SCC may also be situated at any other place specifically authorised by the CAISS, provided, however that the same is shifted to a place within India within two years of the grant of licence.[20]

As per Section 3.6.7., the Authorisation Contemplated under the SATCOM Policy and Norms, is primarily for Satellite Communication Services and specifically, of the following variety:

a. For new Orbit Spectrum
b. In the unplanned bands
c. In the planned bands (in accordance with ITU established Plans)
d. For the allotted orbital slots (in accordance with ITU established plans)
e. At Frequency bands and orbital slots for which India has set up coordination processes already, in anticipation of requirements.

Therefore, once the application for authorisation to operate a satellite system is submitted, the next leg of responsibility is on the Administration, the Wireless Planning and Co-Ordination Wing of the Ministry of Communications, to secure the orbital spectrum from the ITU, upon compliance of ITU regulations.[21] While the Norms do contemplate competition for the same orbital spectrum between different applicants,[22] they do not prescribe an elaborate mechanism or policy framework for resolving such conflicts. In addition, for activities specified in (a) and (b) above, government-owned systems are given first priority.[23]

Use of Foreign Satellites for SATCOM Services

The Norms adopt a cautious approach towards the use of foreign satellites for operations in India. Unlike Indian registered satellite systems, use of foreign satellites in India requires permission of the Indian government and the same is afforded only in special cases. In fact, further reading of the policy suggests that such permissions are afforded to:[24]

- International inter-governmental systems that are owned and operated by Indian parties but registered in other countries prior to the Indian state formulating rules for such registration or

- Where Indian parties have participated in the foreign satellite system through equity or some other contribution.
- Where such permission is necessary to honour reciprocal arrangement with the country/countries of registration or ownership of such foreign satellite systems.

Furthermore, preferential treatment is earmarked for Indian satellite systems over foreign satellite systems.

Reviewing the Effectiveness of the Policy and the Norms

The Policy and the Norms define the role of the government as an enabler or facilitator of commercial space activities. While the portions covering INSAT Capacity management and satellite operations, deals with downstream space activities, the authorisation of launch of the satellite deals with upstream space activities. Policies of this nature governing space activities have to achieve the difficult task of ensuring compliance of international obligations, ensuring encouragement for commercial space sector and ensuring national interests. With this in mind, we now map the areas of the policy and norms, where there is scope for reforms and improvements.

Compliance with International Obligations

India is a signatory to the Outer Space Treaty and is thus responsible for all space activities arising out of its territory or its mandate. In addition, space activities are also governed by a number of other international treaties that, *inter alia*, prohibit the use of weapons in space, require steps towards mitigation of space debris, impose obligations to pay compensation for any damages arising from a nation's space assets and finally mandate fair treatment of astronauts landing back on earth, regardless of the region where they land. This then leads to the question of India's responsibility for compliance with these international obligations.

The essential characteristics of responsibility hinge upon certain basic factors: first, the existence of an international legal obligation in force; secondly, that there has occurred an act or omission which violates that obligation and which is imputable to the state responsible , and finally, that loss or damage has resulted from the unlawful act or omission.[25] In the

Spanish Zone of Morocco claims, it was held that responsibility is the necessary corollary of a right. All rights of an international character involve international responsibility. Responsibility results in the duty to make reparation if the obligation in question is not met.[26] In view of this, it is now necessary to see what is the international obligation India has assumed so far as space activities are concerned and then assess the question of India's state responsibility under International Law.

So far as the activities of private space enterprises are concerned, the Outer Space Treaty does mention that the state party can authorise space activities by non-state actors.[27] Such authorisation is provided either by virtue of law enacted specifically for the said purpose or by virtue of a contract between the Government of the State Party and the private enterprise. India has leaned in favour of the latter category of authorization, i.e., by virtue of contract. Though, it arguably provides a great degree of discretion and flexibility to India to monitor and regulate space activities, an *ad-hoc* contracted based authorisation leaves much to desire for, so far as compliance with international obligations is concerned.

To begin with, the Convention on International Liability for Damage caused by Space Objects imposes fault-based liability for damage arising out of space objects, if the occurrence of such damage is outside of the surface of the Earth.[28] For damage caused to persons or property on Earth, the liability imposed is absolute in nature.[29] The liability for both kinds of damages is imposed on the state party. Article 5 of the International Law Commission Draft Articles on Responsibility of States for Internationally Wrongful Acts ('ILC Articles'), in reaction to the proliferation of government agencies and parastatal entities, notes that the conduct of a person or of an entity not an organ of the state but which is empowered by the law of that state to exercise elements of governmental authority shall be considered an act of the state under international law, provided the person or entity is acting in that capacity in the particular instance. This provision is intended inter alia to cover the situation of privatised corporations which retain certain public or regulatory functions.[30]

Further, Article 8 of the ILC Articles provides that the conduct of a person or group of persons shall be considered as an act of state under international law if the person or group of persons is in fact acting on the instructions of, or under the direction or control of, that state in carrying out the conduct.[31] Thus, whether or not the breach occurs in the hands of the Indian government or a private agency authorised by the Indian government, international law remains insistent on appropriate remedies. Thus, depending upon the nature of breach of international obligation, the consequences could be cessation, reparation or compensation. While India can quantify the liability arising out of these headings, the loss of reputation on account of such a breach would be immeasurable.

International treaty obligations do not automatically become part of Indian law. Article 51 (c) of the Constitution of India stipulates that India shall endeavour to foster respect for international law and treaty obligations in the dealings of organised peoples with one another. However, this is part of the Directive Principles of State Policy and thus not binding on the state as perArticle 37.[32] Therefore, India remains particularly vulnerable in respect of its obligations under International law for space activities because, on one hand, it is responsible for breach of such obligations but it has no domestic law which it can use to enforce compliance of international obligations on non-state actors. That the policy and the norms do not specify specific consequences if a private space enterprise breaches India's international obligations, only aggravates the problem.

To ensure private space enterprises are legally bound to honour India's international obligations towards space activities, the solution remains a legal regime that can either specify civil punitive consequences or criminal punitive consequences. Civil Punitive consequences such as damages and compensation can be achieved through contracts or by way of law. But as far as penal consequences are concerned, such as penalties, fines or imprisonment, Indian law in consonance with international human rights jurisprudence, permits penal consequences only by way of explicitly defined offences under statues. What is not explicitly defined as an offence or a crime, cannot by implication or interpretation become a crime under Indian law.[33] India thus cannot meaningfully safeguard its obligations under international law unless it undertakes legislative exercises to render them enforceable under Indian law.Reviewing the SATCOM Policy and norms, in view of this discussion, is thus critical for India's own interest.

India must also remain mindful of obligations under its Bilateral Investment Treaties (BIT). The provisions of such agreements are remarkably uniform and constitute valuable state practice.[34] India itself has signed BITs with many countries, India is under an obligation to treat members of the contracting state in a fair and equitable manner and must refrain from any action that is arbitrary or discriminatory in nature.Yet, in the recent past, India's actions, though well within its sovereign domain have attracted punitive civil consequences under International Law. The decision of Antrix to cancel the agreement for licensing of spectrum to Devas (initially slated to be based on non-compliance of transparent procedures and later slated to be on account of rationing of S band spectrum), has led to two international arbitrations,[35] one of which culminated in an award requiring India to pay damages to the tune of US$ 672 million.[36] The cancellation of licences in the 2G spectrum case by the Supreme Court of India, has also provoked arbitration proceedings by Khaitan Holdings against the state.[37]

Considering that an ad hoc, contract-based approach to resources have revealed a pattern of arbitral proceedings against India, there is a need to review the SATCOM Policy and norms so thatthe engagement with the private sector is planned and implemented in a manner consistent with International Investment Law, specifically, with India's treaty obligations. While ensuring the review of SATCOM Policy and norms, as set forth above, is necessary to safeguard India's own interests under International law, the other reason why this review is necessary is also to inspire confidence in the private sector. From the point of view of a private sector enterprise, not being able to assess India's position on key facets of international law creates an atmosphere of uncertainty which can adversely affect business strategy and planning.

Lastly, as the US[38] and Luxembourg[39] continue to push the boundaries of space economy by encouraging asteroid mining through appropriate legislations, India must take care not to get left behind. India through the ISRO has always been a responsible spacefaring nation and its history of a value-based space programme also places upon it, the obligation to assume thought leadership on emerging areas in space policy, such as asteroid mining. However, for India to assume its rightful place as a leader among spacefaring nations, it is time that it projected its confidence through a space policy that conveys its position on international obligations clearly and explicitly.

Separating Regulator from Operator

As much as there is a need and a case for enabling a private space economy in India, the paramount considerations must remain national interest and therefore national security, retaining a central role for the Indian Space Research Organisation and mitigating the risk of international liability arising out of space activities. Therefore, the Indian government must retain the function and power of regulating space activities. However, the agency of the government which will retain this function and power is where there is scope for reforms and change.

As it stands now, the Department of Space, the ISRO and Antrix Corporation represent the administrative, executive and commercial wing of India's space programme. These three agencies share a symbiotic relationship and therefore India's space regulator, despite a history of integrity and transparency, has nevertheless failed to win the confidence of the private sector. It is perhaps for this reason that despite the 100-percent FDI in the SATCOM sector, the investments flowing into the country for the SATCOM field is only a fraction of its full potential. In principle, there are two ways of addressing this problem:

1. Creating an independent body similar to the approach of the Commercial Space Launch Act, 1984 which vested regulatory functions and powers to the US Department of Transport.
2. Reducing the role of ISRO in operations by transferring the same to the private sector and retaining only research and development functions with ISRO.

ISRO has already indicated interest to privatise the PSLV program and is increasingly looking to the private sector for satellite integration activities.[40] This indicates thought leadership of the ISRO and a certain drive within the governance circles to align India's space program with international best practices. To lend further support to this drive and initiative, it would be useful for the Indian government to review the powers of space regulations in independent bodies.

Capacity Management: Aligning capacity with Market needs

The recent CAG report disclosed the potential for better commercial exploitation of India's space assets.[41] In other words, satellite capacity, spectrum and frequency related functions represent tremendous potential for commercialisation and India is yet to leverage the commercial potential of its space assets. Furthermore, as India looks to the Goods and Services Tax Network to take its entire indirect tax compliance program online, the rapid percolation of internet to the last mile is now directly linked to India's national interests. This can be better served with High Throughput Satellites rather than through the time consuming and difficult exercise of creating the fibre optic network. Yet, the CAG report referred to above, discloses the need to integrate the understanding of the need on the ground with the capacity and infrastructure available in the sky.

One way of addressing this need is to enhance the role of the Department of Telecom (DOT) together with the Telecom Regulatory Authority of India (TRAI). Under The Government of India (Allocation of Business Rules) of 1961, DOT has, *inter alia,* the following functions:

1. Policy, Licensing and Coordination matters relating to telegraphs, telephones, wireless, data, facsimile and telematic services and other like forms of communications.
2. International cooperation in matters connected with telecommunications including matters relating to all international bodies dealing with telecommunications such as International Telecommunication Union (ITU), its Radio Regulation Board (RRB), Radio Communication Sector (ITU-R), Telecommunication Standardization Sector (ITU-T), Development Sector (ITU-D), International Telecommunication Satellite Organization (INTELSAT), International Mobile Satellite Organization (INMARSAT), Asia Pacific Telecommunication (APT)."

Furthermore, the following objectives identified in the Final Strategic Plan[42] of the DoT reveals its vision and expertise in the area of Communications and broadcasting, namely:

- Optimum utilisation of scarce spectrum resource.
- Ensure security in telecom networks and adopt effective measures to deal with cyber threats.
- Grant of telecom licences in an objective and transparent manner
- Promotion of robust competitive market for telecommunications services.

- Convergence of technologies, services and harmonisation of regulatory framework.
- Convergence of IT, Broadcasting & Telecommunications.
- Refarming of radio frequency spectrum including increased availability for telecommunications services.
- Rapid expansion of Telecom infrastructure for Voice, Data & Video with special emphasis on rural and remote areas.

DoT and TRAI have done an admirable job of ensuring India's edge in the telecommunication and broadcasting sector. Their sensitivity to India's needs on the ground and impeccable understanding of emerging trends in telecommunication industry is unparalleled as was seen in the context of the debate around net neutrality.[43] Therefore, the DOT and TRAI not only have the mandate under the Allocation of Business rules, but also the expertise to manage spectrum, capacity and frequency and also to handle all issues surrounding the same.

Thus, it would be useful for the SATCOM Policy and Norms to be amended so as to ensure that spectrum, satellite capacity and frequency licensing are handled by the DOT and TRAI, with ISRO remaining in an advisory capacity in order to bridge India's resources with needs on the ground.This will ensure that India's national interests are managed by the government and address any fears ofnational interests being overwhelmed by commercial interests. In addition, bridging the understanding of market needs and realities with the planning for space missions will optimise the returns on India's investments into space activities.

It is also relevant to review the procedure specified for allocation of INSAT Capacity where the demand exceeds availability. While the Norms mandate that a transparent procedure must be evolved to address excess demand and insufficient supply, in view of the judgement of the Hon'ble Apex Court in the famous 2G spectrum matter,[44] the procedure to be adopted for resolving such competition must also comply with the requirements of reasonableness under Article 14 of the Constitution of India. Furthermore, one must be skeptical of resorting to the procedure of "First Come First Serve", as means to address competition for capacity in view of the said judgement. Consequently, the existing Policy and Norms must now suitably embrace these changes since 2000 to achieve legal compliance and alignment with market realities.

Authorisation for launch and operation of Satellite Systems

Lastly, coming to the subject of launch of satellites into space, the SATCOM Policy and Norms no doubt creates a Committee for the Authorisation and Establishment of Indian Satellite Systems (CAISS) which will clear applications to build and launch Indian satellite systems. However, some concerns and implications arise in view of the SATCOM Norms and the same are briefly discussed below.

a. The process of applying for and securing licences to own, launch and operate a Satellite System registered in India is time consuming as no deadlines are prescribed for clearances of such applications.

b. In the absence of explicit deadlines for the review and approval of such applications, the Industry must plan for delays in securing necessary approvals and factor that into their business plans.

c. The Department of Space, the parent organisation of ISRO and close affiliate of Antrix Corporation, is not only the regulator, but also a satellite service providerand therefore a competitor in the market for Space-based services.

d. The Norms do not address the question of access to facilities for launch of space objects. In other words, mere securing of the licence to own and operate an Indian Satellite System, does not by itself mean access to the facilities of ISRO for undertaking the actual launch.

e. The Applicant is not only bound by the SATCOM norms, but it must also secure licences for the specific services, it proposes to offer through its Satellite System. For example, telecommunication services must also comply with the Telegraph Act and secure licenses for operations. For broadcasters, specific licenses are required under the Broadcasting Act.[45] Therefore, notwithstanding an effort to consolidate interested regulators into one single committee, i.e., the CAISS- single window clearances[46] for the Applicant's overall business plan and objective in Satellite Communication services does not exist in practice.

f. Section 3.7.4 which addresses the monitoring of the activities of the Applicant, post-grant of license, gives extraordinary powers of inspection and expropriation in respect of the Satellite System and Satellite Control Centres. Not only is the Applicant required to file progress reports in respect of the Satellite System for which license was secured, but it must address and satisfy the Department of Space on key issues such as national security.
g. The CAISS has been vested with tremendous discretion in reviewing applications seeking licenses for operating and managing Satellite Systems. But the SATCOM Policy and the Norms fail to explicitly prescribe a framework for the exercise of this discretion.

Furthermore, by prohibiting the services of foreign satellite systems in India, the only option left for satellite service providers is to launch out of India by registering the system as an Indian satellite system. But considering the fact that the application for building and launching satellite systems is fraught with uncertainties on timelines and costs, private investments in Indian satellite systems has been negligible to say the least. That, a key stakeholder in the CAISS is the Department of Space which also oversees ISRO, there is justifiable apprehension of conflict of interest among the private sector enterprises who wish to attempt the application process for launching satellite systems.

In addition, the Norms and the Policy are silent on key issues surrounding confidentiality of technology disclosures made to the CAISS by Applicants, liability inter se between pay load owners and launch service providers in cases of accidents or failure to place payload in the necessary orbit.

Therefore, key changes are required to inspire confidence in the industry, namely:

1. CAISS as a body must remain completely independent of the DoS.
2. Laying down the clear framework for how "technical, financial and legal" considerations is understood by CAISS while determining whether or not an application for establishment and launch of satellite system is allowed.
3. Introduction of deadlines for clearing specific phases of the

application process. No doubt the Indian government cannot speak for the timelines involved in securing orbital slots from the ITU, but it is reasonable to expect deadlines for decisions that involve the authority of the Indian government exclusively.

4. Introduction of the application fee structure into the policy to enable better planning for prospective applicants.
5. Introduction of provisions to clarify on issues surrounding insurance, liability and confidentiality of disclosures made by applicants to the government while seeking clearances.

Operation of Foreign Satellites in India

At the outset, according preferential treatment to Indian Satellite Systems over Foreign Satellite Systems is a noble initiative which aligns with the spirit of the 'Make in India' and 'Startup India' programmes. Yet, history is testament to the fact that dependence on foreign satellite systems in certain instances is inevitable. In this connection, there is a certain mismatch between the Norms which recognises the need to allow inter-governmental satellite systems to operate in India subject to authorisations, and the policies of the DoT and TRAI. To illustrate this, reference is invited to the case study concerning INMARSAT.

Tata Communications Limited (TCL) was offering INMARSAT services to ships under the International Long Distance License secured by it. However, INMARSAT provides its satellite services through a constellation of 4 (Four) satellites located in Geo Stationary Earth Orbits vide its I-3 satellites, which were retired with effect from September2014. This was substituted by their next-generation satellite services provided vide their IsatPhone Pro.[47] In view of the changes in technology, TCL unsuccessfully attempted an application for a GMPCS license to provide INMARSAT based services.[48] Due to TCL being unable to satisfy the Department of Telecom (DOT) about interception and control technologies, its application was rejected.

Bharat Sanchar Nigam Limited (BSNL) was then tasked with the responsibility of setting up a gateway for providing critical communication services which INMARSAT platform allowed. BSNL entered into a Memorandum of Understanding with INMARSAT to set up the same.

But INMARSAT maintained that its services do not qualify as GMPCS services elsewhere in the world and it would thus be unable to support BSNL's application for a GMPCS licence. INMARSAT's stand was well founded not only because of its unique service description but also because the GMPCS license conditions required a gateway to be set up in India which involves prohibitive costs. Upon this issue being placed before the Telecom Regulatory Authority of India (TRAI), TRAI viaits report dated 12 May 2014 recommended that a separate licence category be evolved for grant of clearance to BSNL to provide INMARSAT based services. However, the time taken for the resolution of this issue left much to desire for. During this time, critical INMARSAT services necessary for India government use were left vulnerable.

This case study raises several key points, namely:

1. As far as operation of satellites, use of capacity and licensing of spectrum and frequency is concerned, TRAI and DOT have demonstrated their expertise and experience very well and thus, roles must be carved out for them in amending the SATCOM Policy and Norms to address latest trends in technology and the industry.
2. SATCOM Policy and Norms, asfar as downstream activities are concerned, must constantly evolve with specific policies and practices of the DoT and Ministry of Information and Broadcasting.
3. It would be useful for the government to draw up a list of essential services which are available only on foreign satellite systems without Indian equivalents, to ensure that permission for such foreign satellite systems will be governed by less red tape and bureaucracy.

Conclusion

India, despite its impressive history, is yet to truly reach the full potential of its space programme. Here onEarth, better internet connectivity in remote areas can be achieved through a forward-thinking approach to high throughput satellites which can then aid the cause of successful and widespread compliance of the proposed Goods and Services Tax and its online compliance system, the Goods and Services Tax network. India can support the aviation sector by adopting a liberal approach to in-flight entertainment and connectivity. Away from Earth, as the world looks to space objects to achieve resource security, India should not stay far behind and quickly move to establish its position in deep-space activities, and go beyond just research.

However, what is needed to complement the vision of ISRO and the Department of Space, is a clear and explicit legislative exercise governing space activities. This will have to either amend existing policies discussed above or substitute them altogether with legislations. However, the emphasis throughout this exercise must be to ensure a collaborative atmosphere between the private sector and the government, as opposed to provoking competition or confrontation. If all stakeholders can be sensitive to the many competing interests India must address and balance, the country can effectively assume its position as a world leader in space activities.

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10

A Review of India's Geospatial Policy

Ranjana Kaul

It is accepted that digital connectivity, i.e., to electronically connect all segments of India's billion-plus population, including the disproportionately high numbers of the vulnerable and marginalised, is paramount for all future developments in India. Prime Minister Narendra Modi's 'Digital India' programme, announced in July 2015, sets out the roadmap to achieve ambitious national goals aimed at inclusive socio-economic development, which includes providing citizens ease of online access to government services through extensive deployment geospatial technologies. The National Geospatial Policy 2016, issued by the Department of Electronics and Information Technology (DEITY), represents an adjunct mechanism for achieving the goals set forth by Digital India. It is in this context that the National Geospatial Policy (NGP 2016) is relevant because it recognises that Geospatial Data, Products, Services and Solutions (GDPSS) are multidisciplinary in nature and are important in the context of national development. The NGP 2016 does not propose the use of open access, high-quality geospatial data and information available in India, although it is being widely usedby the private sector and government departments for more than a decade now. Be that as it may, NGP 2016 mandates the use of government-owned geospatial data and information and sets out terms under which users may access such data and informationas may be necessary for facilitating development of the required geospatial technology applications for Digital India. In this context, it is important to note that although it has issued NGP 2016 and exercises oversight of the Digital India project, DEITY is not a national repository for government-owned geospatial data and information. In fact, the role of DEITY is limited to ensuring that India is electronically /digitally connected- i.e., to provide internet highways to enable geospatial data tools to function efficiently and achieve Digital India's objectives. Thus, despite the fact that NGP 2016 has listed various data access procedures, it is clear that the success of Digital India will depend on whetherthe two national repositories of geospatial data and information—the Survey of India (under the Ministry of Defence) and the National Remote Sensing Agency (underthe Department of Space)—provide other government departments the ease of access to government-owned geospatial data and information. In turn, this will aid in the timely implementation of Digital India, which is underthe purview of DEITY. Thus, the merits of the NGP 2016 wish list and geospatial data access mechanisms notwithstanding, unless a single statutory national mechanism to govern the distribution of geospatial data is established, there is the possibility that NGP 2016 and Digital India may not meet with success. Thereby hangs the tale.

It is self-evident that pan-India connectivity is a prerequisite to successfully achieve the 'Nine Pillars of Digital India': (i) Broadband Highways; (ii) Universal Access to Mobile Connectivity; (iii) Public Internet Access Programme; (iv) e-Governance – Reforming Government through Technology; (v) eKranti - Electronic delivery of services; (vi) Information for All; (vii) Electronics Manufacturing; (viii) Digital or IT for Jobs; and (ix) Early Harvest Programmes. Towards this end, the government proposes to improve online infrastructure to increase Internet connectivity, thus facilitating the country to be digitally connected and empowered. Arguably and without exception, the type of government services to be provided electronically will necessarily be referenced relative to the geographic location specific to the user. Indisputably, therefore, geospatial data and information—which are available in both analogue and digital formats—is the cardinal content input for developing geospatial technology platforms for Digital India. As such, the ease of access to government-owned geospatial data and information in a timely manner cannot be emphasised enough. Furthermore, because Digital India is also under DEITY, it is reasonable to assume that NGP 2016 will drive the programme designed to provide citizens the ease of last-mile facility, as it were, to enable access to government services electronically through extensive deployment of geospatial technologies. However, this proposition cannot be accepted at face value.

It is well-known that several government agencies, perhaps even including those already executing the Nine Pillars of Digital India, find it easier to use the freely available open-source geospatial products relevant for India from websites like Google and Yahoo, which have been available via the Internet in the unregulated private sector. Therefore, if NGP 2016 is to be actuated, it is suggested that without comprehensive cross-institution coordination rooted in an appropriate statutory mechanisms to ensure ease of timely access to government owned geospatial data and information, by user government departments/agencies, it is not possible to realistically assess the merits and demerits of NGP 2016.

There are three government entities that serve as repository and suppliers of geospatial data and information in India:

(1). The Survey of India (SOI), established by the colonial power in 1761, is under the Ministry of Defence. It caters mainly to the Ministry. (1A) The National Atlas and Thematic Mapping Organization ('NATMO') an offshoot of SOI, is also linked to DEITY which is tasked to convert the vast quantum of data sets of survey maps into digital format and to depict national framework data in the form of thematic maps and atlases to aid in the country's development and planning initiatives, including physiography, hydrology, climate, administrative, political, social, agricultural, industrial, cultural and economic, as well as to record spatial-temporal changes that occur. Moreover, the Indian Space Research Organization (ISRO) is also tasked to provide technical assistance to NATMO for converting its data sets to digital mode maps; to build required infrastructure; and to build capacity for remote sensing GI and digital image processing in the country. Inevitably, the transition of existing digital mode has been slow. The SOI and NATMO are the only sources in India for the supply of maps, whether digital or analogue. The geographical information held by SOI and NATMO is distributed to users in terms of the licence regime prescribed in the National Map Policy of 2005.

(2). ISRO, on its part, hasalso developed indigenous satellite earth observation ('EO') /remote sensing capability. It aims to provide critical spatial information necessary for framing policies for achieving national socio-development goals. Currently, India has eleven operational remote sensing satellites in orbit – RESOURCESAT-1 and 2; CARTOSAT-1, 2, 2A, 2B; RISAT-1 and 2; OCEANSAT-2; Megha-Tropiques; and SARAL. ISRO focuses on the following areas which are critical for the country's socio-economic development:

(i) Natural Resources Inventory & Databases (NRC, CRD, NRDB)

(ii) Food security (FASAL, Cropping System, PFZ, Fish stock)

(iii) Water Security (snow and glaciers, ground water exploration and recharge, surface water inventory, water quality, water harvesting)

(iv) Natural and human-induced disasters (early warning, pre-cursors, hazard zonation, vulnerability assessment, preparedness monitoring and damage assessment) – Support DSC for DMS, NDEM

(v) Infrastructure Development, Urban & Rural planning

(vi) Weather forecasting

(vii) Ocean State Forecasting (Open oceans and coastal)

(viii) Protection of ecosystem & biodiversity (coastal, marine, terrestrial, forest, wildlife)

(ix) Services to society: through synergy of EO, communication and navigation (e.g., VRC)

(x) Climate Variability and Change (GBP, biogeochemical cycle aerosol transport, energy and water balance)

(xi) Earth Science (lithology, geomorphology, mineral (oil exploration, tectonics, terrain & subsidence); and

(xii) Planetary geology.

All the National Remote Sensing Agency (NRSA), under the Department of Space (DOS), is the repository of all the GIS gathered by ISRO. NRSA is the supplier of satellite images data acquired by Indian remote sensing satellites in the country and internationally. The NRSA operates '*Bhuvan*', the online geo-portal which provides satellite imagery under terms of the Remote Sensing Distribution Policy 2011 which laysdown access eligibility and licensing regimes.

(3). In a third vertical, the erstwhile Planning Commission (now Niti Aayog) established the National Natural Resources Management System

(NNRMS) in 1983. The Department of Space (DOS) is the nodal agency. The NNRMS is an integrated resource management system aimed at optimising the utilisation of the country's natural resources by proper and systematic inventory of resource availability using remote sensing data, in conjunction with conventional techniques.

Thus, taken together, the SOI/NATMO; ISRO/NRSA and NNRMS/DOS hold a vast quantum of geospatial data and information acquired from public funds. The licensing mechanism for access to this information—as prescribed by the National Map Policy 2005; Remote Sensing Data Distribution Policy 2011 (including its earlier 2005 version); and the NGP 2016—are unambiguously weighed in favour of government users. The policies are restrictive fornon-government users who are required to comply with cumbersome access eligibility requirements and procedures. This, despite the fact that each of the said policies declares that its aim is "to *create a knowledge based society"*. In this context, it would be instructive to examine the National Data Sharing and Accessibility Policy 2012 (NDSAP 2012), which finds mention under sub-heading, *Existing Related Policies,* in clause 3 of NGP 2016.

The NDSAP 2012 is an unusual document which contains an objective statement by Government entirely devoid of frills and semantic embellishments. The Preamble of the NDSAP 2012 states, *inter alia*, that data and information *collected with the deployment of public funds should be made more readily available to all, for enabling rational debate, better decision making and use in meeting civil society needs*. And, that (the) "*principles on which data sharing and accessibility need to be based include: Openness, Flexibility, Transparency, Legal Conformity, Protection of Intellectual Property, Formal Responsibility, Professionalism, Standards, Interoperability, Quality, Security, Efficiency, Accountability, Sustainability and Privacy."*

Clause 3 of the said Policy, in particular, is key to understanding whether or to what extent the access licence regime prescribed in NGP 2016, indeed in all other data distribution policies, can become a reality. The clause states, inter *alia*, that "*The current regime of data management does not enable open sharing of Government owned data with other arms of the government nor does it expect proactive disclosure of sharable data available with data owners."* Not unexpectedly, since its announcement, the National Data Sharing and

Accessibility Policy 2012,has stagnated. Unless the government seizes the singular challenge, so truthfully articulated in the NDSAP 2012, by its horns, NGP 2016—including Digital India, Smart City, Urban Transportation and other such programmes—will likely fail.

The current geospatial data and information distribution policies are premised on the principle of presumption of '*access denial*'—a stark reminder that the reason for the failure of NDSAP 2012 was the determination of government departments not to disturb the status quo articulated in clause 3 earlier referred to. The access denial approach is thus a singular impediment to the optimum use of the country's valuable national data resources for the purpose of the public good. As an example, while NGP (and other data distribution policies) recognise geospatial data as thepreliminary resource for urban planning, disaster management among other critical national functions, the experience of the monsoon debacle across cities in India,in the recent years, seems to suggest otherwise. It is not known whether the seasonal urban catastrophe is because government departments are not under statutory obligation to share and to use government-owned geospatial information, or whether because government has not yet addressed the urgent need to build inherent competence and capacity for the appropriate use of the national data assets.

Almost all advanced nations have geospatial data distribution policies premised on the principle of presumption of *open access*. As stated earlier, SOI and NRSA each have a different licensing prescription qualified by the fact that both are restrictive across the board qua civilian users and are weighed in favour of government users. It is thus important to properly appreciate the import of clause 3 of NDSAP 2012, particularly because NGP 2016 does not address current roadblocks experienced by government departments, with respect to difficulties in timely and easy access to government-owned geospatial data held by the two national data repositories.

It may be recalled, that following the Gulf War of 1990, space technology applications, including satellite navigation (GPS), remote sensing satellite imagery and the Internet, until then restricted for military use—were made available by the US for civil/commercial use. Consequently, foreign commercial satellite services providers began connecting online worldwide and providing commercial satellite product services. In 1996 the then government-owned Videsh Sanchar Nigam Limited (VSNL) introduced the Internet in India. By 2005 -2008, Indian citizens were accessing the freely available range of commercial satellite images, i.e., geospatial products and services. Since then, Google and other similar service providers have been catering to the massive unserved, unregulated Indian market place. Today, the global commercial satellite service industry is estimated to be worth in excess of $330 billion. Therefore, "*access denial*" to private users, i.e., Indian citizens and companies, under onerous access procedures is a self-imposed roadblock by the government of India, which prevents the acceleration of new technology applications by indigenous innovations and start-up enterprises to assist in the timely achievement of national economic development goals.

Twenty-five years after the US opened use of military satellite technologies for commercial purposes, the impact of commercially available, high-resolution geospatial data combined with satellite navigation and communications technologies, is having a profound impact on national and global security concerns that are mutating in so many lethal forms. This is, undeniably, a matter of legitimate concern nationally and globally.

The fact that citizens have had access via the Internet to unregulated commercially available foreign geospatial products has raised legitimate concerns about its impact on India's national security. Of course, it begs the question as to why the government made has no attempt to regulate this emerging sector. Still, it cannot be anyone's case that that denying, or severely restricting, citizens from accessing geospatial products held in government repositories is a solution for security concerns arising out of easily available geographic information about India. That information is and has been freely available. The recent draft Geospatial Regulation Bill 2016 issued by the Ministry of Home Affairs aims to prohibit and penalise unauthorised access, use, and distribution of geospatial information by private entities, individual and juridical, by visiting draconian penal consequences upon the offenders. While the regulation of unauthorised access and unauthorised use of national GI is necessary, the 2016 draft Bill presented a classic example of 'shooting the messenger'. Following sharp public outcry, the draft bill was withdrawn.

Admittedly, free and easily available geospatial products and services have been available in India for over a decade, made possible because foreign commercial satellite image data service providers were able conduct their business without restriction. As stated earlier, these products and services are commonly used by government departments, since admittedly government departments *inter se* do not share or resist sharing information. While, ordinarily, this ought not to be the case, the positive outcome of the situation has been to serve the excellent purpose of creating awareness among government functionaries which have created tools for governing such domains like land record management. Two outstanding examples are Gujarat and the National Informatics Centre (NIC) which has created unique tools by using open-access satellite imagery available on Google Earth. As described earlier, an eco-system of start-up has seeded in India, typically using open-access satellite images to create location-based services, now increasingly used in transportation among other business verticals. This chapter argues that geospatial data and information vested in the government must be made available to the public at large on the principle of *presumption of open access,* albeit within a carefully drafted statutory framework, necessarily supported by technical and institutional mechanisms capable of meeting challenges to national safety and security, including those caused by the unauthorised acquisition, distribution, publication and use of geospatial products. It cannot be overlooked that the country's technology-savvy private entrepreneurs have already successfully opened up commercial opportunities for themselves by converging geospatial information and positioning products freely available on online search engines. They have developed special applications to create products that address several location-specific management and governance challenges unique to India.

In this context, it is noteworthy that the NGP 2016 recognises the multidisciplinary nature of Geospatial Data, Products, Services and Solutions and its importance for national development. However, even though the Policy sets out an excellent set of propositions, it is not nearly good enough. Civil society and industry may take heart, but it will get no further. NGP 2016 reads like a vision statement, and framing a national geospatial policy remains a challenging and unfinished task.

At this point, it is important to ask a basic question. Do policies, issued occasionally by government agency or department, have statutory authority? Can such a policy stand scrutiny in a court of law as to its enforceability? The short answer is 'No'. A government policy, at best, articulates purpose or a wish list for the future development of a specific sector. It does not have statutory authority, in the same way as a law enacted by Parliament. Unfortunately, though, policies such as the data distribution policies such as they are discussed here, subsist because they offer the only gateway through which private citizens and entities can access the required GI information. Compliance without demur was the only way, and until recently, challenge was not an option. Relevant to the topic under discussion, the National Map Policy and the Spatial Data Distribution Policy 2011 are examples which prohibit or restrict citizens to access to GIS products, collected at considerable cost to public funds, are impeding the commercialisation of such information. In fact, the Remote Sensing Data Distribution Policy of 2011 is currently under challenge before the High Court of Delhi.

In the 1990s, the 'sunshine' private airlines were regulated by government in terms of the *Draft Aviation Policy 1991*. It is no secret that government's policy not to allow a level playing field to the private airlines and government airlines resulted in huge market distortions to the serious detriment of the emerging sector. Moreover, the aviation sector has for long carried the burden of staggering financial losses. Finally, twenty-five years later, India got a national aviation policy in 2016. Perhaps, there is a lesson here to learn.

It would also do well to recognise that no matter the language used in a policy document- e.g., use of the word 'promulgation'in NGP 2016—policies are not rooted in legal authority and will not stand legal scrutiny. As such, it is reasonable to assume that NGP 2016 has limited capacity to drive to fruition the sorely needed pro-active and seamless access to and distribution of geospatial data and information acquired by spending public funds, at least, *inter se* repositories and user government departments to achieve Digital India. This chapter suggests that providing legal basis to the National Data Sharing and Accessibility Policy 2012 may lead the way.

In any event, there is no taking away from the dual-use nature of geospatial data and information. The control of access to and sharing of topographical and geospatial data by government repositories is a complicated matter, nationally and globally. Therefore, when considering a data distribution policy premised on presumption of open access to national geospatial data and information, such a policy must be issued to benefit commercial and civil users only after national security imperatives are already secured. It is nobody's case that countries that implement GI data distribution policies based on the open access principle, do so without securingtheir national interests.

What civil society and industry looks forward to is a multidisciplinary response for the government of India. The self-evident and admitted duplication of institutional, regulatory, human resource inputs at the cost to the public exchequer and the taxpayer is detrimental for national development and national security, imposing avoidable high costs in time and opportunity. India urgently needs a single national spatial data infrastructure, backed by a carefully thought, dynamic National GI policy that will enable the consolidation of the gains in the past several decades and further specific national objectives. It is the government's obligation to find balanced and nuanced solutions, including technological, to assure national security and national interest to deal with the challenge of acquisition, access, use and distribution of geospatial data and information that is detrimental to India and its citizens. The matter of national security, evidence-based national development planning and implementation, enabling private sector to prise open commercial opportunities through right of access on the basis of best practices regulations—and can no longer remain moribund. In fact, national socio-economic development is the paramount building block for assuring that India's supreme national interest can no longer be allowed to stumble upon bureaucratic silos and reluctant mindsets.

11

Formation of PSLV Joint Venture: Legal Issues

Malay Adhikari

Introduction

India today is well-known for its self-reliant space technology. Of the many ongoing advancements in India's space exploration and use, satellite launching is the most important one. The Indian Space Research Organisation's (ISRO) Polar Satellite Launch Vehicle (PSLV) has emerged as its work-horse, which has earned repute both within the domestic and international context. At the same time, the frequency of PSLV launchings attracts many domestic private commercial actors – who have been developing the sub-systemsfor PSLV – who are engaged with ISRO either directly or indirectly. Space may thus be called a 'sunrise industry' in India. It is worthwhile to analyse whether there could be a possibility of joint ventures in the near future with these private actors—which may mean privatisation of PSLV, as the concept of 'joint venture' connotes the first step towards privatisation.

The first point to consider is the legal infrastructure for this joint venture; unless there is legal tie-up between ISRO and these private actors, the feasibility of such commercial venture is meaningless. There are various legal issues that could be solved at the primary stage before proceeding further for its implementation. This chapter examines some of the legal issues along with existing opportunities in the legal domain in India.

Private Actors in PSLV

The best example of a private actor working with ISRO is Godrej & Boyce,which has manufactured the VIKAS engine in PSLV.[1] There may be many more significant contributions from private actors to develop PSLV in future. The private participation raise various questions, foremost among them is whether there is a possibility of engaging in joint ventures in launchings, especially PSLV joint ventures (hereinafter referred to as JV). Does it mean a JV of ISRO with domestic private companies or some international conglomerate? Or does it indicate a green signal for some international consortium or alliance where ISRO is one of the partners? Could it be viewed as first step towards privatisation of PSLV? Does it sound like PSLV without ISRO and could it be possible now? Will ISRO or the government of India provide the necessary permission for its feasibility?

While some of these questions may appear to be hypothetical, they in fact touch upon future reality, considering that the role of ISRO would become more regulatory in nature in the coming decades. The ISRO will likely serve only as a regulatory authority for launchings from India, and not perform thelaunch itself. The following discussion is an attempt to find answers to these queries in the context of existing legislation.

Interpretation of 'Joint Venture' or 'Privatisation'

A brief explanation of "JV" or 'privatisation concerned with space activities', in general, is needed as a first step in understanding JV of PSLV. At the beginning of the space era, it was the state that played the role of both actor and regulator in space activities. This has changed, and today the role of statesis diminished.[2] Increasingly, private actors like national and multinational firms having advanced technology have been taking initiatives to launch into space their privately built instruments. Their purpose would be to gather economic benefits from the potential yields of outer space, and this phenomenon is referred to as the commercialisationof space.[2] The other explanation of this development is that free enterprise does not exist in the long run where there is no possibility of profit.[3]

These private actors are mainly incorporated as companies. National companies are subject to the laws of the country of their registration.

Their structure can be complicated.[4] For example, the state becomes the major shareholder—like in the case of French private launching company, Ariane space, where the country's national space agency, CNES, holds the majority of shares (34.68 percent).[5] Though there is a recent proposal to sell all the shares of the French government to Airbus Safran Launchers, it has not been implemented. In such companies, government control exists by default. It is pertinent to note that the government does not even have to retain equity in an enterprise to have control over it—especially in a sector as strategic as space.[6]

The complexity is increased by interpreting the concept of 'privatisation', a phenomenon that began in the 1980s. Its simplest interpretation is the transfer of ownership from public to private sectors. But its critical interpretation adds the layer of liberalisation. Therefore, the process of privatisation may or may not be involved with liberalisation. One example is that private monopoly could exist in a country when the ownership of a public entity was transferred to a private entity. In the case of telecommunications, a part of the space industry, there are different types of privatisation. One type is private sectors' participation without privatisation or liberalisation, as in the case of the People's Republic of China and of Saudi Arabia. There is also another type –liberalisation without privatisation, such as in Finland with regard to Telecom Finland.[7]

In this context, space activities having commercial interest are not distinctly separate from those having public interest. It is not easy to differentiate clearly between the functions of the private and public (state) sectors. Some enterprises perform dual roles like performing public service but also having commercial operations. The private enterprises in commercial space activities may depend on the public (state) sectors in areas like hiring of launchers, or leasing of communication channels. In the reverse, the public sector may depend on the private sector for the supply of technology and equipment according to a commercial contract between them.[8]

Therefore, private actors in space may co-exist with state actors, who also serve as regulatory agencies. Of course, this inter-dependence varies from one country to another, determined by state policy.

Article VI of the Outer Space Treaty (1967) contains the legal provision about this co-existence or inter-dependency. The relevant portion of the Article says:

> "states are internationally responsible for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental agencies .... The activities of the non-governmental entities in outer space, including the Moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty ...."

This is the only provision in the existing state-centric space law that finds some place or justification for actors in space not to be from governments.[9]

The text of Article VI is concerned not about a principle of 'free private enterprise', but about the indirect recognition of a state's right to permit space activity as an exception by non-governmental legal entities. There are two conditions attached with this exception: (i) the state bears international responsibility for their activity; and (ii) the state authorises and constantly supervises this activity which ensures that it conforms to the provisions of the Space Treaty.[10] But the forms of authorisation and supervision are not specified. No condition is prescribed for this authorisation, although the state indirectly supervises the activity.

Examples of JV in Launching Outside India

The legal interpretation of JV follows the examples of some foreign private companies that have already entered into JVs. There are two categories: (i) state with private companies; and (ii) private companies with other companies in the same country or a different one.

(i) State with private companies

The launching company, Arianespace, first began their joint venture in 1980.[9] In 2003 the same company joined with the Boeing Launch Services and Mitsubishi Heavy Industries (MHI) to create the Launch Services Alliance. The purpose was to provide customers with flexible, reliable and on-time delivery to orbit.[10] This alliance is one of the best examples of a conglomeration. Another example is the Russian company, International Launch Services[11] (ILS). Khrunichev, the Russian government company, became the majority shareholder of ILS.[12]

The European-Russian Organization, Strasem,[13] meanwhile, is unique because of the mixture of a corporation and the national space agency to increase the volume of business. These are Astrium, Arianespace, the Russian Federal Space Agency, and the Samara Space Center (TsSKB-Progress). Starsem was established to commercialise the Soyuz launch vehicle internationally.[14] Therefore, such JV encourages private actors through the infrastructure developed by the state.

(ii) Private companies with other companies in same or different countries

The second type has been basically formed with the expectation of intensive commercialisation of the launching industry. Sometimes the technology can be too costly that small private actors could not sustain themselves on their own and decide to enter into joint ventures with bigger companies. The following are a few examples.

The Russian company, Eurockot Launch Services,[15] was attached later with the EADS to get assistance and support. The two parent companies behind the venture were Khrunichev Space Center and EADS.[16] The presumption is that the EADS would like to survive the fierce competition by having the support of Eurockot.

The service of Sea Launch AG,[17] meanwhile, which was incorporated in Switzerland, has four major subcontractors: Energia Logistics United States, Energia Logistics Russian Federation, S.P. Korolev Rocket and Space Corporation, and Boeing Commercial Space Company.[18] The low-profile Sea Launch AG hired the services of the comparatively high-profile space companies. It could be said that interdependence is the corporate mantra that has allowed low-profile actors to survive.

In India today, there are still no space activities among private actors as extensive as those in European countries and the US. The private actors have worked under different circumstances in India's space sector. They are mainly dependent on ISRO as consumer of their products. The few existing domestic companies associated with PSLV are Walchandnagar

Industries Ltd.[19] Godrej & Boyce,[20] among others that include small and medium-size enterprises that may not be well-known domestically, much less inthe international space market. However, proactive JVs like the above examples from foreign countries are yet to start in India, as the country still lacks the necessary legal infrastructure to work out such joint ventures.

Legal Issues In Joint Ventures

The JV of PSLV may be argued in the context of certain legal issues like liability, IPR, or technology transfer, financing including insurance, safety, and dispute settlement. There may be other issues besides these primary legal issues. These issues are to be solved legally when any JV related with launching is planned in any country, as space is considered as global commons. It may, however, be the case that some issues are regarded as more sensitive in one country compared to another, depending on these countries' overall technological advancement. Thus, it is difficult to predict in which sequence these issues will emerge when PSLV-JV is considered, and not only because the PSLV-JV will take time to obtain final approval. The issues are then likely to become more or less significant than what they appear right now. What is certain, though, is that the primary issue is that of liability.

(1) Liability:

Liability has always been an issue in this arena since the state-centric era of space launches. An effort is made first to analyse how liability is reflected within the texts of space law. Article VII of the Outer Space Treaty[21] makes provisions for liability, imposing it only on states. A separate international liability regime for space activities was eventually enacted with the Convention on International Liability for Damages Caused by Space Objects (1972, or the Liability Convention). This Convention also mentions liability for damages caused by space objects launched by a state.[22] It was unthinkable at the time these two instruments were established that eventually, private actors would pursue the same space activities and therefore liability was attached to states alone. The states were also made responsible *and* liable for the activities pursued by any non-governmental entities. The space treaties are silent about the direct liability of private actors.

This principle of 'liability' within the provisions of space law has become increasingly outdated over the recent decades, as the number of private actors in space increased. Such actors, though engaged with different space activities, encounter similarly crucial areas of liability. One of these is launch activities, where private entities heavily engage and derive profits. Under the existing liability regime, the launching company is not held liable in the event of damage during or after launch; rather, it is the launching state, as defined in Article I of the Liability Convention and whether or not it had knowledge or involvement in such launch.[23] Yet it has become neither feasible nor justified to make the states solely responsible in the context of increasing number of private entities engaged in space activities.[24] The Liability Convention has not considered the individual liability of private bodies. In case, for example, a space object has been transferred whether by sale, lease or secured financing to private operators in countries that are not launching states, then the question arises as to how liability will be imposed on the private satellite operators. It is unfair to hold the original state liable in such cases.[25]

(2) Technology Transfer:

This issue is dealt with under existing Intellectual Property Rights regime. When there is a consideration for joint venture, it is obvious that the parties of such business effort have to exchange technologies. The World Intellectual Property Organization (WIPO) has observed that:

> "…..due to financial and technical resources which are required to realize space projects, collaboration with the private sector is not alien to many of the state-owned space agencies today. Licensing contracts are concluded between governmental space agencies, between governmental agencies and private companies and between private companies. Such private financing has to be motivated by the expectation that the R & D investment could be recovered in the future. Thus, the acquisition and protection of intellectual property rights would have a positive effect on the participation of the private sector in the development of outer space activities and on further development of space technology in general."[26]

This observation of WIPO is a general one related to space technology and its R & D. It is equally true when the launch is to be performed jointly by different actors both from public and private sectors.

(3) Insurance:

The insurance for any launch is another legal issue that comes under financing. The major economic hurdle arises from financing all private space activities that require high-value investment with high risk. Space insurance is a difficult task for any organisation, including the government. The principal difficulty of a financer or an insurer is the security on its investment. In case of any space disaster, how will the resources invested be returned?

To addressthis question, the International Institute for the Unification of Private Law (UNIDROIT) has adopted a Protocol known as the Convention on International Interests in Mobile Equipment on Matters Specific to Space Asset. The matter was discussed during the final proceeding of the Convention, according to Article XXXIV of the Protocol. It shall not affect states' rights and duties under the existing space laws and the legal instruments of the International Telecommunication Union (ITU). Whether the final Space Protocol fully respects this public law supersession clause may be the subject of subsequent scrutiny. The objective is to lower the cost of space asset financing by way of facilitation. But major commercial satellite operators are unconvinced of the need for the new legal instrument. Advocates, however, believe that the space protocol will be a valuable tool for small satellite operators and start-up companies. It will also make the industry more competitive.[27]

This Protocol, however, is not in force because it has not obtained the required number of signatories.[28]

(4) Safety:

The safety related with space activities is going to be a more crucial area in this era of space activity dominated by private actors. The safety question involves the launch site processing, ground safety, launch safety, and many more.[29] Disasters like those of Columbia and Challenger happened under the regime of non-commercial space exploration. Today under the era of commercialisation followed by privatisation, safety becomes a paramount criteria.

The International Civil Aviation Organization (ICAO) took up the issue in their symposium in March 2015, jointly organised with the UN Office of Outer Space (UNOOSA).[30]

The problem is compounded by the involvement of spaceport, aircraft and balloon-launched spacecraft. Some have abort-and-escape systems, whereas others do not. Overall, the safety features of these various launch systems are totally diverse. There are dozens of spaceports being developed around the world under the jurisdiction of different national laws. The safety standards and regulations that govern spaceports and launch and re-entry operations vary widely. There are government-licensed spaceports and there are others that are not.[31]

Indeed, a uniform safety standard under different technical systems within different jurisdictions is difficult to maintain. There are no common safety standards and procedures for space operations, and none is equally protected from the risks attached with a launch.[32]In spite of efforts from the UNCOPUOS and the ICAO to regulate private space ventures, the issue of safety remains problematic. In 2004, the International Association for the Advancement of Space Safety (IAASS) was established as a non-profit organisation, and in 2010 it was granted observer status at UNCOPUOS.[33]

(5) Dispute Settlements:

The probable JV in launch activities could cause disputes of the nature that India had already experienced in the telecommunication sector with the Antrix-Devas deal. This is because the same problems remain, and are applicable in the space as well, whether state-centric or private. To begin with, disputes in general tend to be an 'expected' outcome of commercialisation. But why it is necessary to think about the mechanism for settlement of disputes specifically in the present context of space launch activities? Space activities are becoming increasingly more complex but not always expensive compared to their spin-off benefits. These activities also involve more actors eager to turn in profits from their ventures. The technological impact is on the larger section of society. Further, space is interdisciplinary and related with physics, economics, trade, diplomacy, information technology, and engineering. It thus requires a specific dispute settlement system.[34]

Under the existing provisions of space law, the OST[35] provides some relevant provisions on cooperation, mutual assistance and consultations;there are no rules on actual dispute settlement.[36] The Liability

Convention, meanwhile—which refers to the Claims Commission[37]any issue of damage caused by a space object—has no binding effect. There is no provision for settlement of disputes in any other space law treaties.[38] While the Permanent Court of Arbitration (PCA) has optional rules for arbitration of disputes relating to outer space activities,[39] it is not mandatory to approach them for any kind of disputes related with outer space ventures including launch activities.

Existing Regulations in India for Advancing JV

In India, there are no direct policies on launch activities in the manner of the Remote Sensing Data Policy of 2011, for example, or the SATCOM Policy of 2000. The ISRO has its own well-defined Technology Transfer Policy,[40] but the technology transfer has occurred in other applications and not for PSLV.[41] The JV with a domestic private actor may not be as serious a concern like its foreign counterparts, but a successful JV would likely result in higher revenuesand more business opportunities. The ISRO will then have to cross national boundaries.

The ISRO has an Industry Participation Policy, a Commercialisation Policy, and International Co-operation Policy.[42] Not all policies, however, are available in the public domain and it is difficult to determine whether PSLV-JV may be supported by these policies.

The existing legislations that may be useful for the joint venture are insurance laws, IPR laws, safety laws, and dispute settlement laws. There is a proposed 'Space Act' in the 12th Five-Year-Plan,[43] which may be a comprehensive one. It is not known though when it will be enacted. Insurance laws include the Insurance Act 1938 and Insurance Regulatory and Development Authority Act 1999. IPR provisions are found in the Copyright Act 1957, Patents Act 1970 (Amendment 1999), and Trade Marks Act, 1999; safety is covered in the Explosives Act, 1884, Explosive Substances Act, 1908, Inflammable Substances Act, 1952 and Dangerous Machines (Regulation) Act, 1983. Meanwhile, the dispute settlement provisions are found in the Indian Penal Code, 1860; Code of Criminal Procedure, 1973; Economic Offences (Inapplicability of Limitation) Act, 1974; Consumer Protection Act, 1986; Arbitration & Conciliation Act, 1996 and Competition Act, 2002.

Besides these policies and legislations, there is institutional procedure to regulate Joint Ventures. It could be an existing institution like the Society of Indian Aerospace Technologies & Industries (SIATI)[44] or a separate one that will be established for private launch actors. The discussions and debates within such institution will gradually regulate the PSLV JV. Therefore, the process of institutionalisation is itself part of the regulatory system.

Conclusion

The consecutive and successive performances of PSLV launch activities increase demand all over the world. The same demand is the force that pushes for a PSLV joint venture. Whether or not the Indian government is ready, the launch market is. India has certain policies from the ISRO but when the share in terms of investment is more than that of ISRO in such JV, the existing policy will not be effective. It implies that no suitable policy exists for any type of PSLV JV. The legislations are general ones. If the PSLV will be more demanding all over the world and there is a possibility for ventures in India like Arianespace, the government may then think of a 'PSLV Act'.

It is time to chalk out a National Launching Policy prioritising PSLV. The legal outlook of this Policy should be international, within legal jurisdiction in India. Second, there is a dire need to institutionalise PSLV JV, which should directly reach to the government of India instead of the ISRO.

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12

Exploring Space as an Instrument in India's Foreign Policy and Diplomacy

Vidya Sagar Reddy

Introduction

A country's foreign policy comprises decisions, strategies and procedures guided by the directive principles of the Constitution and past experiences, wielded to maximise national interests. The size, geographic location, history, future aspirations, human and natural resources characterise these national interests from within, while global dynamics casts its external influence. Developments in science and technology both shape and help secure national interests. Some of the niche areas that underpin the global political and economic order include shipbuilding, communications, nuclear and rocket sciences, nanotechnology, robotics and artificial intelligence.

The newly independent India laid emphasis on developing science and technology for the country's socio-economic development. This is the vision that continues to drive development of space technology in India. The Indian Space Research Organisation (ISRO) was created to undertake projects including communications, weather forecasting, and navigation, in the service of the country's development needs. Self-reliance in space technology empowered India to choose its own path of political and economic organisationas well as elevate its standing in the international community. This progress is not without fluctuations, as the country's changing foreign policy attitude since Independence influenced the advances in the space programme, and vice-versa.

Idealism as Working Principle

India had devised the policy of 'Non-Alignment' to guide its foreign relations following Independence. This policy enabled the country to stay neutral amidst competition among the superpowers and create a favourable environment for its economic growth. This policy also allowed India to maintain cordial relations with the rest of the world, including the two centres of power. Cooperation with the two power blocs was critical for increasing food production, mechanisation of various industries and improving the standards of education and producing skilled workforce – measures that were required for revitalising India's economy.

This progress would not have been possible if India neglected indigenous scientific and technological innovation. Therefore, India set up various academic and research institutions like the Council of Scientific and Industrial Research in 1942, the Atomic Energy Commission in 1948, first Indian Institute of Technology in 1951, ISRO in 1969, among others. The father of India's space programme, Dr. Vikram Sarabhai, declared that India should be the foremost among nations in using space technology for society's advancement.[1]

However, India was lacking basic infrastructure and training to develop indigenous scientific products that would solve the country's pressing problems. Necessity thus drove cooperation and foreign assistance. India had to carefully negotiate with the advanced countries and convince them to invest in the country's scientific disciplines without the need to surrender its autonomy.

As a result, India's successes in outer space during the early history of the programme were dependent on the assistance of advanced countries. India received sounding rockets from the United States, had its scientists like Abdul Kalam and his peers trained at American research centres and conducted experiments on satellite communications (Satellite Instructional Television Experiment). The Soviet Union launched India's first artificial satellite Aryabhatta and later its experimental remote sensing satellites. India's first geostationary communications satellite, the Ariane Passenger Payload Experiment, was launched using the French Ariane 1 launch vehicle in 1981. The skill with which India practiced the art of fulfilling its national interests was primarily evident with the Thumba Equatorial Rocket Launching Station where the US, the Soviet Union and France made contributions. Later, India dedicated this station to the United Nations in good faith of the organisation's contributions towards keeping outer space free from conflict.

Adopting Realism

The fast-changing geopolitical situation in southern Asia during the 1960s questioned India's adherence to idealism as the foundation of its foreign policy. China's attack across the Himalayan border in 1962 challenged India's tryst with peaceful principles in international relations. The US military assistance to Pakistan during the 1971 war and its diplomatic recognition of nuclear China permanently altered India's foreign policy calculus.

This embrace of 'realism' also came to challenge India's idealistic perception of high-end technologies, leading to the test of a peaceful nuclear device in 1974. Outer space also became a strategic tool in this scenario. Therefore, India responded positively to the Soviet Union's proposal to launch an Indian to the Mir space station as part of the Intercosmos programme. This programme was designed to launch astronauts from non-Soviet countries to bolster the Soviet Union's technological status as well as strengthen its diplomatic connections. Thus, Rakesh Sharma became India's first astronaut in 1984.

The 1980s and 1990s saw India's space research and launch activities being subjected to international scrutiny and sanctions. The Missile Technology Control Regime (MTCR) was established on the suspicion that ISRO's launch vehicle technology was diverted for building India's missile programme. The MTCR became a tool to upset India's deal with Russia for transferring cryogenic engine technology that would have made India self-reliant in launching geostationary satellites. Sanctions were imposed on India's space entities, ignoring the fact that cryogenic engines offer no strategic value, especially in the development of ballistic missiles. These sanctions turned out to be a blessing as India decided to invest in its scientific potential with renewed emphasis and develop the required technologies indigenously.

Initiating the Era of Technological Self-Reliance

On 20 September 1993, the Polar Satellite Launch Vehicle (PSLV) primarily designed for remote sensing requirements made its debut. It had a tremendous flying record successfully launching India's navigation, weather, remote sensing and communications (GSAT-12) satellites. The PSLV also launched India's mission to the Moon – Chandrayaan-1, and mission to Mars – the Mars Orbiter Mission (MOM). In addition, it launched 74 foreign satellites as of 2016 for about 20 countries including Germany, France, the US, Singapore, Indonesia, and Israel.[2] The international launches between January 2013 and December 2015, totalling 28 satellites, earned India $86 million in revenue.[3]

The PSLV is truly a strategic asset for India, helping the country gain self-reliance in critical technologies and retain strategic autonomy in international affairs. By possessing the capability to reach outer space independently, India need not trade its political or economic interests for an assurance on satellite launch service.

In addition to the launch services, India was also able to market its space services to the outside world, including entering into agreements with US-based companies. In 1995, the US-based space imaging company EOSAT entered into a 10-year agreement with ISRO to market India's own remote sensing products across the globe.[4] Another deal amounting to $10 million was signed with International Telecommunications Satellite Organization (INTELSAT) in January 1995 that allowed the company to lease 11 transponders onboard India's INSAT-2E for a period of 10 years.[5] In the backdrop of India's economic liberalisation, the space launch and applications services developed by ISRO enabled the country to establish business connections with the global space industry.

And despite the impact of MTCR sanctions, Indian and American space research institutions became partners in bilateral and international initiatives. India helped extend the coverage of an international satellite system for search and rescue services initiated in part by the US to the Indian Ocean by launching Satellite Aided Search and Rescue payload on INSAT-2 series starting in 1992. India also joined the Inter-Agency Space Debris Coordination Committee established by the advanced spacefaring countries like the US and Soviet Union.

The signing of memoranda of understanding in 1997 had reinitiated bilateral space cooperation between India and the US.[6] This allowed exchange of data between India's INSAT system and Geostationary Operational

Environmental Satellites of the US for weather modelling and forecasting techniques on monsoons and cyclones and facilitated data transmission from India's remote sensing satellite IRS-P3 to National Aeronautics and Space Administration (NASA). Such partnerships helped build a 'lifeline' between the two scientific communities, enabling better people-to-people contacts. This lifeline is one of the stimulants for restoring and strengthening the political relationship between India and the US in the future.

Elevating India's International Prestige

Space technology clearly emerged as a central element of India's foreign policy with the US when it was identified as one of the "trinity" areas of cooperation for improving the overall bilateral relations with the US. In 2004, India and the US sought to amend their stagnant relationship to respond effectively to emerging geopolitical dynamics in the Asia-Pacific region. The Next Steps in Strategic Partnership (NSSP) was devised, requiring both countries to undertake a series of reciprocal steps in the trinity areas. By the end of that year, ISRO headquarters was removed from the US Department of Commerce 'Entity List' followed by removal of Vikram Sarabhai Space Centre, Liquid Propulsion Systems Centre and Satish Dhawan Space Centres. This set the stage for greater cooperation between ISRO and NASA.

The India-US Joint Working Group on Civil Space Cooperation was established for identifying space projects relevant to both countries. One of the concrete results was the US decision to send two scientific instruments onboard India's Chandrayaan-1. Its data resulted in the discovery of water-ice on the moon, a significant breakthrough in planetary science and astrobiology. NASA supported India's MOM by providing deep space communication and navigation support through its Deep Space Network including confirming the successful orbital insertion of the spacecraft at Mars.[7]

The success of this mission garnered international prestige for India. Not only was India the first country to reach Mars in a first attempt, but was also the first Asian country to do so. Although China has made significant developments in lunar and human space exploration, it continues to make references to India's Mars mission and even suggesting a proportionate response.[8] This signalled a tilt in the Asian space power balance in India's favour. After all, space missions, especially space firsts, represent a country's technological innovation, economic strength and financial planning, as well as future aspirations.

Once a recipient of space technology from developed countries, India has now become a more advanced space power. India demonstrated the robustness of its space programme by organising joint projects, launching satellites and even providing disaster assistance for a number of countries. ISRO's Oceansat-2 satellite helped monitor Hurricane Sandy, the second-costliest hurricane in US history, helping authorities to implement timely disaster mitigation and rescue strategies and in the process, saving lives and mitigating financial destruction.[9] The joint mission, NASA-ISRO Synthetic Aperture Radar—expected to be launched by India in 2021—is in fact a highly recommended mission by the 2007 US Decadal Survey on space missions. India's involvement is helping NASA to finally realise this mission which has thus far been delayed due to budget constraints.[10]

India and France have jointly built Megha-Tropiques and SARAL satellites.[11] These two satellites, along with the French SPOT-6 satellite, were launched by the PSLV. The PSLV also launched Israel's remote sensing satellite TecSAR in 2008. This launch boosted the political and strategic relations with Israel, which is now a major source of equipment safeguarding India's security.

The joint projects with established space powers signal India's ascension in the global space order where it can claim a status at par with the advanced spacefaring nations. As with MOM, these space missions demonstrated India's technological leapfrogging and invariably advanced India's position in the global political order. By assuring India's political administration with independent ability to launch satellites, ISRO has strengthened the country's diplomatic position with major powers. Thus, space technology has emerged a niche area in India's foreign relations which can be further leveraged for securing national interests.

Enabling India's Responsibility: Distribution of Global Public Goods

As India charts its path towards becoming a leading power in the world, it cannot afford to ignore the international responsibilities arising from this aspiration. The distribution of global public goods for the benefit of developing and underdeveloped countries, especially in the immediate neighbourhood, is one such responsibility. Space services have emerged as the new global public goods highlighted by the US decision to allow the world freely access its Global Positioning System. Civilians, businesses, government and legal institutions, scientific establishments and even multiple foreign militaries have become accustomed to using this system in their daily activities.

A prosperous and peaceful neighbourhood is a prerequisite for India's economic growth, national security and its ascension in the global political order. However, this neighbourhood consists of some of the least advanced countries facing acute infrastructure deficit that cripples the ambitions of millions. This situation could be altered by establishing both physical and data connectivity in the region, which will in turn fuel India's own economic growth given the geography of the subcontinent. Therefore, the immediate neighbourhood is now accorded a top priority in India's foreign policy.

The South Asian Association for Regional Cooperation (SAARC) received major boost becoming a common communication node for countries in the region. A wide range of projects for regional connectivity have been proposed and India has initiated steps to augment these projects using its space infrastructure. During his visit to ISRO's spaceport, Prime Minister Narendra Modi proposed that India build a communications satellite, Satellite for SAARC, that can be used by all SAARC members. Accordingly, the ISRO designed a satellite hosting 12transponders expected to optimise direct-to-home broadcasting, tele-medicine, tele-education, disaster management, and a host of communications services in the region.[12] The costs associated with building and launching of the satellite will be borne by India while respective countries contribute for their ground stations.

In addition, the indigenously developed Indian Regional Navigation Satellite System (IRNSS) will now be shared with the SAARC nations, augmenting regional terrestrial and marine navigation, disaster management, vehicle tracking, and other activities.

True to the spirit of a leading power, as India continues to explore the benefits of fusing space technology with various departmental works like railways, shipping, management of natural resources, financial management, urban planning, forestry and others, these technologies and experiences are also being shared with the neighbouring countries for mutual development. These services are now being extended for the benefit of extended neighbourhood as India proceeds to develop a ground station in Vietnam.[13] This ground station will have the ability to downlink data directly from India's remote sensing satellites, helping the South East Asian countries in their own development efforts.

Safeguarding the Global Commons

The competition between the US and the Soviet Union to dominate outer space triggered fears of terrestrial wars extending into this domain. The apparently civilian space launches starting with Sputnik were also perceived as tests of advancing delivery mechanisms for nuclear warheads. Therefore, India along with 18 other countries formed an ad hoc Committee on the Peaceful Uses of Outer Space at the United Nations in 1958, which took on a permanent status the following year.

India was also an active participant in the discussions and negotiations for the 1967 Outer Space Treaty that banned testing and placement of weapons of mass destruction in outer space. However, the treaty failed to appreciate the growing reality of conventional weapons that can be placed in space or used against space assets. The US and the Soviet Union continued to test their ASAT weapons during the Cold War while China demonstrated its ASAT weapon in 2007.

India limited its response to China's ASAT test by signaling restraint despite possession of all the required building blocks for developing and testing such a weapon.[14] India strictly adheres to the peaceful uses of outer space, showcased through its space programme and by its active participation in building international legal regimes. The latest advances in ASAT technology question the validity of the Cold War-era Outer Space Treaty in preventing an arms race in outer space. As a leading power, India carries the responsibility to safeguard the global commons through which it intends to distribute space services to itsimmediate and extended neighbourhoods. Therefore, India should proactively build partnerships at the United Nations for ensuring the sustainability of outer space.

On the bilateral level, India and the US have decided to include a dialogue on space security. The joint statement issued during the 2013 US-

India Strategic Dialogue called for efforts to ensure the long-term sustainability of outer space and discussing space situational awareness as part of the 'Space Security Dialogue'.[15] While India contributes to UN's work on non-proliferation and disarmament, it is apparent that the country should also invest in its own capabilities for protecting the global commons. Space situational awareness that is critical for safeguarding India's assets—as well as investigating unwarranted behaviour in outer space—fits into this thinking.

Bold Decision-Making

Still, there are few areas in India's space vision which could be leveraged for strengthening the country's foreign relations and fulfilling national interests. The latest developments in India's neighbourhood show that these countries are drawn towards financial aid and infrastructure investments. China had categorically emphasised geoeconomics as the central tool in its foreign policy calculus, gaining political influence in Asia-Pacific in return for financing projects. Realising this trend, India's Foreign Secretary remarked that realism applies more to economics than security.[16]

Therefore, if India were to successfully respond to major power advances in its neighbourhood, it has to balance military buildup with building basic infrastructure in the border countries. The Satellite for SAARC project is offering such an opportunity for India. India should take a proactive posture and assist those SAARC countries not possessing the requisite financial or technological capacity to build their individual ground stations. Although building and launching the satellite itself incurs huge expenditure, it should nevertheless also finance, at least in part, the ground stations.

During the negotiations for this project, Afghanistan and Bangladesh pondered whether they require using this satellite since their needs are being fulfilled by other satellites. It is also interesting to note that ISRO has no formal partnership or cooperative agreements with any of the SAARC countries.[17] These points highlight the dearth of attention being paid to the neighbourhood, their development needs and India's own national interests. The Satellite for SAARC could also help fill this gap as ISRO could establish agreements with the SAARC countries, starting with construction of the ground stations and the deployment of training personnel.

The South Asian, South East Asian, African and Latin American countries (collectively referred to as the Global South) are increasingly looking towards space technology to augment their economic development. Their communications and remote sensing requirements are fast accruing and India needs to leverage its foreign relations to secure opportunities from these emerging markets. The current ISRO administration is pacing to expand India's launch capabilities to cater to both small satellite and heavier satellite industries. In addition to showcasing the space capabilities to major powers, India should also communicate the dependability of its space launch and services sectors to these emerging markets. Empowering commercial and NewSpace actors who can better market India's space sector abroad is an absolute requirement in this regard.

Conclusion

Indeed, space technology now forms a central element of India's foreign policy. India's space cooperation today spans major spacefaring countries and other technologically advanced countries. Self-reliance in space technology has helped India to maintain its strategic autonomy in foreign policy decision-making. Space technology has also emerged as a diplomatic asset for India as its economic and security interests span South Asia and beyond. India's willingness to distribute space services to the countries in South Asia, Africa and South East Asia is a hallmark of its status as a leading power. It should also strive to better market its space launch and satellite manufacturing services to the Global South.

India has exercised strategic restraint despite provocations to showcase destructive technologies because of its responsibility to safeguard the global commons. Although India practices self-help owing to the anarchic nature of the international system, it nonetheless supports institutions for ensuring peaceful uses of outer space. It is clear that India's economic development, security and international image are critically dependent on the advances being made in its space programme.

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III

SPACE SECURITY

13

India's Strategic Space Programme: From Apprehensive Beginner to Ardent Operator

Ajay Lele

More than 40 years have passed since India sent its first satellite into space. In all the years since then, the focus of India's space programme has remained civilian. However, due to increasing threat perceptions, and given the fact that modern space technologies offer a variety of strategic benefits as well, India has also been making investments in defence technologies. This paper examines the various facets of India's space programme related to defence.

The Indian advent into space began in the early 1960s. The first Indian satellite, Aryabhata, was launched in 1975 using the erstwhile Soviet Union's space launch vehicle, Kosmos-3M. After five years, in 1980, India acquired the status of a spacefaring nation when it successfully launched its Rohini satellite using an Indian-made launch vehicle, SLV-3. Subsequently, India made rapid progress in the space arena and launched various meteorological, communications, earth observation and navigational satellites in different orbits. India has developed reliable space launch vehicle systems and its activities in space have expanded to the deep space region with successful missions to the Moon and Mars. To support such programmes, India has put in place the necessary ground infrastructure as well.

The evolution of India's space programme has been need-based. India being a developing country was not able to make substantial financial investments to develop its space programme. This led the Indian scientific community to innovate to develop vital space assets. Also, owing to India's nuclear policies, it faced international sanctions during the mid-1970s, and again at the turn of the last century. It led to India's technological apartheid, which could be said to have lasted for more than three decades. Naturally, indigenisation of technology was the only option for India. The key focus of India's space technology development from the beginning has been technology development for socioeconomic benefits.

Over time, and with further developments in technology, India's space programme has also matured. Astonishing technological developments are taking place in the space arena. This has led nation-states to search for additional utilities for such technologies and design new need-specific products or applications. The 1991 Gulf War demonstrated the strategic utility of space technologies to the entire world. Since then, various nation-states have been making investments to use space technologies for military purposes. Basically, militaries are using these technologies for the purposes of intelligence gathering, communications and navigation. It is important to note that use of space technologies for such purposes is not in violation of any global legal regime or norms.

India is also making investments towards using its space capabilities to assist its strategic requirements. There is no specific document like a white paper, doctrine or policy paper providing the rationale behind India's defence-specific investments in space. However, the history of India's space programme does indicate that India's investments are need-based and are based on cost-benefit analyses. To appreciate India's expectations and investments from space technologies for strategic purposes, it is necessary to recognise India's overall threat perception. For defence agencies, space technologies are mostly support technologies. They provide them with real-time intelligence and secure communications and location identification with pinpoint accuracy. Modern-day weaponry also gets assistance from assets in space for target identification and weapon firing.

At present, all modern weaponry and weapon delivery platforms are designed for compatibility with space-based systems. Thus, it is also worth understanding the organisation of India's overall security architecture. The details of various existing military systems/hardware and manpower employed also provide a necessary backdrop for understanding the rationale behind India's military space investments.

India's Security Challenges

The notion of security is always contextual, situational and dynamic. There are different approaches to defining and interpreting national security. Broadly, national security includes military, non-military, external and internal threats. Terrorism and environmental threats normally fall in the category of non-military threats. However, the threat and impact of terrorism in some cases is so huge that militaries are constantly engaged to defeat this threat. Security threats faced by India are both internal and external in nature. Also, 21st-century threats are multidimensional in nature, and nation-states are today experiencing chaos and threats from asymmetric warfare. Some threats do arise from issues related to environmental disasters; others, from conflicts in other parts of the world. India's security establishment is also expected to handle threats to Indian owned/governed critical infrastructure in other parts of the world. Pranab Mukherjee,[1] India's President, has said that the country's security challenges go well beyond its conventional borders and conventional threats in the international arena. The challenges include "a sizeable diaspora to protect in unstable regions in the world, energy security issues and protection of maritime sea lanes". The President also emphasised that the country has often had to turn to its armed forces during times of internal crisis, both man-made and natural. Moreover, environmental degradation is giving rise to problems of deforestation and desertification. Lack of drinking water is posing challenges to various inter- and intra-state water-sharing agreements.

At times, the heterogeneous nature of Indian society poses direct or indirect security challenges. Post-independence in 1947, India has fought fours wars with its neighbours, Pakistan and China, owing mainly to border issues which still remain unresolved. Particularly, the South Asian region (India, Afghanistan, Pakistan, Bangladesh, Nepal, Sri Lanka, and Maldives) features a highly complex security environment. Some of the most dreaded global terrorist organisations operate from this part of the world. Also, states like Pakistan are covert supporters of cross-border terrorism. Apart from state-centric threats and heinous terror threats, the region also faces dangers from cross-border movements of the population; ethno-political, socio-economic, and communal-religious politics; money-laundering operations; and drugs and arms smuggling.[2] The typical topography, terrain and climatic conditions of the Indian peninsula—with deserts in the western part and Himalayan glaciers in the north–make the country more prone to natural disasters. In addition the threats arising from climate-change, epidemics, lack of water, food and energy security, also persist.

The presence of nuclear weapons in the region (Pakistan, India, China are nuclear weapon states) and the dismal non-proliferation record of some powers is a major cause of concern. The danger of nuclear terrorism, too, looms large over the region. Also, there are concerns regarding growing nuclear stockpiles. Pakistan, for example, is known to be developing useable nuclear weapons (or tactical nuclear weapons).

To address such a wide spectrum of security challenges, from nuclear weapons to environmental disasters, and from terrorism to the diaspora's security, India needs to maintain a major military force. The next section provides details of India's overall security establishment.

Indian Defence Architecture[3]

India has three basic defence arms: the Navy, Army and Air Force. It may be noted that at times the Indian Air Force is mentioned as an aerospace force as well, as the country has no separate space arm of defence. Apart from these, there are other security related establishments – the paramilitary auxiliary structures such as the Coast Guard, Assam Rifles and the Special Frontier Force. In March 2011, the Ministry of Home Affairs grouped the following five forces – formerly part of the paramilitary structure – as the Central Armed Police Forces:

- Central Reserve Police Force
- Border Security Force
- Indo-Tibetan Border Police
- Central Industrial Security Force
- Sahastra Seema Bal

All these organisations have specific roles and require various real time intelligence inputs. They also have various modern weapon systems in their inventory.

Currently India is the third largest military force in the world.The Indian security establishment has proved its capability time and again over the course of the last six decades through major military and peace-keeping operations. The Indian armed forces' dependence on technology has increased manifold in the post-Cold War era. The Revolution in Military Affairs concept, accepted by military strategists the world over, has led to the induction of modern state-of-the-art weapons and weapons delivery platforms.

The Indian Army

The Indian army today is a lethal operational strike force, prepared to defend the country's boundaries at any cost. Constantly shifting geostrategic paradigms require the Army to be ever prepared for possible war scenarios. The danger posed by a collusive China-Pakistan threat in a nuclear age, is an all too real concern. The Army has addressed this concern in its military modernisation, doctrines and tactical warfare operations.

- Consisting of 1,300,000 active personnel, 2,100,000 reserve personnel and 1,300,000 paramilitary personnel, the Indian Army is currently the third largest army in the world.
- An adaptive operational force, the army is constantly reviewing its operational preparedness and organisational capability to confront and counter intrinsic as well as extrinsic threats to national sovereignty.
- Current military doctrine is based on effectively maximising the potential of a dual strategy based on strategically collating holding formations and strike formations,the first as a strategy of containment and the latter as a neutralisation mechanism.
- The army is administratively divided into seven tactical commands consisting of three to five corps.
    - The corps fall under two categories, the Strike or Offensive Corps, and the Holding or Mountain Corps
- Based on its operational role, the Army is also divided into three core elements namely :
    - combat elements
    - combat support elements
    - operational logistic elements

- In terms of operational logistics, currently, the army possesses:
  - 6,464 tanks,
  - 6,704 armoured fighting vehicles,
  - 290 self propelled guns,
  - 7,414 towed artilleries, and
  - 292 multiple launch rocket systems.
- The Army has several modernisation plans in the pipeline as well, such as:
  - Upgrading the indigenous Arjun tank and inducting Arjun Mark–IIs with
    - better night fighting capabilities,
    - a 120mm main gun,
    - advanced air defence gun,
    - automatic target tracking (ATT),
    - improved accuracy, and
    - superior laser warning control systems.
  - The Indian Army also aims to procure third generation portable 'fire and forget' anti tank missiles, namely, the Spike Anti Tank Guided Missile Systems which have a range of 4,000 meters. The army aims to import these along with 8,356 missiles and 321 launchers from Israel.
  - In order to upgrade its operational capabilities, the army has instituted an "infantry modernisation programme" called the "Futuristic Infantry Soldier as a System" – (F-INSAS).
    - The aim is to equip Infantry soldiers with modular weapon systems that are multi-functional in nature.
  - Finally, a battlefield management systemis also being developed to integrate the various combat units into a digital network linking together all the various components.

Indian Navy

India being a peninsular region and primarily a maritime nation, the Indian Navy has the incredibly important task of defending the mainland as well as safeguarding its shipping routes and sea lines of communication in a possible state of war. Considering that more than 90 percent of Indian trade takes place over the high seas, the Navy is constantly adapting and reformulating its operational stance and capabilities to deal with emergent threats and safeguard its geostrategic position. Given the increasing interdependence of maritime environment and economic growth, the Indian Navy is well aware of its role as a maritime leader in the Indian Ocean region.

- Currently the fifth largest Navy in the world, the Indian Navy consists of 58,350 active personnel, including 7,000 personnel of the Indian Naval Air Arm, and 2,000 Marine Commandos (MARCOS).
- The Navy also has 55,000 reserve personnel.
- It has an operational fleet of 296 vessels comprising:
  - two aircraft carriers
  - one amphibious transport
  - nine landing ship tanks
  - 14 frigates
  - 10 destroyers
  - one nuclear-powered submarine
  - 14 diesel-powered attack submarines
  - 25 Corvettes
  - seven minesweeping vessels
  - 47 Patrol vessels
  - four fleet tankers and various other auxiliaries
  - 135 coastal defence craft
- Important missile systems the Navy possesses include:
  - Dhanush – for surface targets.
  - BraMos cruise missile – A super-sonic cruise missile that can be launched from submarines, ships, aircrafts, or land. With a speed of Mach 2.5-2.8, this is currently the world's fastest missile with a range of 290 km.
  - Sagarika missile/K-15: This is aballistic missile that can be launched using nuclear capable submarines. It has a range of 700 km and is being tested for integration with the INS Arihant. The primary

aim of this missile is to provide India with retaliatory nuclear strike capability.

- o K 4 Missile –Another nuclear capable ballistic missiles it was successfully test launched in 2014, from an underwater platform. It possesses a range of approximately 2,000 km.
- o Nirbhaya Missile: Still in the stages of development, this missile will be India's first all-weather low cost long range cruise missile. The subsonic missile has a 1,000km range with 0.7 Mach speed.

Indian Air Force

Air power is seen as one of the defining factors of global power projection, and given India's geo-strategic vulnerabilities the Air Force plays an immensely important role in protecting the sovereignty of Indian airspace. The IAF has been modernising its inventory for the long haul. Keeping the larger picture in mind, it has focused on the "Make in India" objective to provide an impetus to indigenous development and participation of the private sector in defence manufacturing.

- The Air Force consists of 127,000 serving personnel.
- It is logistically divided into seven commands, out of which five are operational and two are functional.
- The purpose of the operational command is to conduct military operations within its area of responsibility, while the functional command's purpose is to maintain combat readiness.
- In terms of technical strength, the Air Force consists of 2,086 aircraft with a vast array of fighter aircraft, transport aircraft, helicopters and trainer aircraft such as:
  - o 679 fighters/inceptors
  - o 809 fixed wing attack aircraft
  - o 857 transport aircraft
  - o 318 trainer aircraft
  - o 646 helicopters and
  - o 19 attack helicopters
- The missile systems in place consist of:
  - o Akash missile system: A medium surface-to-air missile with 27

km range and a ceiling of 15km. It can carry a 60 kg warhead and has a speed of up to Mach 2.5

- o Astra missile: A beyond-visual-range missile, it was developed by the Defence Research and Development Organisation (DRDO) and designed to intercept targets beyond visual range.
- o Prithvi II: A short range ballistic missile with a range of 350 km. It has a 350 – 750 kg payload of nuclear, high explosive (HE)sub munitions and chemical warheads.

- The Air Force also has several force multipliers such as Early Warning and Control Systems, Unmanned Ariel Vehicles or Drones, Garud Commando Force, among others.

The above facts clearly indicate that India has put in place comprehensive defence architecture. India's military inventory is a mix of old and new systems. India is also one of the biggest importers of military platforms and weaponry. India's defence modernisation has gathered much steam in the last few years. It is but obvious that India's dependence on space technologies for strategic purposes is going to increase manifold in coming years. It may not be possible to identify the exact utility of assets in space for various military platforms and other systems mentioned above. However, it is important to appreciate that given the nature of threats which India is currently facing/expects to encounter in future and the need for military preparedness, 'systems in space' will emerge as a major constituent both for tactical and strategic requirements and for policy planning.

Military Space Investments

The forefathers of the Indian space programme had argued that India would use space technologies for the benefit of mankind, to eradicate poverty and offer social justice. Indeed, India has been using these technologies mainly for meteorology, remote sensing and communications. Weather information is essential for the main constituent of the Indian economy, agriculture. Remote sensing is essential for the management of land-water-forest resources. Satellite communication has wide utility, from education to linking to villages to tele-medicine.

Since the 1980s India has been using space technologies for socioeconomic development. Investments in space technologies have played a silent role in India's overall development. The Indian economy has witnessed a major revolution post 1990, with India adopting an economic liberalisation path. However, particularly during last few decades, India is also witnessing a greater sense of uncertainty in its strategic environment. This has led Indian policy makers to look at space technologies as an instrument to assist their overall security architecture.

Initially, India depended on dual-use capability of satellite technologies for strategic purposes. There seemed to be some reluctance in accepting that India has interests in using space technologies for strategic purposes. Probably, such hesitancy was the result of India being under the technology sanctions regime. However, post the Indo-US nuclear deal (2005), it became evident that India was no longer considered a pariah by the global community with regard to technology transfer. In 2011, the US removed all sanctions imposed on Indian space following the Indian nuclear tests.

From a strategic perspective, India is using satellite technology for reconnaissance, communicationsand navigation purposes. The Indian Remote Sensing (IRS) satellites are a series of Earth observation satellites built, launched, and maintained by ISRO since the 1980s. Indian capabilities in this field match the best in the world, and India has one of the largest fleet of such satellites globally. Around the year 2000, in some of its official statements, India started mentioning that it was keen to exploit the dual-use capabilities of space technologies. In 2001, the Technology Experimental Satellite (TES) was launched by ISRO, described by its then Chairman as a satellite meant for "civilian use consistent with state's security concerns." Subsequently, mainly for topographic mapping data, India invested in developing the Cartosat (Cartographic satellite) series. These satellites are useful for urban and rural development. They are also known to have significant military utility. Cartosat-1 and Cartosat-2 were high resolution satellites, with 2.5 meter and one meter resolution, respectively, launched in 2005 and 2007. In August 2005, the Indian Defence Minister informed Parliament that India was assembling a military surveillance and reconnaissance system which would be operational by 2007. Within three years of the launch of the second satellite, two more satellites in this series were launched. In April 2008 came Cartosat-2A (resolution of 0.8 meter) while Cartosat-2B was delivered into orbit in July 2010. After a gap of six years, Cartosat-2C satellite was launched in 2016,with a resolution of a few centimetres.

ISRO has made much progress in sensor technology over the years. An important feature of Cartosat-2C was the use of adaptive optics and acousto optical devices. This satellite has micro electro-mechanical systems and adoptive optics that offer better visibility of objects on the ground. Here, the optical system adapts to compensate for optical effects introduced by the medium between the object and its image, while acousto optical devices enable interaction between sound waves and light waves.

According to ISRO, the images sent by the Cartosat series of satellites are useful in various cartographic applications, urban and rural applications, coastal land use and regulation, utility management like road network monitoring, water distribution, creation of land use maps, precision study, change detection to bring out geographical and man-made features, and various other land information system and geographical information system applications[4]. The nature of these civilian applications indirectly reveals that many useful and real-time inputs can be gathered on strategic areas of interest, as and when required over a tactical battlefield area. These satellites together offer the Indian security establishment 24 x 7 capability to monitor various sensitive areas.

Various Indian observation satellites have optical and spectral sensors. Such sensors do not perform correctly when the sky is overcast (cloud cover). In order to overcome the limitations in surveillance owing to lack of night-time and bad weather observational capabilities, ISRO has developed a RISAT (Radar Imaging Satellite) series of reconnaissance satellites. These are the first all-weather earth observation satellites which use Synthetic Aperture Radar (SAR) technology. The first satellite in this series was launched in response to the 26/11 Mumbai terror attack of2008, and was imported from Israel. This was called RISAT-2 and was launched in April 2009. Subsequently, a made-in-ISRO RISAT (called RISAT-1, though it was launched well after RISAT-2) went into orbit in 2012. Both these satellites have day and night viewing capacity and are not blinded by cloud cover/bad weather. They have the capacity for continuous surveillance. RISAT-1 with a resolution of one meter carries a C-band SAR payload, operating in a multi-polarisation and multi-resolution mode to provide images with coarse, fine and high spatial resolutions.

Apart from remote sensing satellites, India has also launched a few meteorological satellites. These provide useful real-time information.

Meteorological inputs are extremely important for the planning of various land based, air and ship/submarine based operations both during peacetime and wartime. India's military meteorologists depend greatly on various inputs received from the satellites. Similarly, the Indian armed forces attempt to gather defence specific information from the data collected by various civilian satellites. It is but obvious that identifying military specific information at times becomes a tedious task. Also, some military specific benefits could be derived from civilian communications satellites.

On 30 August 2013, India's GSAT-7 communications satellite was successfully launched by the European space consortium Arianespace from Kourou spaceport in French Guiana. GSAT-7 can be called as India's first strategic satellite. GSAT-7 has been designed and developed by ISRO with a seven years life span and provides UHF, S-band, C-band and Ku-band relay capacity. This is a dedicated system for the use of the Indian Navy — the first customised satellite made available for the Indian armed forces. Its Ku-band capacity provides high-density data transmission facility, both for voice and video. The satellite has been provided with additional power to communicate with smaller and mobile (not necessarily land-based) terminals.

This dedicated satellite provides the Indian Navy a 3,500-4,000-km footprint over the Indian Ocean region and enables real-time networking of all its operational assets in water (and on land). It also helps the Navy to operate in a network-centric atmosphere. The Indian peninsula is an extremely tricky region for operations because of its geographic location. One of the deadliest terrorist operations on Indian soil, the 2008 Mumbai attack, was launched using the Arabian Sea route. GSAT-7 is useful for gathering communications and electronic intelligence in respect to moving platforms in the sea, particularly through its UHF facility. GSAT-7 also helps the Navy monitor activities over both the Arabian Sea and the Bay of Bengal regions. Broadly, India's strategic area of interest extends from the Persian Gulf to the Malacca Strait, and now a significant portion of this region is covered by this satellite[5].

The second strategic satellite for India called GSAT-6 was launched by ISRO in August 2015. GSAT-6 is a 2,117 kg satellite mainly developed for the armed forces. Indian soldiers operate in diverse terrain and topographic conditions, from the peninsular region to deserts to snow-clad mountains.

Owing to topographical challenges, soldiers on many occasions encounter breaks in communications. GSAT-6 provides quality and secure communication. Induction of this satellite also frees the soldier from carrying bulky communications equipment since very small handheld devices can be used.[6]

In the arena of satellite navigation India has made very quick progress. ISRO has developed an Indian Regional Navigation Satellite System (IRNSS) to provide itself and neighbouring countries with a Position Navigation and Timing (PNT) service. All seven satellites of this system, also known as Navigation with Indian Constellation (NAVIC), have already been launched and the system is expected to shortly become operational. In the future, ISRO may increase the number of satellites to 11 to increase the expanse of this system. The present independent seven-satellite constellation, built and operated by ISRO, has three satellites in geosynchronous orbit (GSO) and four in non-GSO (inclined 29 degrees with the equatorial plane). The IRNSS will provide absolute position accuracy of approximately 20 metres throughout India, and within a 1500-2,000 km region around it. This system will provide two types of services: one for civilian use, and the other, as a restricted encrypted service, for specific users[7], especially defence. This system will discontinue the armed forces' dependence on GPS/GLONASS.

Conclusion

Currently, defence-specific space requirements are handled by the Integrated Space Cell. This is a small unit under the Integrated Defence Headquarters (IDS), a tri-service organisation. There has been a demand for a separate space command but the government is yet to take a decision on this.

There is a clear-cut mismatch between the expanse of India's strategic establishments and the space assets put in place to cater to their needs. It is possible that the Indian armed forces themselves are also not fully aware of how much assistance they can get from systems in space operated by their own agencies. There is a need for education, training and joint planning. India is carrying out joint military exercises with many friendly foreign countries. There is a need to engage with the states which are successfully using space assets for strategic reasons. There is a need to collaborate with the space commands of these states.

ISRO has an unambiguous mandate for developing and researching space technologies for civilian purposes. There is a need to establish a separate agency which could plan, design, develop and manufacture space systems exclusively required for strategic purposes. ISRO's assistance could be taken for launching such systems. On the whole, India appears to have made a good beginning towards using space systems for strategic purposes, but it has a long way to go if it wants to fully exploit the capabilities of space technologies in this regard.

Endnotes

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14

Space Situational Awareness and Its Importance

Moriba Jah

The space domain can be defined as all conditions, areas, activities and things terrestrially relating to space, adjacent to, within, or bordering outer space, including all space-related activities, infrastructure, people, cargo, and space capable craft that can operate to, in, through and from space.

Space situational awareness (SSA), meanwhile, is defined as the effective understanding of anything associated with the space domain that could impact the security, safety, economy or environment of space systems or activities. This definition acknowledges the supportive activities and threats related to land, maritime, air and cyber regimes relevant to space operations. It requires the combination of space situational awareness foundations of detecting, tracking and environmental monitoring, along with space intelligence foundations of characterising normal behaviour and sensitivity, to detecting change to know when something has or is predicted to occur. A purpose of SSA is to provide decisionmaking processes with a timely and actionable body of evidence of behaviour(s) [predicted, imminent, and/or forensic] attributable to specific space domain threats and hazards.

To date, SSA lacks credible scientific and technological rigour to effectively quantify, assess, and predict space domain threats and hazards. SSA's current state-of-practice suffers from myriad privations: no standard definition exists for elements in the space domain; no standard method exists for calibrating sensors and information sources "tracking" those elements; and there are only limited, inconsistent descriptions of what space objects and events are. Moreover, the space community lacks a rigorous understanding of the space environment itself—let alone a holistic, cohesive cause-effect paradigm for understanding and predicting the space environment's effects and impacts on space objects and events. Further, individual sensors are tasked to collect data instead of tasking a sensor network to collect information in order to answer a specific question. Finally, scientific discovery and operational innovation have been inhibited by the lack of a common framework that employs state-of-the-art in data science and analytics across myriad data sources.

The superstructure of near-Earth space—a political, financial, operational, and engineering sphere—has grown out of military considerations originally set in a two-sided cold war; today it is driven by both modern nationalistic defence and intelligence interests, and increasingly commercial interests as well. The primary purpose of the space catalogue maintained by the US Strategic Command (USSTRATCOM) with the help of Air Force Space Command, for example, is to maintain a sufficient level of knowledge regarding the objects in Earth orbit to support US national security space needs and, to that end, know where to place and point the sensors next. In fact, most things in space today are not US-owned, and not even military—yet the imperative to operate freely in space has driven USSTRATCOM to become a *de facto* (if not always welcome) international space traffic monitor.

There is an opportunity to begin looking at the combined set of science, policy, and technology needs from SSA, space protection, space traffic management, and the long-term sustainability and security of the space environment. These space activities have mission-related interdependencies (such as orbital safety of operations) and common underlying space object behavioural injunctions (e.g., space weather, or policies governing graveyard orbits). But the foundational problem, to accurately understand and predict how objects behave in space, is emerging as another classic 'wicked problem' (in the company of climate change, pandemic influenza, and international drug trafficking)—and the responsibility for tackling all the challenges attendant to this problem is both factious and overwhelming. In fact, the space environment should be treated as a finite resource (a 'commons') that is in real jeopardy of being rendered useless if we as a humanity do not understand how it is becoming polluted and how to mitigate and remediate this conclusion.

Unfortunately, there is no existing organisation today chartered with comprehensively quantifying and assessing which countries are following which guidelines for space debris mitigation, and assessing the utility of these guidelines (i.e., are they doing what they are intended to do?). There is no organisation either that is generating or aggregating the scientific knowledge required to better inform space law, policy, or how space insurance companies underwrite insurance policies for things in space. Nor is there an organisation or consortium working on establishing a holistic educational, training, and workforce development programme for the global community to address these challenges.

The need to address these concerns has never been greater. On-orbit collisions, natural or intentional, are a global concern that threatens the long-term sustainability of space activities and environment, and worsens the impact of the space debris population growth in critical mission-dependent orbital regimes. It accounts for an increase in the *trackable*[1] useless space object population of about one percent annually (with isolated events contributing spikes upwards of 20-percent population growth) and jeopardises the livelihoods of tens of millions of people who depend on critical space capabilities and services.

Traditionally, efforts to develop and maintain awareness of all trackable space objects have relied upon the USSTRATCOM's Space Surveillance Network (SSN). But these sensors are often prohibitively expensive for even the richest of nations, and the space domain is too vast for traditional space surveillance, ground- or space-based, to be truly effective by itself. Protecting important space assets, especially those that provide critical services and capabilities such as communication, weather, bank routing, position, navigation, and timing, requires a new approach encompassing 21st-century technology and a fundamental understanding of the processes governing the behaviour of objects in space.

Until now, the global approach to space operations has been largely reactive, following the latest commercial exigency or governmental demand signal of the day. By contrast, the fundamental work required should lead to new ways to understand, measure and predict behaviour in space. In turn, that work will underpin the development of best practices in space traffic management, and inform efforts to improve mission assurance and mitigate the effects of space debris hazards.

In 1833, William Foster Lloyd wrote an essay where he described what he called the *"Tragedy of the Commons"* and posited that a shared-resource system where individual users acting independently according to their own self-interest behave contrary to the common good of all users by depleting that resource through their collective action. This is our current course regarding the Earth space environment in that it is a common resource to humanity and it is becoming increasingly congested and polluted over time. As the cost to access space becomes lower, more entities are attempting to exploit space for a variety of purposes, some of which are very lucrative. This is analogous to the 'Gold Rush' of the American Western Frontier, where the prospect of making quick money drew many entities that operated without regard to the environment or to the benefit of the community. As the cost to space becomes cheaper, the actual risk of operating in space increases, especially when those who are populating the space environment with satellites are doing so "acting independently according to their own self-interest."

India is one of the countries pushing for an increased launch rate per year. This will no doubt attract a lot of business but at what cost to the community as a whole? As India is increasingly becoming one of the world's leading spacefaring nations, it can also lead the rest of the world in setting the example of what it means to be a good steward of the space environment. Moreover, by investing in space traffic management (STM) and space situational awareness sciences and technologies, India can make a significant and critical contribution to this growing problem.

The Inter-Agency Space Debris Coordination Committee (IADC) is an international governmental forum for the worldwide coordination of activities related to the issues of man-made and natural debris in space. India is a participating member via ISRO. Interestingly, neither SSA nor STM are formally addressed in the IADC except that both of these are required if the international community wants to truly address space debris mitigation, remediation, and population assessment and prediction. India could be a thought leader and motivate the IADC community to get more deeply involved in SSA and STM as it relates to its mission.

India would greatly benefit by not repeating what others have done. If one had to design a useful SSA and STM framework, this would doubtfully look like the current US systems and capabilities because these were designed primarily for missile defence and evolved over time to deal with a growing space problem. There is no reason why SSA and STM should be addressed in mutually exclusive sectors such as defence and civil being separate. Each sector has needs but the problems are foundational and common to all sectors. The proper solution should be hybrid and consist of contributions by all sectors acting harmoniously and strategically.

India should design a long-term roadmap which brings all of the sectors together: defence, civil, commercial, and academic, and determine the proper strategic investments required in order to significantly contribute to orbital safety, long-term sustainability of space activities, and space debris mitigation/remediation. Current guidelines and policies (e.g., UN, IADC, and others.) are based upon incomplete science (physical, social, cultural, geopolitical, and legal). India can lead the way in ushering an updated and more rigorously informed set of guidelines and policies with quantifiable mechanisms to measure their utility and progress toward meeting their intent.

Everything in the current resident space object (RSO) population is modeled as a sphere of uniform material. This is state-of-practice. The world's leading government space debris offices do not track RSOs and rely upon other entities to provide them with orbital knowledge. NASA's models are based upon sensor detections but fail to properly account for realistic astrodynamics. ESA's models are based upon astrodynamics but fail to do be rectified via applied estimation theory (i.e., the models are not updated via an orbit determination process but rather by comparison to the statistical distribution of sensor detections available). There is no agreed upon taxonomy for manmade RSOs and no standard for calibrating sensor data. In fact, sensor data are not openly exchanged within the community, severely limiting the science regarding the RSO population's sources, sinks, and evolution. Many SSA studies in RSO catalog development and maintenance make two foundational flawed assumptions: (1) if an RSO is in a sensor field of view, it is detected 100 percent of the time; and (2) all sensor detections can be reconciled as originating from unique objects. These are some of the hardest technical challenges in SSA. Another flawed assumption is that the position and velocity of any given RSO is completely independent of the position and velocity of any other RSO. This obviates the fact that some RSOs are in constellations and formations and thus a set of RSOs are controlled as a whole. It also obviates the fact that similar classes of RSOs in the same orbital regime are exposed to a common set of space environment/ weather inputs and thus their behaviour resulting from this interaction is indeed correlated.

When wildlife biologists wish to understand any given specie, they tag individuals of that population and then track them over time and space and record their individual behaviour, community behaviour, and interaction with their environment; from this analysis they are able to draw scientific conclusions that are, by definition, measureable, testable, and repeatable. No one is performing this sort of study on the manmade RSO population as a whole. India could become a leader in comprehensive and rigorous SSA and STM sciences and technologies by avoiding these unjustified simplifying assumptions and embracing the hard problems and the complexity inherent in them. India could collaborate with all interested global parties in developing an easily accessible International Space Traffic Monitoring Service (like the IGS.org model) to the benefit of the entire planet, one that is based upon rigour, transparency, among other virtues.

In short, there are many problems plaguing the space community. India is uniquely positioned to lead the way toward real and meaningful solutions to these problems if it organises itself in a way that begins with the problem and avoids the pitfalls of other nations in their evolution of SSA and STM activities. India has a responsibility to the world in progressing its own space commerce and activities responsibly.

Endnotes

1. There are many more space objects that are detected than tracked and this is a major source of the space traffic problem. We can only speak to the behavior and knowledge of the trackable set of space objects.

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Need for an Indian Military Space Policy

Rajeswari Pillai Rajagopalan

Over the last few decades, India has become an established space power. Even though its space programme started largely with a focus on the use of space technology for social and economic advancement of its people, new compulsions in recent years are pushing India towards defence and military uses of space. Nevertheless, it must be argued that India's space visionaries did recognise the utility of space technology for national security and the importance of technology demonstration for India to earn its rightful place in the global politics of space. The technological leapfrogging and spinoffs that are achieved through advancing space technologies for earth observation, weather forecasting and communications, also remain significant. A case in point is the utility of remote sensing satellites for military applications. But the importance of space in the national security domain was not given prominence until the mid-2000s. In fact, India had actively championed the cause of non-weaponisation and peaceful uses of space in its rhetoric both within India and at global fora. For a variety of reasons, however, this may be beginning to change, and not a moment too soon. The regional and global landscape in the area of outer space is changing rapidly and India's indecisiveness could have far-reaching impact in terms of both New Delhi's critical technological and security capabilities and its standing in international governance of outer space.

India's Approach to Space: The Early Decades

India is yet to have an open space policy but its approaches can be gleaned from policy statements within the Parliament as well as in multilateral bodies such as the United Nations (UN). For the first several decades since the 1960s, India maintained that outer space was a domain that must be promoted as a realm of peace and cooperation. For instance, in one of his earlier statements at the UN in 1964, India's representative Krishna Rao said that "outer space was a new field and there were no vested interests to prevent the international community from embarking upon a regime of co-operation than conflict. The problems of outer space were fortunately not those of modifying an existing regime but of fashioning a new pattern of international behaviour."[1] Then Prime Minister Indira Gandhi too made a similar pitch at the UN in 1968.[2] India's vehement criticism of the US and Soviet space competition, including their anti-satellite tests, was a reflection of this policy sentiment. Another instance is India's strident opposition to the US Strategic Defense Initiative (SDI) or Star Wars programmes of the 1980s. In fact, India's then foreign minister PV Narasimha Rao made a scathing attack on such efforts when he said, "Extension of [the] arms build-up to outer space would mean a permanent goodbye to disarmament and peace and [would] plunge mankind into a perpetual nightmare."[3]

While India remained concerned about the use of outer space assets for developing offensive capabilities, New Delhi was also beginning to appreciate the use of space assets for passive military applications such as reconnaissance, surveillance and military communications. This was a result of an acknowledgement of the reality that technology plays a role in active conflicts. Even as this recognition came around, there were questions around the definition of concepts like 'space militarisation' and 'weaponisation of space'. These concerns pushed India to seek a ban on space weapons in all available multilateral platforms such as the UN and the Conference on Disarmament (CD).[4] India's pro-activism at that time also led then Prime Minister Rajiv Gandhi to sponsor in January 1985 "a declaration of six nonaligned countries opposing an arms race in outer space and nuclear testing".[5] The Indian debate, seeking a total ban on all global commons, was also being increasingly pursued from a morality and sovereignty angle, which did not find too many takers except for the non-aligned community. Policy perspectives along these lines continued well into the 1990s even after the end of the Cold War. It is only by the early 2000s that India began to reorient itself recognising a range of new threats and challenges and thereby acknowledging the utility of a more determined space security capability. The next sections discuss the changing nature of warfare and military space needs globally as well as India's own requirements for meeting its national security missions.

Changing Nature of Warfare and Military Requirements

The launch of the first communications satellite in the early 1960s can be characterised as the start of the military use of outer space, but it gained greater traction in the last couple of decades. Militaries around the world use satellites for a wide variety of functions including communications, navigation and warning systems, reconnaissance, and surveillance. The initial application of space for military were to aid, enable and enhance the land forces to operate in a more efficient environment. The emergence of the revolution in military affairs (RMA) concept brought in a fresh perspective into the utilisation of outer space. RMA became popular after the first Gulf War in 1990 where use of integrated technology had changed the way the war was fought. The Gulf War was one of the first occasions where satellites played a critical role in a ground and air campaign and the space utilisation completely altered the dynamics of the war, to the point of it being called the 'first space war'.[6] The features of the RMA—including precision strike and dominant manoeuvre—could not be undertaken efficiently without the aid of satellites. The growing importance of space in today's warfare is becoming more clear in the context of the changing nature of warfare: space capabilities are today being integrated into traditional warfare, as seen during the two US operations in Iraq and Afghanistan. Other countries such as China have studied these operations to carefully align their own capabilities and strategies accordingly. India can no longer afford to remain distant from these developments. Therefore, while every space power will pledge that space is truly a global common, the increasingly military space programmes and the trend towards weaponisation by a handful of advanced space powers should drive India to secure its security interests in outer space.

Thus, most spacefaring countries operate an entire fleet of dual-use satellites that have applications for both civilian and military functions. The military utilities have been largely for the purposes of navigation, imagery and reconnaissance, early warning and surveillance. Navigation is one of the most widely used military applications of space assets. The military has put greater use of satellites for mapping, location of targets, and guiding weapons systems. Prominent navigation systems include Global Positioning System (US), GLONASS (Russia), Beidou (China), and Galileo (ESA). Reconnaissance and imagery, early warning and ocean surveillance are other critical functions of military space assets. Satellites have been put to large-scale use for imagery for the purposes of identifying targets, as well as indications of underground nuclear explosions. Some of the satellites in this category include the Space-based Radar (US), Fanhui Shi Weixing (China), and RISAT (India). Space assets have been of immense use in the area of early warning. Infrared satellite sensors can detect rocket and missile launches by sensing hot plumes of missile exhaust. Examples of such satellites include SBIRS (US) and Oko (Russia). Ocean Surveillance, meanwhile, was initially developed in the Cold War context for triangulating the geolocation of enemy fleets. The US' White Cloud Naval Ocean Surveillance System and Russia's EORSAT are foremost examples, though in recent years, more such applications are being developed by other countries, particularly in Asia with its contested waters.

While this is not an exhaustive list of the military utilities, these are some of the prominent uses of space assets in the area of security. As countries increase their reliance on space assets, so also is the growth of vulnerabilities, with the very same systems coming under attack from potential adversaries. This has given way to states pursuing counter-space capabilities as a way of protecting one's own assets in space and also as an access denial measure against adversaries. Access denial can work to a state's advantage in a conflict especially if the adversary is heavily reliant on satellites for precision strikes, target location and communication, such as the US.

The trend towards space weaponisation is also accelerating. While countries have generally used the rhetoric of non-weaponisation of space, several advanced space powers are moving towards testing new anti-space and access denial technologies. China's growing capabilities in this regard should be particularly concerning to India. The annual report on Chinese military power produced by the US Department of Defense has repeatedly highlighted these trends. Since its anti-satellite (ASAT) test in January 2007, China has gone on to develop capabilities that are seen as limiting or preventing an adversary from using space assets in times of conflict.[7] These capabilities include jammers as well as directed-energy weapons. Although Beijing has categorically denied conducting any ASAT tests since 2007, there have been repeated tests shielded as missile defence tests. Its ASAT tests in 2013 and 2014 raised particular suspicion on the nature of such tests. A suspicious test was reported on 13 May 2013 when an object was sent up on a ballistic trajectory that reached close to an altitude of 30,000 km although no object was placed into the orbit. It was also said that it was "inconsistent 'with traditional space launch vehicles, ballistic missiles or sounding rocket launches used for scientific research"' indicating that it might have been an ASAT weapon. Similarly, its test on 23 July 2014 was identified by the Pentagon as "a follow-up of the 2007 destruction of an in-orbit defunct weather satellite."[8] Similarly, the purpose of China's Roaming Dragon satellite launched on a Long March 7 rocket on 25 June 2016 is not clear, though it is officially described by Beijing as being space debris collection – to remove old spacecraft and other debris and get them safely back to the Earth's surface.[9] Space debris indeed is a major issue confronting all states irrespective of the source, and China has conveniently used this as an excuse by suggesting that its mission is to clean up debris in space. However, suspicion abound because the design, manoeuvrability and the extendable robotic arm of this satellite suggest that Roaming Dragon could also be a weapon, with the potential to move in close or even dismantle satellites of adversary countries. In fact, a report quoting a researcher with the National Astronomical Observatories in Beijing anonymously suggested that the mission may not be for entirely peaceful purposes.[10] The US, too, has been developing certain systems which give it greater control and force projection in space. The American Experimental Satellite series is a case in point. The US' counter-space systems like the Counter Communications System (CCS) are also examples of satellites that can potentially interrupt an opponent's communication systems. Potential use of space-based missile defence interceptors are also seen as weaponising outer space.[11] Exploring the use of YAL-1A airborne laser by the US Air Force for targeting satellites is another illustration of this growing trend.[12]

Even as these are perceived as application of military force in a more direct manner in space, it is difficult to determine which of these technologies is a space weapon until it is used. These are not entirely new problems – there have been such concerns for instance in the 1980s in the context of US-Soviet space competition. An additional problem is that there are no rules of the road or legal measures to regulate activities in this regard.

India's Military Space: Utilities, Institutions and Policy

India has been part of this growing trend of greater utilisation of space for military and security purposes. Although New Delhi did not have a dedicated military satellite until August 2013, the country was already utilising the four dual-use satellites for meeting its security requirements. Following China's ASAT test in 2007, there has been a growing recognition of the need to commit more dedicated resources and efforts for securing its interests in this domain. This should translate into India paying greater attention to its technological developments in addition to developing its policy and institutional architecture.

Given the new security trends, there has been a greater sense of purpose in the Indian military's use of space assets in recent years. India's remote sensing satellites, for example, have been of enormous use in the area of mapping although the earlier ones such as IRS-1C and IRS-1D had limited application in the area of defence and security. More advanced ones include the RISAT-1 and RISAT-2 were developed in the last decade. The RISAT series have a particular advantage given the kind of on-board sensors, because it carries an SAR (synthetic aperture radar) payload operating in C-band. India's earlier satellites were dependent on optical or infrared imaging as against the new ones that rely on SAR technology which provides all-weather and day-and-night visibility. The RISAT satellites are thus capable of penetrating through thick cloud cover, thunderstorms and fog. This is of huge strategic importance to India as SAR technologies provide for better reconnaissance, surveillance and location targeting for guidance and navigation.[13] Thus, the RISAT series are considered a "force multiplier" in the defence context. The RISAT series have been put to great use for security-related functions: border surveillance, detection of insurgent infiltration, and facilitation of counter-terrorist operations. India's requirement for such missions grew significantly after the Mumbai terrorist attacks in November 2008. Therefore, even though India was developing RISAT-1 indigenously, the security compulsions following the terrorist attacks pushed India to partner with the Israel Aerospace Industries (IAI) for expediting the development and launch of RISAT-2.

Navigation-related functions have also become critical in India's military space utilities. Both GAGAN and IRNSS are important developments in this regard. GAGAN is GPS Aided Geo Augmented Navigation system in which the ISRO is working with the Airport Authority of India (AAI) for meeting civil aviation requirements.[14] Meanwhile, the Indian Regional Navigation Satellite System (IRNSS) or NAVIC (NAVigation with Indian Constellation), with a constellation of seven satellites and a ground-support unit, is a smaller version of the US Global Positioning System (GPS) that can provide real-time positioning and timing services with a precision better than 20 metres (in the primary service area) over India and a region of 1,500 kilometres around India. India launched its first navigational satellite, the IRNSS-1A, aboard the PSLV-C22 from the Satish Dhawan Space Centre on 1 July 2013 and completed the placement of all the seven satellites for the IRNSS with the launch of IRNSS-1G on the PSLV-C33 on 28 April 2016. Three of the seven satellites are positioned in the Geostationary orbit (GEO), four satellites in Geosynchronous orbit (GSO), and two satellites on the ground are on stand-by in addition to ground stations. The ground support unit that includes control of navigation parameters, satellite control, satellite ranging, and monitoring, and they are located in 15 locations across the country. Even though India has never been denied access to data from other GPS-providers, it felt the need to develop the navigation system in order to avoid being exposed to the possibility of it being denied in the future, especially during a crisis or a war. The IRNSS relays information for two types of users: Standard Positioning Service (SPS) for general use, and Restricted Service (RS) meant for special authorised users—military and other government agencies.

Early warning and military communications are also emerging as big focus areas in India's military space applications. Media reports indicate that India plans to use its constellation of geostationary satellites as the first line of defence as part of its missile defence shield. Scientists in the Indian defence research and development establishment claim that the G-Sats "will be able to capture the slightest of movements or even heat signatures."[15]

For military communications, the launch of GSAT-7 or /INSAT-4F in August 2013[16] and GSAT-6 or INSAT-4E in August 2015 remain important achievements. The GSAT-7 for the Indian Navy, with a surveillance cover of around 1,000 nautical miles, stretching from the eastern coast of Africa to the Malacca Strait, is likely to have a critical impact on India's maritime security and intelligencegathering capabilities. Its relevance is also significant in the context of Maritime Domain Awareness (MDA). But these requirements will increase parallel to India's security interests, especially in the emerging Asian strategic context including the Indian Ocean region.

In terms of the institutional architecture, India has been slow despite noteworthy developments over the last decade. In one of the more concrete actions, on 10 June 2010, India's Defence Minister AK Antony declared the establishment of an Integrated Space Cell under the Integrated Defence Services headquarters of the Ministry of Defence. The integrated cell is jointly driven by the three services of the Indian Armed Forces, the Department of Space, and the ISRO. This institution was necessitated by the need to bring about greater coordination and coherence in its purpose and functions as it pertained to military space needs. In addition, this body is also responsible for articulating India's near-term space policy. Clarifying India's new orientation in India's approach to space, India's Defence Minister AK Antony, in 2011, stated in the Rajya Sabha that the "satellite requirement of the armed forces are being met from the existing facilities. Steps have also been taken for [the] provision of dedicated satellite facilities for the armed forces".[17] While India has taken some small steps in terms of its institutional innovation with the formulation of the Integrated Space Cell, there has been a lackadaisical approach in enumerating further its role and meeting its growing needs. There are also problems in terms of resource allocation including the small budget with which it has been operating. Unless these are attended to and there is aggressive follow-up, India's "space architecture of offensive and defence system" will remain only in paper.[18]

Meanwhile, the Indian Navy has been prompt in conceiving certain institutional reorder – even before the launch of the first dedicated military satellite for the Indian Navy, it had established a new office called the Assistant Chief of Naval Staff (Communications Space and Network

Centric Operations; ACNSCSNCO), which was responsible for administering military space capabilities for the Navy. This was in recognition of the shift taking place from a "Platform Centric Navy" to a "Network Enabled Navy."[19] Other departments such as the Ministry of Home Affairs also plan to have a committed satellite for the ministry including ground-based infrastructure with advanced sensors and fences. Taking note of the increasing security challenges in India's neighbourhood and the country's porous borders, the Ministry of Home Affairs has envisioned a Border Space Command to monitor borders with China, Pakistan, Bangladesh, Nepal and Myanmar. Accordingly, a $2-billion budget for this has been sanctioned.[20]

Another institution that has been in the making is India's aerospace command. The requirement for an aerospace command was first articulated in 1998 by then Chief of Air Staff, Marshal SK Sareen. In 2003 it was reiterated by Air Chief Marshal S Krishnaswamy who said, "Any country on the fringe of space technology like India has to work towards such a command as advanced countries are already moving towards laser weapon platforms in space and killer satellites."[21] After the Chinese ASAT test in 2007, then Air Chief Marshal Marshal SP Tyagi said, "As the reach of the Indian Air Force is expanding it has become extremely important that we exploit space and for it you need space assets. We are an aerospace power having trans-oceanic reach. We have started training a core group of people for the 'aerospace command'."[22] While the establishment of the Integrated Space Cell is an important building block to a fully operational aerospace command, it has been a decade since then and there is little to show on the ground.

The need for greater coordination and sense of purpose is missing in India's military space approach as it lacks both a policy articulation and an appropriate institutional mechanism. An aerospace command would become a single window agency that would be able to better coordinate and cope with the growing requirements of space from a security perspective. Also having a single agency will mean a more coherent sense of promoting India's national interests.

Lastly, India has to attend to its policy architecture if it has to be able to defend its interests in the military space domain. India is yet to issue a comprehensive space policy document. While it has put in place certain sector-specific regulations and guidelines, even those are lagging in many ways, which are addressed in other chapters in this volume. These guidelines simply state the terms of engagement for foreign and domestic players and other related issues, but fall short of providing a policy perspective even in these narrow domains. Moreover, a broad national space policy should be able to integrate the different functions and utilities that belong to these narrow domains if India has to be able to strengthen its gains for the long-term.

More importantly, the changing regional and global security dynamics, including in the space domain, are critical imperatives for India to ponder and address with appropriate counter-measures. The outer space domain has changed with growing demands and challenges, reinforcing the difficulty of the question of space sustainability and uninterrupted access to space. All of these suggest that the need for an overarching space policy has become far more pressing than ever. India's immediate neighbourhood itself has changed dramatically, and inaction could cost it dearly in the strategic space domain.

While India has begun to appreciate the importanceof outer space in the military domain and has taken a few steps in that direction, both in terms of the technology and the institutions, it has done so in a piecemeal style rather than as part of a larger strategy. The benefits of an open, declared, overarching space policy far outweigh the disadvantages. Also given the growing demands of space-based applications, which are competing in many ways between the military and the civilian requirements, the national political leadership should declare the space policy and not an individual agency such as the ISRO. An ISRO-declared space policy will be restricting, focusing only on the civilian aspects of India's space policy and on the other hand, a policy document emanating from the Ministry of Defence or the military would focus on the security domain alone; both scenarios are problematic. India's space policy should ideally come from the Prime Minister's Office, as is done in the case of other advanced space powers such as the US where the White House releases the space policy document.

While there is a requirement for an open declared space policy, the need for a military space policy cannot be ignored. India might not want to go down this path given its long-term approach of utilising space only for peaceful purposes but if the country fails to respond to the changed circumstances, it will stand to lose. Therefore, India must take steps to declare a military space policy, or at least its key aspects. One good place to start may be by issuing a white paper on space. India must then commit and strengthen the resources available in the military space domain. For instance, in order to meet growing demands, the number of dedicated military satellites need to go up from the current one or two. After launching the first dedicated military satellite for the Indian Navy in 2013, the Indian Army and Air Force have been waiting for close to four years for their own dedicated satellites. This scenario needs to change. The reason for the delay is possibly because ISRO has had difficulty meeting these demands – the number of launches that the ISRO is able to undertake has set certain restrictions but also there are limitations on India's launch infrastructure that need to be addressed. A second related point that the government must address relates to creating a more favourable ecosystem for India's talented private sector to play a more judicious role in meeting India's multiple requirements. This requires a change of mindset because for long, private sector has been seen as the "other" that needs to be kept at an arm's length. Instead the government must introduce tough yet reasonable regulations for both the public and private players and create a more level-playing field, instead of favouring public-sector enterprises just because they are state-funded. The US would not be a big player with an edge in the high-technology domain if not for the private sector that has had a critical role in keeping the US as the number one power in outer space.

Further, of critical requirement is for India to have a longer-term perspective of its goals. This has been problematic on India because New Delhi is yet to issue a long-term strategy document. This would bring about greater clarity and better resource allocation although the scientific and technical community associated with the Indian space programme could vouch that the space programme has never been short on resources. However, in reality, ISRO's tiny budget has been spread too thin to meet all the growing requirements. There have been repeated articulations that ISRO's budget will be increased, but even the 2016 allocation did not see any improvement. A lot of work lies ahead.

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IV

INTERNATIONAL COOPERATION

16

Cooperation in Space Between India and France

Jacques Blamont

For France, space was never going to be a solo effort. From the outset, in 1959, the Space Research Committee that was the forerunner of CNES (Centre National d'Etudes Spatiales) focused its attention on two avenues to be explored: the interdisciplinary nature of space research and the possibility of finding international partners, materialised in 1961 by the signature of a first agreement with the US National Aeronautics and Space Administration (NASA). This agreement provided for a satellite project and training of French personnel in the United States. In 1962, then President Charles de Gaulle's government created the CNES and gave it the task of shaping the nation's space policy. One 'space giant' followed the other, and in 1966 CNES signed a cooperation agreement with the Soviet Union. Also, France has extended its partnership to other major space players, namely, India, Japan and China.

I. Space Exploration: A brief history

In the 1960s there was no objective reason for India to develop a space programme; it was a luxury it could not afford to indulge in. But one man, Vikram Sarabhai, had a vision: *"Space technology is most essential for the all-round economic development of India."* He proposed to consider space applications as a major contribution to the country's self-reliant fulfillment of solutions to its pressing problems. Among these applications included telecommunications (which was directly relevant to addressing issues like low literacy rates), and meteorology (that had an impact on agricultural practices).

It was a miracle that this man with a vision had enough charisma and clout to push for the embodiment of his dream into a real national programme, considering thathe had nothing to start with. At the COSPAR (Committee on Space Research) 1962 Assembly in Washington, this author, as scientific and technical director of the then newborn CNES, had the opportunity to meet Vikram. Highly impressed by Vikram's ideas, this author decided to help him in spite of the weakness of the French assets at the time.

As France and India's situations were similar, India had just to follow the path taken by France five years earlier: to learn the trade by launching sounding rockets. Under the Indian National Commission for Space Research set up by Vikram, the launch site TERLS was built at Thumba near Trivandrum, with the help of NASA, the Soviet Union, and CNES. Since nobody in India could build a payload, the CNES suggested as a first step in the learning process, to start by scientific studies of the high-atmosphere dynamics with the creation of sodium clouds by rockets, an experiment which needed no on-board electronics equipment. On 20 November 1963, an American provided Nike-Apache carried with success a sodium ejector payload fabricated in CNES laboratory, and it was immediately followed by three similar sodium clouds launched at Thumba by French Centaures, a two-stage solid propellant rocket also provided by CNES. That was the birth of the Indian space programme.

Technology transfer in propulsion

Solid propellants

The Indo-French collaboration was formalised through a memorandum of understanding signed in May 1964 between CNES and India's Department of Atomic Energy (DAE). CNES gave a variety of equipmentto TERLS including a COTAL radar. Sarabhai decided to manufacture Centaure rockets in India under license. CNES helped in concluding agreements with the French aerospace industry and provided specialised training to a number of Indian engineers and scientists every year. The propellant plant was commissioned in Thumba by the end of 1968, and the first indigenous Centaure launched on February 1969, with an Indian payload onboard. Concurrently, the propellants were indigenised and used for the development of the all-Indian Rohini rockets: the two-stage RH560, very similar to the French Dragon (a more powerful brother of Centaure), reached a 350-km altitude with a 150-kg payload on 27 January 1973.

The indigenisation of imported Centaure technology was a major milestone for India, establishing the future growth of rocketry in the country, even though plastolite propellants, not suitable for a launch vehicle, were replaced by other chemicals developed by ISRO scientists: PBAN was used for the launch of SLV-2 on 18 July1980 which launched India to the status of a spacefaring nation.

SLV-2 was powered by solid propulsion in all its four stages: liquid propulsion was left by ISRO on the slow burner.

Liquid propellants

For India, the major breakthrough in liquid propulsion systems came in 1974 when ISRO signed an agreement with the SEP (SociétéEuropéenne de Propulsion) located in Vernon (France). At that time, France was developing the Viking liquid engine for its Ariane launch vehicle programme. Without any exchange of funds, this agreement provided for technology transfer from SEP to ISRO for theViking liquid engine. In return, ISRO would extend the services of 100 man-years of ISRO engineers and scientists to SEP for their Ariane launch vehicle development.

To acquire the Viking engine technology, ISRO engineers worked in all areas of development activities of the Ariane programme. They participated in design reviews, progress reviews and even had interaction with European industries. They received all detailed design drawings and documents, and participated in inspection and quality assurance of systems, subsystems and components. They were also part of assembly and integration, checkout and testing operations in SEP facilities. They had discussions with SEP specialists and received clarifications to understand the technology fully. Some 40 engineers, working under a five-year contract, participated in the technology acquisition program at Vernon and Brétigny in France.

The ISRO Chairman created in 1980 a Liquid Propulsion Project (LPP) which organised three teams under the leadership of three SEP-trained experts—the first team developed the system, the second was tasked to realise all hardware in India in association with Indian industries, and the third team was to establish all development facilities at Mahendragiri. Indian industries and academic institutions were associated in the development effort. The Viking engine, renamed Vikas, today powers the second stage of PSLV and GSLV launchers. The first Vikas engine was realised with the active contributions from MTAR Technologies, Hyderabad, Godrej and other industries. It was successfully tested in SEP facilities in 1985, demonstrating the triumph of the acquisition of the technology.

TheVikas agreement between ISRO and SEP is the seedling which has grown today as a big tree called Liquid Propulsion Systems Centre (LPSC) with branches in Bangalore (Karnataka), Mahendragiri (Tamil Nadu), and Valiamala (Kerala). The ISRO-SEP agreement and the consequent acquisition of technology for Vikas engine had a great impact on the very configuration of the PSLV launches and therefore played a crucial role in making PSLV the workhorse of ISRO.

From assistance to commerce: Communications

The essential feature of the cooperation between India and France has been to gradually mature from assistance to cooperative action and then to commercial contracts.

In 1968-70, Vikram worked hard with CNES, under the leadership of this author, to provide a space link to his pet Education program. He had obtained a letter from then Prime Minister Indira Gandhi, proposing to the French government a joint mission similar to the German-French Symphonie: a geostationary relay for cultural and educational TV emissions. The proposal was, unfortunately, not accepted, and Symphonie (launched in 1974) was later made available to Indian research and enabled numerous ground experiments conducted by ISRO and the P and T Department of the Ministry of Communications, spurredby exchanges of scientists for trainings, discussions and workshops. Vikram had had better luck with NASA, which provided access to its ATS-6 (Applied Technology Satellite) for the requested relay; this became the SITE project in 1975-76. However, the Symphonie multiple experiments, along with SITE, *"laid the foundation on which the applications of INSAT series of satellites have grown in India"*[1]. They appear therefore as one of the major cooperative successes of the India-France space cooperation since *they laid the foundations for using satellite-based communications in India* (ibid).

After a long period of cooperation between agencies without the exchange of funds, the space relations between France and India adopted commercial ventures between industrial partners as a new mode of action.

This pattern was exactly followed for communication satellites. Following a proposal by CNES, APPLE, Indian's first geostationary experimental communication satellite was placed in orbit free of cost by the third Ariane on 19 June 1981. Dedicated to the nation on 13 August 1981 by then Prime Minister Indira Gandhi, it was used by ISRO and Telecommunication Research Centre of P and T over a period of 27 months for many experiments including tracking Indian Railways wagons or telemedicine, and was the test bed for learning for many Indian engineers. Following the choice of Ford for the development of the INSAT satellite, ISRO used US launchers for its satcoms. Then after INSAT 1-A and 1-B, ISRO turned to Arianespace.

Arianespace launched 11 out of the 22 Insat ISRO communication satellites, from Insat 1-C on 21.07.1988 to Insat 3-D on 25.07.2013. All launches were successful. Also,six out of 16 GSAT have been placed in orbit by Ariane, the last of them on 10/11/ 2015.

But India had become a full-size space power by then. In September 2008, an agreement was signed between the French firm Astrium (now a part of Airbus DS) and Antrix, ISRO's commercial arm, covering the launch of the French 712 kg imaging satellites Spot 6 and 7, together with the construction of a communication payload for the ISRO satellite Hylas-1 operated by Avanti Communications of London. Hylas-1 was launched by Ariane-5 on 26/11/ 2010. PSLV placed Spot 6 on a nominal heliosynchronous 694 km circular orbit on 9 September 2012 and Spot 7 on 30 June 2014 on a similar orbit.

Cooperation on scientific missions

Megha-Tropiques, a joint ISRO-CNES mission, is dedicated to the documentation of the water and energy cycles in the convective oceanoatmospheric systems of the tropics, by acquiring frequent measurements of the parameters associated with radiative fluxes, water vapour and precipitations.

ISRO provided the PSLV launch on 12 October 2011, the platform and the major part of the MADRAS instrument. CNES provided the Saphir and ScaRab instruments.

MADRAS is a microwave imaging radiometer giving data on rains, water vapour and clouds; Saphir is a microwave sounding radiometer providing vertical profiles of humidity; ScaRab is a wideband radiometer for measuring radiations fluxes; ROSA, provided by Italy, obtains temperature and humidity profiles by GPS occultation. The Megha-Tropiques data contribute to the cooperative ensemble GPM (Global Precipitation Measurements) coordinated by NASA, as the first spacecraft of its eight satellites constellation.

The important feature of the mission is the combination of its instruments with a 20 degree circular orbit (altitude 865 km), enabling up to five observations per day at the same location.

Saphir and ScaRab function nominally with performances well within specifications. MADRAS has failed on 26 January 2013, and experienced during its 16 months of operation electrical difficulties delaying its validation; efforts are directed towards making a final version widely available.

The Saphir data, distributed in real time via Eumetsat's EUMET Cast system are being fed to prediction models since April 2015. The consequence is an improvement up to 10 percent of the root mean square error in the relative humidity between 200 and 300 hPa. A product called TAPEER, combining Saphir data with contributions of other satellites has been developed to estimate cumulative precipitation at a resolution of 1° and 1day. This product shows a strong potential for accelerating progress in models, especially in Africa.

The loss of MADRAS is mitigated with Saphir being used as a surrogate. As of April 2016, some 90 papers have been published, 70 of them written by French scientists, with more than 1,400 citations. Preliminary results show that the low inclination orbit brings in useful information for rainfall estimation and convective events monitoring, even under an already dense observing system. The operational use of Saphir is in its infancy and it results from Megha-Tropiques that this type of measurement will have a positive impact on numerical weather forecasts.

SARAL-Altika, a joint ISRO-CNES mission is dedicatedto altimetry. Previous altimetry missions such as Topex-Poseidon and Jason conducted by CNES in cooperation with NASA,Eumetsatand NOAA, all operated in Ku-band (13.6 GHz) coupled with S or C band. SARAL uses Ka-band (35 GHz) for enhanced performances in terms of vertical resolution, time decorrelation of echoes, spatial resolution (8 km footprint) and range noise. The satellite has also enabled a better observation of ice, rain, coastal zones, lakes, rivers and wave heights.

ISRO provided the platform and the PSLV launch on 25 Feb 2013 to a heliosynchronous circular (800 km) orbit. CNES provided an integrated payload module including the instruments and an Argos-3 mission payload, and a part of the ground system. The payload includes an AltikaKa band altimeter and an embedded dual-frequency radiometer (23.8 GHz/37 GHz); the radio-positioning DORIS system for precise orbit determination using dedicated ground station; a laser reflector array to calibrate the orbit determination system; an Argos-3 instrument as part of the Argos system.

In orbit the behaviour of SARAL has been flawless. The quality of data has been generally better than Jason-2's products and demonstrated new capacities (coastal, inland, ice). It has filled the gap between Envisat and Sentinel-3 and played a key role in the ocean-surface topography virtual constellation, which requires a minimal configuration of four satellites simultaneously in orbit (Jason 3 and Sentinel 3A were not yet launched, Cryosat not optimised for ocean observation and HY2 suffering from data outage). A large scientific community of users has been assembled, as was reported in a special issue of the journal, *Marine Geology*.

SARAL-Altika has been a pertinent precursor for the future NASA-CNES altimeter mission SWAT.

Research in atmospheric physics using balloons

There is a history of successful research in tropospheric physics pursued in India by the Laboratoire de Météorologie Dynamique, with the support of CNES.

Participation in the international program of monsoon studies (MONEX) organised in 1979-80 within the scope of GARP (Global Atmospheric Research Program).

- *PreMonex*: launch of 45 super-pressurised 2.50-m-diameter balloons from Seychelles (1975), floating inside the boundary layer (around 900 hPa) for days to weeks. The experiment was a success: the flights were able to characterise different phases in the monsoon flux due to the interaction between the lower layers jet and intense convective cells originating off the eastern shore of Somalia.
- *Balsamine*: launch of 60 similar balloons from Seychelles and 30 from Madagascar (Diego Suarez) in 1979. Good surface wind data were obtained and associated with the other MONEX measurements retrieved from ships, airplanes, drop sonde satellites. They proved useful for the evaluation of the equilibrium between the advection, forcing and wind friction terms in the boundary layer and the parameterisation of small scales in the numerical models of weather and climate prediction.

Participation in INDOEX (1999)

The purpose of the INDOEX international programme was to study the transport and evolution of aerosols and trace constituents issued from the Indian subcontinent, and their interaction with clouds and radiations. The contribution of the balloon flotilla proposed by LMD was to observe directly the wind field in the lower layers above the Arabian Sea and the transport of polluted air masses coming from the subcontinent.

Seventeen balloons were launched from Goa in January and February 1999. The flights discovered that the transport of pollutants isdominated by the anticyclonic circulation off the western coast of India due to orographic subsidence behind the Ghats and to the diurnal cycle of sea breezes.

The future

The recent success of the two joint ISRO-CNES missions, Megha-Tropiques and SARAL, leads to the idea that the 50-year-old Indian-French cooperation in space should now be expanded.

The *"Programme between CNES and ISRO for Reinforced Cooperation in Space Activity"* was inked in Paris on 10 April 2015. Then on 25 January 2016 in New Delhi, in the presence of French President François Hollande and Prime Minister Narendra Modi, CNES President Jean-Yves Le Gall and ISRO Chairman A.S. Kiran Kumar signed three implementing agreements providing the future framework for closer ties between the two nations in space. What are the ingredients of this augmented cooperation?

Scientific research

Climatology and meteorology

The Asia-Pacific Remote Sensing Symposium (APRS) was held from 4 to 7 April 2016 in New Delhi. For its 10th edition, this event brought together heads of space agencies from around the world focused on the use of satellite-based remote sensing in managing disasters and monitoring climate change—two particularly hot issues in the wake of the December 2015 COP 21 climate conference in Paris. The *Declaration of New Delhi* was adopted, stressing the will of all Space Agencies to play a major role in climatology research, and specially maintain continuous global monitoring of climatology parameters: space data provide half the data used to understand climate. Jean-Yves Le Gall explained that France has made climate research a national priority, citing the missions it is pursuing in this field with Europe and its partners, like MERLIN with Germany and CFOSat with China.

As a consequence, the above mentioned bilateral agreements stipulate that CNES and ISRO will jointly develop an infrared climate-monitoring satellite designed to map heat exchanges on the Earth's surface and support new applications in agriculture, forest monitoring, soil and groundwater pollution monitoring, and volcanology. This mission will be devoted to remote sensing of Earth in the thermal infrared (TIR) and a visible part of the electromagnetic spectrum, at a high spatial scale (resolution of a few tens of meters) coupled with a high temporal scale (revisit of one to three days) with two main objectives: ecosystem stress and water use monitoring; coastal zone monitoring and management. On the other hand, the signed agreements foresee that in 2018, the ISRO Oceansat 3-Argos mission will fly France's latest-generation Argos 4 environmental data collection and location instrument. Sometime in the future, such ventures may lead to a world space system of surveillance of the compliance of countries to agreements on carbon emissions.

The 2016 ISRO-CNES agreements also contain the creation of a joint space science group tasked with studying France's participation in future Indian interplanetary missions. This paper argues for this joint group to focus on atmospheric, oceanic sciences and climatology. If (as has been seen) the ISRO-CNES balloons and satellites have provided good scientific results, these operations have happened on a sporadic, haphazard road map, without any strategic view. Balloons studies of monsoon or pollution were interrupted when LMD scientists obtained their D.Sc. The Megha-Tropiques program was virtually abandoned after many years of hopeless discussions between engineers of Toulouse and Bangalore, when during the experts' flight to Trivandrum for the 40th anniversary of the first Indian rocket experiment, this author managed to convince the Chairman of ISRO, Madhavan Naïr, to save the project and make it happen; it has since succeeded. The programmatic management of the cooperation has not been up to par with the excellence of the instrumentation and to the potential of Saphir and Altika.

The method used in the Soviet-France Space cooperation programme should be used in the ISRO-CNES joint ventures: a programme committee should be established, tasked with the elaboration of research projects in climatology -atmospheric science - oceanography to be submitted on a regular basis to the two agencies. The projects would involve whenever needed satellites, balloons, general equipment (lidars, radars, sounders ships, aeroclippers, buoys, among others).

The purpose would be to support a wide scope use of many techniques in a strategic approach providing extensity and continuity in the acquisition of data. This policy could mean reflights of proven instruments such as Saphir and Altika.

Planetary exploration

Beyond its space community, India is rightly proud of its successful missions to the Moon and to Mars. On the other hand, CNES has participated in a large number of planetary ventures as provider of high-quality scientific or technical hardware, from the SovietVenera missions to the American Clementine to the Moon or Curiosity to Mars, and ESA's ExoMars.

The "new step forward in cooperation" announced by the political leaders should be symbolised by a flagship venture prepared and proposed by the joint science group.

The choice of the target is therefore not yet known but this paper recommends a French participation in the Venus mission inscribed in ISRO's plan for the early 2020s.

As having worked many years in Venus space research, including the successful balloons of the Soviet mission Vega (1985), this author believes that the complex physicochemistry of Venus cannot be understood without in-situ long duration measurements and that balloons can provide vehicles adapted to the Venus atmosphere, already qualified for such a mission, relatively easy to use, and cheap. They are well-suited to the solution of the riddles of the Venus atmosphere: the super rotation and the sulfur cycle. A first-class French scientific community would have the capacity, working with its Indian colleagues (for instance) of the NARL, to obtain a breakthrough in the most mysterious phenomena offered by planetary atmosphere. This type of mission, which would become a part of a long duration program with launches every two or four years, appears as a natural complement to the program of terrestrial atmosphere research proposed in the precedent section.

Defence

The following section involves unchartered waters, and the views expressed are this author's own.

Today all conflicts have become information wars. Space being the essential global asset for collecting, transmitting and disseminating information plays ipso facto a vital role not only in the formulation and implementation of great power strategies, but also in the daily management of theater operations. The acceptance of this reality and the consequent need to restructure their entire national security complex figure obviously among the most important tasks ahead of every state. Most important will be the acquisition of space-based C4ISR capacities which, complemented by ground-based components, will be critical for preserving peace through deterrence and for waging war. India and France are nations faced with this fast evolution.

In India, the Ministry of Defence has created inside the Integrated Defence Staff a think tank devoted to Space Defence called Integrated Defence Cell, and invested in space hardware servicing the military: 2013 launch of GSAT-7, devoted to Navy communication; 2015 launch of GSAT-6 for Army communication. In November 2015, the Prime Minister's Office has openly mentioned working on the concept of an eventual *Space Defence Agency* whose action would have to be consistent with the current international posture of the "peaceful uses of outer space". Following this line, it could be useful to colour its strategy with international cooperation, even if this mixture appears at first glance as a paradox. Space tends to be international by nature and the International Chart on Space and Major Catastrophes initiated as an initiative of CNES and ESA in 1999 is an example of cooperation for providing sensitive data in some circumstances. The organisation, Sentinel Asia proposed by Japan for the Asia pacific zone, or the Emergency Services of ESA's Copernicus program, offer similar products.

As CNES helped India in the 1960s towards the creation of a civilian Space capacity, it could also help into the development of a Defence space capacity. France has deployed itself a number of Space Defence assets with the telecommunication Syracuse; the imagers Helios-Spot and Pleiades; the radar Cosmo-Skymed;the ELINT Cerise, Clementine, Elisa, Essaims; localisation through its partnership with ESA in the Galileo program. A strong space industry and operational experience obtained in the recent conflicts are assets that could form the basis of cooperation.

It is suggested that discussions would be started at a high political level in order to explore the ways and means of such a delicate venture. Even if it is too early to specify what type of programs would be chosen in this cooperation, some trails can be mentioned, corresponding to basic needs for the Indian Defence space program.

1 - *SIGINT.* After learning the trade of the space monitoring of electromagnetic signals for Defence purpose in successive missions, the

French Ministry of Defence intends to deploy the CERES ELINT system in 2020 for detection, positioning and characterisation of transmitters radar and of telecommunication. It will comprise three satellites in formation. Thales Alenia Space will provide the platforms and Airbus DS the payload.

2 – *Sea surveillance.* Pirating and migrations have made sea surveillance a priority for the Indian Department of Defence. Space offers, with a combination of radar, radar detection and monitoring of the Automatic Identification System (AIS), strong tools against illegitimate vessels, since they fill in the open-ocean gap, capturing signals that base ships already emit but, more important, extending the surveillance to smaller ships.

Governments in Europe are becoming more aware of this potential, as migrant issues become more pressing. The next generation of Copernicus Sentinel satellites for the European Union will carry AIS terminals.

Up to now, Canada retrieves AIS data and sells them to government customers.

SSTL has recently signed with the UK Space Agency for an advanced AIS receiver carried by a VESTA nanosat precursor of a constellation. France has deployed a maritime surveillance system over the Caribbean area called Trimaran, which buys its AIS data from Canada and its radar data from various providers.Trimaran enables maritime zone commanders to access a portal for surveillance services using optical and radar imaging and AIS data to enhance the effectiveness of their national maritime missions. France has the second largest economic exclusion zone in the world behind the United States. No such system exists on the Mediterranean where it would be useful. Italy, which obtains radar data from Cosmo Skymed, is thinking about some development. A joint India-France venture, which could use an extension of Trimaran and space hardware from both countries, could pave the way for the establishment of an international system.

Small satellites

Small satellites are now understood to complement the operational capabilities of larger space systems byproviding real-time coverage and support. As an example, Cartosat-2 (700 kg) and Cartosat-2A form the backbone of high-resolution imaging for the Indian armed forces, but they have a revisit time of four days. The RISAT 1 and 2 provide a complementary all-weather, day-and-night capability, and SKYSAT-2 (125 kg) quick response on target monitoring.

Small satellites started in India with the academic ANUSAT more than a decade ago. However, the expansion of this technology and its accessibility to a large number of customers lack a programmatic approach. ISRO launched in 2008 the 100-kg Indian Mini Satellite (IMS): the IMS has led to only one replication with Youth Satellite.

Everywhere, military applications of nano/micro satellite platforms are now expanding including technical demonstration, responsive remote sensing AIS, ELINT, and telecommunications. In India, the Integrated Space Cell of the Ministry of Defence has identified such needs in its roadmap. However, both military and civilian lack a sustained plan concerning small satellites. In contrast, CNES has developed the Myriade platform, successfully used in 16 missions including the military Essaim program for ELINT. Further, in 2015, an agreement was signed between the American company Oneweb and Airbus DS, creating the 50-50 joint venture OneWeb Satellite in order to conceive and fabricate for 2018 the 900 satellites of a constellation dedicated to the diffusion of high bit rate Internet communications. The first ten spacecrafts will be developed in Toulouse and the others in Florida. The company will also produce satellites, platforms or any equipment commercialised by Airbus DS for any customers. Such a scheme could be applied between Indian and French industries or agencies.

There is a need in India for a dedicated effort on small spacecrafts with proper timescale, financing and goals, which could contain a large co-operative branch with France. Already, in March 2016, Thales Alenia Space and Airbus DS have jointly presented to the Indian Ministry of Defence an offer for the joint development of a constellation of reconnaissance and intelligence satellites (SAR radar imagery, ELINT, SIGINT) with technology transfer from France to India via indigenous companies.

A new vision: the taming of the Crowd

Today the landscape of technology in the world is dominated by the creativity of Silicon Valley enterprises whose main trades are communication, networking and advertisement. Their enormous investments and their innovative management techniques have given birth to what is called *NewSpace*, characterised by a collection of private initiatives in propulsion, space systems and missions. Non-state players have emerged and will emerge from nowhere, accelerating the proliferation of space technologies across borders. A major question is the ability of established space powers, agencies and industry to embrace and absorb NewSpace. They will have to accept the diversification of activities and consider fundamental changes: the newcomers do things differently with short schedules, lean manufacturing and horizontal management, and they succeed.

In the Internet exist many networks of hyperactive young enthusiasts of technology and space, known as hackers, makers, members of fab labs which complement and feed the start-ups of NewSpace. Miniaturisation and the possibility to accomplish big missions, even planetary, with nanosats and 3 D technology (additive mechanical fabrication) fit very well with the ambitions of many makers and hackers. The success of San Francisco's Planet Labs in orbiting many cubesats is an encouragement for the Crowd (or the private sector).

India is today the third partner of the global ecosystem of start-ups with 42,000 of them in 2015. Most of them exist only on paper, struggling for financial support from benefactors such as Tata, Mohandas Pai, and Rajan Anandan. Their birth and growth are helped by accelerators and incubators like the Global Superangels Forum (GSF).

India has already supported several NewSpace firms, such as Planet Lab, Terra Bella (previously Sky Box Imaging), and Spire, by orbiting their satellites. Fifteen international organisations have also helped several small business initiatives. CNES has created for this purpose a *nanosat club* regrouping several university groups.

At the Toulouse Space Show on 28 June 2016, CNES signed an agreement with the Bangalore-based firm, AxiomsResearch Labs, in order to contribute to the *Team Indus* mission, a private initiative that is set to land a module and a rover on the Moon in 2017, competing for the Google Lunar X Prize. CNES will supply a latest generation CMOS microcamera developed by the French firm 3D Plus. This partnership plays into CNES's strategy of developing closer ties with the new generations of players from the NewSpace sphere in which India is a prime mover.

CNES studies the concrete steps to create a virtual *Space Federation*, which would use the Net to organise real projects with the participation of groups scattered all over the world at various levels of involvement. Some kind of directorate, basically controlled by space agencies, would circulate proposals of space programmes issued from the Crowd: organise filtering and assessment of ideas, choose some of them and assemble partners into a project structure. This structure would connect knowledgeable specialists from agencies, universities, research groups and industry with the interested clubs, fablabs or equivalents for concrete realisation. Crowdfunding would be used for some part of the financing. The participative Federation would rest on autonomy, diversity, horizontality and open source. It would replace Brownian chaos by order, that is, on one side enlist enthusiasm and competence and, on the other, impose the doctrine of quality and risk management which has made the success of space. The participation of the agencies implied on projects would guarantee the technical soundnessof the products and provide access to orbit, usually as piggybacks.

As an example, constellations could be launched by various contributors, each of them following its own rules and schedules inside a wide scheme fixed by a directorate. What about making the *Moon Robotic Village* a product of the Crowd?

ISRO could be a main partner in this CNES initiative, which is in line with major trends: miniaturisation of hardware, extension of networks towards total global connection, advent of a world culture based on numerical (digital) technology—all tendencies very much present on the Indian scene. A joint Indian-French federation would trigger a global motion towards its incorporation of the Crowd into the future space missions of the 21th century.

Conclusion

There is no doubt that international cooperation is difficult. To move beyond ministerial declarations of intent there must exist not only a deep conviction shared by the top echelons of an agency supposed to engage in a cooperation programme, but also a permanent structure containing some committees and staff, devoted to make things happen. All these ingredients have been wanting in the course of Indian-French cooperation in space, kept at a relatively low level by lack of motivation and general sluggishness. CNES in 1970 was unable to convince its authorities to accept the Indira Gandhi proposal of a joint satellite education programme. ISRO, even after the free ride offered for Apple, disregarded its links with its French teachers in propulsion technology for the launch of Insat 1-A, B and D, to come back in 1988 to the faultless performer Ariane for its communication satellites. Negotiation for Megha-Tropiques drained for years and the project was saved in extremis by ISRO Chairman.

India has greatly benefited from its cooperation with France. Today India needs again to find a solid partner: if its space programme is currently gathering momentum with a roadmap ahead comprising 71 satellites to be built by 2021, and a target to increase the launch frequency to 12-18 annually during this period, the closed structure of ISRO has deprived its private industry of the maturity achieved by its American and European peers. India has been unable to make its space community to go global, and especially its industry. Its programmatic objectives will be met with great difficulties without an opening towards the world, and this paper suggests that this revolution would be helped by international cooperation, for instance with France, provided that it is built with efficient tools.

First, an overall Program Committee, as in the Soviet-French space cooperation, should be set up and activated, with a yearly meeting of the whole community concerned. Industry should be represented and heard. The committee would be animated by the heads of ISRO and CNES, and would be helped by *ad hoc* sub-committees, one for each of the main disciplines entering in the cooperation (Climatology, Planetary, Defence, and others). Experience has shown that such a structure can be kept light. Modern technology enables committees to meet in visio-conferences; but what is needed is will and commitment.

Such an organisation remains distant at the moment: the committee on planetary exploration created by the heads of government in January 2016 has yet to meet as of September 2016, but meanwhile, ISRO has proceeded with the preparation of its next mission to Mars MOM-2 and issued a call for proposals without informing CNES. During this period, fruitless meetings have been held on Venus missions, and only industry has shown interest in a follow-on to Altika.

A second tool would be the participation of ISRO in the 'Federation of the Crowd' that CNES is considering to create. In this area, everything has to be invented, and it is expected that a large part of the innovation will surge in a bottom-up manner. Here is an example: Narayan Prasad and colleagues have proposed to start, fund and run a space specialised Business Incubation Centre (BIC) involving ISRO, startups, governmental departments, industry and venture capital firms in a public-private mode. The idea follows ESA's BIC program which has created more than 50 viable firms. Aspace-BIC would build on ISRO's success to create markets and to render easier access to global activities. Such a BIC (and others) seem an obvious partner for the Federation and a joint India-France BIC would become a main enabler of change by cooperation.

Below is a summary of the domains where CNES-ISRO cooperative space projects could be implemented:

- Climatology, oceanography and meteorology: good bases already exist in this area but they should be upgraded into a structured programme replacing the collection of successive unrelated items that it has been. A programme committee should be appointed with scientists from both nations involved in order to define a long-term vision based on joint research projects, joint scientific teams, and joint missions. The concerned community should be comforted by symposia, student exchanges (both pre- and post-doctorate) and a complementary research programme on Big Data management. One of the objectives of the cooperation may be to set up an international network of carbon use monitoring.
- Joint missions to telluric planets. Complementary roles are here offered with CNES providing instruments or equipment to ISRO missions. Clearly, a long road has to be travelled before anything concrete is decided in this matter, though a joint Venus Balloon programme is not farfetched.
- Security. This is a domain where nothing has yet been done, even

if links exist in the Defence industry of the two countries. A potential is latent here and is awaiting an initiative. The two nations could work together towards the establishment of a space surveillance of the high seas, which is of great necessity for both.

Would there be a possibility for restarting cooperation in the domain of propulsion? Europe has a priority, the development of Ariane-6 for the maintenance of the Ariane family at the top of the world's commercial launcher fleet. This leaves no place for any other venture up to 2020. But the post-Ariane-6 time period has to be explored. What about an airplane for space access? India and France aircraft industries are already cooperating on large programmes.

Meanwhile the voice of the Crowd may be heard as it did in the US, creating Space X, Orbital, and others. There is a need for cheap launchers adapted to small spacecraft. Let the Crowd speak. Is there hope on the possibility for an India-France space team to exert an influence on mankind's space activities in this century, including Moon occupancy, Mars colonisation, interstellar missions? One of the reasons for ISRO's success (in the words of ISRO Chairman K. Radhakrishnan), is that it has given national priority over everything else. This legitimate position will not change, as the 'Make in India' doctrine is implemented. The above mentioned suggestions have been made considering the dominating trends. Compared to these immense ventures they are modest, but the international community will be fortunate enough even if a few of them ever materialise.

Acknowledgments

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17

India-US: New Dynamism in Old Partnership

Victoria Samson

India and the United States have over 50 years of experience in cooperating on space efforts, going as far back as when India launched a US-built sounding rocket from a launch site in southern India in 1963. This relationship has been beneficial, both in terms of enhancing scientific and technical achievements and also in bolstering the relationship between the two democracies. The cooperative efforts have largely focused on civil space projects, however, so there is room for increasing the cross-cutting alliances between the two countries by expanding joint efforts to include those that affect security and stability. Furthermore, the two countries can work together in multilateral fora to encourage the development of norms of responsible behaviour that will help make the space environment stable and predictable. To allow for cooperation on security space issues, issues that could potentially warp the US-India relationship must be dealt with, like using Indian launchers to put US satellites in orbit. While these are complicated issues, they are not impossible to work through, given sufficient leadership and support from both sides.

Much of the cooperation between India and the United States in space has been, reasonably so, via the two countries' respective space agencies: India's Indian Space Research Organisation (ISRO) and the United States' National Aeronautics and Space Administration (NASA). The first meeting of the US-India Civil Space Joint Working Group was held in June 2005, allowing for discussions that would identify future possibilities for collaboration and sharing information about what each side is currently focusing on. India's Chandrayaan-1, launched in 2008, carried (among other objects) scientific instruments built by NASA; this mission helped detect water on the Moon. In September 2014, India and the United States had spacecraft arrive in Mars orbit within two days of each other, leading to the creation of the Mars Working Group. Most recently, the two countries created a Heliophysics Working Group in order to consolidate efforts researching the Sun. Also being worked on is a Memorandum of Understanding to allow for sharing Earth observation data. Work continues on the NASA-ISRO SAR Mission (NISAR), a joint effort intended to build a satellite that will be able to observe Earth day and night through cloud cover in order to get a comprehensive mapping picture of land surface changes, including their causes and consequences; it is intended to be launched by 2021.[1] A Memorandum of Understanding to allow for sharing Earth observation data was signed in July 2016 between ISRO and the United States Geographical Survey (USGS) and formally approved by the Indian government; this will allow for the exchange of data from the United States' LANDSAT-8 satellite and India's RESOURCESAT-2 satellite.[2] There have also been some rumblings about India participating in the International Space Station, and, given that both the United States and the European Space Agency have agreed to extend their funding of it through 2024, there might be some openings for new contributors to it. (Although that will be right around the time the Chinese space station will be coming on-orbit, so it will be interesting to see how the two space stations interact and reach out to external participants.)

The two countries have also been looking to enhance their relationship when it comes to defense issues. A joint statement released in June 2016 noted that "the U.S.-India defense relationship can be an anchor of stability, and given the increasingly strengthened cooperation in defense, the United States hereby recognizes India as a Major Defense Partner."[3] This announcement also acknowledged that India and the United States had "reached an understanding under which India would receive license-free access to a wide range of dual-use technologies in conjunction with steps that India has committed to take to advance its export control objectives."[4] But even this statement kept the space cooperation to the civil side, identifying "earth observation, Mars exploration, space education and manned space flight"[5] as areas for future cooperative efforts.

One new area for cooperation in space is satellite navigation. The United States has the Global Positioning System (GPS), which has been hugely important in expanding the use of space assets for benefits here on Earth. India has developed its own regional satellite navigation system which could be used together with the US' GPS system (and other satellite navigation systems, like Russia's GLONASS, Europe's Galileo, and even China's Beidou) to expand the satellite navigation network so that positioning data can become even more accurate. India's system, Navigation with an Indian Constellations (NavIC, formerly known as Indian Regional Navigation Satellite System or IRNSS), intends to use the seven satellites which have all been launched to create highly accurate positioning data over the Indian subcontinent; as of September 2016, the system has not been declared operational yet.[6] When it is, it intends to offer two types of service: a less accurate one for civilian users, and a more accurate one for the military. NavIC receivers are supposed to be able to receive data from the GPS and GLONASS networks as well. It would be interesting if GPS users would be able to access NavIC data when in its coverage area; of course, it does raise the question about compatibility and interoperability, particularly when it comes to transmissions. Cooperation would be difficult if one system accidentally broadcasts too near the other, creating large amounts of background noise and thus interfering with users' ability to access the data. This requires getting out ahead of the issue and working out agreements now, before it becomes an issue. India has also been working on its GPS Aided Geo-Augmented Navigation (GAGAN) system, which is intended to help aircraft with improved navigation over the Indian subcontinent and surrounding areas by using satellites to augment data from GPS satellites and increase the accuracy of the aircraft's positioning data.

Another area where the United States is actively looking for international partners is in sharing weather data. In August 2016, the US Air Force sent its long-term weather satellite data strategy to Congress, where it had a strong focus on using international partners in order to fill gaps.[7] One such partner specifically mentioned was India, with the idea that data could be taken from Indian satellites Insat and Oceansat. Winston Beauchamp, deputy undersecretary of the Air Force for space, commented that this would be a good option for cooperation, as "We have a very robust capability internationally and weather data is one of the less sensitive missions when it comes to sharing."[8]

Both countries have strong incentives to want to improve domain awareness, so it should be a likely candidate for efforts to cooperate in space. The first is space situational awareness (SSA). The US-India Joint Statement of September 2014 highlighted SSA (and collision avoidance in outer space) as an issue of potential interest. Frank Rose, Assistant Secretary, Bureau of Arms Control, Verification and Compliance at the US State Department, told a conference in New Delhi in January 2015 that "As we deepen our strategic relationship, we share an interest in addressing the emerging security challenges of the 21st century. Ensuring the long-term sustainability and security of the outer space environment is one of those challenges, and one that the United States and India are uniquely situated to address together."[9] He went on to highlight SSA sharing as one of several "areas of concrete collaboration."[10] The United States has signed SSA sharing agreements with 11 countries which are intended to expedite sharing data about objects on orbit in order to reduce the chances of catastrophic collisions on orbit; the most recent agreement was signed with the United Arab Emirates in April 2016. India has not signed an agreement with the United States yet on this issue, but its owner-operator data could prove highly useful in increasing the reliability and accuracy of the US space objects catalogue, which in turn could help protect Indian assets on orbit.

Another area that could be ripe for cooperation is using space for maritime domain awareness (MDA). Cooperating on MDA in general has long been part of US policy: National Security Presidential Directive (NSPD)-41/Homeland Security Presidential Directive (HSPD)-13, released in December 2004, calls for "Enhancing international relationships and promoting the integration of U.S. allies and international and private sector partners into an improved global maritime security framework to advance common security interests in the Maritime Domain."[11]Indian Minister of Defense Manohar Parikkar and US Secretary of Defense Ashton Carter released a statement in April 2016 that discussed, among other things, "new opportunities to deepen cooperation in maritime security and Maritime Domain Awareness."[12]Space for MDA is a natural outgrowth of this mission, particularly given the explosion in number of Earth observation satellites in recent years. With long shorelines necessitating aggressive vigilance and space assets in place to provide information about possible threats to those shorelines and/or national assets in the maritime domain, space-based MDA should be of interest to both India and the United States. The first bilateral Maritime Security Dialogue was held in New Delhi in May 2016, but it did not include a space element to its MDA issues, instead choosing to focus primarily on challenges affecting the stability of the Asia-Pacific maritime domain. Perhaps future iterations of this dialogue can include a space track.

Cooperation in space does not have to limit itself to strictly bilateral discussions. Multilateral fora are possible venues for the United States and India to work together on space issues, particularly on solidifying agreement on norms of responsible space behaviour. The most prominent venue for this is the United Nations' Committee on the Peaceful Uses of Outer Space (COPUOS). It meets three times a year in Vienna, Austria, to discuss technical, legal, and general issues affecting the peaceful use of space. VK Dadhwal, formerly of ISRO and currently director of the Indian Institute of Space Science and Technology, started his two-year tour as the chair of the COPUOS' Scientific and Technical Subcommittee in February 2016.[13] In addition, COPUOS has had a working group dedicated to creating voluntary guidelines for the long-term sustainability of outer space since 2010. India nominated members to the four expert groups that were charged with discussing and writing these guidelines.

India was in attendance at the June 2016 plenary of COPUOS and gave: a general statement on ASTROSAT, India's space-based astronomical observatory; a statement on the report of the 53rd session of the STSC; a statement (about the NavIC satellite navigation system) under the space and sustainable development agenda item; a statement under the agenda item of spin-off benefits of space technology; a statement under the agenda item of space and water; a statement under the agenda item of space and climate change; and a statement under the agenda item use of space technology in the United Nations system.[14] However, India did not give a statement about the long-term sustainability guidelines, which is a missed opportunity to demonstrate that these guidelines created in a multilateral forum dedicated to the peaceful use of space were fully supported by the government of India. This is particularly important, given that India is a leader amongst developing countries and there are some concerns about whether the guidelines will help or hurt them. There were a dozen guidelines that were approved at the plenary session of COPUOS in June 2016; more are still under discussion and will be brought to the STSC in February 2017.[15] Perhaps there, under the leadership of an Indian chair, India will use the opportunity to demonstrate its support of the long-term sustainability guidelines.

In looking for places where the two countries can cooperate on space issues, it is important to also be aware of issue areas that could delay or even prevent this from happening. One such topic is the use of Indian launch vehicles for launching US commercial satellites, specifically using India's Polar Satellite Launch Vehicle (PSLV) for launching American smallsats. India made news in June 2016 when it used its PSLV to launch 20 satellites at the same time in the same orbit; these satellites came from five countries, and 13 of the satellites were American.[16] With that launch, the PSLV had put 113 satellites in orbit since its first launch in 1993, over half of which (74) belonged to other countries.[17] This was the second time the PSLV had launched commercial US satellites; the first was in September 2015, when the PSLV launched four satellites from Spire Global.[18] U.S.-based PlanetIQ has a launch booked with the PSLV program later in 2016.[19] What then is the problem? With the nascent commercial smallsat Earth Observation market continually expanding, one would think that having access to a relatively cheap ($33 million/launch) launch vehicle that can place smaller satellites at their selected orbit at will, instead of having to wait to be a secondary payload for a larger satellite that may end up having its launch repeatedly delayed, would be good for US industry.[20]

It is – but that is only part of the story. To clarify: it is great for US smallsats; but for companies working on developing US small launch vehicles, the concern is that they will not be able to compete with India's PSLV and thus they will lose out on market shares and even fail to develop as a successful and autonomous industry themselves.

This problem goes back over a decade when India and the United States came to an agreement in 2006 about the wording of the Technical Safeguards Agreement (TSA), which was signed in 2009.[21] This TSA was intended to cover launches of US government- or academia-owned satellites, or foreign satellites with US components, and would allow for monitoring of the technology to ensure it was not illegally proliferated. (It was not until June 2016 that India joined the Missile Technology Control Regime and signed onto the Hague Code of Conduct (HCOC) against Ballistic Missile Proliferation.[22]) At the same time were negotiations on the Commercial Space Launch Agreement (CSLA), which was supposed to cover Indian launch vehicles putting US commercial satellites on-orbit, as well as the Next Steps in Strategic Partnership (NSSP), which ended up in the historic 2005 nuclear deal between India and the United States.[23] There were concerns by Indian representatives during negotiations over the NSSP that satellite launches would be introduced into the discussions by their US counterparts, which Indian negotiators worried would extend the discussions out even longer. Complicating matters further was that CSLAs the United States had signed with other countries did not include satellite services; according to S. Jaishankar, then of India's Ministry of External Affairs, "As a market economy, India is entitled to an unencumbered CSLA with the US."[24]

This dispute continues today. Despite official US policy preventing US commercial satellites from being launched via the PSLV, several companies have gotten waivers in order to do so. In January 2016, the US Federal Aviation Administration (FAA)'s Commercial Space Transportation Advisory Committee (COMSTAC) argued that "many dedicated small satellite launch vehicles are currently being developed with private investment. Most of these new launch vehicles are scheduled to be operational in 2016 and 2017."[25] It went on to assert, "India's state-owned and controlled launch providers to compete with U.S. companies runs counter to many national policies and undermines the work that has been done by government and industry to ensure the health of the U.S. space launch industrial bases."[26] In a February 2016 decision, the FAA claimed that because the Indian government supports its launch industry so closely, Indian launch services could "distort the conditions of competition."[27] The U.S. Trade Representative is currently reviewing this PSLV ban in light of the FAA decision. Meanwhile, India announced in February 2016 that it had plans to privatise PSLV operations by 2020 with the hopes of also increasing its number of annual launches.[28] It is not clear what effect this planned privatisation would have on US policy in the interim.

While this is a significant challenge to work through, it does not mean that India-US cooperation in space is doomed to failure. There are many other ways in which the two countries can collaborate on space efforts and build on a relationship that has already been in existence for many decades. By expanding it to include efforts to shore up stability and security (both on orbit and using space for stability on Earth), India and the United States can expect to see the benefits from cooperation far outpace the costs of doing so. This in turn can work towards the long-term sustainable use of space, which will positively affect all space users globally.

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18

Evolution of India-Russia Partnership

Vladimir Korovkin

In 1984 if you met a teenager in a Russian city who was singing the Hindi song, *Goronki nakalonki, duniya haidiwalonki* – you were not necessarily encountering a linguistics genius. Rather, that teenager would be one of the millions of fans of the *Disco Dancer* Bollywood movie, the blockbuster of that year in the USSR. In April of the same year another phrase in Hindi made it to the big news in Moscow media: *"Saare jahan se achcha."* In these words the first Indian astronaut, Rakesh Sharma, replied to the question of then Prime Minister Indira Gandhi, who asked him how India looked like from outer space. On 2 April 1984, he became the 138th person to fly to space, making India the 14th nation in the world to have achieved such a feat. Interestingly, the country was also 14th to launch a national space satellite, in 1975. In both cases, it was the launcher rocket from the USSR that powered the mission.

At that time, over 30 years ago, space exploration was quite different from what it is today. Manned orbital flights had their heyday with record-breaking missions over hundreds of days (culminating in 1995 with 438 days spent by Valery Polyakov on board the Mir station). In 1986 the SPOT satellites set new standards in high-resolution imaging of the Earth's surface. This set a new trend for themore active participation of private corporations and academic institutions in the area of earth observation--. The communication satellites were becoming a global alternative to telephones, providing mobile services to maritime customers since the establishment of INMARSAT by the United Nations in 1979. The scientific exploration for Far Space was advancing, with Soviet and American stations frequenting Venus and Mars, and Voyagers already on their course to Jupiter and Saturn. Space was mostly a governmental matter, yet the club of space nations was becoming increasingly inclusive. Dozens of nations already had their first satellite launched mostly by the Soviet or American vehicles. The Soviet program *Interkosmos* put a total of 15 astronauts from 13 nations to the space orbit since 1978. The US followed the course in 1985, picking up the tempo, as the Space Shuttles allowed for a bigger crew on a shorter mission.

In the 1980s India was making quick strides to turning into a fully self-reliant space nation, putting the first satellite in orbit with its national launcher in 1980, starting to build the Asia's biggest domestic communications system INSAT in 1983, and launching the original design of augmented SLV in 1987. It was in those years that the country firmly demonstrated its resolve to be among the leaders in space exploration. The development of Russian space programmes, on the other hand, had quite more dramatic twists due to the political and economic turbulence of the early 1990s. Three spacefaring nations – Russia, Kazakhstan and Ukraine – emerged in the place of the USSR, with certain unavoidable setbacks in the goals and capabilities. Still Russia managed to hold a prime position among the space exploring nations, with one of the most universal launcher fleets, new launch sites and an effective pragmatic general strategy in space.

Today, some 30 years since the Rakesh Sharma flight, the world is on the verge of completely new space era. Private space is the growing phenomenon. The satellite DIY kits are available through Internet. Micro-, nano- and even pico- satellites will soon work in constellations of hundreds. Hi-resolution real-time imaging of most of the Earth's surface will be available for plenty of practical purposes. The private launches and private launch pads are already here. Space tourism will soon turn into a real industry. These developments may sometimes overshadow the "big space" in media headlines, yet the progress here never stopped. Lunar and Martian manned flights are plans, not dreams. Increasingly complex missions target distant planets like Jupiter and beyond, with the new focus on exploring their numerous moons. The number of space nations is constantly growing, at the same time the international cooperative projects become ever more ambitious in goals and multi-lateral in participants. Both Russia and India are on the frontlines of these processes, setting new strategic horizons, developing their space capabilities, and entering new partnerships.

Early history

The Russian-Indian cooperation in space started at the early stages of the development of India's space project. Though the first rocket launched from Indian territory on 21 November 1963 was designed by NASA (Nike Apache),[1] the Soviet Union soon joined the program of launches from TERLS (Thumba Equatorial Rocket Launching Station). The facility allowed to launch only relatively light suborbital rockets like the Soviet M-100. This was the most used sounding rocket model in the world, produced since 1957 until the 1990s with the astounding number of almost 6,500 total launches.[2] The rocket lifted the payload of 15 kg of meteorological equipment some 90 km above the surface, then the nosecone part was descending under a parachute for about 50 minutes collecting information and transmitting it to the ground station. Tracking by radar the trajectory of descend below the altitude of 50 km allowed to map the high-altitude winds. Thus the M-100 (and the other sounding rockets) were filling an important gap in meteorological observations going higher than aerostatic devices, but lower than orbital space satellites.

A Soviet stamp celebrating the space cooperation with India picturing the M-100 rocket

The length of history and the intensity of M-100 launches – which peaked at 484 a year in 1979 – permitted observing long-term climate trends like a steady drop in temperature of 0.3 to 1.0 deg C per year at an altitude of 80 km.The program of observations implied diversified geography which included a few pads on the territory of the USSR, launches from specially equipped scientific ships, and extensive international cooperation. France, Greece and later Japan were participating, yet it was India who became the leading foreign partner.

Since the first launch from Thumba in 1970, the total of almost one thousand followed – accounting for about 15 percent of all launches, by far the biggest number for a pad outside the Soviet Union (with a peak of 77 launches a year in 1980). In 1976 the M-100B variant of the rocket appeared which was calibrated for compatibility with Western equipment allowing for integration of observational data into international databases. Most of the launches of this model were performed from Thumba pad.[1]

The data collected through the TERLS launches of M-100 was an essential contribution to the major international effort in studies of monsoons, the MONEX (Monsoon Experiment), part of a larger GARP (Global Atmospheric Research Project) study.[2] Understanding of the processes that drive monsoons was and is of paramount importance to Indian agriculture and thus to overall economic and social development. MONEX was a breakthrough in getting this understanding. It resulted in important insights brought to light through an impressive mass of international publications and scientific conferences, with significant contribution from Soviet meteorologists.

Political context

Understanding the development of international, particularly Soviet-Indian space cooperation in 1970s and 1980s, requires reconstructing the political context of this period. The Cold War between the 'Western' bloc led by the US and the 'East' headed by the USSR was largely shaping events across the globe. The 1970s saw marked decrease in the level of hostility on both sides, the so called 'détente'. With the end of Vietnam War, and the signing of important international treaties including the Helsinki accord and SALT, there emerged a trace of cooperation between the USSR and the US. Its manifestation in space was the Apollo-Soyuz docking in 1975.

At the same time, there was an important crank in the socialist bloc with China-Soviet relations at their low. In 1969 there were border clashes that claimed lives on both sides. Though the border violence was not repeated, the two biggest socialist countries were in bitter controversy over a number of international issues, including the reign of the Khmer Rouge regime in Cambodia. The end of the decade was marked by Chinese invasion into Vietnam, a close ally of the USSR, in response to Vietnamese involvement in the overthrow of Pol Pot. Since mid-1970s the US made efforts to improve relations with China, and these moves were seen by the USSR as a source of strategic threat.

The global political situation was significantly disrupted by the Soviet intervention in Afghanistan in late 1979, which initially had a limited goal of stabilising the country against the dangerously growing sectarian split in the ruling Party. The move triggered a chain of reactions that brought in prolonged violence in the country itself, re-aligned politically the whole region, and ended the period of detente. In particular, Pakistan became the core source of support to anti-Soviet insurgents, the monarchies of the Gulf led by Saudi Arabia were heavily involved in funding of these operations and even the revolutionary Iran (which initially saw the USSR as the lesser of the evils compared to the US) threw in active assistance to *mujahidin.*

Against this background, India was seen by the USSR as the key strategic partner in the region. While in the 1950s the blossoming Sino-Soviet relations were, to the USSR leaders, overshadowing the role of India in the continent, by the end of the 1960s there was clear understanding in Moscow that partnership with Delhi is the key area of not just regional, but of global policy. India's leading role in the Non-Aligned movement was appreciated and supported. The economic policies of the Indira Gandhi government were also seen as increasingly socialist, which paved the way for the level of Soviet cooperation usually maintained only with the countries of the COMECON (Council for Mutual Economic Assistance). The USSR was firmly supporting India on the international issues with Pakistan and China, and in its internal policies as well. The tragic death of Indira Gandhi in 1984 was mourned deeply across the Soviet Union, and her funeral was broadcast on national TV, the only such case for a foreign leader at the time.

Soviet international space programmes

Since the first flight of Sputnik in November 1957, space development was recognised by the Soviet leadership as a matter of political influence, as much as a scientific and technological endeavour. The USSR was slower than its American or European competitors in development of commercial use of space in most of the areas, including telecommunications. The one important exception was TV broadcasting, where the Soviet Union was the first country to build the national television system based on satellites in the late 1960s. The Soviet Ekran satellite, launched in 1976, was the first in the world to allow the direct-to-home broadcast[3] (though it was actually working through public relay stations). Yet the country's core focus in space were high-profile endeavours, including prolonged manned flights onboard the orbital stations (Salyut, Almaz, Mir), and numerous automatic missions to the Moon, Venus and Mars. Rivalry with the US was part of the paradigm, as each of the nations was aiming to collect the most badges of being the "first to achieve" as they could.

Both the USSR and the US saw international cooperation in space as an important instrument of cementing the political alliances and projecting their 'soft power'. Starting from 1962, the US was commissioning its launch facilities to its allies to put their national satellites in orbit. In this way the UK and Canada became space nations in 1962, Italy in 1964, France in 1965, Australia in 1967 and West Germany in 1969. The US-based commercial international program Intelsat started in 1964 and a year later, *Early Bird,* the world's first commercial communications satellite was in operation. Though the launch was made by the American Thor rocket from an American pad, the satellite itself was classed as "international", the precedent in space exploration.

The Soviet response were the programs *Interkosmos*, inaugurated in 1970, and *Intersputnik*, a consortium of nine COMECON countries founded in Moscow in 1971 to develop satellite communications. Under Interkosmos, mostly Soviet satellites were launched, yet with international participation in design and ground reception. In 1973 Interkosmos-9 also called Copernicus-500, a joint production of the USSR and Poland went to orbit, however it was not officially recognised as Polish national satellite. Only in 1977 did the program result in the launch of a foreign device, the

French Signe 3. The last Interkosmos mission went to orbit in 1994, while Intersputnik managed to survive the political turbulence of the 1990s and expand the membership to 28 nations.[4]

At the same time, the USSR began to promote the idea of fully national satellites among its strategic political partners, offering support in design, production, launch and operations, including the ground facilities for reception of the information. India was the first country to participate in the program, with a successful launch in 1975 (followed by COMECON member, Czechoslovakia, three years later).

First Indian satellites

On 19 April 1975, India joined the club of satellite-owning nations. The first national satellite was named Aryabhata after the classic mathematician and astronomer of the 5th century AD. The project was initiated in 1972 by a contract between the Soviet Academy of Science and the Indian Space Research Organisation (ISRO). Under the contract Russia was to consult on the design and construction of the satellite, support essential systems, and perform the launch. Indian scientists and engineers were responsible for the production of the satellite. Most of the scientific equipment on board was of original Indian design and production. The deal was non-commercial, as both sides carried all the expenses of the fulfillment of their contractual obligations.

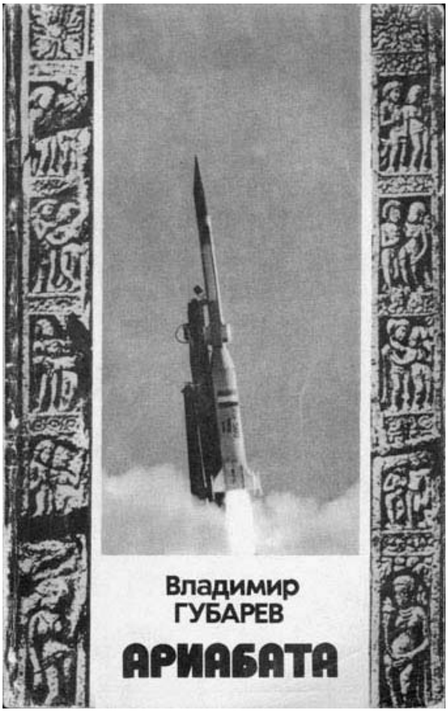
The project was kicked-off by a joint Soviet-Indian seminar in August 1972 in Ahmedabad which also set a broader set of goals for India's space program, including the resolution to develop a national launcher by the end of the decade. The scientific programme for the first satellite was somewhat limited with focus on registration of radiation flows in Earth ionosphere. Actually pioneering the original design and technology of the satellite was the key objective.

The satellite was non-hermetical, weighed 358 kg and had solar batteries capable of producing 46 Watt of electric power. The batteries were not stretched out like in many iconic satellite designs of that time, but were covering the whole surface of the device. For this reason its shape was not round, but rather a polyhedron with 26 edges. This gave Aryabhata series (two more satellites in the Soviet-Indian programme used essentially the same approach to the form) a unique look, pictured in many memorabilia items in both countries.

According to some sources the signal of the satellite was lost in five days, presumably due to a malfunction of power circuit.[5] The device stayed in orbit until 10 February 1992. It was a milestone for India's space programme, the live-test of many important technologies. They were further developed in the two Bhaskara satellites launched in 1979 and 1981. While looking similar to the pioneering device, the two "younger brothers" were radically different in their research goals and equipment. The focus of their mission was exploration of land resources, thus they were packed with imaging equipment: a two channel visible-range television camera with frame capture of underlying surface. The two missions were successful in achieving their goals. Yet Bhaskara II was the seventh, not the third Indian satellite. Three devices of Rohini series were launched in between 1979 and 1981 with the national carrier SLV-3 while one more was put in orbit in cooperation with France rather than the USSR.

For India, it was the dawn of the era of self-sufficiency in space exploration. At the same time, India was pursuing a pragmatic approach to the objectives of space program, always seeking to bring the immediate benefits to the country's economic and social challenges. The vision was famously worded byVikram Sarabhai as follows: "There are some who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the moon or the planets or manned space-flight. But we are convinced that if we are to play a meaningful role nationally, and in the community of nations, we must be second to none in the application of advanced technologies to the real problems of man and society."

To fulfill the mission India was to follow the best international benchmarks of commercial applications of satellite technologies, and the USSR was by the 1980s not the leader in this field. Consequently, the building of INSAT program and further developments in Indian satellite constellation were performed without direct Soviet contribution. Still, the experience gained during the Aryabhata-Bhaskara project was instrumental in the quick success of national space endeavour. And the heyday of Indo-Soviet space cooperation still lay ahead.



The cover of the book by prominent journalist Vladimir Gubarev dedicated to Aryabhata launch.[8]

Two Soviet stamps dedicated to space cooperation with India, featuring the drawings of the Aryabhata-series satellites (the specific version is not mentioned).

Space cooperation with India was seen as being of paramount importance to Soviet international image. In the 1976 series of stamps dedicated to space cooperation India, France and the US were each represented by a separate stamp, while other projects were grouped into the Interkosmos program.

Manned flight

The manned orbital flights were always at the core of the Soviet space programmes and in many aspects the capabilities of the USSR in this field were second to none in the world. By the 1980s the country had mastered the launch of crews of three astronauts to permanently operational orbital stations, which were built to support very lengthy stay in space. Importantly, the USSR never had a launch accident with a manned flight, and this safety record allowed the start of an ambitious program of bringing nationals of strategic allies to space. Thus in the mid-1970s it was decided to give new impetus to the Interkosmos programme with a series of joint missions of Soviet and foreign astronauts (or 'cosmonauts' in Russian). On 2 March 1978 Vladimir Remek from Czechoslovakia became the first non-Russian or non-American person in space. This was followed by nine missions with COMECON member nationals, from Poland to Cuba to Vietnam. Then, in 1982 a Frenchman, Jean-Loup Chretien became the first representative of a non-socialist country to board a Soviet launcher. The next flight of the programme was reserved for an Indian astronaut.[1]

In 1982 the programme to launch the first Indian cosmonaut was officially announced and over 240 pilots of the Indian Air Force applied for the unique opportunity to become part of the nation's history of space exploration. Two were selected, Rakesh Sharma and Ravish Malhotra, aged 33 and 39, respectively, and both having test pilot qualification. The training program implied two years of extensive technical learning and physical drills performed mostly on the premises of the Zvezdny Gorodok (Star Town) nearby Moscow, Russia. Accommodation to the unfamiliar climate and cuisine were part of the challenge (though the Soviet party reportedly made efforts to teach the cooks of the training center to make decent curry).

On 2 April 1984 Rakesh Sharma boarded the Soyuz T-11 rocket together with the Soviet mission commander, Yuri Malyshev and flight engineer, Gennady Strekalov. After the successful launch the ship docked the Salut 7 orbital station on April 3. Rakesh spent seven days, 21 hours and 40 minutes aboard the station, conducting scientific and technical studies, which included 43 experimental sessions with focus in the fields of bio-medicine and remote sensing.[2] The crew held a joint television news conference with officials in Moscow and Prime Minister Indira Gandhi. It was then that he quoted a poem by Iqbal, in reply to the Prime Minister's question. *Saare Jahan Se Achcha* – was his description of India when looked at from outer space. India became the 14th nation in the world to have its own astronaut.

Hardly anyone who was related to this landmark achievement would expect that it would not be followed by Soviet-Indian cooperative projects in space of comparable size. Actually, in 1988 and 1991, Indian imaging satellites were launched by Vostok rocket – the devices were too heavy to be carried by national launchers yet. However, India was becoming increasingly self-reliant in its satellite programme and quickly upgraded its launchers to perform effectively for the goals of building national communications and meteorological constellation. At the same time, the USSR ran into substantial economic difficulties which triggered a series of internal events that ultimately led to the dissolution of the country. A new space nation, the Russian Federation, largely inherited the space capabilities and competences of the Soviet Union.

Official badge dedicated to the flight of Rakesh Sharma.

The book on Rakesh Sharma flight ('USSR-India: The way to stars') was widely popular in the USSR.[3]

Indian-Russian space cooperation in 1990s- 2010s

Though Russia inherited most of the Soviet space industry, it had to follow a radically different approach to national and international space missions in 1990s. The deteriorating economy of the country demanded that high-profile projects were put aside and the new priorities were set by the opportunities to bring in commercial revenue. On the other hand, the end of the Cold War lifted many of the limitations on cooperation with the Western countries, resulting in a reshuffle of focus towards the joint programs with NASA or the European Space Agency. The Western counterparts were, in turn, curious to get a peek into the operation of the space industry, which was their major rival for decades. As was mentioned earlier, the last Interkosmos mission went to orbit in 1994, marking the end of a bright era of essentially non-commercial multilateral space endeavours. A year later the launch of an Indian satellite IRS-1C by a Russian Molniya rocket was performed (from Baikonur pad which is leased by Russia from Kazakhstan), the only cooperative launch by the two countries to date. By that time India has developed the PSLV (Polar Satellite Launch Vehicle) launcher capable of delivering the observation satellites to orbit, another major step in achieving self-sufficiency in space.

The remaining important gap in Indian national capabilities in satellites was the launch to geostationary orbits. For this purpose the French vehicles Ariane were used, launched from Kourou in French Guiana, a highly effective location due to its proximity to the equator. Though the Indian site of Shriharikota was almost as effective in terms of geography,[4] India lacked the powerful vehicles capable of putting enough of the payload on a geosynchronised orbit. The development of such vehicle was seen as a national priority. This implied obtaining a technology for cryogenic engines for the upper part of the rocket.

Russia was seen as a preferred partner in the project, as it had the technology, and was ready to license it and supply immediately a few assembled engines. The negotiations started in late 1980s, back in the Soviet era and in 1992, the contract was signed with Russia on supply of engines and technology for national production.[5] However, post-Cold War politics interfered. The US claimed that the technology transfer would be in violation of international ballistic non-proliferation agreements and could trigger the missile arms race with Pakistan. The claim was hardly substantiated, as cryogenic engines require a long period of pre-launch preparations (up to a month) and for this reason are ineffective for any military purpose. American companies were bidding for the contract and many observers regarded the US action as a move to clear the competitive scene. Still, the Russian diplomacy of the times lacked the skills of moderating this type of situation and was over-idealistic with regard to the new level of partnership with the US.

As a result, the new contract was negotiated in 1994 with no technology transfer yet a bigger lot of seven engines supplied ready-made from Russia. They were used in Indian GSLV Mk. I launcher. The first of the series was launched on 18 April 2001 (missing by just one day the 26th anniversary of Aryabhata going to orbit) and was a partial success, as the payload was delivered to the lower orbit than planned. ISRO declared the launch a success and claimed that the failure was with the satellite GSAT-1. Two fully successful missions followed in 2003 and 2004, delivering GSAT-2 and GSAT-3 (each with the weight of almost two tonnes) to designated orbits. Six of the seven engines supplied by Russia were used, and India successfully tested its own cryogenic technology in GSLV Mk. II launchers (in January 2014, the second attempt was made, after a failure in 2010).

In the beginning of 2000s the Russian economy began to grow quickly, due to successful internal restructuring and high international prices for export commodities like oil and metals. This allowed the country to re-approach its space exploration programmes, bringing some investment into the industry which was on the verge of survival for almost a decade. The new strategy in space was seeking to leverage the scientific and technological advances inherited from the USSR and combine them with a more pragmatic set of goals. Satellite navigation, telecommunications and surface observation were among the priorities. However, the manned orbital missions continued as part of international cooperative efforts within the project of International Space Station. More so, since the retirement of all Space Shuttles by the US in 2011, Russia became the only country capable of delivering crews to the Station and bringing them back to Earth.

India was not participating in the ISS perhaps with the view of developing an authentic manned mission. The country was seeking to cooperate with Russia on two other important projects. One was GLONASS, Russia's effort to build its own version of global positioning system, independent of GPS. The other one was India's second lunar mission, Chandrayaan-2. The cooperation agreements on the projects were signed in 2004 (with revision in 2007[6]) and 2007, respectively.

Under the GLONASS cooperation project, India was to launch several satellites by GSLV vehicles and to get preferential access to data. The Russian participation in Chandrayaan-2 was in providing the landing module based on the latest technologies developed for the Fobos-Grunt mission. Unfortunately, both projects did not come to life. Russia has launched all the GLONASS satellites with its own launchers from the Plesetsk pad. The reason for not cooperating with India as per agreement of 2004 was never announced. However, there was an agreement in 2011 to grant the Indian military a preferential access to positioning data.[7]

As for the Chandrayaan-2 mission, the Russian party did not provide the landing module in time, rescheduling the delivery first for 2013 and later for 2016. Some experts cited the failure of Fobos-Grunt mission in 2011 to be part of the reason,[8] though the mission failed due to an unsuccessful launch and never managed to test the landing device. ISRO announced in 2015 that it will develop the whole set of equipment for the mission on its own, with rescheduling of launch to 2018.

Thus the space cooperation between the two countries for the past 20 years has been a mere shadow of their joint projects in the 1970s and 1980s.[9] In fact, the countries even began to compete in the international space market as India included commercial payloads on board its launcher vehicles since 2000. Still, the development of global space market now brings a completely new class of opportunities for the joint projects of the two countries.

New era in space

In the heyday of cooperation in space between India and Russia/USSR, the space exploration was almost exclusively the domain of governments. Though some commercial consortia were owning satellites as early as in the mid-1960s and some fully private satellites appeared in the 1980s (even the Wal-Mart chain of stores in the US used to own one for the sake of coordinating IT between its numerous locations), the cost of the endeavour was high and there were numerous restrictions imposed by governments which strictly controlled the launch facilities.

The situation started to change in the 1990s with some launch pads going first semi-private (like the Sea Launch project owned until recently by a consortium of Boeing and Russian and Ukrainian state-owned companies) and then eventually, fully private: Mojave (US, 2004), MARS (US, 2004), Corn Ranch (US, 2006) and Spaceport America (US, construction started in 2006). A growing number of private companies like Virgin or Space X are now developing the launchers of various classes and for various purposes.

Some of the private projects focus on the idea of space tourism. Only sub-orbital flights ("space jumps") are capable of becoming a relatively mass attraction, as going to orbit implies acceleration that require special physical training of about two years. Such flights will require special types of launchers which will combine absolute safety with a certain level of comfort. Definitely in the near future the idea of just being in outer space will be motivating enough in itself. Yet with further development, the international community can expect the emergence of "space tourism professionals" who would seek to diversify the experience by being launched from various geographies or times of the year. Some enthusiasts of private space have begun to dream of manned flights to the Moon or even Mars, yet these ideas still sound more like science fiction. There is an area though which is already booming all across the globe—the small private satellites.

The so-called small satellites – ranging from mini (less than 500 kg in mass), micro (less than 100 kg), nano (less than 10 kg), to pico and even femto (less than 1 kg and 0.1 kg, respectively) - are believed to be growing exponentially in numbers put to orbit in the coming years. The advances in photo equipment, data storage and data transmission technologies allow the satellites of these sizes to be effectively used for a number of tasks on Low Earth Orbits, first of all – surface observation, for commercial or academic purposes. The advancement of CubeSat format empowers a broad number of private actors to build and operate their own satellite. The experts expect hundreds of launches of small satellites in the coming years (up to 500 by 2020)[10] with market size exceeding USD 7 billion a year.

The effective operations of small satellites require re-shuffle of the existing procedures and approaches in launches and ground infrastructure. The very nature of the devices calls for high cost effectiveness in delivery to orbit and in sessions of data exchanges with the ground. The total cost of ownership of a small satellite should fall in the range of tens of thousands or even thousands of dollars – lower by two to three orders than most of the present-day cases. This needs new launch techniques with clusters of dozens of devices on board one vehicle. A global network of ground reception stations and marketplaces for data exchanges should emerge, leading ultimately to real-time coverage of most of the Earth's surface.

The expansion of the space market through private satellites and space tourism creates completely new opportunities for established players with strong technology like Russia and India. While the 'traditional' segment of heavy launches was growing rather slowly, at four-five percent a year,[11] the new commercial segments of small satellites are expected to demonstrate double-digit growth till 2020 and beyond. Both India and Russia are advancing in the private space market. ISRO has formed a commercial subsidiary called Antrix Corporation in 1992, it had a successful launch of a cluster of five mini-satellites in 2014.[12] Russia, for its part, used effectively converted ICBMs for this type of launches.[13] Russia also has private ground network for signal reception operated by the Scanex company.[14] India and Russia have naturally complementing geographies, commanding low and high latitudes, respectively. This gives an opportunity to create a comprehensive offer on the space market which would include both launch and operations services.

Deeper space scientific exploration remains a promising area, despite the unsuccessful experience with Chandrayaan-2. Russia and India can complement each other in designing and fulfilling joint missions to the Moon, to Mars and beyond. Multi-lateral settings are also an interesting option for this type of projects which require significant funding and take a long time to implement. Russia's participation in the ExoMars endeavour can give an example of such approach.

The cooperation of Russia and India in space has a glorious history which spans almost half a century. The joint efforts of the two countries have not only advanced their national space capabilities but also contributed to the global pool of scientific and technological knowledge. The excellent level of political cooperation that was renewed during the Goa Summit in October 2016 opens the broad way to a still brighter joint future in space.

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Cooperating with Israel: Strategic Convergence

Deganit Paikowsky and Daniel Barok

The question of why countries cooperate with each other has varied answers. For the most part, cooperation between countries can be explained by a combination of reasons and motivations. Nations cooperate in technological projects like space programmes for several reasons, among them the desire and need to maximise benefits while minimising resource utilisation. Cooperation enables all the players to improve coordination, reinforce their relationships and increase their commitment to one other. Such commitments serve other goals as well, like national security and/or the economy. Technological cooperation often constitutes a tool used to build trust, thereby bridging differences and difficulties in other areas, and founding strong relationships between nations. In addition, international ooperation is meant to deal with problems and challenges shared by all the involved parties, principally regional or global problems that affect every nation, and which can only be solved through widespread cooperation. This chapter will address the potential motivations for cooperation between India and Israel in the field of space.

In 2017, Israel celebrates 69 years of independence, and India, 70. Two relatively young nations, whose peoples have ancient histories and cultures. During their years of independence, India and Israel experienced challenges that led each nation individually to recognise that they had accumulated a lot of knowledge and experience in a broad range of fields, and could contribute a great deal to each other. During the Cold

War, India was among the leaders of the non-aligned nations, and the relationship between the two nations developed quite slowly. Momentum only developed after the fall of the Soviet Union and the Communist bloc and in the 25 years since then, the relationship between the two countries has only strengthened. Cooperation between India and Israel expanded and deepened in a wide range of areas, and a tremendous potential exists for continued development and expansion of this cooperation.

India and Israel have both been involved in space for several decades. India's first independent launch took place in July 1980; Israel's, in 1988. Both of the launches, which brought India and Israel into the "space club", took place in the ecosystem of space activities during the Cold War. During that era, only the Great Powers proved their ability to independently develop satellites and launch them into space. Commercial space activities were almost non-existent, and the distribution of know-how and space technology was strictly limited and monitored. In this ecosystem, both India and Israel were very different in the 'look' of nations active in space. Israel was and is a small nation with few resources; India, although a large country, was also poor and was considered to be underdeveloped in many fields. Nonetheless, they both played in the field of the political and economic giants. Why did nations like India and Israel, each independently, choose to act in the field of space? The answer, in both cases, is that the decision to invest in a space programme was made precisely *because* of the special conditions in which each nation found itself, and not *despite* those conditions. Thus, to a great extent, it can be argued that the State of Israel chose to create a space programme because of the security challenges and strategic difficulties it faced in the region, especially in light of its small size. India, as the leader of the non-aligned nations, chose to invest in space because of demographic, economic, technological and scientific challenges, all deriving from its poverty and lack of development, due to its geographic size and the dimensions and distribution of its population.

For each one of them, developing space capabilities provided solutions and a bridge over disparities and problems that they had identified. In Israel, the challenge was primarily in security. The peace treaty that Israel signed with Egypt entailed Israel's relinquishing the Sinai Peninsula, which created a security challenge: how to monitor and enforce the peace treaty without violating Egypt's territorial sovereignty. The space programme, therefore, was created to help produce high-quality intelligence, so as to provide early-warning and deterrence capability, by expanding Israel's strategic depth. Thus, Israel's supremacy in know-how and technology reinforced its qualitative advantage in the region. India's space programme was meant to rapidly link distant areas and populations of the country, and improve the quality of life through know-how and technology, among other things. The point of departure for this chapter is that both countries, India and Israel, are active in space because of these challenges rather than despite the unique challenges that they face. This chapter argues that despite the many differences between the two nations, this shared circumstance is the theoretical foundation of the cooperation between them in the field of space.

For many years, in both India and Israel, development of the space programme focused on three principal pillars: Developing capabilities in Earth observation and remote-sensing; developing satellite communications; and developing launch capabilities that would support these platforms. The ambition of both countries was to achieve all of these goals by self-reliance, even if only partially. Leaders of both nations attributed utmost importance to the achievement of self-reliance because they viewed it as having strategic value in and of itselfto fulfill broad national needs.

In India, the primary incentive was developing the nation and improving the lives of its citizens. Therefore, the space programme focused on developing capabilities for civilian space applications although in recent years, its security activities in space have also grown and strengthened. Today, India's space programme serves its broad strategic interests, the goal of which is to situate India as a significant player in world politics. For this reason, India's space programme covers a range of ambitious civilian and scientific missions, including space exploration, as well as security missions.

In light of the mandate given to the Indian Space Research Organisation (ISRO) to significantly expand its space activities and their scope in the coming years, and the need to meet the schedules of not a few ambitious projects, India changed its policies. It went from developing independent capabilities to enabling the adoption of technologies and products that were developed abroad. This was primarily done to shorten the time needed to develop large systems and meet the required schedules.

For many years, the principal incentive for Israel to invest in space derived from national security considerations. Change occurred a number of years ago, and the decision was made to develop and expand the national involvement in space to the civilian field, and to reinforce the local space industry. One of the ways to do this was international cooperation.

The change in direction that each of the two nations experienced, provides a better basis for cooperation between them in the field of space. The relationship between them is likely to improve, to the benefit of both countries, due to the reasons that both nations have in common, as well as those that are unique to each.

Cooperation in Maintaining Space as a Secure and Sustainable Environment

In recent years, the number of nations that have satellites has steadily increased, as has the number of states around the world that rely on satellite services for civilian, commercial and military activities. The dependency of nations and of the global economy on satellite systems increases their vulnerability to accidental or deliberate harm. Therefore, a mutual goal exists amongst nations that utilise satellites (whether they have the ability to produce, launch and operate them, or if they depend on the services of other states). That mutual aim is to secure the safety and sustainability of these satellites in the space environment, for the benefit of all. In fact, this is a worldwide objective, and not merely that ofthe great powers. This challenge requires cooperation; a nation by itself, even one of the world's great powers, cannot deal with the substantive, technological and/or economic problems by itself. The concern is that, in the absence of appropriate solutions, the space environment will become unusable for everyone.

To this issue must be added the fact that some of the actions that can be taken to secure regular space activities—like monitoring and tracking the movement of objects through space in order to provide early-warnings of collisions, active debris removal, and others—can be used in a diametrically opposite way to what is intended, i.e., can cause damage to satellites. Thus, the principal problem that the international community has to address at this moment is to find ways to create confidence building measures and cooperate with one another.

Most of the treaties and conventions concerning space that are in effect today were drawn up during the Cold War, and some of them are no longer applicable to the incredible technological development that has taken place since then. These treaties certainly cannot keep pace with the increasing activities in space, whether private or governmental. For example, the UN Outer Space Treaty of 1967 stipulates that space will be used for peaceful purposes, but does not explicitly state that attacking or damaging satellites is prohibited. Space systems have tremendous value and significance for the continued normal and regular existence of the world's economy, but are also a means for many states to achieve political and military power. Thus, the discussion of what is allowed and prohibited in space has turned into a wrestling match between the Powers. The US, Russia, China and Europe agree that security operations in space are extremely important objectives, but disagree on the methods of achieving them. Each has different needs, ambitions and goals. At this stage, the suspicions of each player challenge the ability to solve the problem. The obstacles to cooperation are really the lack of trust between the participants, the need to coordinate amongst a very large group of nations, lack of transparency, and the absence of effective enforcement mechanisms. Many of the players are concerned that their freedom of action in spacewill be curtailed; that they will be unable to protect their properties in space from irresponsible players; and that their independence and identities will be lost under a global regime.

Both India and Israel perceive space as a strategic arena that has importance for the world's economy and security, but also as a strategically important one for their regions, South Asia and the Middle East, respectively. Therefore, each one attributes a great deal of importance to maintaining security and sustainability in the changing space environment. Given this and the fact that both India and Israel are considered responsible international actors in general, and in the field of space specifically, cooperation between them has a role in the global process, the aim of which is to build confidence building measures to earn trust. Such measures may be the establishment of norms for responsible operation in space, which would ensure that the space environment will be accessible and useable by everyone.

Cooperation in Scientific and Research Missions

World politics accepts that national space programmes are an indicator for a country's eminent strategic capabilities, and a way to project power without the need to resort to violence or aggression. As a result, many countries are active in space. In addition, the tremendous strides taken by private enterprises in space, particularly in launching of satellites into near orbits around Earth, enable many countries to become players and penetrate the field of space. This trend has eroded the prestige and exclusivity that had been enjoyed by nations that were active in space for many years. These traditional spacefaring nations act to differentiate themselves from the emerging spacefaring nations, as well as the private sector players. In light of the fact that the dream of space exploration and its value still holds sway and attracts a great deal of support, spacefaring nations turn their attention further away from Low Earth Orbits, into deeper space. The space agencies of the US, Russia, China, Japan, Europe and India have announced their intentions of reaching the Moon, Mars and even further into deeper space with both unmanned and human spaceflights. In recent years, the world has witnessed not a few such missions that have registered significant achievements. In this field, India achieved significant success when the spacecraft it launched toward Mars at the end of 2013 entered into orbit around the planet in September 2014. This impressive achievement proved that even with a modest budget, such an accomplishment can be attained. In December 2014, India chalked up another achievement, when it successfully launched an unmanned capsule and returned it to Earth, an important stage in its planned human space missions.

Israel, for its part, has had a successful space programme for many years, primarily based on the country's investments in defence. Israel's space programme is highly pragmatic, and does not seek to take an active and independent part in the scientific and technologic race to space. Nevertheless, in recent years, the Israel Space Agency began to implement new space programmes, which emphasise civilian activities. Their aims are to promote research and development in academic and industrial research institutions, nurture international cooperation, and inspire a new generation to see its future in science and technology. Cooperation with India in scientific or exploratory missions will enable India to lead projects of this type as a primary player; at the same time, Israel can take part in existing programmes utilising its complementary capabilities. Thus, cooperation between India and Israel in this field will fulfill the needs and ambitions of both nations, and show the world that even with modest budgets, objectives in space activities can be achieved.

The Whole is Greater than the Sum of its Parts: Cooperation to Lighten Economic Burden

In line with the argument made above, India's and Israel's ability to advance in the sustainable and competitive fields of space technology and space industry require State support. Such support is primarily required to promote research and development via national, multi-year programmes, due to the substantial financial resources required. Even large, wealthy countries prefer that their missions stay within the budgets allocated, and have reduced space budgets. International cooperation is a tool that lightens the economic burden for each participating nation, and they can each achieve more with less. India and Israel, separately, have worked and proven that impressive achievements are attainable even with modest budgets. Cooperation between them in the field of space will further reinforce this concept and enable each one of them to achieve the maximum possible with their investments and abilities, demonstrating that the whole is greater than the sum of its parts.

Government Activity in the NewSpace Ecosystem

In recent years, dramatic changes in space activities took place by countries throughout the world. These changes are manifest, among other ways, by the huge involvement of the private sector in space activities. These changes have been termed the "NewSpace". In this ecosystem, space is perceived not only as a strategic arena, but as a resource and business tool, to be used to create profit and foster economic development. Thus, new companies, as well as large, wealthy, venerable companies, are interested in operating in space and developing new space technologies and services based on these new technologies, at relatively low costs, so as to enable much greater access to space. Many of these are private, commercial initiatives. Nevertheless, the State has a significant role to play in promoting these initiatives, from supporting generic R&D, through establishing new infrastructure, to developing regulatory mechanisms that will promote and enable these activities.

India and Israel, two nations for which investment in science and technology for many years was key to development, advancement and national security, made sure to develop high-tech environments for the betterment of their societies and economies. They both should continue to be active in this sphere, advancing national activities in space, which will continue to serve as the technological and scientific engines for their countries. Each one has increasing interest in the services that are based on space systems. Thus, cooperation between them in these fields as well, is likely to enable each one of them to develop more rapidly in the new space ecosystem.

Cooperation Towards Security and Stability in India and Israel's Regions

In recent years, the strategic environment of both India and Israel has changed. Geo-political changes, the development of new technologies and with them new capabilities, accessibility of weapons of mass destruction to entities that had previously been denied them, all endanger regional and global stability. In addition, every arena is more exposed to the threat of terrorism in its many forms and manifestations. The need to defend its sovereignty and citizens, and maintain regional stability, creates overlapping interests and raises the importance of the relationship between the two nations, which are moderate and democratic entities in each region. Among other things, the relationship can be enhanced through coordinating on defence and strengthening the links between them. In this context, the field of space can assist in strengthening the national security of both India and Israel, by improving early-warning capabilities of both states, and monitoring existing and developing threats. Cooperation and coordination can serve as a force multiplier of each country, and in certain cases even serve as deterrents.

Recommendations

This chapter addresses the possible motivations for cooperation between India and Israel in the field of space. Strengthening the ties between the two nations in space endeavours requires deepening of each country's understanding and acquaintance of the other's needs, goals, aspirations and capabilities. Thus, as a first stage, the two countries can identify the important areas and subjects within the overall rubric of space, in which cooperation would be most effective and beneficial to both nations. As set forth in this chapter, a broad spectrum of possibilities exists. Included are scientific research in deeper space, scientific research about Earth and its environment, technological development, components, sub-systems and even joint space missions, development of civilian and security applications based on their space capabilities such as communications, navigation, meteorology, warnings and monitoring natural disasters, defence, long-distance medical services, and others.

Beyond these and other practical ideas, cooperation in the field of education is possible, starting with pre-school children and ranging through advanced academic degrees, including exchange programmes for students and academics. In light of the developing NewSpace economy, the possibility exists of creating joint business ventures and establishing a joint infrastructure in both countries. Alongside advancing economic, scientific and technological endeavours, it is important to coordinate activities in international forums and in the international organisations that have an impact on the space agenda, e.g., UN institutions. Perhaps deeper coordination in international forums should be examined concerning issues on which the two countries' interests are similar. Such coordinated positions and efforts would not only provide tangible benefits to both countries, but would contribute to the development of confidence building measures at the international level.

20

An Asian Space Partnership with Japan?

Kazuto Suzuki

For many years, there was a huge gap between the philosophy of space development between India and Japan. Under the direction of Dr. Vikram Sarabhai, Indian space programmes were conducted under the principle of "space activities for developing nation", focused on "the application of advanced technologies to the real problems of man and society". On the other hand, Japan, from the beginning of its space programme, pursued the strategy of "catching up" with advanced spacefaring nations. Although India and Japan began their space programmes at nearly the same time – the Indian National Committee for Space Research (INCOSPAR) was established in 1962 and the Indian Space Research Organisation (ISRO) in 1969, while the Institute of Space and Astronautical Science (ISAS) launched the first sounding rocket in 1960 and the National Space Development Agency (NASDA) was created in 1969 – the paths that India and Japan took were quite different. Japan, as a relatively small island country with densely populated cities, developed its social infrastructure even before the second World War (though they were severely damaged during the war), while India struggled to improve its social infrastructure for sub-continental scale for economic development. These geographical and historical differences provided different reasons for India and Japan to engage with space programmes. Also, during these periods, India took the strategy to develop its autonomous technical capability in the context of the Non-Aligned Movement, whereas Japan received technical support and assistance from its ally, the United States. While India struggled to develop its economic capabilities after its independence and conflicts with its neighbouring countries, Japan enjoyed relative peace and unprecedented economic growth. Such economic and political differences also created the unique contexts for both countries to develop their own space programmes.

Japanese space policy thinking

India and Japan have not crossed their paths for cooperation. For Japan, the major objective of its space programme was to develop cutting-edge technology regardless of its application to society. Initially, Japanese space development was led by developing telecommunications, broadcasting and meteorological satellites as well as launcher to deliver them to Earth orbit with technological assistance from the United States. However, the situation gradually changedas Japanese engineers began to question the seemingly permanent second-class status relative to US technology. Many in the Japanese industry believed that the country's technology has become mature enough, and most of them were frustrated by the low level of disclosure of technical information coming from the US companies. For the Japanese engineers, the next step for Japan's industrial objective was clearly to produce satellites and launchers with a 100-percent domestic technology.

It is interesting to note that the logical step for the Japanese industry and for NASDA was neither 'commercialisation' nor 'industrialisation (independent R&D from NASDA and pursue corporate strategy)' of space, but the improvement of domestic technology and technological autonomy. Even when Japanese technology became more mature, the industry still considered that space activities were only a 'jacket for entering a major industrialised countries' club'. It has never considered seriously taking risks of 'industrialisation' and 'commercialisation' of space, and instead continued space R&D for their sheer prestige.

Indeed, Japanese space policy achieved some of its objectives—pacifist policy, alliance with the US, and most importantly, 'catch-up' with technology—by the end of the 1980s. H-II launcher and ISS were the important cornerstones for the industry and NASDA, and representing that they had achieved the objective to "join the club". By the end of 1980s, many had started to consider Japan's next goals. People in NASDA and in the industry were not completely satisfied by the technological achievement. There were still a lot of technologies that they could learn from the US. Meanwhile, industry people began to consider the possible challenge of the commercialisation of space. Also, this was the time when Japanese economy was booming. There was a serious trade friction with the US and Japanese space industry considered that if automobile and semi-conductors were able to penetrate the American market, it would be possible in space too, since automobile and semi-conductors were also based on the technologies that came from the US.

By that time, the Japanese government has had to deal with the US pressure in two fronts. One was the direct intervention to the key products (automobile and super computers), and the other was the intervention in government's procurement procedures. The US government was not only claiming that Japanese were exporting too much, but they also accused the Japanese market to be very closed with US products not being able to penetrate because of what it called "non-transparent" business culture and public procurement procedures. In the end, Japan and the US made an agreement to open the public procurement procedure on application satellites. Obviously, this agreement was in favour of the US industry to penetrate Japanese market for application satellites. The consequence of the 1990 Accord made a significant change to the Japanese space policy. The decision to open up the procurement process for application satellite meant that NASDA would only be able to contract with Japanese industry for R&D satellite. However, the accord was welcomed by NASDA and industry because it would promote for more "technological autonomy". Because many Japanese satellite manufactures were electronic companies, they found the 1990 Accord acceptable, because it saved their business in super computers and semi-conductors. The priority for these companies was mostly on avoiding US retaliatory tariff for their products, and not on the application satellite procurement which mattered little for their business.

As a consequence of the 1990 Accord, the Japanese space community—namely, the government, STA, NASDA and industry—focused on the new projects which were more technologically-oriented. Industry, of course, aimed to get some contract for application satellite, but it was in vain if the American competitors were applying for the same programme. The industry did not challenge the government for such a decision, and they did not find a way to improve their competitiveness. Instead, they set their expectations too low and were satisfied to get contracts for numerous technology-oriented engineering satellites.

The way in which Japan pursued its space objective was quite different from India's policy norm. The application programmes, on which India has focused, were not the major concern for Japan. In fact, Japan was not allowed to invest public funding into application programmes. Thus, the cooperation with India was not on the radar screen for Japanese international strategy. The situation, however, is changing.

Changes in Japanese space policy

There are several major issues which have changed Japanese space policy after the end of the Cold War. First, the changes in the security environment have made it difficult for Japan to continue its pacifist policy. For Japan, the alliance with the US was the core of its pacifist principle for not possessing any offensive military forces. However, the threat of Communism has dramatically reduced by that time, and the reasons for stationing US troops in Japan also became ambiguous. Japan is expectedto contribute more for the actions of the United States concerning security matters. Furthermore, the imminent threat of North Korea became visible with the number of nuclear and missile tests that it had conducted. There was a strong demand to do something to prevent North Korea from launching missiles with nuclear warhead towards Japan and protect the homeland.

However, the development of the Missile Defence (MD) programme and the Cabinet decision in 2003 to take part in it raised another difficult question. On one hand, because of pacifism being deeply embedded in Japanese society, Japan should not be able to develop, launch and operate their own early warning or tracking satellites to gather crucial information about missile launch. This means that without its own early warning satellite, Japan is dependent for early warning data on the United States. Thus, many people in Liberal Democratic Party (LDP), particularly those who are interested in defence issues, strongly demanded to reconsider the "exclusively peaceful purpose" clause of the Diet resolution in 1969 which prevented Japan from owning, operating and using military purpose satellites.

This effort of LDP, together with its coalition partner, Komeito, and the opposition party, Democratic Party of Japan (DPJ), resulted in the establishment of the Basic Space Law in 2008. This changed the entire landscape of Japanese space policy. There are three major points of this law.

First, it changed the authority of space policymaking—from the Ministry of Education, Science and Technology (MEXT) to the Cabinet Office—to facilitate better coordination and lend heavier political weight to space policy. In order to do so, the law set up a new Minister for Space and Space Development Headquarters, equivalent with Ministerial Cabinet. This was designed to be a departure from the technology-oriented catch up strategy to more policy- and user-oriented strategy. It is also notable that the Ministry of Foreign Affairs created an office responsible for space diplomacy and the Ministry of Defensedesignated its staff at the Defense Policy Bureau for space affairs.

Second, the law changed the interpretation of the concept of "exclusively peaceful purpose". The Basic Law states that one of the objectives of Japanese space activities is "to promote the security of our homeland and international peace and security". During the Diet debate, it was strongly emphasised that this change of interpretation does not aim for aggressive use of space, i.e., enhancing Japanese military capability for invasion or using military forces to solve international disputes. Instead, this Basic Law confirms the principle of the Article 9 of the Constitution. The space assets will be used for crisis management and disaster monitoring in the Asian region or for peacekeeping missions in distant territories.

Third, the Basic Law underlined the importance of 'industrialisation' of the space industry. Since 1990 when the Accord with the United States for satellite procurement entered into force, the Japanese satellite industry lost its opportunity to improve international competitiveness through government programmes. A long history of concentrating on R&D and technological development had made Japanese industry entirely reliant on government R&D funding, which was decreasing due to the fiscal constraints. The Basic Law defines 'industrialisation' as strengthening industrial capability and autonomous business foundation from public budget. Given the emergence and growth of commercial ventures such as SpaceX, the Basic Law aims to strengthen the private sector's role in improving its competitiveness to meet the newchallenges in the commercial market. Following the establishment of the Basic Space Law, the government submitted two new bills to facilitate the entry of private entities into space activities.

Implications for India-Japan Cooperation

The change in space policy has increased the potential for cooperation between India and Japan. First, the shift of focus from R&D-oriented policy to strategic use of space has created a situation where the Japanese government would take international strategic issues into account. The emergence of China as a regional power implies the necessity for India and Japan to cooperate more in strategic domain. From Japanese perspective, the cooperation and quasi-alliance with India is extremely important for balancing the power of China which is pushing towards the East and South China Sea and expanding its sphere of influence towards Central and West Asian regions through its grand 'One Belt One Road' programme.

Second, the shift in the policy focus from R&D to industrialisation and security would bring Japanese space policy closer to the philosophy of India's own. In order to industrialise Japanese space activities, it is required to encourage the utilisation of space technology for various socio-economic purposes. If R&D satellite remains only as research and engineering test satellite, then it would be very difficult to turn the new technology into industrialised goods. Rather, it needs to be tested and utilised in orbit to make sure that these new technologies are reliable and affordable. For demonstrating the reliabilities of the new technologies, it has to be used by both public and private actors. The easier way is to be used by the public sector for socio-economic purposes. Therefore, since the establishment of the Basic Space Law, Japan has launched Quasi-Zenith Satellite Systems, Advanced Land Observation Satellites (ALOS), and has also increased the number of Information Gathering Satellites for intelligence purposes. Such encouragement of the utilisation of satellite technologies would open up new opportunities for India and Japan to cooperate on application programmes.

One of the possible areas for cooperation is disaster monitoring and management. There is a strong demand in Japan to improve disaster monitoring to prevent damages from typhoons and other natural hazards and information for disaster management as in the case of the Eastern Japan Great Earthquake in 2011. India has developed various capabilities for Earth observation for land use and cartography. These capabilities not only in hardware but also software of using satellite images for socio-economic purposes can be of great help for Japan to improve its own capabilities for disaster management. Moreover, Japan can provide sensors and other hardware that have been developed through various R&D satellite programmes, particularly for monitoring weather and humidity in the air. One of the big problems in India is the monitoring of water movement and aerosol for agriculture and environmental purposes. Japan has developed sensors to suit these cases.

Third, the shift inJapan's interpretation of the concept of "peaceful use of space" enables further cooperation between India and Japan to work closer on security issues. It is particularly important for Japan to cooperate with India for monitoring the Indian Ocean region. After all, 80 percent of Japanese energy supply comes from the Middle East, and most of the tankers sail through the Indian Ocean and South China Sea. These are areas where China is increasing its military presence through land reclamation and its 'String of Pearls' strategy. From Japanese perspective, the main concern for the safety of maritime issues in the Indian Ocean is absolutely crucial and it is evident that cooperation with India in this matter is extremely important. In doing so, space-based monitoring of sea lanesmay be the ideal way of strengthening cooperation which, in turn, would increase the capability for Maritime Domain Awareness (MDA).

Finally, the best chance for India and Japan to cooperate can be found in the area of science, particularly planetary sciences. Japan has a long history with planetary sciences and, recently, achieved success in Hayabusa, a sample return from an asteroid. However, Japan has also struggled to find a way to conduct research on other planets in the solar system. The devastating failure of Nozomi (Planet-B) for Mars exploration was a shock for Japanese scientists. On the other hand, India has emerged as a new force in planetary sciences. The success of Chandrayaan-1 and Mangalyaan for Moon and Mars exploration marked a historicsuccess in planetary sciences. Mangalyaan, in particular, marked the first Asian probe to fly in the Mars orbit and conduct scientific research on the Red planet. When Chandrayaan-1's mission to the Moon was launched, Japan's own Moon probe, Kaguya, was also conducting its research. It would have been a huge advantage if these two missions were designed to collaborate and complement each other. It would increase the scientific output for both sides for advancing research on the Moon. The mission that Mangalyaan conducts would be similar to what Nozomi would have done if it was in Mars orbit. There are a lot of similar scientific objectives that India and Japan can share. Cooperation in the planetary sciences would certainly prove fruitful if the two countries tightly coordinate their missions.

Conclusion

India and Japan began their space activities for different purposes and objectives. India aimed to develop its space capabilities for their socio-economic benefits, while Japan pursued its strategy to catch up with the advanced spacefaring nations. However, after the end of the Cold War and changing strategic circumstances, India and Japan began to share important strategic objectives in space. Changes in Japanese space policymaking through the Basic Space Law brought Japanese space policy thinking closer to that of India. India, which has achieved a certain level of civilian space capabilities, is moving on to more ambitious space programmes such as deep space exploration. In the new era of space policy, India and Japan share a common ground for closer cooperation.

However, the emergence of space ventures such as SpaceX and the promotion of commercialisation of space in the United States may add new dynamics in the space activities of both countries. India is already active in the launch market for small satellites with its successful PSLV launcher, while Japan aims to develop a new industrial strategy for encouraging private entities to invest and participate in space activities. For both India and Japan, commercialisation is a new domain for space activities where neither have yet to come up with a concrete strategy to confront new challenges. Apart from potential areas of cooperation – strategic, utilisation, Earth observation and science – cooperative approach for commercialisation can provide further opportunities for India and Japan to strengthen their ties.

21

India and Australia: Emerging Possibilities

Jason Held

India and Australia share many similar conditions showing traditional markets being disrupted by NewSpace. This chapter looks at the barriers and opportunities for both nations and discusses how NewSpace can collaborate in a way that ensures the best path to markets.

The Australian Scene

Australia has many strategic reasons to be invested in space technology. It is the 6th largest nation in the world, and with only 23 million people, it is the 12th largest economy. With its close association with the United States (US) and having forged regional agreements with New Zealand, the United Kingdom, Malaysia and Singapore, Australia shares a large part ofthe responsibility to preserve the Earth's resources and population.

This convergence of economy, landmass and regional agreements makes space a vital domain for Australia. Indeed, Australian national defence has critical requirements for satellite imagery, satellite communications (SATCOM), and Global Positioning System (GPS) navigation. The country is also a location of value to its strategic partners, many of whom rely on its large, relatively low signal-to-noise environment for regional intelligence and as a relay for space control stations. The US' Apollo11 moon landing in 1969 is a well-cited example of Australian support to strategic partners, where Australian stations acted as the prime reception for telemetry and TV signals from the lunar surface.

Australia relies on its bilateral agreements with strategic partners to meet national needs. Many of these agreements are data-sharing arrangements such as satellite communications and imagery support agreements with the US. The Australian leadership has made an active decision to forego the large infrastructure expenditure needed to build a domestic space programme. For example, Australia's own national space policy specifies that rocket launch is not a priority.

Australia has an estimated $3–$5 billion investment in the space economy. There is no formal civil space programme (the government instead formed a Space Policy Unit in 2010), nor substantial collaboration between national agencies using space data. So far, Australian has declined several invitations to join the European Space Agency (ESA) to avoid any political fallout (whether real or perceived) with the US.

What Australia has, to be sure, is a robust academic community producing quality research on space exploration and use. The Australian research fields related to space physics, robotics, hypersonics and, especially, astronomy are considered world-class. Other associated fields, such as astrobiology and planetary science, are also internationally lauded. Several high-profile projects, such as the Square Kilometre Array and Advanced Instrumentation Technology Centre, have attained global visibility. The Australian Centre for Field Robotics is the largest funded robotics lab in the world. Several areas, for example the Arkaroola Desert, are listed internationally as Martian Analogues, and researchers from across the globe frequently visit them for scientific investigations.

Research funding comes from established academic grant sources, and many Australian space projects have successfully competed for funding against traditional Australian industries such as mining, banking and agriculture. Adelaide was chosen to host the International Astronautical Congress in 2017, in part due to this reputation.

There is no doubt that while Australia lacks a space programme, it has strong potential for commercial space-related activities. Major US prime contractors have an Australian presence, competing directly either for defence contracts or for acquisition opportunities with Australian researchers. Australia's relationship with the US was further strengthened recently, with the signing of the International Traffic in Arms Regulations

(ITAR) agreement in 2013. The government now provides tax incentives for companies that import space equipment purchased from overseas.

Birth of the Australian NewSpace Market

For a NewSpace company, the characteristics of Australia's space technology can be daunting—the country's needs are met through either large prime contractors, bilateral agreements or academic relationship; there is no government acquisition programme, nor incentive for established players to include upstarts. At a glance, Australia seems to have stagnated in the current scenario, and the lost potential to their economy can be measured in the dollars raised by citizens who have left the country. According to anecdotal reports, Australians leading new companies under PlanetLabs (US), Deep Space Industries (US and EU) and RocketLabs (New Zealand) have raised nearly $500 million in investments, put together. This is money that Australia possibly forfeits due to its current policies.

Yet at the same time, the Australian NewSpace sector is experiencing rapid growth, with over a dozen new companies born in 2015 alone. By mid-2016, roughly one-third of these companies had raised investments ranging from seed funding to Series A. The question that arises is this: What has changed to enable such resilience in a hazardous market?

The resounding answer is CubeSats, a special category of small satellites and semi-standardisation with enough technical maturity and flight heritage to appeal to highly conservative Australians. Previously, most Australian national infrastructure and bilateral agreements considered large satellites, which normally cost between USD $250 million and $2.5 billion. With small satellite successes in PlanetLabs and TerraBella (a Google subsidiary), many local entrepreneurs are realising a potential market. For an entrepreneur in Australia, the decision to invest in the space sector is also more affordable. CubeSat businesses are starting from between USD $150,000 and $250,000, well within the range of a Kickstarter or a small business loan and less than half the cost of gaining a food franchise distributorship. Space business also appeals greatly to entrepreneurs in a country with such strong academic output, producing a large number of PhDs per capita, and a difficult job market. While startups can be risky, and claims of a 90-percent failure rate are common,[1] this new and coming field holds a better promise for PhD engineers than the hopes of becoming tenured professors, which has a 95-percent failure rate.

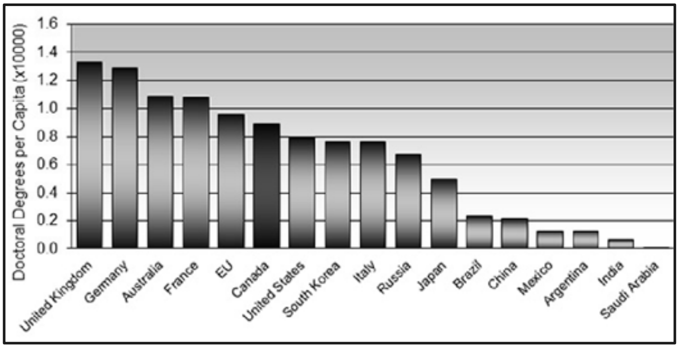
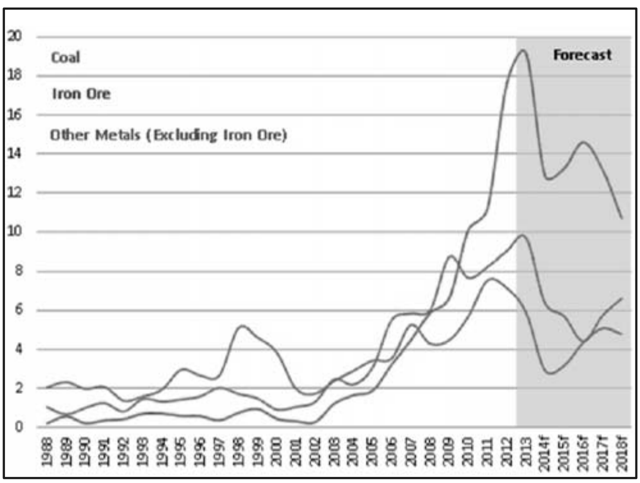


Fig.: Doctoral degrees Granted per Capita, G20 Countries, 2010 or Most recent Year

The businesses that entrepreneurs start reflect both the advantages and disadvantages of Australia's market and conservative culture. Many companies tend to be data- and web-focused, which has traditionally been the trend in Australia; such companies are fairly low risk. They also aim to leverage the large data need that results from low population and a large landmass. Many founders are former (or part-time) academics and are thus familiar with a range of grant proposals that require tie-ins to terrestrial markets. Business mentors often push their startups to establish a relationship with downstream markets. Startups aligning with national goals in Cleantech, agriculture and mining find it easier to gain support.

In parallel with new businesses, new markets are also emerging, such as space applications to STEM (Science, Technology, Engineering and Mathematics). STEM markets have a strong demand for space but few outlets. STEM is often seen as a "Segway" business, a way to grow market share and experience with a larger and motivated customer base without the challenge of competing with prime contractors. Customer channels are convenient, because they are closer to mass markets and have quicker funding pace than B2B. Balloon flight providers, ride share, and Space Camp ventures are examples of noteworthy startups. As the companies grow in size, they become increasingly interested in partnering with Australia's strong universities, often forming lasting relationships with well-funded prime contractors in the process.

Investors have also started reacting to slumps in traditional markets and are actively seeking new opportunities. The mining boom, for example, ended in 2013, with a sharp drop in Chinese purchasing. Enterprises that successfully exited this boom are available for new markets and are open to high technology. The success of NewSpace in other nations is of key interest to investors, who now realise both the income generated in this field and the increase in the number of successful space exits. PlanetLabs, TerraBella and RocketLabs are specific examples of successful exits discussed by investors in Australia. A strong media story is helping to fuel the discussion with investors, many of whom realise they are missing opportunities to build business at home. Thus, Australians are showing early signs of following investment patterns, a trend previously seen in the US, where successful entrepreneurs from the dot-com era transitioned to become investors in space.



Graph: Mining Fixed Capital Investments, $ Billion, 2010/11 Prices

As these fledgling companies gain branding and media attention, the Australian government is responding with support, even if nominally. Prime Minister Malcolm Turnbull announced space as an objective in the nation's innovation policy in 2016 and the Space Policy Unit is tasked with reviewing the original anti-rocket policy. Acquisition methodologies are now under discussion. These announcements of public support, highly repeated in the mass media, also motivate investors to consider space markets more closely.

Marks of a CubeSat Disruption

The real potential of CubeSats is to produce space data at costs low enough to be useful for the general population. This democratisation of space both benefits and disrupts traditional industries. Agriculture, cleantech and mining normally pay high values for space products. A company that needs satellite imagery, for example, has to pay US or European suppliers $100,000 per photo and are forced to purchase large terrain sizes. This price point dissuades all but the largest companies, thus limiting purchasing patterns. Satellite communications are available from traditional SATCOM companies at a rate of $9/minute, reasonable enough for a single user who requires only short-term data support but still costly for the volume being used currently within the Internet of Things (IoT).

With CubeSats, the cost of creating data has been reduced in orders of magnitude. However, the price being offered and the selected distribution channels have not expanded beyond serving the government and large corporate customers. Cost inflexibility is likely a sign that the disruption is still in its early stages, and many opportunities still remain for NewSpace companies seeking to provide data to mass markets.

There are other signs that indicate that the disruption is still in its early stages but accelerating rapidly. As more companies experiment with democratised space data, they can measure its value and compete accordingly. Companies are now starting to contest over space data. A well-publicised example is the bitter legal battle over GPS-tracking technology between the Australian startup Precision Tracking, a small business innovator, and Domino's Pizza, a global pizza delivery service. Precision Tracking alleged that Domino's Pizza stole their technology after Precision Tracking installed their equipment and vehicle tracking services in 50 stores in a commercial trial. Domino's announced the technology after much fanfare, citing a nearly 30-percent increase in profits due to operational savings. An identical lawsuit is in progress between Domino's and GPS company Prostar in the US. It is not clear who is likely to win either case. However, two things can be gleaned from these examples:

1. Space domain is increasingly and substantially adding value to traditional business.
2. The value of this domain is measurable and high enough to pursue in court.

It is important to note that Precision Tracking and Prostar are data distributors, not data producers, and the fact that entities are competing relentlessly illustrates how valuable space data has become to companies such as Domino's. Navigation data is still produced for free by governments, so this is an imperfect, albeit measurable, lesson on its increasing effects to downstream industries.

As NewSpace companies start to build assets and new distribution methods, there will likely be a similar emergence of experimentation-adoption-value-competition.

Comparing Indian and Australian NewSpace

There are many similarities between the NewSpace communities in India and Australia. Both countries have a small but growing space entrepreneurial community, seeking to make an entry into a highly embedded establishment. Cost reductions provided by CubeSats open opportunities outside this establishment. Many grant opportunities favour academic markets over commercial ones, although there are a few joint mechanisms encouraging collaboration. For both nations, disruption is available, but not required, for NewSpace companies to survive, as some of the opportunities from CubeSats open data for new markets not traditionally considered part of the space domain.

However, the similarities end there. India has far deeper flight heritage in space than in Australia, and a greater population base. There is also a far richer industrial base for space. This means disruption may have a greater effect in India than it does in Australia. On the other hand, a richer industrial base also means investors and government members are more familiar with opportunities and may be more open to new ventures. While the establishment may seek to limit disruption, India's relatively low launch costs are a great opportunity for experimentation. New ventures in India have greatly reduced overheads to get to a "Minimal Viable Product" (MVP) compared to Australia, which has one of the most expensive rents in the world.

While India, too, allows imports, compared to Australia, they do so with far greater protection of their own supply channels. For example, there is a 20-percent tax on all software imports, which encourages local manufacture of flight software in the same way the tax was originally intended to encourage local development of IT. Avionics and other hardware do not gain the same protections, giving US and European suppliers better inroads to the Indian market. However, cultural differences can add barriers between Indian and US companies, hampering sales in either direction. Many secondary US suppliers are hesitant to do business in India due to ITAR, even though India signed the ITAR agreement in 2009.[2] An indigenous space capability, which is strong, matched with cultural and financial barriers should encourage India to strengthen its domestic space economy.

It is far more viable for an Indian NewSpace company to take a traditional route as secondary supplier to a prime contractor, than it is for Australians. This can be a great advantage for a new Indian venture to follow techniques used by many US startups who gain relationships, experience, branding and cashflow as subcontractors before (or in parallel to) developing their own Intellectual Property.

Australian and Indian Collaborative Opportunities

India's large population provides unique challenges that benefit from the same space-based solutions that are of interest to Australia. Once again, at a glance, there are a lot of overlaps in terms of the products needed; both nations need satellite imagery for agriculture, mining and defence. Space-derived data for emerging markets, especially for IoT, will also be of interest and act as a catalyst for growth when used in conjunction with space imagery. How data is used upon arrival at the consumer end, however, is different, not considering large corporate and government uses.

The idea of the democratisation of space has two directions: "Using the Road" and "Building the Road." A NewSpace company interested in

"Building the Road" manufactures infrastructure, including satellites, hardware, payloads, rockets and control software. Companies that produce and release data products are more concerned with the country of manufacture than the country that purchases the data product. Constellations designed to cover India can potentially sell products to Australian consumers (and vice versa). Infrastructure can also be shared under agreements, as both countries occupy geographic locations of strategic benefit to space operations. Commercial ground stations can share operational data under simple commercial agreements without intervention from governments. Democratisation in this sense, i.e., "Building the road," is about setting a price for the products, independent of government cost models, where price is flexible depending on the cost of the satellite constellation.

NewSpace companies interested in "Using the Road" are distribution channels finding new and creative ways to bring space data to downstream consumers. In many ways, this is a more difficult sales problem in the sense that each product may have a wide range of use cases. For example, imagery for agricultural estimates are also used in banking land valuation. Companies doing fleet vehicle logistics can also provide navigation data for mining. While there is some evidence of market saturation for satellite navigation providers in Australia, the imagery and IoT markets are only getting started. Democratisation of data is a key opportunity for NewSpace companies looking for great potential in India, which is on pace to become the world's second largest internet user and a $15 billion IoT market by 2020.[3] Most of India's population is closely linked to agriculture, so there is a natural potential for IoT and data pipelines to be used as a point of leverage for improving the life of individual families.

Companies formed to service downstream markets are best formed locally, and are usually unconcerned with the satellite's country of origin, and are only interested in the effective cost. The barriers to entry for an Australian to set up a downstream services company in India are cultural more than regulatory. Reaching out to individual consumers, setting up sales systems and staff, and mass marketing need people with high familiarity with communities. Therefore, it is more likely for downstream "Using the Road" companies to stay within their originating nation, even if the satellite constellations themselves are produced elsewhere.

This provides many viable strategies for NewSpace collaboration between Australia and India, where space data is produced by small and medium-size enterprises (SMEs) in both countries and sold locally at prices that allow democratisation. Local consumers benefit greatly from space-derived data and at qualities that can approach or, in some cases, extend services for data that, previously, was only available to governments. Both countries gain additional suppliers for space hardware in the process, with channels to large and dedicated customer blocks. It is not yet clear how many companies can be produced this way, because it is still early in the disruption cycle and there are many new use cases for democratised space data that have yet to be discovered. What is clear, however, is that there is great potential for income generation, and collaboration between commercial suppliers and data distributors can be catalytic in a $360-billion growth industry.

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V

SPACE SUSTAINABILITY AND GLOBAL GOVERNANCE

22

Space Debris Tracking: An Indian Perspective

M. Y. S. Prasad

Introduction

The number of catalogued space objects, as of the end of September 2016, is around 17,800, which includes both functional satellites and debris. The total debris is roughly around 13,600.[1] Around 1,500 of these objects are in the Geosynchronous Earth Orbit (GEO), and most of the remaining are in the Low Earth Orbits (LEO). The term 'catalogued' implies that these space objects are tracked, their orbits are determined, orbital elements are continuously updated, and they are correlated to the original launch and/or on-orbit break ups. These catalogues are maintained by the United States and Russia, both of whom have all the technical capabilities for this task. They provide the orbital elements data to the other countries free of cost, in the general interest of reducing the space debris problem and to implement the necessary mitigation measures.

The present global capability of tracking space debris is for objects bigger than 1m in GEO, and bigger than 10 cm in LEO. This limitation arises from the sizing and capability of ground tracking systems. The objects in LEO are generally tracked by radars, and those in GEO are tracked by optical telescopes. In the case of radars, a pulsed signal is transmitted towards the object, and the reply pulse received is used to find the range, and direction of the object. The amplitude, phase angle and the variations of the reflected (reply) signal are used to infer the object's size and other characteristics. Both mechanically steered and the phased array radars are used by different countries for space debris tracking. The received signal amplitude is inversely proportional to the fourth power of the slant range in the case of radars. As a result, radars with capability to track in the GEO region (with slant range of the order of 40,000 km) are not possible to build. The optical telescopes, which have a received signal strength inversely proportional to the square of the slant range, are used to track objects in GEO region.

The Space Debris Tracking Networks / Systems

The US Strategic Command (USSTRATCOM) maintains and operates the Space Surveillance Network (SSN), the systems of which are located in different regions of the world. The SSN of the US is the largest network in the world today with 29 radars and optical telescopes deployed. The Orbital Debris Program Office of the National Aeronautics and Space Administration (NASA) closely interacts with USSTRATCOM in the maintenance of the debris catalogue. Figure 1 shows the locations of SSN debris tracking systems distributed all over the world.[2]

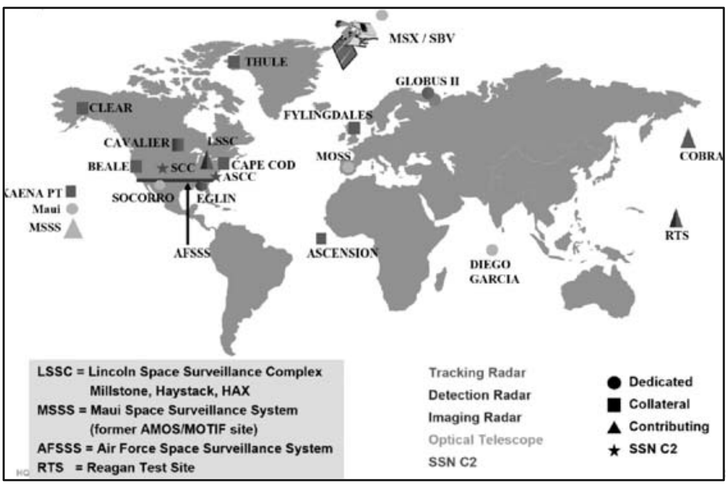

Figure 1: Space Surveillance Network, US

Russia also maintains and operates a network of 20 optical and radar sensors, distributed over different sites for monitoring the space debris. They share the data with NASA, and with the European Space Agency (ESA). Figure 2 below shows the tracking network of Russia for monitoring space debris.[3]

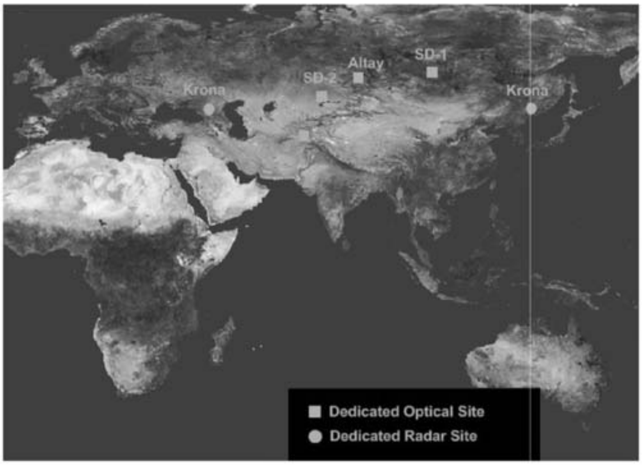

Figure 2: Tracking Network of Russia for Space Debris monitoring

The monitoring and categorisation of objects in GEO is regularly carried out by ESA, which draws on the data of the US' SSN and Russia's network in addition to its own tracking data.

International Scientific Observation Facilities Network (ISON) is a network of optical (Astronomical) telescopes coordinated by Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences for tracking and monitoring space debris. The network locations are shown in Figure 3.[4] The ESA uses the data from this network, along with its main data source from SSN, in the categorisation of GEO objects.

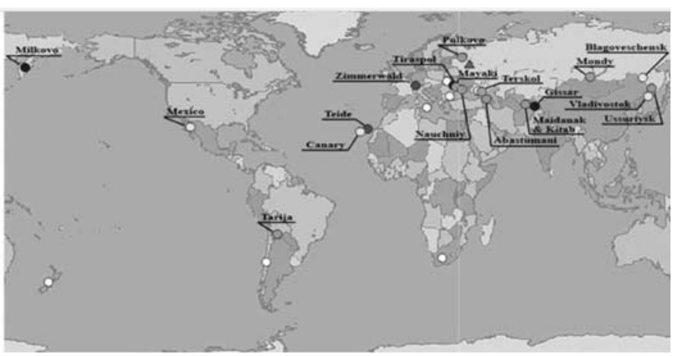

Figure 3: International Scientific Observation Facilities Network (ISON)

Europe has a few high capability radars and optical telescopes, which are used for tracking and monitoring space debris. A few simultaneous tracking campaigns are carried out to track objects in LEO, and to compare with debris prediction models. Germany's FGAN Radar, France's GRAVES (*Grand Réseau Adapté à la Veille Spatiale*) Radar, and Flying Dales phased array radar of the United Kingdom are Europe's most important tracking systems. FGAN Tracking and Imaging Radar (TIRA) operates in L and Ku bands and has the capability to track two-cm objects at a range of 1,000 km. Its Ku band radar is used to image the objects after processing the tracking data.

Japan has a few optical telescopes of different apertures from 0.35m to 1m, which are used for tracking space debris. Japan Space Forum (JSF) deploys a 0.5m telescope and a phased array radar for LEO debris tracking, and 1-m telescope for GEO debris tracking.

China has a network of at least nine optical telescopes and observatories, four tracking ships, and one phased array radar, which it deploys for tracking and monitoring space debris. China's capability to track non-cooperative targets is not certain due to lack of technical details on their tracking systems, especially radars.

The SSN, it should be noted, has no other comparable system / network exclusively meant for tracking and monitoring space debris, and also in providing globally the Two-Line Elements (TLEs) of the catalogued space objects.

Space Debris Tracking by Radars

For space debris tracking, there is generally *a priori* information available, such as NASA's TLEs and the approximate size of the object in terms of Radar Cross Section (RCS). The radar beam is pointed to a predetermined direction and the object is tracked after detection, and observation vectors are collected. The main components observed include, time, azimuth and elevation angles, range, range rate, amplitude, and the phase data of the reply pulse. This tracking data can be used to refine the orbit for further use. This mode of observation is called 'target directed', and is used when the object to be tracked is known and its orbital data needs to be improved for more accurate information.

Another method of tracking space debris by radars is the 'Beam Park method'. In this method, the radar antenna beam is maintained in a fixed direction, and the small size debris flux passing through the beam are counted and characterised. As the beam is in a fixed direction with respect to Earth, the latter's rotation scans 360 degrees in inertial space.

Radars with mechanically steered antennae, and phased array radars are employed in tracking space debris. The phased array radars with beam steering technology have additional advantage of tracking multiple objects near simultaneously by time sharing. However, it is to be noted that so far radars are used for tracking debris only in LEO.

Usually, the same radar is used for transmission and reception of the pulses in time-shared mode. Sometimes, one radar is used as a transmission system, and another radar, either co-located or far away, is used as the receive system. Radars configured in this manner are called "Bi-static Radar". Bi-static radars have increased sensitivity, which can be used to detect weaker signals.

In an excellent survey article on radars used for tracking space debris, a few radars are verified technically for their potential to track small debris.[5] Table 1 gives the details of those radars along with their important features. These are by far the best radars deployed for tracking and monitoring space debris in different frequency bands.

Table 1: Radar Parameters (In Debris Collection Modes)

Radar Parameters	FPS-85 *(Trans/REC)*	Haystack	HAX	TIRA *(L/Ku)*	Don-2N
Peak Power (KW)	32000	250	50	2000/13	25000
Frequency (GHz)	0.442	10	16.7	103/16.7	4
Beamwidth (deg)	1.3/0.7	0.058	0.10	0.5/0.039	0.27
Antenna Gain (dB)	13/48	64	67	51/73	57
Available LFM BW (GHz)	0.001	1	2	0.06/0.8	0.0033
Pulse Width (msec)	0.25	1.64	1.64	1/0.26	0.0625
Single Pulse SNR on 0 dBsm @ 1000 km (dB)	64	59.2	40.6	51.2/27	45

The AN/FPS-85, and Russian Don-2N are phased array radars. AN/FPS-85 is the key sensor in the SSN and contributes significantly for tracking and maintaining the space debris catalogue. It has 5,928 transmitting antennas, and 19,500 receiving antennas. It covers 120 degrees in Azimuth and 100 degrees in Elevation. The combined peak power, from all transmitting elements, is 32MW, and it can track 200 objects simultaneously.

Don-2N radar, essentially an anti-ballistic missile defence system's tracking radar, is used by Russia for tracking space debris. The radar is a passive phased array system, and is housed in a truncated pyramid-shaped building, with each side covered with a 18m dia antenna array. It has a 360-degree coverage, and is the most powerful radar with respect to detection of small size debris, partly due to its operating frequency of S-band.

Two other phased array radars, not covered in the above table and used for space debris tracking, are Cobra Dane AN/FPS-108 radar (of SSN – USA), and the Japanese KSGC radar. The Cobra Dane radar is an active phased array radar with 29m size, 15,360 radiating elements, 15.4 MW peak power, and operates in L-band. The KSGC radar is relatively small with 2.8x2.8m size active phased array antenna with 1,400 elements, 70 KW peak power, and operates in S-band.

The other powerful radars, used for tracking space debris, are Haystack and Haystack Auxiliary (HAX) radars of USA, and FGAN (TIRA) radar of Germany. Haystack radar operates in X-band with a mechanically steered antenna of 36.6 m dia size. The HAX radar operates in Ku-band with a 12.2 m dia antenna. The FGAN radar operates in L-band with a mechanically steered 34m dia parabolic dish antenna. It also operates in Ku-band, which allows for imaging of the tracked object (with post processing).

The above radars can track space debris of 10cm dia to a range of 1,000 Km, but many have the capability to track below that size also down to a few centimetres in size, with the exception of the KSGC radar.

Radar Cross Section (RCS)

The RCS of the tracked objects plays an important role in non-cooperative tracking (or skin mode tracking). The reflected signal strength, and consequently the received signal strength at the radar from the tracked target, is directly proportional to the RCS. In turn, the RCS depends on the physical size, reflectivity of its surface, and directivity of the radar reflection caused by the target's geometric shape. The detection thresholds, and accuracies of radars' tracking data depend on Signal-to-Noise ratio, and, thus, on the tracked target's RCS.[6]

The variations in the received signal strength, after other causes are compensated or accounted for, show the variations of the target's RCS with respect to time due to its relative motion and resulting change of the aspect angle of tracking. This is vital information in determining many details of the tracked target. In fact, repeated observations and the signal variations can even help in imaging the tracked target/ debris.

The Linear FM of the RF pulses also helps, when the modulation on the reply pulses is demodulated/analysed, in determining the variations in the instantaneous RCS data.

Although RCS is described above in simple engineering terms, it is a complex concept and many models have been developed to translate the received signal strength into the target's RCS. There are again models to translate the derived RCS into the physical size of the target/object. NASA's Size Estimation Model (SEM) is the one popularly used in characterising the space debris objects from the RCS, which is derived from the tracking data.

Certain fundamental relationships between the radar's frequency, the physical dimensions of the debris objects, and RCS are essential in the design and sizing of the radars for space debris tracking. Figure 4 highlights the important fundamental relationships modelled for computing RCS.

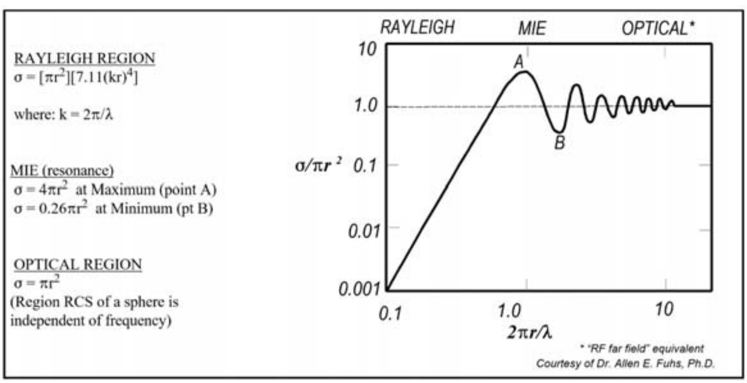

Figure 4: RCS of a sphere in different regions

If the combination range, radar's frequency, and the size of the object result in optical region, then the RCS is independent of the frequency, and depends on the area offered by the target to the signal. Generally, such simplified assumptions can be used in the sizing and design of the space debris tracking radar.

The RCS data of the catalogued objects are available in the "Database and Information System Characterising Objects in Space (DISCOS)". However, the DISCOS database has used the measurements in the UHF frequency range, and the RCS over time can change due to the slow tumbling of the debris in orbit. Such uncertainties are to be taken into account while using the RCS data in interpreting the tracking data of other radars. The RCS data obtained from Beam Parking Experiments (BPE) may contain incorrect compensation of the angular offsets, and also due to short dwell times.

Accuracies and Calibration

The orbits of the debris objects are determined from the tracking data. The accuracy of the orbital elements naturally depends on the tracking data's accuracy. Range accuracy of 10m (one sigma), and angle accuracy of 0.1 degree (one sigma) are achievable with about 15 dB Signal-to-Noise Ratio (SNR). However, achieving that level of SNR for debris objects of smaller size requires tracking over a longer arc, and/or multi-station tracking, integration of multiple pulses, and employing Linear FM. The orbital position accuracy improves by one order if two station tracking is employed, which may not be possible without a big network of sensors. The Doppler frequency determination from range rate tracking improves the accuracy of the estimated orbital inclination.

The radars are calibrated for their detection and tracking capabilities by using simulated targets. Usually, the calibrations are carried out using reflecting spheres as these offer the same cross-section irrespective of the aspect angle, removing one big uncertainty. NASA deployed in 1999 from its Space Shuttle in the LEO metallic spheres of 5cm, 10cm, and 15cm dia to calibrate debris tracking radar systems. Such calibrations are essential when new radars are brought into regular operations.

Optical Tracking

The visible light as reflected by the object is received by the optical telescopes and the brightness of the reply depends on the size of the object, and the slant range. The optical brightness number, or Apparent Magnitude, as per the measurement practices, decreases with the brightness. This means that an object with Apparent Magnitude of 20 is less bright as compared to an object with Apparent Magnitude of 12. The Apparent Magnitude of the Sun is -27, that of the Moon is -13, and star Vega is referenced as magnitude 0.[7] The brightness number of objects of 1m size in GEO is roughly 19 to 20. Usually an optical telescope of 1m dia aperture can track objects of 1m size in GEO.

The monitoring of space debris with optical telescopes are carried out in two modes. In the Earth-fixed mode, the GEO objects appear as bright spots, and stars in the field of view appear as arcs, which are in fact a small segment of the elliptical orbits. In the Star-tracking mode, stars appear fixed and the debris appear as elongated arcs proportional to exposure time. In both the modes, appropriate software is used to eliminate the stars by using the multiple frames of observation, and the angle tracking data is obtained for debris objects, which are used for computation of orbits.

NASA conducts optical surveys of GEO with a 0.32 m Schmidt telescope equipped with a CCD detector. This sets the lower limit of the SSN's catalogue of GEO objects to 1 square meter. ESA carries out extensive survey of GEO regularly, and uses its space debris telescope located in the Canary Islands.[8] It is a classical astronomical telescope with 1m primary mirror and an English mount. For monitoring debris, they use modified Richey-Cretien focus equipped with CCD Cameras (a mosaic of four 2Kx2K pixel CCDs). ESA's observations have a limit of about 15 cm in GEO.[9]

Data Processing and Information Generation

Space debris tracking is only one of the many steps in the more complex process of creating debris information. It involves:

(i) Determination of orbits of the debris using range, range-rate, and angle data; and orbit determination models.

(ii) Estimation of RCS values of the debris by using return signal data, and also using repeated observation data,

(iii) Estimation of the debris objects' sizes from RCS data using appropriate models.

(iv) Refining the orbits (TLEs) of the catalogue using the freshly determined orbit.

(v) Carrying out a close approach analysis for the operational satellites of interest

(vi) Executing Collision Avoidance Manoeuvers for the satellites for which the close approach of debris is critical.

The above process involves the development/use of many Models, and refining them over time. The debris related work is a form of art, which has to be acquired and refined with repeated work and experience.

ISRO's Space Debris Tracking Systems

The Indian Space Research Organisation (ISRO) is an active participant in many international space debris fora. For instance, ISRO is a member of the Inter-Agency Space Debris Coordination Committee, which coordinates the development of expertise in the subject of space debris with many member space agencies. ISRO actively participated and contributed to the evolution and development of Space Debris Mitigation Guidelines in the UN. It also carries out debris related analysis for its launch and satellite operations. ISRO uses the TLEs of the catalogue of USA/NASA for all its debris related work.

ISRO till recently had no space debris tracking systems, except for use of some astronomical telescopes for occasional GEO observation. ISRO, a few years back, initiated, under the leadership and guidance of this author, systems meant for tracking space debris.[10] The systems that were established are one large phased-array-antenna-based tracking radar, and two 1m telescopes. The radar is installed in ISRO's SDSC–SHAR Centre, and the telescopes are being installed at Mount Abu and in Ponmudi, which will be controlled and operated by ISRO's MCF Unit. The following paragraphs give a few important details of those systems.

Multi Object Tracking Radar (MOTR) of ISRO

ISRO's multi object tracking radar is designed to track 50cm X50cm debris at a slant range of 1000Km, and 30cm x 30cm debris at a slant range of 800Km. This will result in approximately object RCS of 0.1 metre square. With this capability, most of the debris, which cause damage to operational satellites can easily be tracked, and their close approaches can be predicted. The debris of size lower than 30cm x 30cm may be tracked and characterised by tracking over a number of days and passes.

The primary mode of usage of MOTR is:

- Select the space objects passing very near to ISRO's operational satellites.
- Obtain the latest TLEs for those debris objects.
- Track the selected debris, and obtain tracking data over a few passes.
- Use the tracking information to refine the debris' orbit.
- Estimate close approach of the debris objects to the satellites.

Other modes of usage are:

- Search for any debris very near to the operational satellites - using time dependent tracking vectors of the satellites and searching around that position.
- Detect and track any debris unpredicted from the catalogues.
- Use the tracking information for close approach analysis.

Based on the requirements of multi object tracking, the final specifications are detailed below.

Parameter Specifications

Frequency of operation:	L Band (1.3 – 1.4 GHz)
RF bandwidth:	100 MHz approx
Maximum tracking range :	1000 km for 0.25 metre square objects @ 10 dB S/N & 800 km for 0.1 m2 objects
Size of Antenna:	Rectangular planar array 6mx12m
Radiating elements:	Micro strip patch (4608 elements)
Gain:	40 dB
Object tracking method:	Mono pulse Scan and track:
Beam steering Beamwidth:	Az: 1.1 deg& El: 2.1 deg
Scan angle: Az:	± 60 deg& El: ± 45 deg
Transmitter type:	Solid state Peak power830 KW, with 4608 T/R modules each with 200 W peak power

Pulse width:	10 μs to 2000 μs
PRF:	50 Hz to 10 kHz (duty ratio of 10%)
Pulse compression:	Linear FM, ratio of 8000
Mono pulse receiver sensitivity :	-132 dBm for tracking and -142 dBm for detection
Antenna positioning range:	Az, 0 to 360 deg& El, 0 to 90 deg
Cooling system:	Liquid cooling

The major sub-systems of MOTR include, the antenna having 4608 radiating patch elements, T/R modules, feeder network, digital receiver, data processing system, cooling system for T/R modules and antenna pointing system. The schematic diagram of the MOTR is shown in Figure 5.[11]

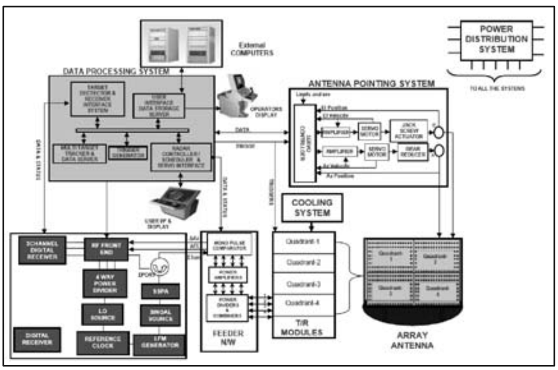

Figure 5: Schematic of sub-systems of MOTR of ISRO

The following pictures show the installation process and other views.

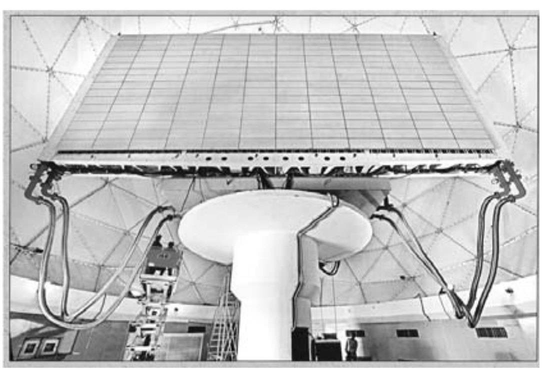

Fig.6: The phased array antenna of MOTR on the positioner, with cooling pipes interface.

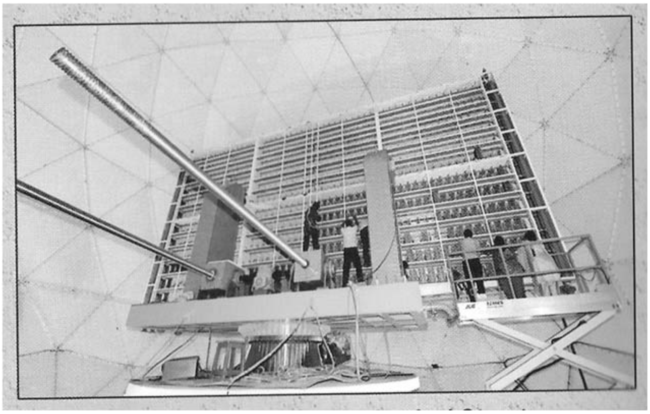

Figure 7: Back-up structure on the antenna mount with Elevation screw-jacks visible.

Figure 8: MOTR Building, with 18m Radome visible.

At present, the MOTR is operational and trial debris tracking is in progress. This radar will play an important role in the future in enabling ISRO to enter the space debris tracking field.

Optical Telescope Systems of ISRO

ISRO is installing two 1m optical telescopes for monitoring and tracking space debris at Mount Abu, and at Ponmudi. The primary mirrors are of 1m size, and optics are of the Ritchey Cheritien type.

The telescopes are equipped with 4Kx4K CCD detectors. As explained earlier, telescopes of this size can track 1m size debris objects in GEO. The telescopes are also equipped with high accuracy laser ranging systems.

ISRO can take a more active role in space debris tracking in the future with MOTR and optical telescope systems, possibly along with mutually beneficial international collaborations.

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Astro-propriation: Investment Protections for and from Space Mining Operations

Daniel A Porras

Introduction

Imagine this scenario: In the cold vacuum of space, nearly 250,000,000 miles from Earth, a private-company probe sits on an asteroid. It has deployed a high-tech drill into the asteroid, digging deep into the alien surface. This giant rock has only ever been studied from a distance, and no human has even come close to it. The probe is digging into the ground and collecting valuable minerals, simultaneously sending priceless scientific data back to researchers on Earth. Meanwhile, in a commercial control centre in California, a technician is studying the readouts from the probe. Everything looks the same as it has in the last few weeks of the mining operation. Most importantly, the probe is functioning just as it was designed. The billions of dollars and countless man-hours invested in this state-of-the-art piece of equipment is paying off. The results are everything that the engineers, technicians and, in particular, private investors could have hoped for.

Suddenly, the technician notices something different in the readouts. Something new. He looks and checks a different reading. This can't be right. He calls a colleague to take a look and confirm his suspicions. She is also puzzled. "We should call the people upstairs," she says, "This could be the most important discovery in the history of humanity!" Soon, all of the decision-makers of the company are called into a room. The technicians present their findings: they found frozen bacteria buried deep beneath the surface of the asteroid. They are ready to break the news to the whole world. Suddenly, one of the directors raises his hand and says, "Wait, what about our investment?" While noone in the room wants to say anything, everyone is thinking the same thing. When dealing in the amounts of money needed for a space mining venture, even the most idealistic explorer would have to stop and think.

While this scene may sound like the beginning of a science-fiction novel, recent technological developments in outer space exploration have moved humanity one step closer towards making space mining a reality. These advances have been so significant that in December 2016, the United States Congress passed the US Commercial Space Launch Competitiveness Act (or the Space Competitiveness Act), a bill that authorises private citizens to recover "space resources" and "asteroid resources".[1] The drafters of the bill considered the off-chance that a mining operation might discover bacteria to be sufficient that they included language in the text that would prevent citizens from being able to lay claim to any 'biotic' material, including something as 'simple' as bacteria. Such a provision might seem far-fetched, but space mining could prove to be an incredibly profitable venture and, if so, private companies might someday be racing off to dig in places that no one has ever been. Moreover, they will be conducting operations at depths where current sensors cannot get sufficient data regarding living organisms. In other words, the space companies of tomorrow will be reaching into places that no one has ever been able to see before. And that could be for better or worse.

Biotic material in outer space is not the only discovery that could potentially reshape our understanding of the universe as we know it. What if a private company were to discover a new elemental compound? Or an artefact from an old probe? Does it belong to them? To their government? To the world? What about the company—what are its duties, and rights, if any? The Space Competitiveness Act raises many questions for such a short piece of legislation, particularly because the probabilities and stakes are so high, it makes risk assessment difficult.

This chapter analyses three hypothetical scenarios that could provide models for measuring competing interests in space mining under the US Space Competitiveness Act:

- The discovery of bacteria;
- The discovery of a new compound; and
- The discovery of an artefact.

It will draw parallels with existing laws for investment protection and the preservation of scientific and cultural discoveries in order to get a better picture of the legal framework being proposed by the Space Competitiveness Act.

While these hypothetical scenarios may never play out, providing legal certainty and transparency in these matters will give assurance and confidence to two very important groups regarding the laws for space mining. The first group is the investors in space mining companies who will have to consider these hypothetical scenarios as possibilities, however unlikely they may be. Outer space activities are already fraught with risks, so any foreseeability is useful. The second group is the rest of the world, whose own space capabilities have not yet reached the level of space mining. In particular, a significant number of States have raised concerns about the legality of space mining at the recent session of the United Nations Legal Subcommittee of the Committee on the Peaceful Uses of Outer Space (or the *LSC*).[2] Understandably, they will not want to forego their own interests in space, which includes access to major scientific discoveries. By shedding light on the framework of rules implied by the Space Competitiveness Act, it is hoped that both of these groups will be able to approach the US proposed space mining regime with greater confidence. This chapter does not aim to determine whether the Act is lawful under international law, but rather seeks to explore the legal framework proposed by the US Congress and how it might be reinforced to achieve its goals.

The Space Competitiveness Act – Title IV

At its most basic, the Space Competitiveness Act is legislation intended to spur and protect investment in the US outer space sector. This is a common practice whereby States offer legal stability and predictability for investments in the hopes of attracting larger sums and longer commitments to the national economy. [3] This objective is evident from the full title of the Act: *To facilitate a pro-growth environment for the developing commercial space industry by encouraging private sector investment and creating more stable and predictable regulatory conditions, and for other purposes.* [4] Title I is called "Spurring Private Aerospace Competitiveness and Entrepreneurship" and tasks the Secretary of Transportation with amending existing liability regulations in order to further promote commercial launch services, a nascent industry that is still coming into its own.[5] And while Titles II and III deal with generally internal, administrative issues (namely, the way reports are issued regarding commercial remote sensing activities and renaming the "Office of Space Commerce") it is Title IV that holds the most polemic provisions.

Title IV, entitled "*Space Resource Exploration and Utilization*", contains three short sections and a disclaimer. First, it defines an "asteroid resource" as a "space resource" found within a single asteroid.[6] A "space resource" is defined as "an abiotic resource *in situ* in outer space" and explicitly includes both minerals and water.[7] In short, Title IV of the Space Competitiveness Act covers all minerals and water that are found in space, either on the Moon or any other celestial body, that do not qualify as being "biotic" or alive.

What about these "resources"? Title IV goes on to state that:

> "*A United States citizen engaged in commercial recovery of an asteroid resource or a space resource under this chapter shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States.*"[8]

This provision can be broken down into three distinct parts:

- recognition of the legitimacy of US citizens to engage in commercial recovery of asteroid and space resources;
- specific rights to "obtained" resources; and
- limitations under applicable law, including US international obligations.

There has never been any legislation like this for outer space activities and many are still wondering what these assertions might mean.

On the first point, it is assumed that US companies like Planetary Resources and Deep Space Industries will even be able to go to bodies in space, like the Moon or an asteroid, and physically remove materials like minerals or water. This also assumes that such an activity will be seen as being consistent with the Outer Space Treaty. On the second point, there has been concern that the rights to minerals in space could be secured merely by detecting a celestial body and claiming it.[9] However, the words of Representative Brian Babin (R-TX), Chairman of the Space Subcommittee of the US House Committee on Science and one of the sponsors of the Space Competitiveness Act, provided some clarity:

> "The term 'obtain' was ultimately chosen because it carried no presumption about the technical means with which the resource was to be recovered. However, it was never our intent that 'obtainment' would allow a company to remotely sense a resource and assert a right of possession. Only through physical recovery does this right manifest."[10]

This explanation confirms that the rights to possess, own, transport, use or sell a space resource can only be incurred by physical acquisition and control, whether by robot or human form.

The third point has two sub-categories, namely, applicable law and US international obligations. To understand what might be the scope of the "applicable law", one should look not only to existing domestic regulations for space activities and international treaties, but also environmental, commercial and intellectual property laws. This analysis will be important not only to determine what restrictions on activities will be put in place, but also to be aware of what fundamental legal protections already exist for commercial space miners. In this regard, it should also be noted that, as a matter of policy, the final provision of the Space Competitiveness Act directs the President of the US to:

- facilitate commercial recovery of space resources;
- discourage government barriers to the development of economically viable, safe, and stable industries for commercial recovery of space resources; and
- promote the right of United States citizens to engage in commercial exploration for and commercial recovery of space resources free from harmful interference.[11]

This paragraph authorises the US President to use the full force of his office to facilitate space mining. As a matter of policy, enforcing the rights of space miners will be a fundamental aspect for inviting investment. Furthermore, the President is directed to submit a report to Congress within 180 days that specifies what authorities will be needed to carry out space mining in accordance with international US obligations (the deadline for this report was 25 May 2016; no report was issued).[12] This particular provision will play a significant role in ensuring that the proposed US regime is accepted by the international community.

Where does this leave our intrepid space mining investors? Going back to our lonely asteroid probe and the team back on Earth, what are their obligations and duties as envisaged by the Space Competitiveness Act if they were to make a major scientific discovery like bacteria?

Obligations beyond the Outer Space Treaties

While the Outer Space Treaty did establish the fundamental principles of liability in space (discussed in the full text), there were still numerous provisions that were full of ambiguity. To create additional certainty in space, the Convention on International Liability for Damage Caused by Space Objects (or the *Liability Convention*) was adopted in 1972.[13] The Liability Convention establishes two types of liability on the "launching State": fault-based liability for damage caused to other space objects[14] and absolute liability for damage caused on the surface of the Earth or to aircraft in flight.[15]

In the context of space mining, under the Liability Convention, companies will only be liable for damage to other space objects if they are at fault. This could become an issue in situations where competing mining operations are located closely. However, it is the notion of absolute liability for damage caused on the surface of the Earth that is most relevant to our examples, particularly in the case of bacteria. If there were to be any type of contamination on Earth by an American enterprise, the US government would be absolutely liable. Given that it is not clear just how widespread a contamination of this nature could be, the US government will likely lean on the side of caution and institute rigorous non-contamination requirements once mining operations start launching for places like Mars where bacteria might exist. For guidance on how to prevent such a catastrophe, the US will most likely look to existing regulations under the Committee on Space Research (COSPAR) and NASA's Office of Planetary Protection.

COSPAR

In 1958, there was an international meeting in London of COSPAR, intended to promote scientific investigations in outer space as well as the free exchange of data and information.[16] This international organisation is comprised of thousands of the world's leading scientists as well as representatives from 40 national institutions.[17] Its reports and findings are not legally binding, but they are often incorporated into domestic and international legislation and policies, including the NASA Planetary Protection Policy.[18]

COSPAR has worked significantly on the question of biological contamination through space activities and, in accordance with Article IX of the Outer Space Treaty, adopted its own policy on planetary protection.[19] This policy is intended to provide guidelines – which, as mentioned, are not in and of themselves legally binding – that act as a rubric for compliance with the Outer Space Treaty.[20] It does so by offering five distinct categories of missions for potential contact with extra-terrestrial bacteria, each with increasingly stringent protections.[21] These range from missions to bodies with no interest "in the process of chemical evolution or the origin of life" (which requires no protections) to missions that involve landing on, and returning from celestial bodies that might contain life.[22] Protections for the higher categories include documentation and implementing procedures, including:

- Having a microbial reduction plan
- Providing an organics inventory
- Sterilization or containment of contacting hardware
- Continual monitoring of project activities[23]

This presents an interesting range of obligations on space miners, though not unexpected. Different missions to different classes of celestial bodies will necessarily have their own requirements. For example, a mission to an asteroid, which has no atmosphere and has a small chance of sustaining life, will have much lower contamination protection requirements than a mission to Mars. For our space miners, this means that they will likely have fewer expectations about being prepared to deal with a major discovery like bacteria if they are mining an asteroid than if they are mining on Mars. In fact, they may not have a requirement to be able to detect microbial life on an asteroid at all, nor a duty to report any findings. Interestingly, the language in the last requirement, "continual monitoring", is distinct from the language in Article VI of the Outer Space Treaty, which calls for "continuing supervision" of a space activity. Since all activities must have supervision, we can infer that monitoring involves more in-depth involvement by a supervisory authority.

It is also important to note that the COSPAR policy requires continual government monitoring. However, this is only for a restricted Category V return mission, one in which the possibilities of contact with extraterrestrial microbes would be at its highest. It is not clear, though, what the extent of monitoring means. For the purposes of our space miners, a mission to an asteroid would be classified as a Category I, which requires no planetary protection requirements and no obligation for the US Government to monitor. Were it to be a mission to Mars, then it is likely that the US Government, perhaps through NASA, would have to have an officer on hand at all times to monitor mining operations.

NASA Planetary Protections

The NASA Planetary Protection Policy, which is also not legally binding, gives effect to the COSPAR guidelines for domestic US civil space exploration.[24] However, the policy applies only to NASA, and not to commercial space actors. The question of regulation for commercial space mining must still be answered by the US President under the Space Competitiveness Act. That being said, the NASA Policy offers a blueprint of what could be applied to space mining activities, particularly since it is recognised as meeting international COSPAR standards.

The Office of Planetary Protection is a branch of NASA tasked with the following mandate:

- "to preserve our ability to study other worlds as they exist in their natural states;

- to avoid contamination that would obscure our ability to find life elsewhere — if it exists; and
- to ensure that we take prudent precautions to protect Earth's biosphere in case it does."[25]

This Office covers both outward-bound contamination (microbes from Earth contaminating other celestial bodies) and in-bound contamination (microbes from space contaminating the Earth). The NASA protections have five different mission categories, as enumerated by the COSPAR guidelines, but NASA has gone on to list which celestial bodies fall into the separate categories. For example, return missions to Mars, Europa or Enceladus are Category V restricted Earth return missions.[26] However, missions to "undifferentiated, metamorphosed asteroids" are a Category I and require very little by way of protecting against contamination.

In the case of our space miners, as mentioned above, what they are likely to experience in the future is a set of regulations that imposes strict contamination requirements for missions to celestial bodies such as Mars. However, our intrepid space miners on the asteroid are likely not to have been required to do much by way of contamination protection other than file a mission plan. And since space missions tend to discard all unnecessary hardware, it is highly unlikely that this particular asteroid mining probe would even have the capabilities to detect biotic material in space. Regulations for space contamination will likely not become a material issue until companies begin launching missions to Mars, where it might conceivably make more sense to search for biotic material at all.

Convention Concerning the Protection of the World Cultural and Natural Heritage

Another treaty that could offer some guidance on space mining by way of parallel is the Convention Concerning the Protection of the World Cultural and Natural Heritage (or Cultural Convention). Adopted by the UN Educational, Scientific and Cultural Organisation in 1972, the Cultural Convention aims to preserve both cultural and natural heritage for future generations.[27] The United States is one of 191 States Parties to the

Convention, making it widely accepted among the international community.[28]

This treaty could not, technically, apply in outer space because under its provisions, each State Party is responsible for the cultural and natural heritage "on its territory", and Article II of the Outer Space Treaty prohibits States from having territorial claims.[29] However, it does contain certain definitions that might be transplanted to outer space. For example, under Article 2, "natural heritage" is defined as:

> "-natural features consisting of physical and biological formations or groups of such formations, which are of outstanding universal value from the aesthetic or scientific point of view;
>
> -geological and physiographical formations and precisely delineated areas which constitute the habitat of threatened species of animals and plants of outstanding universal value from the point of view of science or conservation;
>
> -natural sites or precisely delineated natural areas of outstanding universal value from the point of view of science, conservation or natural beauty."

Under Article 3, each State Party is responsible for designating its own areas that fall under this definition. Furthermore, under Article 5, States Parties are responsible for introducing protections and measures capable of counteracting dangers to heritage sites.

What is interesting about the Cultural Convention is that it shows that the US is not unfamiliar with the application of international terms to discoveries of significant cultural or scientific value. In fact, the US has 19 designated cultural and natural heritage sites, including the Statue of Liberty and Mammoth Cave.[30] Among the criteria used to designate sites as having cultural value are places that exhibit "significant on-going ecological and biological processes" or are "important and significant natural habitats for in-situ conservation of biological diversity".[31] In the context of space mining, this indicates that the US at least recognises that there are certain conditions that might arise where natural or cultural heritage must be preserved. Extra-terrestrial bacteria would likely fall into the category of "on-going biological process", and a celestial body could be categorised as a natural habitat for *in situ* biodiversity.

National Environmental Policy Act of 1969

The National Environmental Policy Act (NEPA) ensures that all branches of the US government give due regard for all federal actions that significantly affect the environment and "biosphere".[32] It requires that environmental impact assessments be made whenever the Government undertakes projects such as building airports, military bases, highways, and others.[33] In particular, NEPA instructs the Federal Government to use "all practicable means … to improve and coordinate Federal plans, functions, programs and resources to the end that the Nation may … preserve important historic, cultural, and natural aspects of our national heritage, and maintain, wherever possible, an environment which supports diversity and variety of individual choice."[34]

NEPA also applies to NASA activities, including extra-planetary missions such as Mars 2020, through specific procedures found in the National Aeronautics and Space Act of 1958.[35] It also applies to commercial launch actors whose activities are licensed or approved by the Federal Aviation Administration, including "where the FAA has sufficient control and responsibility to condition the license or project approval of a non-Federal entity."[36] For example, commercial launch actors, such as Blue Origins and SpaceX, must provide environmental impact assessments of their launch facilities and activities.[37] Similarly, NEPA will also apply to space mining operations, particularly if NASA is involved in any way, if the FAA must issue a launch licence, or if there is any possibility of contamination of the Earth's biosphere.[38] This means that whatever regulations emerge will also have to consider how to "preserve important historic, cultural, and natural aspects of our national heritage". In the hypothetical scenario described to open this chapter, the discovery of either bacteria, a compound or an artefact, would be the only samples available to humankind and, by extension, the nation. It would most likely qualify as an important historic aspect of national heritage.

This will be a critical consideration for regulators as they consider the wide array of possibilities that might be uncovered in the whole enterprise of space mining. Likewise, they will not wish to let these infinite permutations hinder humankind's exploration and exploitation of space resources. The trick, then, will be striking the right balance to promote investment in space mining without risking inactivity. Fortunately, commercial space miners are not totally unarmed in the legal arena.

Pre-existing rights

One of the benefits of the law is that it is a sword that cuts both ways: where there are obligations, there are also rights. The Space Competitiveness Act is no different. In seeking to give rise to a new stage in the space economy, it must also provide certain legal assurances that will invite investment. These rights will come from both national and international sources. Interestingly, most of the rights and protections afforded to space miners will come from domestic legislation. While other countries will also be looking to be hubs for emerging space activities like mining, investors may find that the US is still the most attractive "launching State" by virtue of its domestic laws.

Returning to the hypothetical scenario, the question is what would happen if a space mining company were to notify the US government that they had positively identified biotic material on a celestial body. It would not be beyond the imagination that the government would exercise its powers to preserve and protect the specimens for further discovery. It is also not beyond the imagination to think that the government would, understandably, wish to exercise control over the mining operation. What then are the space miners' rights?

National expropriation guidelines

It is a long-established custom that a government has the right to appropriate private property to "promote the general welfare of the people", a power known as 'eminent domain'.[39] Under the 5th Amendment of the US Constitution, the Federal Government may exercise the eminent domain but only where there is just compensation to the owner. This power is further hemmed in by the Due Process Clause of the 14th Amendment, which prohibits the government from taking private property without due process of law. While the US has a long history of honouring and protecting property rights, it also has a long history of expropriation, whether it be through the aligning of property sales, regulatory adjustments or even revolutions.[40] In truth, the purpose of the US regime is to avoid a situation where a private citizen may have to bear a public burden that should be borne by all.[41] This right of the government extends not only to real but also to private property.[42]

Eminent domain, or a taking, comes as either direct or indirect condemnation.[43] The former occurs when the government admits that it has made a taking while the latter is when the government has made a taking but denies that it is invoking eminent domain.[44] Inverse Condemnation can come in three forms: physical, regulatory or as an exaction.[45] As the first and last categories deal with real property, they are not applicable to space miners. However, a "regulatory" taking occurs when the value or usefulness of private property is essentially eliminated because of a government regulation, even without physical occupation.[46] In particular, this can occur when the regulation interferes with legitimate investor expectations.[47] For space miners, this means that should they discover something of significant importance, and should the government deem it necessary to suspend all activities in order to study the discovery, they could argue that the US government has committed either a direct condemnation or an indirect condemnation by way of taking and must, by law, compensate the space miners.

But what would be the compensation? That will likely depend upon the level of interference. For example, if a space mining probe were to discover an artefact from the Apollo lander on the Moon, the US government might require that the space mining probe retrieve the artefact, but for "just compensation" for the retrieval and transport of the object (which can be quantified). However, should a probe find bacteria on an asteroid (and be capable of detecting it), it is not beyond the realm of reason that the government might require the space mining activities to cease altogether for fear of harming any specimens. What then would be "just compensation"?

The Supreme Court has said that the purpose of the 5th Amendment is to make the offended party whole, usually by paying fair-market value or "what a willing buyer would pay in cash to a willing seller at the time".[48] Importantly, there are certain exceptions that the government does not have to pay for, including incidentals (relocation costs, cost of replacements), subjective losses (sentimental value) or future gains (or rather, the Government does not owe the offended owner any future profits once paid for).[49] Importantly, there are some federal and state statutes in the US that do offer, in some circumstances, compensation for incidentals, but these are the exception, not the rule.[50] Further, anticipated profits are not included in the calculation of "just compensation", only the value of property or a contract at the time of the taking. [51]

Where does this leave our space miners? Assuming the most protective (and costly) measures are taken in our hypothetical, all space mining activities are suspended by federal regulation in order to preserve any bacteria discovered on the asteroid. The US Government would, therefore, have to pay fair-market value for the equipment, though not for any anticipatory profits that might have come from the mining operation. What about incidentals? Will there be any compensation for the amount of time it will take to rebuild and re-launch another probe?

It should be recalled at this point that, if nothing else, existing Outer Space Law does support eminent domain in at least one case, and it applies to our artefact hypothetical. If a space mining company were to alert the US government that it had discovered, say, a Chinese probe, the US government would be under an obligation to alert China. China could then request that the space mining company either return or hold the object until the launching authorities could retrieve the object. If the Chinese were to request that the probe be returned, the costs would be borne by the Chinese Government. The space mining company would, therefore, be made whole.

Intellectual Property

While international intellectual property law has not yet developed, the US has built some protections into its legislation to encourage commercial activities in space: the Patents in Space Act of 1990. Typically, intellectual property and patent law is subject to territorial rules; this does not change just because the object is in space.[52] The Patents in Space Act states that any invention "made, used or sold" in space that was under US jurisdiction remains under US jurisdiction unless specified by an international agreement to which the US is a party.[53] This means that anything that would be governed by US patent law on Earth would still be subject thereto even if it has physically left the territory. And any US citizens who invented anything in space would be entitled to the full protections and remedies embodied in the US Code on Patents, including injunctions and damages.[54]

It is here that one can see interesting applications of legal concepts. Under 35 USC §101, both living and inanimate "things" can be patented, provided that they are not the product of nature but of human-made invention.[55] Even without the application of the Space Competitiveness Act, under US law, a party would not be able to put a patent on a newly discovered strand of bacteria or a mineral compound "created wholly by nature unassisted by man".[56] The exclusion of "biotic" material from the Space Competitiveness Act is, in fact, superfluous. However, what is capable of being patented is any invention or development that takes place in space. For example, if a space mining company were to discover a new mineral on an asteroid, they could not patent the mineral itself; however, if they were able to significantly change the physical properties of that mineral and create a wholly new material, both the process and the product could be protected under US patent law. While the space mining company might be obliged to share data with the rest of the world regarding the discovery of any naturally occurring phenomenon in space, its obligations would be limited by existing domestic patent protections.

Recommendations

Having surveyed both the Space Competitiveness Act and the major applicable legal frameworks, we can now better describe the parameters within which space mining activities will likely take place and what regulations will apply in the event that there is a major scientific discovery. What kinds of regulations could be put in place to ensure the goals espoused by the Space Competitiveness Act are reached?

Discovery of bacteria

The level of responsibilities and obligations on space miners in relation to the discovery of space bacteria will most likely depend entirely on the destination of the mining mission. In order to make sure that space miners are not over-burdened by technical requirements, it is highly probable that the US Government will adopt policies similar to those contained in the

NASA Planetary Protection Policy, not least of all because they comply with COSPAR recommendations and international law. This way, space mining missions bound for Category I destinations - namely those that are highly unlikely to have any type of biotic material on them, like asteroids - will not be burdened with the costs of contamination prevention. In this context, it is unlikely that space miners will be required to carry out any type of detection sensitive to the presence of bacteria. Should our space miners be on an asteroid, they would be under no obligation to even be testing for bacteria. However, if the mission were bound for Mars or another Category V body, it is highly likely that space miners would be required to include equipment capable of detecting life. If the mining regulations are in line with the current Planetary Protection Policies, these missions would also have to be continually supervised.

In this context, given that the space miners represent unique opportunities for the gathering of scientific data, it would be useful for a partnership to be developed between commercial space miners and NASA. For those missions bound for Category V bodies, the government could require the presence of a planetary protection officer, a requirement not inconsistent with current planetary exploration policies. This officer could also be in charge of collecting data to be transmitted to federal authorities. These authorities would then be responsible for determining what data will be forwarded to the international community, in compliance with international law. This information will, however, be limited by national interests such as export controls or national security concerns. This is not inconsistent with how exploration is carried out today.

If the space miners were to alert the government about the discovery of bacteria, then it is likely that the government would seek to preserve and observe the specimens to the best of their abilities. If this entails any interference with space mining activities, the company would be able to press the government for just compensation. However, it is unclear what this compensation would entail. Would it cover the cost of the space asset itself? Would the government rent the asset to conduct its own studies? Would it cover any incidentals such as the time it would take to launch a replacement mission? For the time being, this will not be of too much concern to companies like Planetary Resources and Moon Express, their missions largely take them to Category I bodies. However, should they opt to send probes to Mars, then it will be necessary to have these questions answered by Congress.

Discovery of a mineral compound

Under the Space Competitiveness Act, a US citizen can claim any space resource, including a new mineral compound. With guidance from instruments such as the Cultural Convention, such a discovery could be classified as being a part of the natural heritage of the US and, consequently, as being of universal value to the international community. However, the requirement to preserve such heritage, and the obligation to share information about such a discovery, is binding only on the federal government. The US government would have to enact regulations that require space miners to provide samples or data about their activities which the government could in turn transmit to the international community.

The US government would also have to provide guidance on what the space miners would have to do in the event of such a discovery because, under the Space Competitiveness Act, the space miners could claim the compound. Furthermore, without clear guidance, the space miners could conduct experiments on the compound in space and file for intellectual property rights over any new materials that might result from this work. The US Government would then be barred from transmitting sensitive information protected by intellectual property laws to the international community, as well as data prohibited by export controls or national security policies.

Discovery of an artefact

As mentioned above, ownership does not change just because an object has been launched into space. Likewise, there is no concept of abandonment, and so it does not matter how long an object has been in space, it still belongs to the party that left it behind. If a space mining operation were to discover an artefact, it would not be able to claim it, but it also would not be under any obligation, under current laws, to report their findings to any authority. Nor would they want to since, if they alerted the launching authority of the object, they could be obliged to return the object should they be asked. Even if the launching authority bears these costs, it could still prove to be of significant inconvenience to a space mining company, potentially even putting them at a competitive disadvantage.

In order to pass on the protections that were intended to be found in the Rescue Agreement to both US space mining companies and space actors from other States, the US should include in its licensing requirements regular reporting of space objects found in space. In this way, the US Government can both inform the relevant launching authority that its object has been found and it can ensure that any requests stemming from the launching authority are "practicable" for the space mining company. This policy would be in line with the aims of the Space Competitiveness Act by removing the possibility of harmful interference by way of enforcement of rights under the Rescue Agreement.

Conclusion

What happens then to the hypothetical asteroid probe, far away from Earth? Under current legislation, the investors of the probe are under no legal obligations to announce their discovery to anyone beyond the licensing authorities, which have also not yet been established. Since the asteroid is a Category I body, the US government will likely require very little data or information beyond basic technical details of their operation, but nothing currently requires that biological readings even be taken. However, once they have established that bacteria has been found, the space miners will likely be bound by domestic law to disclose this information to the US government. If they do not, they could be found liable for contravening far-reaching regulations such as NEPA. Once notified, should the government go on to interfere with the space mining operation, the investors will, at the very least, receive some type of compensation, though the extent of this is still unclear. The same would be the case if they found a new mineral compound or an artefact.

Looking over this result, one can see that mining activities will not, in fact, be so different from activities here on Earth. The US laws that exist are already largely capable of balancing the needs of investors with the rights of humankind in celestial bodies. However, in order to ensure that space miners know their limits and are able to plan accordingly, the US government should quickly seek to establish the following. First, the US government needs to authorise a regulatory body for the supervision of space mining operations. Second, the US government needs to incorporate contamination policies like those of COSPAR or the Planetary Protection Policy into its licensing framework, making sure to include NEPA requirements so that space mining companies can address all environmental issues in a single request. Third, the US government should include a notification requirement for findings of scientific value, including a provision that ensures space miners will only have to return space objects when it is "practicable". And finally, within those policies, the US government should provide some guidance on those situations that might call for government interference in an operation, particularly where specimens of scientific value might be discovered. By doing so, the government will afford space mining companies a chance to prepare themselves for the risk of uncovering monumental scientific evidence, whether it be through technical or financial planning. Providing this legally certainty will play a critical role in meeting the principal aims of the Space Competitiveness Act: namely to "facilitate a pro-growth environment for the developing commercial space industry by encouraging private sector investment and creating more stable and predictable regulatory conditions."

Yet perhaps the most important benefit that might result from adopting these recommendations might not have anything to do with outer space but, rather, with relations here on Earth. The Space Competitiveness Act has caused a tremendous stir around the world, partly because it signals an unsettling new era in human existence. Much like our ancestors, humans are gradually leaving familiar shores and heading off towards the unknown. This prospect makes many people uncomfortable, particularly those that cannot yet make such a journey. The US should seek to make commercial space mining activities as transparent as possible in order to further its case at the international level.

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Sustainability, Security and Article VI of the Outer Space Treaty

Charles Stotler

Introduction

In the 20^{th} century, the exploration and use of outer space were largely the provenance of a few governments and government-funded agencies. Today, these activities are carried out by an increasing number of emerging spacefaring nations and non-governmental actors.

The increase in actors in outer space has accompanied advancements in science and technology, such as the development of small satellites, mega constellations, on-orbit servicing, and new commercial launch services that are easing access to space and broadening the scope of space applications. The diversification and growth of new actors and new activities in outer space – particularly commercial actors – raises new concerns over the sustainability of outer space activities.[1]

Companies in the US are pushing the envelope in space applications. For instance, SpaceX announced plans to launch a constellation of more than 4,000 satellites into orbit.[2] Planetary Resources and Deep Space Industries are actively pursuing new applications, specifically the exploitation of outer space resources.[3]

Although the US currently is the epicenter of commercial space activities, the forces of globalisation are changing this landscape. Notwithstanding efforts of US launch companies to enforce a ban on the use of Indian launch services,[4] the Indian Space Research Organisation (ISRO) has been regularly launching payloads of US commercial satellite companies. In 2017, India announced plans to deploy 103 satellites, mostly commercial, on a single launch, thereby breaking Russia's 2014 record for the most satellites deployed in a single launch (39 satellites).[5]

In addition, an indigenous commercial space industry is developing in India. In 2016, India announced that Antrix, the commercial arm of ISRO, will handle the manufacture and operations of its Polar Satellite Launch Vehicle (PSLV).[6] New Delhi corporation Team Indus is a finalist in the Google Lunar X Prize.[7] Thus, India is also pushing the envelope in new commercial activities and space applications.

In tandem with these developments are ever blurring distinctions between defence and national security uses of space, on the one hand, and commercial uses on the other. Policies for the purchase of commercial space applications by defence and national security agencies, the hosting of military payloads on commercial satellite buses, the use of commercial technologies for space situational awareness, amongst other dual-use capabilities, have brought defence and national security communities closer to non-governmental actors carrying on activities in outer space. In many ways, sustainability and security are now inextricably linked.

Article VI of the Outer Space Treaty recognises the responsibility of States for non-governmental activities carried on in outer space and creates the obligations of authorisation and continuing supervision of such activities. Thus, Article VI sits at the heart of sustainability and security concerns raised by increasing non-governmental – particularly commercial – exploration, use and exploitation of outer space.

India has not implemented laws or regulations for commercial space activities.[8] As ISRO continues to launch commercial payloads and Indian commercial companies forge new paths in the exploration and use of outer space, India must consider enacting policies, laws and regulations to meet its obligations under Article VI.

The progressive development of Article VI

In the inaugural edition of the *Annals of Air and Space Law*, Eilene Galloway described the process for making new space treaties. She wrote:

> "The formula that has been followed is that of recognizing the 1967 Treaty on Outer Space as the major source of guiding principles, and when there is a consensus that any one or more of

> those principles do not seem to cover fully a given situation, then a new treaty may be drawn up in more detailed provisions."[9]

She notes that subsequent space treaties resulted from this process. The Rescue and Return Agreement is a progressive development of Article V of the Outer Space Treaty;[10] the Liability Convention, Article VII;[11] the Registration Convention, Article VIII;[12] and the Moon Agreement, *inter alia*, Articles I, II and IV.[13]

All of these agreements were negotiated under the auspices of the UN Committee on the Peaceful Uses of Outer Space (COPUOS) during what can be considered as the first phase in the progressive development of international space law. This phase was characterised by a rapid development in the body of treaties on outer space activities and culminated with the conclusion of negotiations over the 1979 Moon Agreement.

Notably, there has been little progressive development of Article VI through subsequent treaties.[14] Rather, the progressive development of Article VI has occurred mainly in two ways: the development of 'soft-laws' at the international level, and the implementation of international obligations at the domestic level. With regard to the former, COPUOS played an active role in the negotiation of many non-binding international instruments. These include UN General Assembly Resolutions,[15] as well as principles and guidelines.[16] This period can be thought of as a second phase of COPUOS, beginning approximately in 1980.

A third phase in the progressive development of space law appears to be emerging due to threats to sustainability and their overlaps with international security. To understand the significance of this transition, this article will consider the evolution of COPUOS.

Sustainability and security efforts in COPUOS

The Outer Space Treaty, particularly Article IV, addresses arms control.[17] The 1979 Moon Agreement strengthened these arms control provisions.[18] Both of these agreements were negotiated under the auspices of the COPUOS.

Indeed, the mandate of COPUOS, which includes the study of legal problems that may arise out of the exploration and use of outer space, is broad enough to address arms control in outer space.[19] That COPUOS would engage in such considerations, however, has been the subject of dispute. The establishment of fora dedicated to disarmament issues appears to have precipitated this dispute.

In 1978, the UN General Assembly adopted a resolution declaring that, "In order to prevent an arms race in outer space, further measures should be taken and appropriate international negotiations held in accordance with the spirit of the [Outer Space Treaty]."[20] In the same resolution, the General Assembly reestablished the Disarmament Commission with a mandate, *inter alia*, to "consider the elements of a comprehensive programme for disarmament to be submitted as recommendations to the General Assembly and, through it, to the negotiating body, the Committee on Disarmament."[21]

The Committee on Disarmament was established the following year in 1979 and was the predecessor to the Conference on Disarmament (CD).[22] The dispute over whether or not COPUOS is the appropriate forum for the negotiation of disarmament and arms control agreements for outer space likely began around the same time. The 35th session of COPUOS in 1980 appears to be the first time that an annual report of the Committee recorded disparate views exchanged by member States on the propriety of disarmament issues being addressed therein, with some delegations expressing the view that other bodies within the UN are more appropriate for such negotiations.[23]

The second UNISPACE in 1982 did not expressly recognise a role for COPUOS in preventing an arms race and hostilities in outer space.[24] It did, however, describe the prevention of these as "an essential condition for the promotion and continuation of international co-operation in the exploration and use of outer space for peaceful purposes."[25] In the same year, the Committee on Disarmament adopted a new agenda item on the Prevention of an Arms Race in Outer Space (PAROS).[26]

In 1984, COPUOS had on its agenda an item entitled, "Questions relating to the militarization of outer space."[27] That agenda item lasted only one year. In 1985, a new standing item on "Ways and means for maintaining outer space for peaceful purposes" was established.[28] This item has since remained on the agenda of COPUOS.[29]

Notwithstanding this long-standing agenda item, the notions took root that COPUOS deals exclusively with peaceful uses and the CD deals with issues of arms control and disarmament.[30] These notions were challenged by a 2013 report of a Group of Governmental Experts (GGE) on Transparency and Confidence Building Measures (TCBMs).[31]

The Report of the GGE on TCBMs

Concerns over sustainability and security manifested in calls in the UN General Assembly for TCBMs in outer space activities.[32] Pursuant to UN General Assembly Resolutions, the UN Secretary General twice convened GGEs on TCBMs in outer space activities.[33]

The 1993 GGE Report focused on the military uses of space and the dual-use nature of space assets.[34] The sustainability of outer space activities was not directly addressed. However, soft laws providing for the progressive development of Article VI, some of which directly affect the conduct of non-governmental actors in outer space, were identified as confidence-building measures.[35] This begs the question of whether COPUOS ever was not involved in security concerns.

This question was answered in 2013 when the most recent GGE issued a report making recommendations and reviewing current efforts to address sustainability and security through TCBMs.[36] The report tied an increase of actors in outer space to threats to international peace and security.[37] Moreover, the report recognised substantive discussions not only in the CD, but also in COPUOS, the International Telecommunications Union, and the World Meteorological Organization, as reflective of a transition in the political climate regarding outer space sustainability and security.[38]

The Report of the GGE went further, expressly invoking the Article VI obligations of authorisation and continuing supervision.[39] It stated:

> "With regard to maintaining international peace and security, it is clear that it is in the shared interest of all nations to act responsibly and in accordance with international law when carrying out outer space activities, in order to help to prevent mishaps, misperceptions and miscalculations."[40]

Thus, the increase of actors in outer space, including private commercial actors, raises issues of sustainability, which in turn, have been recognised as matters of international security by the GGE Report.

The effect has been a bolstering of COPUOS involvement in security issues. Specifically, the UN General Assembly agreed that COPUOS "should continue to consider the broader perspective of space security and associated matters that would be instrumental in ensuring the safe and responsible conduct of space activities…."[41] Moreover, in a series of resolutions, the General Assembly called upon all relevant entities within the UN system to coordinate on matters related to the recommendations of the GGE Report on TCBMs.[42] One of those recommendations called for coordination to be established between the Office of Outer Space Affairs (OOSA) and the Office for Disarmament Affairs (ODA) on matters related to TCBMs.[43]

Pursuant to this mandate, OOSA organised, in cooperation with ODA, a 2016 UN Workshop on Space Law.[44] The Workshop recognised that, "In order to avoid duplication of effort in the field of space security considerations, [OOSA] and [ODA] should continue coordinating efforts to promote the implementation of transparency and confidence-building measures in outer space activities."[45]

Thus, the third phase of COPUOS can be characterised as addressing not only sustainability but also security. Given the history of resistance to COPUOS addressing security issues, particularly arms control and disarmament, this is a somewhat radical development. The focus on sustainability, with its incumbent security aspects, has hampered the work of the Scientific and Technical Subcommittee in the development of Guidelines on the Long-Term Sustainability of Outer Space Activities (LTS Guidelines). At the same time, it also re-energised the work of the Legal Subcommittee (LSC).

New efforts at the progressive development of Article VI in COPUOS

In 2015, items on legal aspects of space traffic management and on the application of international law to small satellite activities were added to the agenda of the LSC.[46] Delegates to the LSC offered views on these items for the first time in 2016.[47] In addition, an item on potential legal models for activities in exploration, exploitation and utilisation of space resources was added to the LSC's agenda in 2016.[48]

Also in 2016, COPUOS adopted a first set of Guidelines on the Long-Term Sustainability of Outer Space Activities.[49] The formulation of the LTS Guidelines began in 2009, prior to the formation of the most recent GGE and the issuance of its report in 2013.[50] Development of the LTS Guidelines became contentious following the issuance of the GGE Report, with member States of the Working Group on LTS unable to agree upon some of the Guidelines.[51] An eleventh-hour compromise was reached at the end of the 2016 session of COPUOS to tentatively adopt a first set of LTS Guidelines and to extend the mandate of the Working Group on LTS by an additional two years to consider remaining guidelines upon which consensus could not be reached.

Guidelines 1 to 4 pertain to policies and national regulatory frameworks for space activities.[52] Notably, they invoke Article VI, stating that "States bear international responsibility for national activities in outer space and for the authorization and continuing supervision of such activities, which are to be carried out in conformity with applicable international law."[53] They recall other binding and non-binding instruments that affect the conduct of non-governmental actors in outer space.

Thus, upon acceptance by member States via UN General Assembly resolution, the LTS Guidelines will serve the progressive development of Article VI in the two ways identified in the introduction to this chapter. First, they will be a non-binding arrangement that further informs States as to their international responsibility for national activities. Second, they will further guide States in the implementation of authorisation and continuing supervision obligations.

Revisiting Article VI

Because Article VI is a key provision of the Outer Space Treaty for ensuring the long-term sustainability of outer space activities, and efforts at sustainability are now overlapping with efforts to bring about international security in outer space activities, it is an auspicious time to reexamine Article VI *vis-à-vis* provisions affecting non-governmental actors carrying on activities in outer space.

International Responsibility under Article VI

International responsibility for national activities in outer space is recognised by the opening clause of Article VI, which provides that, "State Parties to the Treaty shall bear international responsibility for national activities in outer space…." This part of the first sentence of Article VI does little more than reiterate what was already recognised by Article III, namely, that international law applies to the activities of States carried on in outer space.

Specifically, the first clause of the first sentence of Article VI recognises that the rules of State responsibility, as articulated in the draft Articles on Responsibility of States for Internationally Wrongful Acts (ARS), apply to national activities in outer space.[54] These secondary rules are "the general conditions under international law for the State to be considered responsible for wrongful actions or omissions, and the legal consequences which flow therefrom."[55] The ARS codified secondary rules that become relevant upon the breach of a primary rule.[56]

Given Article III, the international laws, which underpin State responsibility, would apply to national activities carried out in outer space with or without Article VI. What then is the gravamen of the first sentence of Article VI?

In order for responsibility to attach to a State, there must be a breach of an international obligation that is attributable or imputable to that State.[57]

> "[T]he general rule is that the only conduct attributed to the State at the international level is that of its organs of government, or of others who have acted under the direction, instigation or control of those organs, i.e., as agents of the State. As a corollary, the conduct of private persons is not as such attributable to the State."[58]

The second clause of the first sentence of Article VI, however, renders State Parties responsible for national activities in outer space, "whether such activities are carried on by governmental agencies or by non-governmental entities…." This is an exception to the general rule on attribution, in that the conduct of private entities is attributable to the State under Article VI.[59] Thus, the gravamen of the first sentence of Article VI is that activities of non-governmental entities are attributable to States Parties to the Outer Space Treaty.[60]

From the perspective of interpretation, Article VI presents a case of the *lex specialis* principle: "[I]f a matter is being regulated by a general standard as well as a more specific rule, then the latter should take precedence over the former."[61] The more specific rule in Article VI is an exception to the general rule of international responsibility regarding attribution.

Where a general international law is derogated by way of an exception, "…whatever is being 'set aside' will continue to have an effect on the interpretation and application of the exception."[62] The general rule remains in the background, influencing the interpretation of the special rule. Thus, even to the extent that Article VI presents a derogation of the general rules regarding attribution, it must be understood through the lens of the secondary rules of international responsibility.

The conditions under which conduct can be attributed to a State are determined by international law, rather than domestic law.[63] They are limited to a few specific situations identified in the jurisprudence of international tribunals as described in Articles 5 to 11 of the draft ASR.[64] Article VI effectively adds a new condition under which conduct can be attributed to a State.

According to Shaw, "The doctrine [of State responsibility] depends on the link that exists between the state and the person or persons actually committing the unlawful act or omission."[65] Article VI recognises a link between the State and national activities carried on by non-governmental entities. Thus, the additional condition under which conduct can be attributed to a State occurs where national activities are carried on by non-governmental entities in outer space.[66]

The impact of this exception from customary provisions regarding responsibility is profound. Article VI raises the spectre of a breach of international obligations by non-governmental actors, which may lead to reparations. These obligations include the authorisation and continuing supervision of non-governmental actors.

Authorisation and continuing supervision under Article VI

In addition to expanding the traditional scope of international responsibility to include the activities of non-governmental actors, Article VI creates the obligations of authorisation and continuing supervision of such activities. These are primary obligations, the breach of which could give rise to international responsibility under the secondary rules described above.[67]

Authorisation is fairly straightforward – the obligation has been implemented through domestic legal regimes that typically require a licence or permit prior to the conduct of space activities by a non-governmental entity.[68] Various interpretations have been put forth as to which State is the 'appropriate State Party' to authorise an activity.[69] Nevertheless, the obligation has been successfully implemented by many States.

The concept of 'continuing supervision' is less straightforward.[70] It raises questions of duration. For instance, how long must an activity be supervised? It also raises questions of the extent of supervision – how closely must activities be supervised? What would the obligation mean, for instance, where a change in circumstances causes a national activity to deviate significantly from the activity authorised?

A statement delivered on behalf of the US Department of State at the 11th Galloway Symposium described the US interpretation of the phrase 'continuing supervision'.[71] This was the first official statement on the Outer Space Treaty by a US State Department Legal Advisor in more than 30 years.[72]

In the statement, the Legal Adviser mused, "What does it mean for a State to supervise non-governmental activities in outer space? What space activities must States supervise?" His response was somewhat circular:

> "The meaning of the term "continuing supervision" in the second sentence of Article VI can be found in the first sentence, which creates the obligation to ensure conformity of all national activities, whether governmental or non-governmental, with the Treaty. The supervision required for any given activity will depend on the provisions of the Treaty it implicates. "Continuing supervision" means a legal link between government and operator sufficient to ensure the activity is carried out in conformity with the Treaty."[73]

It was further explained that under this interpretation, the US employs a fact-specific, two-part enquiry that examines, first, which provisions of the Outer Space Treaty are potentially implicated by the proposed activity, and second, whether the applicable governmental oversight arrangements are sufficient to ensure conformity with those provisions.

By way of example, two payload review requests were contrasted: one submitted in 2014 for a lunar habitat that would serve a wide range of functions over a 20-year lifespan; another submitted in 2016 for a lunar lander mission with limited scope and short duration, approximately two weeks.[74] Both missions, according to the US statement, raised issues with Article IX obligations to avoid harmful contamination and requirements to adopt measures for this purpose.

The 2014 application for a lunar habitat was denied. On the contrary, a launch licence was issued for the 2016 application.[75] The US explained this discrepancy as follows: Given the limited duration of the second mission and that company's commitment to adopt COSPAR's planetary protection guidelines,[76] the US State Department determined that a sufficient legal link existed to enforce compliance with Article IX, and that the issuance of a licence in this case would not contravene US obligations under the Outer Space Treaty.

The US interpretation of 'continuing supervision' and the two-part enquiry appear to be somewhat groundbreaking in State practice and *opino juris* relative to Article VI. In essence, the US is interpreting the phrase 'continuing supervision' to mean whatever act the US must take to fulfill its treaty obligations under Article VI. This definition is adequately broad to capture all US obligations arising under the Outer Space Treaty. Moreover, by focusing on particular provisions of the Outer Space Treaty that are brought to issue by the specific facts of each mission, it can be argued that the two-part enquiry is in keeping with methods for determining when a breach of a treaty obligation occurs.[77]

It can also be argued, however, that the first prong of the US two part test is too narrow. It seeks to know "which provisions of the Outer Space Treaty are potentially implicated by the proposed activity." Given Article III, the whole of international law – including customary international law, the Charter of the United Nations and other treaty obligations – will have to be examined to determine whether the US is in compliance with the Outer Space Treaty.

If the US narrowly interprets its obligations arising under Article VI as requiring an examination only of provisions of the Outer Space Treaty that create specific obligations (as opposed to the more general principles identified in other articles), it runs the risk of neglecting other obligations that might arise out of international law. India should pay attention to these considerations as it considers the implementation of continuous supervision obligations.

Conclusion

Article VI obligations of authorisation and continuing supervision require the implementation of international laws on the exploration and use of outer space. Authorisation and supervision entail the development of domestic laws, regulations and policies on outer space activities carried on by non-governmental entities.

Thus, Article VI serves as a lynchpin between international obligations and domestic laws, regulations and policies for the use and exploration of outer space. It tethers private, commercial actors to the international laws that govern the exploration and use of outer space.[78] As India continues to privatise commercial launch services and as new commercial actors in India continue to develop space applications, India must enact laws and regulations to meet its Article VI obligations.

State responsibility for non-governmental activities incentivises the progressive development of international law pertaining to outer space activities. This includes the creation of non-binding instruments.

It should go without saying that non-binding international instruments have profound effects on non-governmental, particularly commercial, space actors. One need look only to export controls for an illustration of this phenomenon.[79]

Non-binding instruments guide government agencies in the interpretation of international obligations and the proper adherence to international norms. Government agencies, in turn, affect the conduct of private actors by promulgating regulations, by supervising private actors, and by setting the terms of contracts for the purchase of goods and services from private actors. ISRO, as an agent of the Indian government, must consider non-binding legal norms as it privatises launch services and as it contracts with commercial providers of space applications.

Moreover, non-binding instruments have led to consensus on language that later was converted into binding legal agreements.[80] Thus, non-binding international instruments set trends that shape future law-making at the international level.

Thinking of non-binding instruments merely as 'soft law' diminishes their importance at both national and international levels. These instruments are negotiated and approved via consensus by agents from ministerial or executive departments of governments – often the same entities that make and approve policies at the domestic level. They are space policies created at the international level that indirectly affect the private, commercial uses of outer space.

As described at the beginning of this chapter, Eilene Galloway identified the process for making new space treaties: when there is a consensus that general principles embodied in the Outer Space Treaty no longer fully cover a given situation, then a new treaty may be drawn up elaborating those principles. Galloway also described the *raison d'être* for this process:

> "The texts of [the Rescue and Return Agreement, Liability Convention and Registration Convention] stem from provisions in the 1967 Treaty on Outer Space, elaborated to take care of more clearly perceived legal problems which might arise from the use and exploration of outer space."[81]

The LTS Guidelines and new agenda items on the LSC seek to elaborate more clearly the perceived problems that arise out of the increase in new actors and new activities in outer space. They do this because of concerns over sustainability, which has been identified as an issue of international security.

The statement by the US Department of State likewise addresses concerns over the increase in new actors and new activities in outer space and further elaborates the obligation of 'continuous supervision'. Interestingly, that statement also referenced an article by Myers McDougal and Leon Lipson published in 1958 in the *American Journal of International Law*.[82] Therein, McDougal and Lipson advocate a wait-and-see approach based on advancing technologies.

As legal problems with the exploration, use and exploitation of outer space become more clear, States should consider drafting a binding legal instrument that further elaborates the Article VI obligations of authorisation and continuing supervision. This proposition is in keeping with the theories of McDougal and Lipson, who also favored "a series of agreements, gradually arrived at, on particular subjects" and noted that some of these agreements may arise from "consensus achieved by the gradual accretion of custom from repeated instances of mutual toleration."[83]

Should non-binding international instruments and state practice lead to consensus that Article VI does not cover fully non-governmental activities in outer space, the time will be ripe for a new treaty. Regardless of whether or not States come to this conclusion, India should formulate laws and policies implementing its Article VI obligations.

Endnotes

1. As of 2013, more than 1000 operational satellites in orbit around the Earth were owned or operated by more than 60 States, government consortiums, universities, and private corporations. (See, "Group of Governmental Experts on Transparency and Confidence-Building Measures in Outer Space Activities," *Note by the UN Secretary General*, UNGA 68th Sess, UN Doc A/68/189* (29 July 2013)). As of mid-2016, that number exceeded 1400 operational satellites. (See, "USC Satellite Database" Union of Concerned Scientists (30 June 2016) online: http://www.ucsusa.org/nuclear-weapons/space-weapons/satellite-database#.WFmdylcxXzI). These numbers do not include space debris, of which there are approximately 17,729 objects being tracked. (See, Orbital Debris Quarterly News, NASA (July 2016) at 8, online: https://orbitaldebris.jsc.nasa.gov/quarterly-news/pdfs/odqnv20i3.pdf). Estimates of objects in orbit that are too small to be tracked range wildly but are on the order of 500,000 objects.
2. Avery Thompson, "SpaceX Wants to Launch Over 4,000 Satellites Into Orbit" Popular Mechanics (17 November 2016) online: http://www.popularmechanics.com/space/satellites/a23937/spacex-launch-4425-satellites/
3. See, respectively: Planetary Resources, online: http://www.planetaryresources.com/#home-intro; and Deep Space Industries, online: http://deepspaceindustries.com
4. Peter B. de Selding, "U.S. launch companies lobby to maintain ban on use of Indian rockets" Space News (29 March 2016) online: http://spacenews.com/u-s-space-transport-companies-lobby-to-maintain-ban-on-use-of-indian-rockets/
5. "Indian to launch 103 satellites in record single mission" Physics.org (4

January 2017) online: http://phys.org/news/2017-01-india-satellites-mission.html

6. Jeff Foust, "India to hand over PSLV operations to private sector" Space News (15 February 2016) online: http://spacenews.com/india-to-hand-over-pslv-operations-to-private-sector/

7. Caleb Henry, "CNES supplying cameras to Indian X Prize team, talks reusability with ISRO" Space News (10 January 2017) online: http://spacenews.com/cnes-supplying-cameras-to-indian-x-prize-team-talks-reusability-with-isro/

8. Paul Stephen Dempsey, "National Laws Governing Commercial Space Activities: Legislation, Regulation, & Enforcement" (2016) 36(1) Nw J Int'l L & Bus 1, 17 (fn. 74), 28, 42, 43.

9. Eilene Galloway, "Applicability of Space Treaties to the Uses of Outer Space" (1976) 1 Annals of Air and Space Law 205, 207.

10. *Agreement on the Rescue of Astronauts and the Return of Objects Launched in Outer Space* (opened for signature on 22 April 1968) 672 UNTS 119

11. *Convention on International Liability for Damage Caused by Space Objects*, (opened for signature on 29 March 1972) 961 UNTS 187

12. *Convention on Registration of Objects Launched into Outer Space* (opened for signature on 14 January 1975) 1023 UNTS 15; See also, *International co-operation in the peaceful uses of outer space*, UNGA Resolution 1721 (XVI) (20 December 1961).

13. *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies* (opened for signature on 11 July 1984) 1363 UNTS 3

14. Some scholars identify the Liability and Registration Conventions as developing Article VI. (See, e.g.: Ronald L. Spencer, Jr., "International Space Law: A Basis for National Regulation" in Ram Jakhu (ed.), *National Regulation of Space Activities* (London: Springer, 2010) 1, 12-21; *Accord*, I. Marboe & F. Hafner, "Brief Overview over National Authorization Mechanisms in Implementation of UN International Space Treaties" in Frans G. von der Dunk (ed.) *National Space Legislation in Europe* (Leiden: Martinus Nijhoff, 2011) 29, 31 at fn 9.) The preamble to the Registration Convention expressly recalls that States shall bear international responsibility for national activities in outer space. The Liability Convention does not. For reasons described in Part 3.1, *infra*, on the meaning of international responsibility under Article VI, it is posited that the Liability Convention does not serve to develop Article VI.

15. See, e.g.: *Application of the concept of the 'Launching State'*, UNGA Resolution 59/115, UN Doc A/Res/59/115 (10 December 2004); *Recommendations on enhancing the practice of States and international intergovernmental organizations*

in registering space objects, UNGA Resolution 62/101, UN Doc A/Res/62/101 (17 December 2007); *Recommendations on national legislation relevant to the peaceful exploration and use of outer space*, UNGA Resolution 68/74, UN Doc A/Res/68/74 (11 December 2013).

16. See, e.g.: *Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting*, UNGA Resolution 37/92 (10 December 1982); *Principles Relating to Remote Sensing of the Earth from Outer Space*, UNGA Resolution 41/65 (3 December 1986); *Principles Relevant to the Use of Nuclear Power Sources in Outer Space*, UNGA Resolution 47/68 (14 December 1992); "UN Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space" UN Office of Outer Space Affairs (2010) online: http://www.unoosa.org/pdf/publications/st_space_49E.pdf (Adopted by the UN General Assembly in 2007. See, *International cooperation in the peaceful uses of outer space*, UN General Assembly Resolution 62/217*, UN Doc A/Res/62/217* (22 December 2007)).

17. Statement by Ambassador Arthur J. Goldberg Before the Committee on Foreign Relations, U.S. Senate, on the Outer Space Treaty at 148 (U. Mississippi, National Center for Remote Sensing, Air and Space Law, online: http://www.spacelaw.olemiss.edu/library/space/US/Legislative/Congress/90/Senate/hearings/Outer%20Space%20Treaty%20Hearings.pdf (Stating at page 22: "This would be – article IV is the key provision of the treaty…. This is the arms control provision of the treaty.")

18. Moon Agreement, *supra*, note 13 at Article 3(2) (prohibiting "any threat or use of force or any other hostile act or threat of hostile act on the Moon"); See also, Peter Jankowitsch, "The background and history of space law" *in* Frans von der Dunk and Fabio Tronchetti, eds. *Handbook of Space Law* (Cheltenham, UK: Edward Elgar Publishing, Ltd., 2015) 1, 15.

19. *International co-operation in the peaceful uses of outer space*, UNGA Resolution 1472 (XIV) (12 December 1959).

20. Resolution Adopted on the Report of the Ad Hoc Committee of the Tenth Special Session, General Assembly – Tenth Special Session, UNGA Doc A/S-10/2 (30 June 1978) at para. 80

21. *Id.* at para. 118 (Stating, also, that the Disarmament Commission is the successor to a committee of the same name established under the U.N. Security Council by General Assembly Resolution A/Res/502(VI) of 1952.)

22. Jankowitsch, *supra*, note 18 at 18.

23. *Report of the Committee on the Peaceful Uses of Outer Space*, UN General

Assembly, Official Records of the 35th Sess., Supplement No. 20, UNGA Doc A/35/20 (1980) at para. 57.

24. The United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE) are a series of conferences of the heads of States, arranged by COPUOS pursuant to its mandate to continue with the scientific cooperative program established as the International Geophysical Year. (See, UNGA Resolution 1472 (XIV), *supra*, note 19). All UNISPACE have been held in Vienna: the first in 1968 (*Report of the Committee on the Peaceful Uses of Outer Space*, UN General Assembly Resolution A/7285 (1968)); the second UNISPACE82 fourteen years later (*Report of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space*, UN General Assembly Doc. A.CONF.101/10 (1982)); and UNISPACEIII in 1999 (*Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space*, UN General Assembly Doc. A/CONF.184/6 (1999)).

25. UNISPACE82 Report, *supra,* note 24 at para 14.

26. In 1981, the U.N. General Assembly adopted a resolution requesting the CD to take up the issue of PAROS (See, UNGA Doc. A/Res/A/36/97C (1981)). The following year, PAROS was inserted as an item on the agenda of the CD. (See: Fabio Tronchetti, "Developing a European-Chinese/Russian Approach to the Issue of Non Weaponization of Outer Space: A Feasible Goal?" 53 Proc. Int. Inst. Space L. 191, 195).

27. *Report of the Committee on the Peaceful Uses of Outer Space*, UNGA, Official Records of the 39th Sess., Supplement No. 20, UNGA Doc A/39/20 (1984).

28. *Report of the Committee on the Peaceful Uses of Outer Space*, UNGA, Official Records of the 40th Sess., Supplement No. 20, UNGA Doc A/40/20 (1985).

29. *Report of the Committee on the Peaceful Uses of Outer Space*, UNGA, Official Records of the 71th Sess., Supplement No. 20, UNGA Doc A/71/20 (2016).

30. See, e.g.: Jankowitsch, *supra*, note 18 at 18-19 (Stating, "[The Committee], while inhibited by its mandate from taking up matters of arms control in outer space and putting them on the agenda, thus became one of the main fora for the expression of international movements of concern on developments threatening the uses of outer space for peaceful purposes.")

31. 2013 GGE Report, *supra*, note 1.

32. *Prevention of arms race in outer space*, UN General Assembly Resolution 45/55A (4 December 1990); *Transparency and confidence-building measures in*

outer space activities, UN General Assembly Resolution 61/75, UN Doc A/Res/61/75 (6 December 2006); *Transparency and confidence-building measures in outer space activities*, UN General Assembly Resolution 62/43, UN Doc A/Res/62/43 (5 December 2007).

33. *Confidence-Building Measures in Outer Space*, UN General Assembly Resolution 45/55B (4 December 1990); *Transparency and confidence-building measures in outer space activities*, UN General Assembly Resolution 65/68, UN Doc A/Res/65/68 (8 December 2010).

34. "Study on the application of confidence-building measures in outer space" *Report by the Secretary-General,* UN Doc A/48/305 (15 October 1993).

35. *Id*. at paras. 78-80 (Discussing elements of the Direct Broadcasting, Remote Sensing and Nuclear Power Sources Principles as possessing aspects of confidence-building measures).

36. These efforts included the development of draft Guidelines on the Long-Terms Sustainability of Outer Space Activities by a Working Group of the Scientific and Technical Subcommittee of COPOUS, and a draft International Code of Conduct (ICOC) for Outer Space Activities by the European Union. (See, 2013 GGE Report, *supra*, note 1 at paras. 13, 16). Following several rounds of State consultations and several drafts of an ICOC, the EU convened multilateral 'negotiations' on an ICOC in July 2015. The meeting was hosted by the EU and the Office for Disarmament Affairs – the secretariat to the CD. Although the meeting was held at the UN headquarters in New York, it was not held under the auspices of the UN and therefore was not classified as a UN meeting. From the outset, States disagreed about the appropriate forum for the negotiation of an ICOC for outer space activities. Most States favoured either COPUOS or the CD, but some also recommended the First and Fourth Committees of the UN General Assembly. Most States expressed the view that an ICOC should address not only military but also civil and commercial uses of outer space. ("European Union convened Multilateral Negotiations on an International Code of Conduct for Outer Space Activities" *Chairs' Summary*, UN PaperSmart (27-31 July 2015) online: http://papersmart.unmeetings.org/secretariat/codeofconductfor outerspace/documents/ Because efforts at creating an ICOC have stalled, they will not be examined in this chapter. For a discussion of some substantive aspects of the EU's proposed ICOC, see Fabio Tronchetti, "Legal aspects of the military uses of outer space" *in* Frans von der Dunk and Fabio Tronchetti, eds. *Handbook of Space Law* (Cheltenham, UK: Edward Elgar Publishing, Ltd., 2015) 331, 379-381.

37. 2013 GGE Report, *supra*, note1 at para. 6 (Stating, "The result of the increase in space actors and space users is that the space environment, especially key Earth orbits, has become increasingly utilized over the

past few decades. As a consequence, the outer space environment is becoming increasingly congested, contested and competitive. In the context of international peace and security, there is growing concern that threats to vital space capabilities may increase during the next decade as a result of both natural and man-made hazards and the possible development of disruptive and destructive counterspace capabilities.")

38. *Id.* at para. 7.

39. *Id.* at para. 8 (Stating, "…States are ultimately responsible for the authorization and continuing supervision of all space activities under their jurisdiction.)

40. *Id.* at para. 9.

41. *International cooperation in the peaceful uses of outer space,* UNGA Resolution 70/82, UN Doc A/Res/70/82 (9 December 2015) at para. 13.

42. *Transparency and confidence-building measures in outer space activities*, UNGA Resolution 70/82, UN Doc A/Res/70/53 (7 December 2015); *Transparency and confidence-building measures in outer space activities*, UNGA Resolution 69/38, UN Doc A/Res/69/38 (2 December 2014); *Transparency and confidence-building measures in outer space activities*, UNGA Resolution 68/50, UN Doc A/Res/68/50 (5 December 2013).

43. 2013 GGE Report, *supra*, note 1 at para. 66; OOSA and ODA serve as the secretariats to COPUOS and CD, respectively.

44. "Contribution of space law and policy to space governance and space security in the twenty-first century" *Report on the United Nations Workshop on Space Law* UNGA Doc A/AC.105/1131.

45. *Id.* at para. 50(d).

46. *Report of the Legal Subcommittee on its fifty-fourth session*, UN Doc A/AC.105/1090 (30 April 2015).

47. 2016 COPUOS Report, *supra,* note 29.

48. *Report of the Legal Subcommittee on its fifty-fifth session*, UN Doc A/AC.105/1113 (27 April 2016).

49. 2016 COPUOS Report, *supra*, note 29 at Annex, 55.

50. For an overview of the formulation of the Long-tern Sustainability Guidelines and the set up of the Working Group, see: Christopher Johnson, "The UN COPUOS Guidelines on the Long-Term Sustainability of Outer Space Activities" Secure World Foundation (December 2014) online: https://swfound.org/media/189048/swf_un_copuos_lts_guidelines_fact_sheet_december_2014.pdf

51. 2013 GGE Report, *supra*, note 1 at para. 13 (Stating, "These guidelines will have characteristics similar to those of transparency and confidence-

building measures; some of them could be considered as potential transparency and confidence-building measures, while others could provide the technical basis for the implementation of certain transparency and confidence-building measures proposed by this Group of Governmental Experts.")

52. 2016 COPUOS Report, *supra*, note 1 at Annex, 56.
53. *Id.* at 58.
54. "Responsibility of States for internationally wrongful acts" UNGA Resolution 65/63, UN Doc A/Res/56/83 (2001) (The UN International Law Commission (ILC) finalized the text of the draft ARS in 2001. The UN General Assembly took note of the draft ARS and commended them to the attention of Governments during its Fifty-sixth session.)
55. The rules are described as 'secondary' in order to differentiate them from primary rules. For instance, Article IV of the Outer Space Treaty creates an obligation not to place in orbit around the Earth nuclear weapons or other kinds of weapons of mass destruction. A breach of Article IV would be an internationally wrongful act that gives rise to new international legal relations that are additional to those which existed before the breach. (See, *Commentaries to the draft Articles on Responsibility of States for internationally wrongful acts*, UNGA ILC, 53rd Sess, A/56/10/chp.IV.E.2/Sup.No.10 (2001) at 65).
56. Compensation owed under Article VII of the Outer Space Treaty and the Liability Convention should be differentiated from the duty to pay compensation that might arise arises out of Article VI and the secondary rules of State responsibility. (See, generally, Frans von der Dunk, "Liability Versus Responsibility in Space Law: Misconception or Misconstruction?" (1991) 34 Proc Colloq L of Outer Space 363.) The former is a primary obligation to provide compensation for the consequences of acts, which are not unlawful. (See, James Crawford & Ian Brownlie, *Brownlie's Principles of Public International Law*, 8th Edition (Oxford: Oxford University Press, 2012), stating at 561: "[T]he sole example unanimously accepted as creating a liability framework for an act that is completely lawful under international law is contained in the 1972 Liability Convention on International Liability for Damage Caused by Space Objects.")) The latter is a type of reparation sometimes owed as a consequence of an unlawful act, such as the breach of an international obligation. (Crawford & Brownlie at 567).
57. ARS, *supra*, note 54 at Article 2.
58. ARS Commentaries, *supra*, note 55 at 80-81.
59. Malcolm N. Shaw, *International Law* (7th Ed.) (Cambridge: Cambridge University Press, 2014) 572 (Stating, "The state is not responsible under

international law for all acts performed by its nationals. Since the state is responsible only for acts of its servants that are imputable or attributable to it, it become necessary to examine the concept of attribution. * * * Attribution is the legal fiction that which assimilates the actions or omissions of state officials to the state itself and which renders the state liable for damage resulting to the property or person of an alien."

60. Manfred Lachs, *The Law of Outer Space: An Experience in Contemporary Law-Making* (Leiden: Martinus Nijthoff, 1972) at 122 (Stating, "The acceptance of this principle removes all doubts concerning imputability….")

61. *Fragmentation of International Law: Difficulties Arising From the Diversification and Expansion of International Law*, UNGA ILC, 58th Sess, A/CN.4/L.682 (2006) [hereinafter, "ILC Fragmentation Report"] at 34-35.

62. *Id.* at 56.

63. ARS Commentaries, *supra*, note 55 at 82-83.

64. See, ARS Commentaries, *supra*, note 55 at 92-122.

65. Shaw, *supra*, note 59 at 81 (Stating, "The attribution of conduct to the State as a subject of international law is based on criteria determined by international law and not on the mere recognition of factual causality.")

66. Scholars have sought to clarify the meaning of the term 'national activities.' (See, e.g.: Bin Cheng, "Article VI of the 1967 Outer Space Treaty Revisited: 'International Responsibility', 'National Activities', and 'the appropriate State'" (1998) 26(1) J Space Law 7, 20-25; Francis Lyall and Paul Larsen, *Space Law: A Treatise* (Farnham, UK: Ashgate Publishing, Ltd., 2009) 57-58 (equating the term 'national activities' with 'national entities')). A general consensus appears to have crystalized around the notion that the term 'national activities' should be interpreted to mean those activities carried on from the territory of a State and those carried on by a State's nationals. (See, Michael Gerhard, "Article VI" in Stephan Hobe, *et al.* (eds.), *Cologne Commentary on Space Law, Vol.* 1 (Cologne: Wolters Kluwer Deutschland, 2009) 103, 113).

67. Cheng, *supra*, note 66 at 14 (Stating, "[F]ailure to subject non-governmental national space activities to authorization and continuing supervision would constitute an independent and separate cause of responsibility.")

68. For more on the implementation of Article VI, including examples of domestic legislation, see: Jakhu, *supra,* note 14; Dempsey, *supra*, note 8; Imgard Marboe, "National Space Law" *in* Frans von der Dunk and Fabio Tronchetti, eds. *Handbook of Space Law* (Cheltenham, UK: Edward Elgar Publishing, Ltd., 2015) 127.

69. Karl-Heinz Böckstiegel, "The Term 'Appropriate State' in International Space Law" (1994) 37 Proc Colloq L Outer Space 77 (Illustrating several interpretations of the term 'appropriate state', most of which support a definition that includes more than one State as appropriate under the terms of Article VI).

70. On state supervision generally, see, Ronald L. Spencer, Jr., "State Supervision of Space Activity" (2009) 63 Air Force L R 75.

71. Brian J. Egan, "The Next Fifty Years of the Outer Space Treaty" Statement of US Department of State delivered at the 11th Annual Galloway Symposium on Critical Issues in Space Law (7 December 2016), online: http://www.state.gov/s/l/releases/remarks/264963.htm [hereinafter, "Statement of the US State Department"]. Since the inauguration of Donald J. Trump on 20 January 2017, this statement has been removed from the US Department of State's website. It can still be found using the internet archive, Wayback Machine, online: https://web.archive.org/web/20170101155011/https://www.state.gov/s/l/releases/remarks/264963.htm

72. Marcia Smith, "State Department Legal Advisor: The Outer Space Treaty – 50 Years On" Space Policy Online (14 December 2016) online: http://www.spacepolicyonline.com/news/the-outer-space-treaty-50-years-on

73. Statement of the U.S. Department of State, *supra*, note 71.

74. A payload review is prerequisite for the issuance of a launch license by the FAA Office of Commercial Space Transportation. Payload reviews are required by U.S. statute (51 USC § 50904). Under U.S. Federal Regulations (14 CFR § 415.23), interagency consultations between the FAA, Departments of Defense and State and other Federal agencies, such as NASA, are required before a launch license will be issued. Under 14 CFR § 415.23, the Department of State must determine whether a license application presents any issues affecting foreign policy or international obligations.

75. On 20 July 2016, the FAA issued a favorable payload determination for the Moon Express MX-1E mission. See: "Fact Sheet – Moon Express Payload Review Determination" FAA Office of Commercial Space Transportation (Press Release, 3 August 2016) online: https://www.faa.gov/news/fact_sheets/news_story.cfm?newsId=20595

76. The Committee on Space Research (COSPAR), part of the International Council of Science, has formulated a Planetary Protection Policy that is implemented through national space agency policies and procedures, such as the NASA Policy Directive (NPD) 8020.7G: Biological Contamination Control for Outbound and Inbound Planetary Spacecraft and NASA Procedural Requirements (NPR) 8020.12D: Planetary

Protection Provisions for Robotic Extraterrestrial Missions. See: NASA, Office of Planetary Protection, online: https://planetaryprotection.nasa.gov/overview. The U.S. has not otherwise implemented planetary protection principles through statute or regulation. Thus, U.S. companies are not bound by planetary protection policies. However, Title VI of the 2015 US Commercial Space Launch Competitiveness Act (CSLCA), states: "The term 'space resource' means an abiotic resource in situ in outer space." (51 USC § 51301(2)(A)). That space resources can only be 'abiotic' implies that a determination as to whether biotic materials are present must be carried out prior to harvesting such resources. This definition may require the inclusion of planetary protection principles in future statutes and regulations implementing the CSLCA.

77. In addressing what constitutes the breach of an obligation that gives rise to international responsibility, Crawford and Brownlie caution that, "Legal issues, particularly in disputes between states, have an individuality which resists a facile application of general rules. Much depends on…the content of the relevant substantive rules or treaty provisions." Crawford & Brownlie, *supra*, note 56 at 559.

78. Gerhard, *supra*, note 66 at 105 (Explaining that Article VI resulted as a compromise between the United States and Soviet Union on non-governmental activities in outer space. The former envisioned private actors in outer space; the latter, that all activities in outer space would be carried out solely and exclusively by States.)

79. For descriptions of the International Code of Conduct against Ballistic Missile Proliferation (Hague Code of Conduct or HCOC), the Missile Technology Control Regime and Wassenaar Arrangement, see: Fabio Tronchetti, "Legal aspects of the military uses of outer space" *in* Frans von der Dunk and Fabio Tronchetti, eds. *Handbook of Space Law* (Cheltenham, UK: Edward Elgar Publishing, Ltd., 2015) 331 at 346-347 & 360-366.

80. See, e.g.: *Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space*, UN General Assembly Res. 1962 (XVIII) (13 December 1963); Stephan Hobe, "Historical Background" in Stephan Hobe, *et al.* (eds.), *Cologne Commentary on Space Law, Vol.* 1 (Cologne: Wolters Kluwer Deutschland, 2009) 12-13.

81. Galloway, *supra*, note 9 at 207.

82. Myers S. McDougal and Leon S. Lipson, "Perspectives for a Law of Outer Space" (1958) 52 Am J Int'l L 407.

83. *Id.* at 429-430.

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Space Security, Sustainability, and Global Governance: India-Japan Collaboration in Outer Space

Yasushi Horikawa

Introduction

Since the world's first satellite was launched in 1957, many countries have been involved in the development and utilisation of outer space. Space science and technology and their applications, such as satellite communications, Earth observation systems and satellite navigation technologies, provide indispensable tools for achieving viable long-term solutions for sustainable development. Active space development and its application can contribute effectively to promoting global development, improving people's lives, conserving natural resources, and enhancing preparedness for natural disasters and mitigating their impacts. Further, efforts are being made to address threats to space security, since the protection of the space environment is crucial to those applications. This paper addresses these issues in the context of India and Japan's partnership.

Sustainable Development

The benefits of space activities are of a global nature. There is no doubt that satellites provide significant and unique benefits to Earth's inhabitants. Space capabilities are utilised for the sake of the whole world, to develop repeatable measurements, revisit capability, long-time series of data, and nurture strong disaster preparedness. The benefits derived from these capabilities cannot be dismissed.

A tremendous increase in human activities in the last century has caused rapid reduction of fossil fuels, land productivity, and global forest coverage, and at the same time, a significant increase in freshwater consumption. Global warming has resulted in rising sea levels, glacial melt and icecap shrinkage, in turn, leading to changes in weather patterns. This has become a significant problem. Disasters continuously hit many parts of the world, repeatedly demonstrating the vulnerability of humans against the forces of nature and how important it is to build capacities to mitigate the devastating effects of disasters. Loss of life and property could be reduced if better information were available through improved risk assessment, early warning, and monitoring of disasters. In this regard, the integrated and coordinated use of space technologies and their applications can play a crucial role in supporting disaster management by providing accurate and timely information and communication support.

The imperative is to create a holistic approach to the various problems and make sound, long-term decisions for humanity. Sustainable development policies must be established based on accurate information about the Earth in order to gauge societal impacts. A timely and coordinated integration of the space-based technology applications of remote sensing, satellite telecommunication and global navigation satellite systems to multi-source geospatial datasets will provide some of key factors to resolve these difficulties. In addition, environmental change and effectiveness applied by various mitigation measures can be evaluated by those technologies.

The post-2015 global development agenda was adopted in September 2015 with the establishment of new Sustainable Development Goals (SDGs) at the United Nations General Assembly. These major goals argue for stronger space governance and supporting structures at all levels, including improved spatial data infrastructure. Accurate information will enable informed decisionmaking at all levels of society. Without space applications, it will be difficult to resolve these issues in a timely manner. Therefore, it might be useful to devise cooperation schemes that will foster the integration of such space-based services and products into the implementation of regional and national plans to achieve the sustainable development goals.

In this regard, there is a need to strengthen international collaboration and support for data sharing and access to geospatial information, which is expected to be useful to address climate change associated with global warming, carbon cycle, water cycle, as well as human health, food security relating to agriculture and fisheries, and natural disasters. More specifically, new projects to be carried out through regional cooperation efforts can advance the promotion of data utilisation and relevant scientific research. There are high expectations for India-Japan cooperation, in the context of either regional or bilateral cooperation—where both countries can bring their respective expertise and capabilities toward tackling common issues in the region and the world.

Space Governance

Various satellites are operated to serve for science and technology development and their applications, manned and unmanned space exploration, and security and military use. The limited nature of space resources will require some governance strategies to promote equitable access for all, while ensuring the efficient and effective use of space.

The UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) is the highest international forum for political, scientific, technical and legal debates connected with space. It is the exclusive platform in the area of peaceful uses of outer space, for negotiations, elaboration and promotion of important international treaties, agreements, UN resolutions and guidelines for all member states. For more than half a century now, UNCOPUOS has worked to resolve complex issues that have influenced space activities of many states around the world while simultaneously maintaining the principle of consensus in its decisionmaking process. UNCOPUOS has also been at the center of humankind's efforts to peacefully explore and utilise the outer space environment with the objective of bringing the benefits of space science and technology and their applications to contribute to the social development of all countries. In this connection, UNCOPUOS has been instrumental in the development of five UN treaties on outer space, with the Outer Space Treaty establishing the fundamental principles of international space law, and ten sets of legal principles and declarations on outer space activities.

There have been active discussions for several years in addressing the increasing involvement of private actors in the exploration and use of outer space. Ongoing are discussions on national legislation relevant to the peaceful exploration and use outer space. It will continue to be important to reflect and review the implementation of international obligations and the way in which States can best act and cooperate for the safe, peaceful and sustainable use of outer space, particularly in view of the increased private sector involvement.

During this author's term as UNCOPUOS chair, three key main ideas were proposed related to space research and utilisation in response to the 50th Anniversary of the UNCOPUOS in 2011: a) to promote the role of UNCOPUOS and its Subcommittees as a unique platform at the global level for international cooperation in space research and long-term space utilisation; b) to promote greater dialogue between UNCOPUOS and regional and inter-regional cooperation mechanisms in space activities for the benefit of global development; and c) to strengthen the relevance of space science and technology and their applications in meeting the outcomes of the UN Conference on Sustainable Development.

These should be pursued for a governance of space activities for future generations. In recent years, the number of space actors—including developing countries, private sectors and even universities—has been rapidly increasing. It is noteworthy that some space actors are not in compliance with the provisions of UN treaties as well as their registration and liability obligations. States should authorise and supervise their activities. Specifically, looking at the recent trend in space activities, small satellites for educational purposes that are rather cost-effective and easy to manufacture should not be encouraged unless they comply with the guidelines on space debris prevention. Further, a significant number of pico-satellites and chip-type satellites in planning should be carefully examined in light of the question related to the sustainability of outer space activities.

There is no doubt that dynamism of commercialisation and privatisation of outer space is becoming more prevalent across the world. Space activities are getting increasingly closer to people's daily lives and vitalising national economies. However, the international community must be more cautious since outer space activities—because of orbiting in space—are entirely different from those that are terrestrial. There should be a regulatory framework or controlled measures for outer space activities for collision avoidance. Technical and legal investigations must be launched in this regard.

UNISPACE+50 in 2018

The first UN Conference on the Exploration and Peaceful Uses of Outer Space or UNISPACE-I was held in Vienna in August 1968. This Conference served as an important platform for the exchange of information and consultation in the field of practical application of space technology, and as an impetus for considering the establishment of fellowship and technical assistance in support of national efforts to develop space activities, taking into account the needs of developing countries. The second such conference (UNISPACE-II) was held in Vienna in August 1982. This conference discussed the use of space science and technology and their applications for economic and social benefits as well as the development of international cooperative programs. Several other important issues were discussed, such as the allocation of the geostationary orbit, direct broadcasting by satellites, and remote sensing. The third conference (UNISPACE-III), held in Vienna in July 1999, expanded the notion of 'international cooperation' by looking into how space can help humankind in tackling global problems, from protecting the Earth's environment and managing its resources to using space applications for human security, development and welfare.

The year 2018 will mark the 50th year since UNISPACE-I, providing an excellent opportunity to review all the contributions of the three UNISPACE conferences to global space governance. It is also a timely opportunity to consider the current status and chart the future role of the UNCOPUOS at this present time when space actors, both governmental and non-governmental, are increasingly getting involved in ventures to explore space and carry out space activities. The planned anniversary event is being called UNISPACE+50.

The interrelationship between major spacefaring nations and emerging space nations as well as the dialogue between them relating to increased international cooperation and capacity-building efforts for the benefit of developing countries, have laid the groundwork for success over the years. The space agenda is evolving and becoming more complex, in particular, due to the broader concept of space security and the expanding commercial space sector. The development of international mechanisms such as guidelines, codes and other confidence-building measures are reflective of this new environment.

The SDGs have set targets for stronger space governance and supporting structures at all levels, including improved spatial data infrastructure. The outcomes or recommendations of the third UN World Conference on Disaster Risk Reduction, held in Sendai, Japan, in March 2015 and the 21st session of the Conference of the Parties to the UN Framework Convention on Climate Change conducted in 2016 will be incorporated in the discussion at UNISPACE +50 as well. The 2016 UNCOPUOS meeting decided that the following thematic priorities be considered toward UNISPACE + 50.

1. Global partnership in space exploration and innovation
2. Legal regime of outer space and global space governance: current and future perspectives
3. Enhanced information exchange on space objects and events
4. International framework for space weather services
5. Strengthened space cooperation for global health
6. International cooperation towards low-emission and resilient societies
7. Capacity-building for the 21st century

These themes should be seriously examined for effective use of outer space for future generations. Individual states, and non-governmental organisations such as the academia and private sectors are also expected to be involved in this activity.

Sustainability of Outer Space Activities

Current threats in the domain of outer space activities include orbital debris, radio frequency interference, and near-Earth objects or the collision with asteroids. Some of these threats are induced by humans. The factors which might aggravate the threats include spontaneous increase of space debris, technical difficulty of active space debris removal, lack of transparency and confidence building measures, different utilisation priorities and funding levels of space actors, and Anti-Satellite weapon or A-SAT testing. There has been a rapid rise in the number of space actors including new emerging countries and nongovernmental entities such as private sectors or universities. This increase cannot be avoided because the right to access to space, consistent with international law, is guaranteed to everyone. This principle exacerbates the threat to the sustainability of outer space activities.

The international community must study space security because the safe and sustainable environment of outer space is mandatory for those outer space activities that contribute to the sustainable development of human societies. It is obvious that by its very nature, the space environment is different from that of the ground and in airspace. The position of a space vehicle, for example, cannot be easily changed as its movement or orbital behaviour is strictly constrained to the orbit onto which it has been launched. Given the already congested space environment owing to the presence of many satellites, the space environment condition has deteriorated further because of the large number of space debris. Space utilisation for all space actors could soon become unnecessarily constrained unless the operations of all space vehicles and other space objects are well managed. Except for some specific missions that require the most advanced technologies or specific scientific research, small satellites and even larger Earth observations and communications satellites are not too difficult to manufacture as demonstrated by the development of spacecraft by governmental and non-governmental entities with varying levels of financial and technological resources. The operation of small and nanosatellites gives rise to matters that could be further explored and discussed, such as responsibility and liability under the legal regime on outer space.

The application of the concept of the launching State in national regulatory frameworks, registrations and notification measures and the continuing development of national regulatory frameworks as well as guidance to space actors should be understood. To implement a set of practical and prudent measures to enhance the long-term sustainability of space activities, a dedicated Working Group was established in 2010 within UNCOPUOS to address sustainable space utilisation supporting sustainable development on Earth, space debris, space weather, space operations, tools to support collaborative space situational awareness, regulatory regimes, and guidance for actors in the space arena. The establishment of this Working Group was a significant step with the objective of identifying and examining a wide range of issues and concerns related to the long-term sustainability of space activities. It was also tasked to prepare a consolidated set of practices and operating procedures and guidelines.

After six years of extensive efforts in coordinating and negotiating with participating states, the UNCOPUOS adopted 12 best practice guidelines in 2016, by consensus as required for UNCOPUOS decisionmaking. These best practice guidelines cover the following four fields: a) policy and regulatory framework for space activities; b) safety of space operations; c) international cooperation, capacity building and awareness; and d) scientific and technical research and development. This is a historic achievement from the viewpoint of reaching an international consensus at UNCOPUOS in spite of current circumstances – a growing number of participating States with different views and opinions does not easily allow UNCOPUOS to come to a consensus. The additional efforts will be continued towards UNISPACE+50 to achieve a set of consolidated guidelines which incorporate those not adopted in the 2016 meeting, and eventually draft a UN resolution.

In addition to the discussion on the UNCOPUOS Long Term Sustainability Working Group which is making efforts to establish voluntary-based Best Practice Guidelines, the International Code of Conduct (ICoC) for Outer Space Activities initiated by the European Union is also set to establish best practice guidelines through a voluntary but politically-binding instrument. The UN Group of Governmental Experts (GGE), whose members were selected by the UN Secretary General, issued a report in 2014. The discussions are all political, and a consensus seems hard to achieve. In this deliberation, all states are called upon to understand the criticality of safe, stable, secure and sustainable outer space activities, setting aside old political arguments. Bilateral and regional coordination and cooperation should be encouraged to foster mutual understanding.

International Cooperation

It is widely recognised that international cooperation, an indispensable principle from the very beginning of the space age, has garnered tremendous success in the exploration and use of outer space for peaceful purposes. In its early stage, international cooperation was unilateral, facilitating the transfer of expertise and technology from advanced spacefaring nations to emerging space actors. Over time, bilateral or multilateral cooperation has been promoted for mutual benefits and roles/missions sharing between or among the involved organisations or states, as successfully envisioned in the construction and operation of the International Space Station (ISS) Program.

Space utilisation activities should be conducted focusing on resolving the issues of humankind through international cooperation. International cooperation which pursues compatibility and inter-operability can also provide transparency to users. For example, in the field of application satellite, the continued utilisation of satellites for the improvement of people's daily lives is essential, in addition to technological advancement. These goals can be achieved through international cooperation.

Today, with an increasing number of space actors, the international community is provided with a worthy occasion to consider each other's future activities and roles. What is becoming increasingly important is to reassess the significance of international cooperation and its future perspectives based on the past and present situations of space research and utilisation for peaceful purposes. Further, recent cooperation calls for transparency and confidence building measures and demands to share viable information to achieve safe, stable, secured and sustainable space activities. Concrete steps should be taken to open the door for a new era of international cooperation and international harmonisation. Of course, conventional international cooperation as well as capacity building for developing countries must be continued to achieve significant benefits from space for the future. East-West or North-South cooperation and bilateral or multilateral cooperation must also be pursued. Ultimately, UN-level cooperation to secure space traffic management is also necessary to sustain future peaceful use of outer space, since outer space is a limited resource. In order to establish such a mechanism, bilateral and regional cooperation through regional platforms and forums like ASEAN and APRSAF should be exploited.

India-Japan Partnership

India and Japan have enjoyed a long history of cooperation in various arenas, from cultural exchanges to economic and science endeavours.

However, few significant collaborative projects have been realised so far in the area of outer space.

The Indian Space Research Organisation (ISRO) and Japan Aerospace Exploration Agency (JAXA) have been working together in the field of Earth observation for socio-economic benefits. A successful cooperation example that should be noted is cooperation for disaster prevention through the Sentinel Asia project under the framework of the Asia-Pacific Regional Space Agency Forum (APRSAF).

As of 2015, Japan has 189 registered space objects (satellites) while India has 66. Japan's space activities have a longer history than India's and yet, recent progress in India's space activities is remarkable, highlighted by the success of its Mars orbiter mission in 2015. Both India and Japan are pursuing similar space programmes such as launch vehicle development, Earth observation, communication and broadcasting, and navigation, similar to those of other advance spacefaring nations like US, Russia, European countries, and China.

Because of several setbacks in launch vehicle and satellite programmes during the early 2000's and a long-lasting deflation in its domestic economy, Japanese space programmes suffered stagnation. Further, natural disasters including the Great East Japan Earthquake followed by Tsunami in 2011, the Kumamoto Earthquake in 2016, and multiple floods in recent years had slowed the Japanese economy. Japanese policymakers have been hesitant to invest in space programmes given tight national budgets.

Even as that may be the case, Japan is undertaking numerous satellite development programmes for Earth observation and navigation to contribute to a better society. In particular, Japan is currently focusing on the following three fields: disaster risk management by utilising land observation satellites such as ALOS and its successor ALOS-2 as well as their follow-on satellites; water cycle and climate change through observation by Global Precipitation Measurement Mission (GPM) and Global Change Observation Mission (GCOM-W); and global warming monitoring by Greenhouse gas Observation Satellite (GOSAT) series. In addition, Japan is developing high accuracy global positioning, navigation, and timing system named as Quasi Zenith Satellite System (QZSS).

India has application satellite programmes similar to Japan's. The Indian Remote Sensing Satellites (IRS) including RISAT, CARTOSAT, RESOURCESAT and Indian Regional Navigation Satellite System (IRNSS) called GAGAN are proceeding well.

India's Prime Minister Narendra Modi and his Japanese counterpart, Shinzo Abe, held several discussions on various occasions such as mutual visits, ASEAN conferences, and COP-21 and discussed economic, scientific, technological, cultural, and security cooperation. These summit meetings have fostered intimate relations between the two countries. Both have significant potential to create future prosperity of the world and contribute to the realisation of sustainable development for humankind. Space programmes of both countries will be integral for such a future.

At the India-Japan Summit meeting convened in New Delhi in December 2015, the two nations jointly released the "India and Japan Vision 2025 Special Strategic and Global Partnership – Working Together for Peace and Prosperity of the Indo-Pacific region and the World" and acknowledged, in a Fact Sheet, the ongoing civil activities in space between JAXA and ISRO expecting enhanced cooperation in the areas such as Earth Observation, Satellite Navigation, Space Science and Planetary Exploration.

In 2017, Japan is scheduled to host the 2nd International Space Exploration Forum (ISEF-2) to coordinate future cooperation of in space exploration. This forum will provide not only the collaboration scheme on space exploration but also new framework of space activities among spacefaring nations. A strong leadership between India and Japan is highly desirable. As mentioned in UNISPACE+50, India and Japan have broad capacity to lead these themes and are expected to set up initiatives together.

Conclusion

Three aspects are key in the area of space for national prosperity and sustainable development for all humankind. First, space technology applications must be for users; second, space activities should vitalise industries; and third, space activities must be undertaken in a manner conducive for future generations' use as well. In order to promote these activities, it will be necessary to consider the following factors: making space activities an integral part of society at large, enhancing international cooperation at the regional and global levels, strengthening capacity for technology development, developing human resources, and securing resources.

Japan will further strive to enhance space development activities under the newly formed framework of the space strategy, focusing on technical innovation and international cooperation and providing effective solutions to society as a whole. The practical benefits of space technology applications today virtually touch every facet of human endeavour—extending over communication, navigation, meteorology, education, health, agriculture, resource management, environmental protection, and disaster management. To adapt to emerging and future challenges, the global community, in close coordination with each other, need to find effective solutions to current and emerging global problems.

As described in the aforementioned India and Japan Vision 2025 Special Strategic and Global Partnership, both nations have significant potential to lead and achieve future prosperity including through space activities. By gathering their expertise and wisdom, it is expected to raise the collaboration in space to a new level, thus contributing further to regional efforts in tackling global challenges including climate change and sustainable development. India-Japan collaboration will be crucial for the future.

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India and Global Space Governance: Need for A Pro-active Approach

Rajeswari Pillai Rajagopalan

Introduction

A domain that for a long time remained the monopoly of two or three big powers, outer space is today a crowded, congested and contested territory, with more than sixty players including non-state actors. The very nature of space programmes is also undergoing important changes. After decades of competition between the US and USSR, outer space has come to be dominated by peaceful and civilian uses. This, though, is beginning to change especially in Asia—and such shift is driven by a combination of factors including the growing space-based applications for social, developmental and security-driven utilities, as well as the changing global balance of power dynamics.

The next section deals with certain contextualising factors that have a bearing on the evolving global governance mechanisms.

Growth Trends

Outer space domain has undergone big shifts in the last decade. To begin with, the number of stakeholders has increased; the nature of activities has also changed drastically. Both these developments would indicate the crowding of outer space, making the question of its long-term sustainability even more challenging. Growing dependence on outer space, combined with potentially destabilising trends, call for renewed debates on space sustainability.

Contrary to popular perception, outer space is a limited commodity and it is the responsibility of every state to ensure that their activities are peaceful and do not harm the outer space environment. Secure and uninterrupted access to outer space had already been challenged by the spiraling competition witnessed in the earlier decades. Unless corrective steps are taken to address the growing number of challenges—including space debris, spectrum allocation, and radiofrequency interference—access to space in the future, especially for the emerging actors, will only prove to be more precarious. Even a marginal increase in activities by emerging space players compounds the problem. However, this process cannot be stemmed if one understands the demand and supply dynamics in this domain. On the supply side, growing prosperity and higher economic growth rates would allow for greater resources available for space programmes. On the demand side, there are multiple competitive pressures that come into play as states contemplate on their space programmes.

Do more states mean a spurt of regional space agencies? While regional space cooperation may gain traction in the Latin American and African context, Asia presents a different picture. Common socio-economic problems and limited resources have acted as push factors for regional cooperation. Such has been the story of regional mechanisms such as the African Union, and they have been a relative success. Asia's trajectory, on the other hand, has been different– the existence of two major cooperation organisations in the region is reflective of its divisive politics. Neither the Asia-Pacific Regional Space Agency Forum (APRSAF) under the leadership of Japan, nor the Asia-Pacific Space Cooperation Organization (APSCO) driven by China, provides a mechanism for these countries to interact with each other or coordinate their activities. The fundamental tenets of regional cooperation escape these organisations.

A third related question is whether increasing space activities and actors translates to greater private sector participation, which was previously a western phenomenon but is likely to happen in Asia. In India, too, the private sector has yet to play a big, independent role. But the growing presence of a mix of traditional, small- and medium-size enterprises along with NewSpace actors can challenge this phenomenon in the coming years.

The leadership of ISRO is beginning to acknowledge the role of private players in India's space story.

Irrespective of the logic, the growing number of space programmes will be accompanied by serious consequences. While the issue of spectrum allocation has not become serious yet, if the current trend continues, radio-frequency interference-like challenges will mount. As things are, states are already confronted with the overcrowding of satellites and debris, and its resultant access issues. There are also concerns that as space technologies spread, it will be more difficult to discern legitimate against illegitimate activities. States can gain access to space technologies for civil space cooperation but it is difficult to monitor to see if these are being diverted for military space programmes or to develop ballistic missile programmes. There are also fears of states deliberately attempting to damage or destroy satellites, and these could play out particularly during the eruption of conflicts. Lastly, the threat of inadvertent incidents and accidents cannot be ruled out in a crowded space.

The Need for Regulation

With growing dependence on outer space assets for a variety of applications, space exploitation has become inevitable. The growing trends in the form of more actors, new types of activities, access issues, point to the need for regulation of outer space activities. The spread of space technologies is a reality as many countries—particularly in the developing world in Africa, Asia and Latin America—are only now beginning to appreciate the utility of space for meeting their economic and developmental requirements. Even as this will likely spur both regional and international cooperation on outer space, the need for certain broad 'rules of the road' in outer space cooperation cannot be emphasised enough. Inter-state cooperation is always perceived as being beneficial to all sides but cooperation without proper multilateral rules can also pose dangers. The spread of technologies associated with outer space such as rocket launchers can potentially be converted into military space programmes, or worse, to developing long-range ballistic missile programmes. These scenarios call for regulation of cooperation in outer space. However, the emergence of new space actors and the shifting global balance of power dynamics have had a determining say in how outer space is governed globally.

What kind of mechanisms would work? Given the dual-use nature of space technology and its relevance in the context of civilian application, technology denial must be avoided, and thus, mechanisms akin to the Nuclear Non-Proliferation Treaty (NPT) are difficult to pursue in the outer space domain. Instead, the more applicable instruments may be the Chemical Weapons Convention or the Biological Weapons Convention. Outer space may be compared to the chemicals which have large-scale civilian application, due to which technology will spread. Therefore, mechanisms in this regard should consider regulations in terms of the use of technology rather than seek to control the spread of technology. Mechanisms could evolve to monitor how and if states are diverting civil space technology for military space programmes or for ballistic missile programmes although one must be mindful of the challenges of monitoring in this regard. Nevertheless, efforts must be made to frame rules for operations and activities rather than the control of technology.

Further, space traffic management is also becoming a serious issue. Space traffic management is defined as "the set of technical and regulatory provisions for promoting safe access into outer space, operations in outer space and return from outer space to Earth free from physical or radio-frequency interference."[1] With new types of space activities, new actors and technological innovations, safe and secure access to outer space is facing enormous challenges.

Given the increase in the activities, states and multilateral organisations are beginning to pay attention. Both the International Academy of Astronautics (IAA) and the European Space Agency (ESA) have been engaged in this exercise. Is the International Civil Aviation Organisation (ICAO) an appropriate model for a governing body to deal with the issue?

The next section details the current instruments in the area of global governance of outer space and gives an analysis of whether these serve the growing requirements in this domain.

Why Are Existing Mechanisms Insufficient?

In rhetoric, all the spacefaring powers endorse the need to keep outer space safe, secure and sustainable; in the real world, however, the gaps are yawning. There are rapidly advancing military space programmes, including anti-satellite (ASAT) capabilities which are inherently destabilising, and increasing space debris as well as a proliferation of small satellites including mini, micro and nano satellites which lead to congestion in outer space. Each of these needs to be addressed in a priority manner if there is to be uninterrupted and secure access to outer space for the future generations.

There is a body of treaties and regulations in place that regulate activities in outer space. These include the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (1967), Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (1967), Convention on International Liability for Damage Caused by Space Objects (1972), Convention on Registration of Objects Launched into Outer Space (1974), and Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (1979). These conventions have proven to be insufficient for a variety of reasons. While there are many challenges facing the outer space domain, the most significant is the state of the outer space regime. The lack of consensus among major spacefaring powers in identifying challenges to ideating possible solutions has become the biggest stumbling block in developing an effective outer space regime.

The Outer Space Treaty (OST) is the oldest and most comprehensive mechanism regulating outer space activities. While it prohibits states from placing weapons of mass destruction (WMD) in outer space, it leaves out a bigger challenge of conventional weapons in outer space. Another concern is that the OST was formulated in the 1960s and thus far removed from today's realities and challenges. Similarly, the Prevention of Arms Race in Outer Space (PAROS) is an important proposal for tackling the challenge of arms race in outer space. Despite the fact that there has been a resolution on PAROS passed in the UN General Assembly as far back as in 1981, a meaningful session on the treaty has yet to be held by the Conference on Disarmament (CD) in Geneva. This also reflects the larger problem faced within some of the UN institutions dealing with security and arms control. CD has been locked in a stalemate for more than two decades, with parties failing to arrive at a consensus even on the agenda.

Transparency and Confidence Building Measures (TCBMs) have gained traction in the last couple of decades owing to the state of the regime.

However, the lack of consensus among major powers has contributed to the slow development of space norms, and their disagreement on both current challenges and the way forward has made the formulation of legal regimes extremely challenging. Meanwhile, TCBMs suffice as intermediary measures between acknowledging the need for a mechanism and framing legal measures.[2] They are typically voluntary, non-legal measures that would enable better understanding, potentially reducing wariness, competition and rivalry. They also provide a solid base for establishing greater confidence between nations and help in mitigating inter-state political difficulties, which may be the biggest hurdles in developing an effective regime. TCBMs can also contribute to greater interactions and dialogue processes among states that could gradually lead to openness, transparency and information-sharing. Outer space TCBMs have begun to be acknowledged as critical components of the entire process for the sheer magnitude of challenges that potentially put access to outer space at risk.

Some of the prominent TCBMs in the recent years include the Group of Governmental Experts (GGE) and the International Code of Conduct (ICoC). These have their own share of advantages and disadvantages but considering the challenges, there is a need for all spacefaring powers to join hands in devising certain common standards of responsible behaviour that would avoid the pitfalls of arms race and additional debris-generation activities. GGE is a multilateral initiative under the United Nations and the effort is to develop consensus among the fifteen member countries. They have succeeded in doing so as some level of consensus within the GGE has been achieved. While this is positive, the GGE has come under criticism for its limited representation. The five permanent members of the UN Security Council are permanent members of the GGE, and the remaining 10 are selected on other criteria including geographical representation. India was not part of the last GGE on outer space because it was established at the same time as the GGE on cyberspace. As a non-UNSC member, India had to choose between the two; it chose to join the GGE on cyber space. Critics also point to GGE's recommendations not being binding and rather merely recommendatory. These recommendations, though, can gain some traction and possibly be carried forward if they are introduced as resolutions in the UN General Assembly, sponsored by the member countries.

The ICoC, meanwhile, has been another important step taken in the recent years to address and regulate activities in outer space. Initiated by the European Union, ICoC has run into trouble not so much for the provisions it contained but for the lack of an inclusive process, with the Code being prepared without prior consultation with all the spacefaring powers. The EU had expected to have it endorsed globally by all the major spacefaring powers before the end of 2012, but when it was introduced outside the European community, it was received with skepticism. To give the EU credit, it recognised the mistake and began to take corrective measures, holding regional meetings to understand the different perspectives and suggestions and how the Code could be taken forward. These regional outreach meetings and the three Open Ended Consultations – in Kiev in May 2013, Bangkok in November 2013, and in Luxembourg in May 2014 – were productive to a degree but the Ukraine crisis that erupted in 2013 damaged the consensus-building towards ICoC.

The Treaty on the Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force against Outer Space Objects (PPWT) is a draft treaty first proposed by Russia and China in 2008 and re-introduced with a new draft in June 2014, a couple of weeks after the EU ended its third Open-Ended Consultations in June 2014. This treaty seeks to bring about a ban on the weaponisation of outer space. The draft though is yet to gather the support of a majority of states owing to several factors including the fact that it was not verifiable.[3]

The 2014 text of the treaty was introduced with a new explanatory note that said, "We consider a legally binding ban on the placement of weapons in outer space as one of the most important instruments of strengthening global stability and equal and indivisible security for all." The draft treaty and the explanation are important objectives that must be pursued, but the treaty suffers from several loopholes that are not addressed in an appropriate fashion even in the 2014 text. One of the biggest gaps in the draft is the absence of any reference to ASAT weapons as well as the soft-kill weapons such as lasers that can be used to disable a satellite temporarily or on a permanent basis. These break-out weapons and technologies are particularly potent in the event of hostilities. One can be reasonably certain that no state is going to actually place weapons in outer space but the bigger challenge is the ASAT-like weapons that will be shot from the ground to damage and destroy another country's assets in outer space. Given the state of play in both the technological and geopolitical realms within Asia, this is particularly significant. Also, the over-emphasis on arms race in the PPWT is seen as problematic. Lastly, the PPWT makes no mention of space debris, which is already a huge live problem. Ecuador, for instance, lost its one and only satellite to space debris.

There have also been challenges with some of the existing institutions such as the Conference on Disarmament (CD) and the International Telecommunications Union (ITU). The performance of the CD, the "single multilateral disarmament negotiating forum for the international community", in the last two decades has been questionable. It has met for years without making any progress, not even arriving at an agreement on a Programme of Work. The last successfully negotiated instrument was the Chemical Weapons Convention in 1992. Even though the Comprehensive Test Ban Treaty was negotiated in 1996, and was adopted by the UN General Assembly, it is yet to enter into force. Even as a Programme of Work was agreed upon in 2009, the CD could not implement it.[4] Problems within the CD are only a reflection of the larger political difficulties that exist today among major powers. Efforts are being made to reinject political will and revitalise the CD. In one of its firsts, an Informal Civil Society Forum on the Conference on Disarmament was held in March 2015, with an objective of "generate[ing] ideas and inject[ing] different perspectives into the discussions on the agenda items of the Conference through informal interaction among States and civil society representatives."[5]

The ITU, for its part, have met with its own problems. For one, ITU failed to foresee the huge quantum of LEO activities (Low Earth Orbit) which calls for the institution of a separate mechanism altogether, perhaps via ITU that will manage the spectrum usage in an effective manner.

India and Global Governance

India has remained an active player in the global governance of outer space. India supported multilateral institutions including the UN Office of Outer Space Affairs (OOSA) and the UN Committee on the Peaceful Uses of Outer Space (COPUOS). Given the significant benefits to the social and economic development agenda, international collaboration was pursued right from the beginning with countries like the United States, France and Russia.[6] Pursuing this agenda of peaceful cooperation, UN OOSA organised three global Conferences on the Exploration and Peaceful Uses of Outer Space – the UNISPACE conferences of 1968, 1982 and 1999 – bringing together both states and multilateral organisations. The conferences, held in Vienna, provided a unique opportunity to further economic, social and scientific benefits of space research to all mankind. India utilised these platforms both for gaining know-how and expertise from other advanced space players and for sharing its own knowledge and skill-sets to other countries especially in the developing world. For example, in furthering the objectives of UNISPACE-2 conference, India initiated a training programme to share space technology applications to technical personnel from other developing countries.[7]

Marking the 50th anniversary of the first UNISPACE conference held in 1968, OOSA is organising UNISPACE+50 in 2018.[8] Despite the growing requirements on India's space programme, New Delhi has not been particularly active in either UNISPACE or COPUOS. However, UNISPACE+50 offers India a unique opportunity to share its expertise to advance international cooperation and promote its foreign policy objectives.

Though outer space was not immune to the Cold War competition between the US and the USSR, there was a clear acknowledgement even between them of the common challenges to space sustainability. This gave way to cooperation in the development of certain regimes, one of the first of which was the Outer Space Treaty (1967). The two countries had an inherent interest in controlling the spread of space technology and thus they managed to come together in writing certain rules of the road. But such treaty-making efforts have become more difficult in the last couple of decades.

From a security and arms control perspective, India has for long articulated the need for legally binding, verifiable measures governing outer space. Traditionally, at the CD, India had championed this cause while partnering with the Group of 21 countries (the non-aligned group of countries) articulating the need for a treaty-like mechanism banning the placement of weapons in outer space. Also, India has not been comfortable with political instruments that are merely political commitments and do not have binding effect on states. Questions such as punitive measures if states break their political commitments have remained a puzzle for India. Further, there is no certainty that a code or other TCBMs will bring about responsible behaviour on the part of states, though not being part of them or violating the commitments after signing on to them makes them more like a pariah state.

For close to a decade now, India's approach has become more pragmatic as it moved away from the moralistic and sovereignty-driven arguments it had adopted for the first several decades. As a corollary, India's own approach to TCBMs has evolved over the past few years. From an earlier paradigm that viewed TCBMs as good supplementary measures to legal regimes, New Delhi has begun to approach TCBMs with a more pragmatic sense to acknowledge that one might need to start with the least controversial and minimally acceptable set of measures such as Group of Governmental Experts (GGE) and International Code of Conduct for Outer Space Activities (ICoC). More importantly, these measures could provide the basis for greater understanding among states, which is a prerequisite to tackling political differences. Once the political issues are addressed and there is a greater sense of confidence among the states, one could make progress towards developing more binding agreements. Thus, while one may see some Indian insistence on legal measures, there is a greater sense of pragmatism to understand and acknowledge that it has to possibly start from a normative exercise and gradually move to legally binding measures.

As India's rise picks up pace, its approach to collective governance of global commons has also begun to change. India has shed its past apprehensions for a more pro-active approach wherein it looks to play the role of an active party shaping the debate along with other major spacefaring powers. India began to undertake this gradual shift in the face of more direct threats in the form of growing missiles and anti-satellite weapons in its own neighbourhood. The logic is quite clear – India has made significant investments in the outer space domain and thus, there is a material stake in the kind of rules that are being written. Also, India's desire to be part of the global governance mechanism as a solution provider and norm-shaper has driven India in this direction. The national security-driven approach, as against the moralistic drive, is far more sustainable both within the country as well as in the global governance circles.

And after several decades of lack of substantial activity on the global governance front, there is a sudden rush to institute new norms and regulations governing outer space activities. India's interests are also driven by the fact that it is one of the earliest space powers. Taking on the role of a norm-shaper has become an important character of this new approach. India also understands and appreciates the geopolitical value of its efforts in this normative exercise. Given the current state of play in the outer space domain, India should make efforts to develop all measures – treaties, TCBMs, norms of responsible behaviour, and code of conduct. Efforts must also be made to strengthen the existing instruments such as the OST, the UN-COPUOS, Conference on Disarmament and the GGE. Nevertheless, the major global space powers, including India, will have to recognise and address the political difficulties that have contributed to the crisis in decision-making in the global governance of outer space.

Endnotes

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8. UNISPACE+50 is being organised with three key objectives of identifying major contributions of the three UNISPACE conferences held so far, determining the future course for institutions such as COPUOS and its associated bodies like OOSA at a time when outer space domain has become so complex with increasing number of actors including non-state players and diverse set of space activities that are not entirely peaceful in nature, and lastly to beef up the efforts in developing an effective outer space regime. For details, see United Nations Office of Outer Space Affairs, "Fifty years of the first United Nations Conference on the Exploration and Peaceful Uses of Outer Space (1968 - 2018): UNISPACE+50," http://www.unoosa.org/oosa/en/ourwork/unispaceplus50/index.html

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With six decades of experience in exploring space for the benefit of its citizens, India has emerged as a major spacefaring nation with self-reliant capacity to undertake planetary and interplanetary missions. Having built up these capabilities while journeying through the most trying circumstances, India today stands at the crossroad: it can maximise its gains and build on its potential to build complex space missions. Several strategies are open for India's policymakers, both short-term and long-term, to expand the utilisation of space assets and increase the overall size of the country's space economy. This book addresses many of the prevalent policy issues in space and suggests measures to address them, from the varied perspectives of space commerce, space policy, space security, global governance, and international cooperation.

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