In collaboration with the

# Europe-India Space Cooperation: Policy, Legal and Business Perspectives from India

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# Foreword

As one of the first nations to foray into outer space, India's choice of tailoring the exploration of space to benefit its society led to several inventive solutions relying on space-based infrastructure to address socio-economic problems. The utility of satellites and rockets for social good is increasingly generating interest around the world. India stands as a role model for the international community to look up to for its ability to leverage space technology as a modern tool enhancing the welfare of citizens, the protection of nature and the quality of governance, as well as expanding the scientific horizon. India is a prime example of how developing countries' sustained investments in space technology can create a multidimensional scientific institution which can catalyse the local economy and pay long-term dividends.

The diversification of the Indian space programme into the exploration of the solar system and beyond, and the development of technologies for human exploration of the universe provide new pivots to enhance cooperation and share common objectives, particularly in complex high-technology space science and human spaceflight missions.

We in France have had a longstanding relationship with India in space activities over the last 50 years. The sheer number of agreements and activities over the past five decades is unparalleled and has made France one of India's most reliable and dependable partners in space. And our most recent agreements bode well for the future. The India-France Joint Vision for Space Cooperation has identified new avenues of cooperation in different areas including Earth observation satellites, space science missions, space situational awareness, human exploration, satellite navigation and space transportation systems. Our cooperation with India has evolved into one of the most mature international partnerships that France has with any spacefaring nation in the world.

I believe there is an increasing need for the space community to work together to provide tools to tackle global challenges such as climate change, which stand to disrupt the functioning of societies across the world as an impending threat to human survival itself. India's frugal innovation in space can provide inspiration and increased impetus to working together in tackling sustainable development problems in all societies around the world. India is also an important partner in addressing international issues of common importance including space security, safety and sustainability.

The European Space Policy Institute (ESPI) and Observer Research Foundation's (ORF) initiative to create a platform to take stock of developments in the Indian space programme and provide insights for policymakers in Europe to expand the scope of cooperation between the two sides is commendable. I believe that such discourse will provide national and international experts with highly relevant analyses in the context of future developments of space activities.

This report gives insights by providing a glimpse into the most recent developments in India's space programme. The chapters cover a broad range of topics including the roadmap of India's space missions, the emergence of local industry and NewSpace, space policy, space security, the status of cooperation with Europe, and cyber security applied to space. Each chapter delivers educated suggestions and opinions to policymakers, which can help them to review their approach and strategies on these issues in light of cooperation with India. Understanding expert opinions in these areas also provides holistic insights to emerging managers of space programmes and industry on the trends within India's space activities, and therefore highlights potential opportunities for collaboration.

This report will allow policymakers in Europe to reflect on important opinions from within India and help them review their position on the continuing discourse on varied subjects of cooperation with India. As always, there can be differences of opinion between the positions taken by the contributors to the report as well as the stakeholders in policymaking. However, the report as non-formal academic literature will hopefully drive the momentum towards a more cohesive and harmonious framework for cooperation in space activities between India and Europe.

Jean-Yves Le Gall

President of CNES

01 April 2019.

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# Introduction

By Marco Aliberti and Narayan Prasad*

## India in Space: An Evolving Endeavour

India has been an "early adopter" of space technology. However, its journey into space is unique in the sense of being conceived *from* the perspective of a developing country *to* meet the socio-economic needs of a developing country. Since the establishment of a space programme in the early 1960s, space activities have been understood as a very useful tool to address many of the societal issues faced by a huge and economically backward country. At the same time, India has successfully joined the club of spacefaring nations and is now in the process of establishing itself as a full-flagged space power with key independent technological capabilities across the whole spectrum of activities.

In its execution, India's application-driven and societal-oriented space programme has followed what Perumal dubs as a '*strategy of backward integration'*. Starting with "the demonstration of the efficacy of space application with borrowed satellites, it progressed through bought-out and indigenous satellites with procured launch services and finally building the indigenous launch capability"[1]. While this path has been marked by a slow pace of development that has lasted more than three decades, in the process, India has grown to become an influential space actor with a number of achievements to boast: an autonomous access to space with the Polar and Geosynchronous Satellite Launch Vehicles (PSLV and GSLV), the INSAT communication satellite system, the IRS remote sensing constellation, and more recently the IRNSS positioning and navigation satellite system as well as significant science and exploration missions such as the Chandrayaan-1 mission to the Moon and Mangalyaan probe to Mars, among others.

Besides its impressive achievements, since the mid-2000s, India´s space efforts have also seen a remarkable *acceleration*, with an almost vertical take-off in both the number of missions and the budgetary allocation of ISRO. Propelled by an ambitious roadmap of dozens of missions to be launched over the next few years and the target of tripling the launch frequency from the current 4-6 to 12-18 rockets annually the Indian space programme is now emerging as one of the fastest growing programmes in the world and gathering a swelling impetus in the level of ambition.

In addition to this acceleration, India's space programme is now undergoing an equally remarkable *diversification* in the scope of activities. Acceleration, after all, often entails not only a change in velocity but also in direction. While the vision enunciated by Vikram Sarabhai of harnessing space for national development has loomed large over Indian space policy over the past four decades, the changing internal and international environments have increasingly urged the subcontinent to depart from its narrow application-based and societal-oriented space programme and move towards a fully-fledged endeavour driven by a combination of factors that simultaneously span from societal development and economic growth to military security and diplomatic goals. A renewed strategic vision is hence unfolding at the nexus *societal utility, commerce, security* and *geopolitics.*

The utilitarian focus certainly remains the overarching paradigm of India's posture in space. In this context, many new efforts are being devoted to further the penetration and integration of space-based services in Indian economy and society. Through his meetings with the different user agencies, Prime Minister Modi has been a strong supporter of the utilisation of space applications as a model of "leapfrogging development". Besides the development of a plethora of applications bringing direct and quality-of-life benefits to large segments of India's society, India's space programme is being aptly leveraged as an enabler of economic expansion also in terms of macroeconomic production functions, particularly scientific and technological innovation as well

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1 Perumal, R. (2015). Evolution of the Geosynchronous Satellite Launch Vehicle. In P. M. Rao, From Fishing Hamlet to Red Planet. New Delhi: Harper Collins.

as industrial upgrading and creation of skilled workforce).

On the commercial and industrial side, private actors' involvement is gaining increasing traction. The currently unfolding privatisation trends in launch and satellite manufacturing (which range from the manufacturing of space assets or anything in between through "contractorship", to the private ownership and exploitation of said assets) are intended not only to fulfil the primary objective of meeting skyrocketing Indian demand faster and at a lower cost through commercial solutions, but also to contribute to the further development of Indian space capabilities and pave a lucrative path for Indian products and services in the global marketplace.

India has already demonstrated its capacity to capture a share of international commercial demand with competitive solutions. While the commercial space ecosystem continues to be centred on Antrix Corporation, the marketing arm of ISRO, India is also witnessing the emergence of a New Space dynamic, with many Indian astropreneurs kick-starting space ventures to provide innovative end-to-end solutions in both the upstream and downstream segments. Several analyses have opined that there is a large scope for these New Space companies to provide independent services and achieve economies of scale[2], particularly if considering such factors as India's burgeoning demand for space products and services, its huge and growing market size as well as its favourable market conditions (in terms, for instance, of low labour costs, talent pool, innovation competences and space technology know-how). In addition, new policy and legal developments are under way to create a more favourable environment for public-private partnerships and to enable entrepreneurship and development of private endeavours in the operational space activity of India.

Finally, on the strategic front, although the case for India's utilisation of outer space has always been on harnessing space technology for development, in recent years, space activities have gradually emerged as a central element in India's foreign policy and diplomacy[3]. The country, in addition, has dramatically increased its interest in the area of security- and defence-related space activities, thus bringing its programme in line with the rationales typical of the other major space powers[4]. Broadly speaking, this policy shift in India's policy posture has entailed four broad dimensions: the projection of soft power through national space efforts, the utilisation of space activities as a tool for pursuing India's foreign policy objectives, the overture towards military applications (mainly passive and to a lesser extent also offensive space capabilities) and an ongoing change in the institutional architecture to better address India's space-related security needs.

All in all, this unprecedented acceleration and unfolding diversification of India's space activities are bound to generate important consequences, not only internally but also internationally. On this latter side, these developments will most likely position India as an indispensable pillar in the future space governance as well as a prominent actor in the future global space economy. Surely Europe cannot afford to ignore a future behemoth…

## *ESPI Activities on Europe-India Space Cooperation*

Consistent with these evolutions, over the past three years ESPI has undertaken a number of activities revolving around the topic of Europe's space relations with India. Among the various undertakings, in February 2017 ESPI organised a workshop on the topic *"India in Space: The Forward Look to International Cooperation"* at the margins of the third day of the 54th Session of the Scientific and Technical Subcommittee of UNCOPUOS. The event, featuring the participation of representatives of ISRO, ESA and national space agencies, including CNES, DLR and ASI, reviewed the current status of India's international cooperation with key European players and shed a light on the growing engagement opportunities that are emerging at both government-to-government level and business-to-business level.

Since 2017, ESPI also started to partner with the Observer Research Foundation (ORF), within the framework of its Kalpana Chawla

2 See: Rao, M. K., Murthi, S. K., & RaJ, B. (2016). Indian Space - Towards a "National Ecosystem" for Future Space Activities. New Space, 4(4); Prasad, N. (2017). Space 2.0 India - Leapfrogging Indian Space Commerce. In N. Prasad, & R. P. Rajagopalan, Space India 2.0. Commerce, Policy, Security and Governance Perspectives. New Delhi: Observer Research Foundation; Prasad, N., & Basu, P. (2015). Space 2.0: Shaping India's Leap into the Final Frontier. New Delhi: Observer Research Foundation.

3 Prasad, N. (2016). Diversification of the Indian space programme in the past decade: Perspectives on implications and challenges. Space Policy, 36, 38-45.

4 Paracha, S. (2013). Military Dimensions of the Indian Space Program. Astropolitics: The International Journal of Space Politics and Policy, 11(3), 156-186; Moltz, J. C. (2012). Asia´s Space Race. National Motivations, Regional Rivalries, and International Risks. New York: Columbia University Press; Reddy, V. S. (2017). Exploring Space as an Instrument in India's Foreign Policy and Diplomacy. In R. P. Rajagopalan, & P. Narayan, Space India 2.0 Commerce, Policy, Security and Governance Perspectives (pp. 165-176). New Delhi.

Annual Space Policy Dialogue, a yearly event that to aims to bring together different stakeholders to discuss and debate various space-related issues pertaining to India. ESPI took part and supported this Dialogue in 2017, 2018 and 2019.

Furthermore, ESPI conducted a number of in-house analyses on the Indian space endeavour**,** including a research on the role of space in EU-India strategic partnership relations, a report on the growth potential of New Space in the sub-continent and, most notably, in-depth study entitled *"India in Space: between Utility and Geopolitics",* which was published by Springer in January 2018.

The book responded to a need of raising awareness among Europeans about the growing significance that this country is bound to play both in space and here on Earth and hence find ways to seize the too-often unleveraged cooperation potential. The overarching objective was to reflect on India's unique place in the realm of major spacefaring nations and to disentangle, from a wide range of perspectives, the country's evolving strategy and expanding rationales for engaging in space. Consistently, the book devoted much attention to understand the progressive diversification of the Indian space programme. The assessment was performed by embedding the country's space activities within the broader context of India's society, economy and politics and hence by assessing the domestic, regional and international factors influencing the pace and directions of the country's space activities. The book more specifically put the spotlight on the transition from the traditional uses of space as a tool of India's developmental and economic emersion strategy towards the emerging uses related to India's diplomatic and security objectives.

The study also provided an extensive analysis of India's path forward, including a reflection on the long-term evolution of its civil, military and commercial space efforts as well as an assessment of the international implications of these evolutions. A central part of this final analytical part was in particular devoted to elaborating on what the consequences and opportunities for Europe are to foster closer and mutually beneficial space cooperation with this country, both at the pan-European and individual nation level.

In fact, one of the major findings of the study is that the diversification of the Indian space programme is accruing a multitude of cooperation opportunities for Europe in all the three main form of policy dialogue, data & information exchange, and joint activities. Importantly, these opportunities are not simply open at the G2G level, but also at B2B, B2C levels.

However, the assessment of the current interplay between the two continents shows that there is still a large gap in grassroots level co-operation between the stakeholders in Europe and India. Whereas India's cooperation potential has been fully sized by a handful of European organisations, most notably CNES and EUMETSAT, it has been only partially leveraged by industry and largely missed at EU and ESA level.

To be sure, there are still some hurdles that prevent closer cooperation, particularly so from a regulatory and legal perspective, but it is clear that there is a large scope for overcoming them and for creating lasting ties among all stakeholders in both ecosystems.

In this context, the study identified four major fields that may be ripe for closer cooperation, namely scientific research, downstream applications, space exploration, including future human spaceflight activities, and security – both from and in space. Remarkably, these are domains a) can simultaneously involve multiple stakeholders (at both national and European level and at both institutional and commercial level) and b) respond to multiple drivers, i.e. political, programmatic, business drivers.

## *Objectives and Structure of the Report*

Building on the findings of this book, on the great interest expressed by both Indian and European stakeholders in ESPI activities, and with the goal of having a dedicated and thorough assessment of this engagement potential, in the second half of 2018 ESPI launched a follow-up study, the overarching aim of which is to provide a comprehensive framework for creating roadmaps for active engagement among actors on both Europe and India. As part of this follow-up project, in June 2018 ESPI organised a workshop at the margins of the Toulouse Space Show (TSS) which gathered several Indian stakeholders to discuss the potential of Europe-India space cooperation at both government-to-government and business-to-business level (see Annex 1 for an overview). Following this well-attended initiative, in September 2018, ESPI was invited to lead supplementary stakeholders' round-tables at the Bangalore Space Expo (BSS) and at the National Institute of Advanced Study (NIAS) in Bangalore.

These events, which featured the participation of representatives of public institutions and private companies from both India and Europe, served not only to draw attention on both sides about the potential win-win avenues for cooperation identified by ESPI, but also to gauge the views of Indian stakeholders and lay the basis for this follow-up study.

This research report is in fact primarily envisioned to complement ESPI in-house assessment of this engagement potential with perspectives from India. The overarching objective is to raise awareness for avenues of mutually beneficial space cooperation between India and Europe in space. The various contributions from Indian space experts contained in this ESPI study more specifically aim to:

- Review current status of engagement over space matters between Europe and India
- Investigate most recent space policies and programmes' development in India and assess how these developments may provide the two actors with opportunities to foster closer and mutually beneficial space cooperation.
- Identify opportunities of G2G engagement, research and academic engagement as well as industry engagement also in light of the industrial and entrepreneurial dynamics unfolding in both regions.

In addressing these objectives, the study will conduct a comprehensive exercise to comparatively map engagement opportunities by taking into account all verticals within the value chain, including space transportation and spacecraft manufacturing on the upstream segment and satellite communications (DTH, satellite broadband, etc), Earth observation, geospatial and PNT services for the downstream. Some of the insights that are to be covered under the study also include the analysis of the policy and regulatory frameworks, which prove crucial aspects to be tackled for unfolding the cooperation potential. A sound policy, legal and procedural framework is indeed quintessential for ensuring predictability, transparency, responsiveness, efficiency; in short for meeting the requirements of a fruitful collaboration, particularly from the perspective of G2B and B2B engagement. Consistently, among other aspects, the report will look at the Indian Tax code, at the Export Control, at the regulations on supervision, authorisation and liability, at the FDI and IPR and their effect on the ease of doing business in the upstream and downstream. The study, however, will also look at possible lessons for drafting the "Commercial Space Act in India", which could be modified to adopt some best practices from European stakeholders, at both EU level as well may be insights from specific Member States.

The report is comprised of 10 thematic chapters, each offering educated suggestions and analyses on matters relevant to Europe-India cooperation in space. The authors are experts from India with the most diverse professional profiles – from research analysts in leading Indian think tanks to space lawyers and astropreneurs – addressing the theme of Europe-India cooperation from the perspective of space policy, space law, space commerce and space security.

**Chapter 1**, by Narayan Prasad, Chief operations officer at Satsearch, reviews the most recent developments and trends in India's institutional space efforts. Particular attention is devoted to the area of space transportation, to the satellite programme and related applications as well as to recently announced forays of India in the area of manned space activities.

**Chapter 2**, by Vidya Sagar Reddy, a Research Analyst at Jane's by IHS Markit, provides a comprehensive overview of the state and potential of G2G cooperation between India and various European stakeholders, at both pan-European and individual national level. The chapter also offers key insights on the development of space industry in these countries with the objective of assessing the policy elements India could absorb from the European countries in developing a globally competitive space industry.

**Chapter 3**, by Ranjana Kaul, Partner at Dua Associates, complements the previous chapter with informed suggestions on how to best harness the opportunities offered by EU-India framework for space cooperation. The chapter in particular looks into the way India could take home some lessons from the EU's experience. It further offers some considerations for short term and long-term policy interventions to support the active participation of diverse users in the development of space products and services and maximise the opportunities embedded within the 2018 EU-India Cooperation Agreement.

Consistent with these suggestions, the following three chapters provides a thorough review of the legal and policy frameworks related to space activities in India and how these may encourage or encumber cooperation opportunities. More specifically **Chapter 4**, by Pushan Dwivedi, Associate at Ikigai Law, focuses on the legal framework relevant to the development of the upstream space industry in India. The author sheds light first on the obligations stemming from the international legal framework and then on the domestic provisions enacted under the Explosives Act of 1982 as well as the regulatory landscape proposed under the Draft Space Activities Bill of 2017, which is indicative of the growing importance attached to regulate private sector-led space initiatives in India.

Moving into the examination of the downstream regulatory framework, **Chapter 5**, by Kriti Trehan, (Partner at Panag and Babu Associates) puts the spotlight on satellite communication and internet access. The chapter more specifically assesses the opportunity for the satellite industry in India to effectively participate in these highly promising fields. In doing so, the paper analyses this opportunity from the lens of both the market and regulation. It finally provides some insight into potential means and methods, for interested members of the industry, of entering the Indian ecosystem and efficiently becoming part of this revolution.

**Chapter 6**, by Ashok Gubbi Venkateshmurthy, Partner at Factum Law provides a detailed analysis of the policy and legal framework for geospatial technology exploitation in India. The author sheds lights on the policy governing the launch and operation of remote sensing and earth observation satellites in India and reflects on some policy reforms that could potentially unleash the full potential of the remote sensing data industry.

The focus of **Chapter 7** lies on satellite navigation. In this chapter, Narayan Prasad, Chief operations officer at Satsearch, explores the historical context, the bottlenecks in the operationalization of and the strategies being used to catalyse the downstream adoption of India's indigenous navigation satellite system. The chapter also underpins some of the similarities in the challenges in the development and operationalisation of the navigation systems of India and Europe to provide a context for further cooperation between the two sides.

**Chapter 8**, by Rajeswari Pillai Rajagopalan, Distinguished Fellow and Head of the Nuclear & Space Policy Initiative at ORF discusses the security challenges driving India and Europe to join hands in the field of space security, the strengths and weaknesses of this partnership and a possible way forward for further strengthening this cooperation. In the concluding section, the chapter also identifies a set of key measures that could be taken by India and Europe to transform their shared interests and priorities into shared strategies and efforts in the area of space security.

**Chapter 9,** by Rajaram Nagappa, PM Soundar Rajan and Mrunalini Deshpande, scholars at the School of Conflict and Security Studies at the National Institute of Advanced Studies, discusses Europe-India cooperation in the realm of cyber security for space. The chapter provides key insights on cyber-threats and vulnerabilities, sheds light on the different approaches to cyber-security, of both space and terrestrial systems, and finally reviews Europe-India cooperation in this exceedingly relevant domain, offering key points for joint consideration and action.

Finally, **Chapter 10**, by Narayan Prasad, provides an assessment of the current outlook and future trajectory of the NewSpace ecosystem in India. The paper first maps this emerging commercial ecosystem and then reviews its weaknesses and strengths – also in relation to the traditional space industry – in order to disentangle its growth potential and implications at international level. The chapter, more specifically, demonstrates that there is an inherent growth potential for New Space in India and that such growth will provide multiple opportunities to nurture mutually beneficial B2B solutions between Indian and foreign space companies in a variety of fields.

It the hope of ESPI and ORF that the expert insights offered in each individual chapter will help draw a holistic overall picture of the engagement potential between the space efforts of Europe and India and bestow policy-makers of both regions with informed views to further strengthen their policy dialogue and cooperation in this exceedingly relevant domain.

# 1. Recent Developments and Trends in India's Space Missions and Industry

By Narayan Prasad*

India's space program has diversified over the past five decades from one that initially invested in establishing the foundation technologies and infrastructure to conduct space missions independently, to one that is able to explore interplanetary missions and human spaceflight. The Indian Space Research Organisation (ISRO) has been consistently supported by the policymakers in the country by providing sufficient budgetary allocations to establish such capacities. Figure 1 provides an overview of the evolution of the India's space missions and the budgetary allocations over the 10th to the 12th five-year plans (with the 12th corresponding to the years 2012 – 2017)[5]. 2019 is said to witness 32 space missions with 14 planned launches, making India one of the most active space nations in the world[6]. The aspiration of India's space programme is also edging towards grabbing a larger pie within the international space market with the commercial arm of ISRO, Antrix Corporation aiming to double its revenues by 2023[7]. With all these ambitions in place, ISRO is now looking to the local industry to help meet its targets and already taken steps in the direction of having the local industry assemble its satellites[8] and rockets[9]. In this article, we review the significant trends within India's space missions from the lens of the development of a holistic local ecosystem.

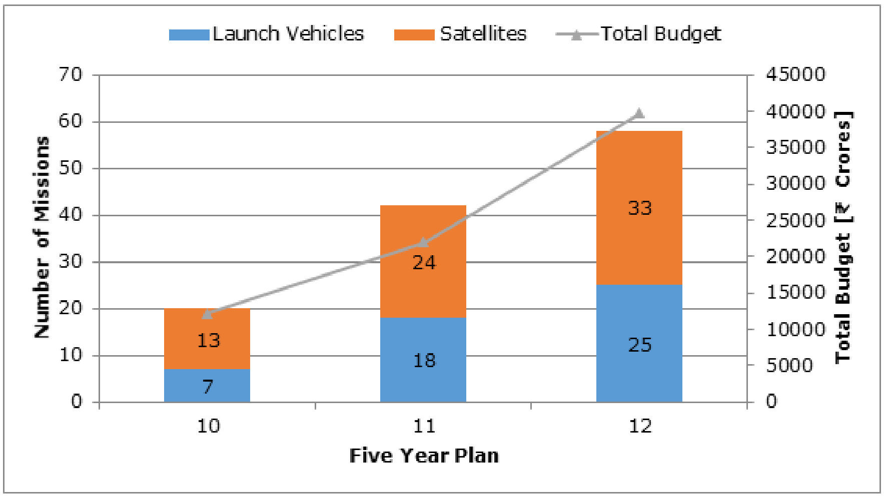


Figure 1: Evolution of the Indian space missions

* Narayan Prasad is a cofounder at satsearch and an Associate Research Fellow at the European Space Policy Institute (ESPI).
5 Nagendra, Narayan Prasad (2016). "Diversification of the Indian Space Programme in the Past Decade: Perspectives on Implications and Challenges". Space Policy, 36:38–45. Web. https://doi.org/10.1016/j.spacepol.2016.05.003.
6 Tejonmayam, U (2019). "ISRO's New Year Resolution: Launch 32 Missions, 14 from Sriharikota". The Weather Channel. Web. https://weather.com/en-IN/india/science/news/2019-01-01-isros-new-year-resolution-launch-32-missions-14-from-sriharikota.
7 Narasimhan,T. E. (2018) "We Aim to Double Our Revenue in next 5 Years: Isro's Antrix Corporation CMD", Business Standard India. Web. https://www.business-standard.com/article/current-affairs/we-aim-to-double-our-revenue-in-next-5-years-isro-s-antrix-corporation-cmd-118090900194_1.html.
8The Hindu (2018). "ISRO Ropes in Three Partners to Assemble 27 Satellites". Web. https://www.thehindu.com/news/national/isro-ropes-in-three-partners/article24454488.ece
9 PTI (2018). "ISRO Keen to Outsource PSLV, Small Satellite Launch Vehicle". The Economic Times. Web. https://economictimes.indiatimes.com/news/science/isro-keen-to-outsource-pslv-small-satellite-launch-vehicle/articleshow/65598362.cms.

## 1.1 Space Transportation

The traditional space transportation infrastructure of India was fundamentally architected to provide self-reliance to transport satellites to LEO and GEO orbits. These were served by the maturity of the Polar Satellite Launch Vehicle (PSLV) and the Geostationary Satellite Launch Vehicle (GSLV) programmes within ISRO. The PSLV not only turned out to be a reliable launch vehicle, but also now serves as one of the most versatile launch vehicles. In February 2017, ISRO successfully launched the highest number of satellites to be launched on a single launch vehicle with 104 satellites flown on a single PSLV of which 88 satellites were from the U.S.[10]. Earlier in 2016 the PSLV also demonstrated the ability to inject satellites into two separate orbits by re-ignition of the fourth stage[11]. A three-orbit mission is now being planned to be executed in March 2019 to further improve the versatility of the rocket[12]. The GSLV which initially had problems during its development phase[13], flew successfully for the first time in 2014[14] and has been slated to be used in India’s human spaceflight programme[15]. ISRO has been relying on the launches by Arianespace for its heavier satellites[16] but is now developing a semi-cryogenic engine that will be able to lift payloads of 5 tonnes to GEO to end reliance on foreign rockets[17]. In 2018, the Government of India has approved the development of 30 PSLV and 10 GSLV Mk III rockets with a total budget of ₹10,000 Crore (~€ 1.2 billion)[18]. With such volumes in requirement, ISRO plans to use a consortium of private sector actors who have been contributing to the production of the PSLV rockets to off load the production of the rockets to be able to focus on other areas of research and development[19].

ISRO is also working on keeping abreast with the global trends of development of reusable launch vehicles. In May 2016, ISRO conducted the first demonstration test of India's winged body aerospace vehicle with a solid rocket booster carrying the Reusable Launch Vehicle – Technology Demonstrator (RLV-TD) to a height 65km and then started its descent to successfully demonstrate the glided down to the defining landing spot over the Bay of Bengal. Through this test, ISRO was able to validate critical technologies such as autonomous navigation, guidance and control, reusable thermal protection system and re-entry mission management have been successfully[20]. ISRO is planning to conduct its second RLV test in 2019 where a helicopter will lift the RLV to a height of 3 km and drop the RLV to test the glide and land on an airstrip[21]. Post this stage, ISRO plans to carry out an orbital re-entry experiment and latest reports suggest that the site for the experiment and configuring landing runway with navigational aids for an autonomous descent has been identified[22]. Apart from the space shuttle like configuration

10 The Hindu (2017). "ISRO Launches 104 Satellites in One Go, Creates History". Web. https://www.thehindu.com/news/national/ISRO-launches-104-satellites-in-one-go-creates-history/article17305373.ece.

11 Punit, Itika Sharma(2016). "ISRO Pulls off an Unusual Challenge—Launches 8 Satellites into Different Orbits’, Quartz India. Web. https://qz.com/india/790928/isro-pulls-off-an-unusual-challenge-using-the-pslv-launches-8-satellites-into-different-orbits/.

12 Prasanna, Laxmi (2019). "ISRO Set for First Three-Orbit Mission of PSLV-C45 on March 14". The Times of India, p. 14. Web.https://timesofindia.indiatimes.com/india/isro-set-for-first-three-orbit-mission-of-pslv-c45-on-march-14/articleshow/68016364.cms.

13 Singh, Surendra (2017). "GSLV Mk III Breaks Isro’s Jinx of Failure in Debut Rocket Launches". The Times of India. Web. https://timesofindia.indiatimes.com/india/gslv-mk-iii-breaks-isros-jinx-of-failure-in-debut-launches/articleshow/59008331.cms.

14 ET Bureau (2018). "GSLV-Mk3 Take-off Clears Way for Human Spaceflight". The Economic Times. Web. https://economictimes.indiatimes.com/news/science/gslv-mk3-take-off-clears-way-for-human-spaceflight/articleshow/66629308.cms.

15 Bansal, Aanchal (2018). "India’s First Manned Space Mission, Gaganyaan, to Send Three Persons for 5-7 Days". The Economic Times. Web.https://economictimes.indiatimes.com/news/science/indias-first-manned-space-mission-to-send-3-persons/articleshow/65576098.cms.

16 Tech2 (2018). "ISRO GSAT-11 Successfully Launched: Ariane-5 Rocket Lifts India’s Heaviest Communication Satellite into Orbit”. Web. https://www.firstpost.com/tech/science/isros-gsat-11-launch-ariane-5-rocket-to-lift-indias-heaviest-communication-satellite-to-orbit-on-5-dec-5670811.html.

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18 ET Bureau (2018). "Government Approves Rs 10,000-Crore Continuation Programmes for PSLV, GSLV". The Economic Times. Web. https://economictimes.indiatimes.com/news/science/government-approves-rs-10000-crore-continuation-programmes-for-pslv-gslv/articleshow/64483323.cms.

19 The Financial Express (2018). "With PSLV-Funding Requirement, Govt Encouraging Larger Private Sector Role in Space-Tech". The Financial Express. Web. https://www.financialexpress.com/opinion/with-pslv-funding-requirement-govt-encouraging-larger-private-sector-role-in-space-tech/1199265/.

20 Mehta, Nikita (2016). "Isro Carries out Successful Demo of Reusable Space Launch Vehicle". Web. https://www.livemint.com/Politics/6FqSLGv9y5ccXoAjcB5GpK/Isro-carries-out-successful-test-demo-of-its-own-reusable-la.html.

21 Singh, Surendra (2018). "Manned Mission: Isro to Hold 2nd Test of Reusable Launch Vehicle next Year". The Times of India. Web. https://timesofindia.indiatimes.com/india/manned-mission-isro-to-hold-2nd-test-of-reusable-launch-vehicle-next-year/articleshow/65377953.cms.

22 Kumar, Chethan (2018)."Isro Plans Orbital Re-Entry Test for Re-Usable Vehicle". *The Times of India*. Web. https://timesofindia.indiatimes.com/india/isro-plans-orbital-re-entry-test-for-re-usable-vehicle/articleshow/63863869.cms.

of reusable rockets, ISRO is also working on a two-stage launch vehicle called ADMIRE whose first stage will be recoverable after launch in similar fashion to the first stage of SpaceX's Falcon 9 rocket[23]. ISRO has also successfully demonstrated scramjet engine in August 2016[24] and now has the potential to experiment the integration of the engine into RLVs[25].

Space transportation is arguably the biggest part of the value chain that India has found international commercial traction in the recent years. Out of a total of 237 foreign satellites launched in nearly 25 years since 1993, as many as 202 foreign satellites were launched by ISRO between 2014 and 2018, earning amounts to over 22 million USD and 159 million Euros[26]. Most of these satellites being small satellites, ISRO has ventured into developing a new rocket called the Small Satellite Launch Vehicle (SSLV) with a payload capacity of 500-700 kg in Low Earth Orbit (LEO) to target this market[27]. The difference between the ISRO approach and several of the commercial small satellite launch vehicle innovators is that ISRO is not looking into developing any new technologies such as additive manufacturing, complete liquid fuel rockets, etc., to serve the small satellite market. Several of the small satellite innovators have taken several years in maturing their technology while ISRO is likely to use its legacy technology and has a roadmap to fly the first SSLV as early as July 2019[28]. The Department of Space has also floated a new public company called Newspace India Limited which will look to commercially exploit the technology transfer of SSLV, PSLV programmes[29].

## 1.2 Satellite Programme

India's satellite programme for 25 years since 1980 focused primarily focused on remote sensing through the Indian Remote Sensing (IRS) and communications through the Indian National Satellite System (INSAT) themes. Within the IRS, several thematic applications of remote sensing and Earth Observation (EO) have evolved over the past four decades with Oceansat, Resourcesat. Cartosat, Radar Imaging Satellite (RISAT) series of satellites. Similarly, the INSAT/GSAT satellites that were supporting both meteorology and communications applications have been systematically been upgraded to provide a diverse range of services in weather, telemedicine, connectivity for education, etc. Both the IRS and the INSAT series for satellites have been seeing systematic upgrades to the capabilities of the spacecraft such as increasing the resolution to 0.25cm in the cartosat series of satellites, adding geo-based imaging in thermal bands[30], and diversifying into areas such as providing broadband internet based on GEO satellites[31]. Within the remote sensing framework, the most noted missions conducted through international cooperation are the joint Indo-French satellites Megha-Tropiques and SARAL launched by the PSLV-C18 in 2011 and PSLV-C20 in 2013 respectively[32]. The Indo-French missions is set to continue with a planned a land infrared monitoring satellite called Trishna and the integration of the French Argos into Oceansat-3[33]. India is also advancing its cooperation with the U.S. with the first joint satellite mission called NASA-ISRO Synthetic Aperture Radar (NISAR), a dual frequency (L & S Band) radar imaging satellite to be

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[24] The Indian Express (2016). "We're the Fourth Nation to Conduct Scramjet Engine Test: ISRO Chief". *The Indian Express*. Web. https://indianexpress.com/article/technology/science/isro-successfully-test-launches-scramjet-engine-from-sriharikota-3000016/.

[25] Subramanian, T.S. (2016). "Scramjet Success". *Frontline*. Web. https://frontline.thehindu.com/science-and-technology/scramjet-success/article9153834.ece.

[26] State Times (2018). "ISRO Launched 202 'Foreign' Satellites in Four Years: Jitendra". *State Times.* Web. http://news.statetimes.in/isro-launched-202-foreign-satellites-in-four-years-jitendra/.

[27] PTI (2018). "SSLV Will Offer Cost-Effective Satellite Launch Options in India: Antrix CMD". *The Economic Times.* Web. https://economictimes.indiatimes.com/news/science/sslv-will-offer-cost-effective-satellite-launch-options-in-india-antrix-cmd/articleshow/65740378.cms.

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[30] Datta, Anusuya (2018). "What Are the Forthcoming Satellite Launches from ISRO?". *Geospatial World.* Web. https://www.geospatialworld.net/blogs/forthcoming-satellites-isro/.

[31] Singh, Surendra (2018). "4 New Satellites to Provide Fast Internet Speed by 2019: Isro Chief". *The Times of India*. Web. https://timesofindia.indiatimes.com/india/4-new-satellites-to-provide-fast-internet-speed-by-2019-isro-chief/articleshow/65925030.cms.

[32] ISRO (2019) "India and France Jointly Released a Set of Two Commemorative Postage Stamps, Highlighting 50 Years of Space Co-Operation between the Two Countries". *Indian Space Research Organisation.* Web. https://www.isro.gov.in/india-and-france-jointly-released-set-of-two-commemorative-postage-stamps-highlighting-50-years-of.

[33] Datta, Anusuya (2018). "India France Collaboration on Satellite Technology to Tackle Climate Change". *Geospatial World*. Web. https://www.geospatialworld.net/blogs/india-france-collaboration-on-satellite-technology/.

launched in 2021[34]. The most recent comprehensive programme taken up by ISRO post 2006 is the development of India's dedicated navigation satellite system called Indian Regional Navigation Satellite System (IRNSS) or Navigation with Indian Constellation (NavIC). The IRS, INSAT and the IRNSS with assets in LEO, GEO and MEO now forms the core satellite infrastructure to deliver services that cater to the socio-economic needs of the country. Clearly the exploration of international cooperation via joint satellite missions within these long term programmes have been limited to the IRS theme and there is tremendous scope to explore development of technology which can better equip the responses to major challenges such as climate change, disaster management, etc.

One of the important areas emerging from the satellite programmes within India is the use of space for defence and security. India's stated position is one of ISRO being a civilian organization focused on producing missions for socio-economic benefits. However, due to the growing security needs of the country, ISRO has been supporting the development of several spacecraft in service of the defence and security apparatus of the country. In December 2018, ISRO launched GSAT-7A as a dedicated asset for the Indian Air Force (IAF) to enhance the networking and communication capabilities of the IAF[35]. The IAF is also sharing 30% of the transponder capacity on the satellite with the Indian Army to support some of their drone operations[36]. The first dedicated Indian military satellite was launched to support the operations of the Indian Navy in September 2013 when GSAT-7 was launched by Arianespace as India's first dedicated defence satellite[37]. 2015 also saw the flight of GSAT-6 as a dedicated satellite support communications needs of the Indian Army[38]. ISRO recently launched Microsat-R in early 2019 into a very low orbit of 274-km polar sun synchronous to support imaging for military purposes[39]. Earlier, some of India's high resolution imaging civilian satellites such as the Cartosat satellites have been purposed for dual-use by the Indian military to support some of their operations[40]. India's first electronic intelligence satellite EMISAT is set to be launched by ISRO in its upcoming PSLV launch[41]. More such dedicated assets for security and military operations are expected to be flown with two defence satellites being planned to be launched on the SSLV later this year and a satellite being planned to be flown for the use by Ministry of Home Affairs (MHA) to securing India's borders[42]. The expansion of the military use of space in India is now also featuring in its international cooperation with the most recent agreement between India and France to work on a dedicated constellation for maritime security[43].

The other major area of novel interest over the last decade has been in the realm of space science. After the success of discovering water on the Moon[44] and India establishing itself as the first nation in the world to orbit a spacecraft around Mars in its first attempt,[45] there is a wave of interesting space science missions being planned by ISRO. More recently, AstroSat,

[34] Department of Space (2015). "ISRO and NASA Jointly Working on NASA-ISRO Synthetic Aperture Radar (NISAR) Mission". Web. http://pib.nic.in/newsite/PrintRelease.aspx?relid=123963.

[35] ET Online (2018). "ISRO Launches Military Communication Satellite GSAT-7A from Sriharikota". *The Economic Times. Web.* https://economictimes.indiatimes.com/news/science/isro-launches-military-communication-satellite-gsat-7a-from-sriharikota/articleshow/67160964.cms.

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[37] Indian Navy (n.d.). "Navy Gets a Boost with Launch of First Dedicated Defence Satellite". *Indian Navy.* Web. https://www.indiannavy.nic.in/content/navy-gets-boost-launch-first-dedicated-defence-satellite.

[38] Lele, Ajey (2015)."GSAT-6: India's Second Military Satellite Launched". *Institute for Defence Studies and Analyses.* Web. https://idsa.in/idsacomments/GSAT6IndiasSecondMilitarySatelliteLaunched_alele_310815.

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[40] Kumar, Chenthan (2016). "Surgical Strikes: First Major Use of Cartosat Images for Army". *The Times of India.* Web. https://timesofindia.indiatimes.com/india/Surgical-Strikes-First-major-use-of-Cartosat-images-for-Army/articleshow/54596113.cms.

[41] Swarajya Magazine (2019). "ISRO Special Mission For DRDO: PSLV To Launch Electronic Intelligence Satellite 'Emisat' In March Along With 28 Others". Web. https://swarajyamag.com/insta/isro-special-mission-for-drdo-pslv-to-launch-electronic-intelligence-satellite-emisat-in-march-along-with-28-others.

[42] PTI (2019). "ISRO to Launch Exclusive Satellite to Help MHA in Securing Pak, Bangladesh Borders". *The Economic Times*. Web. https://economictimes.indiatimes.com/news/defence/isro-to-launch-exclusive-satellite-to-help-mha-in-securing-pak-bangladesh-borders/articleshow/67575568.cms.

[43] PTI (2018). "India-France to Begin Work on Maritime Surveillance Satellites next Year". *The Economic Times*. Web. https://economictimes.indiatimes.com/news/defence/india-france-to-begin-work-on-maritime-surveillance-satellites-next-year/articleshow/65550108.cms.

[44] The Hindu (2018). "Chandrayaan-1 Data Confirms Presence of Ice on Moon: NASA". *The Hindu*. Web. https://www.thehindu.com/sci-tech/science/chandrayaan-1-data-confirms-presence-of-ice-on-moon/article24742929.ece.

[45] Amos, Jonathan (2014). "Why India's Mars Mission Is so Cheap - and Thrilling". Web. https://www.bbc.com/news/science-environment-29341850.

India's first dedicated astronomy satellite discovered a black hole in the binary stellar system 4U 1630−47 spins at a rate that is close to the maximum possible rate in conjunction with NASA's Chandra X-ray Observatory[46]. The follow up missions of these spacecraft are already under way with the announcement of opportunity for payloads for Astrosat-2[47] and Mangalyaan-2[48]. The Moon mission follow up has found an upgrade by a rover being planned to be placed on the surface of the Moon in April 2019[49]. Aditya - L1, study the sun is set to launch during 2019-2020 timeframe[50]. ISRO is also planning a first mission to Venus in 2023 and has announced a call for payloads[51]. International cooperation in space science from India has mostly been conducted through hosting of payloads from foreign teams, cooperation with established space agencies such as NASA for utilization of their expertise and existing infrastructure[52]. Chandrayaan-1 saw major cooperation between India and the EU with three payloads coming from the European Space Agency (ESA) and one from the Bulgarian Space Laboratory[53]. France again has emerged as India's biggest European partner in interplanetary missions with a framework to working together on interplanetary missions like Mars, Venus[54]. A recent report also indicated talks having been carried out between China National Space Administration (CNSA) and ISRO to potentially host Indian payloads on the Chang'e-4 lunar mission based on ISRO's reply to an invite to participate in the piggy-back cooperation of Chang'e-4[55]. Unfortunately, the cooperation did not materialize into concrete action. However, this does provide a litmus test to India's openness to both offering opportunities and participating in space science missions through international cooperation.

An overall 60 satellites projected to be launched between 2017 and 2022 according to an interview in early 2017 by the then ISRO satellite centre's Director Annadurai[56]. In order to achieve such volumes in satellite production, ISRO is now engaging the local Indian industry to assemble several of these satellites. ISRO recently signed an agreement with three different industry partners who are expected to build at least 7-9 satellites per year over the next three years[57]. The consortium led by Alpha Design Technologies Pvt Ltd, Bharat Electronics Limited and Tata Advanced systems have been selected to assemble satellites for ISRO[58]. Alpha Design delivered the first assembled satellite IRNSS-1H in mid-2017. However, a rare glitch in the PSLV heat shield separation led to the failure of the injection of the satellite into the orbit[59]. Given the opportunities expanding for the local industry, expansion of investment by the industry leaders are expected in the next few years. Alpha Design which initially planned to raise about ₹400 crores (€ 50 million) by going public to support

46 Fernandes, Snehal (2018). "Isro-Nasa Project Finds Black Hole That Spins near Max Possible Rate". Web. https://www.hindustantimes.com/mumbai-news/isro-nasa-project-finds-black-hole-that-spins-near-max-possible-rate/story-fKCARQcL31VY74fVjgTrJJ.html.

47 Singh, Surendra (2018). "Isro Plans to Launch India's 2nd Space Observatory". *The Times of India*. Web. https://timesofindia.indiatimes.com/home/science/isro-plans-to-launch-indias-2nd-space-observatory/articleshow/62975636.cms.

48 The Indian Express (2016). "ISRO Seeking Proposals for Mars Orbiter Mission-2". *The Indian Express*. Web. https://indianexpress.com/article/technology/science/isro-seeking-proposals-for-mars-orbiter-mission-2-4396357/.

49 India Today (2019). "Chandrayaan-2 to Launch by Mid-April, Will Place Rover on Moon". *India Today.* Web. https://www.indiatoday.in/india/story/chandrayaan-2-launch-date-isro-announcement-k-sivan-1428539-2019-01-11.

50 India Today (2018). "All about the Aditya - L1, ISRO's Satellite to Study the Sun". *India Today.* Web. https://www.indiatoday.in/education-today/gk-current-affairs/story/aditya-l1-isro-s-satellite-study-sun-1317088-2018-08-17.

51 PTI (2018). "ISRO Calls for Global Proposals to Carry Experiments on Venus Mission'". *The Economic Times*. Web. https://economictimes.indiatimes.com/news/science/isro-calls-for-global-proposals-to-carry-experiments-on-venus-mission/articleshow/66587748.cms.

52 Evans, Ben (2013). "NASA Will Support India's Mars Mission, Despite Government Shutdown". *AmericaSpace*. Web. https://www.americaspace.com/2013/10/08/nasa-will-support-indias-mars-mission-despite-government-shutdown/.

53 *EoPortal Directory* (n.d.). "Chandrayaan-1". *EoPortal Directory*. Web. https://directory.eoportal.org/web/eoportal/satellite-missions/c-missions/chandrayaan-1.

54 Singh, Surendra (2018). "India France: India, France to Work Together on Inter-Planetary Missions". Web. https://timesofindia.indiatimes.com/home/science/india-france-to-work-together-on-inter-planetary-missions/articleshow/63792194.cms.

55 Patranobis, Sutirtho (2019). "India Engaged with China for Lunar Mission, Talks Failed to Take Off". Web. https://www.hindustantimes.com/india-news/india-china-space-mission-fails-to-take-off/story-fJssc1E22JxJEUPVIJZ81O.html.

56 Scroll (2017). "Isro Turns to Private Sector for Help as It Targets 60 Satellite Launches in next Five Years". Web. https://scroll.in/latest/858653/isro-turns-to-private-sector-for-help-as-it-targets-60-satellite-launches-in-next-five-years.

57 Gill, Prabhjote (2018). "ISRO Creates a Space for the Private Industry, to Collaborate for 27 Satellites". Business Insider India. Web. https://www.businessinsider.in/isro-creates-a-space-for-the-private-industry-to-collaborate-for-27-satellites/articleshow/65073240.cms.

58 Narasimhan, T. E. (2018). "Isro Ropes in Pvt Firms, Inks Pact with a Consortium to Assemble Satellites". Business Standard India. Web. https://www.business-standard.com/article/current-affairs/isro-signs-agreement-with-alpha-design-bel-tata-to-assemble-satellites-118071800548_1.html.

59 Datta, Anusuya (2017). "Failure of ISRO's First Privately Built Satellite Blow to Commercialization Efforts?". Geospatial World. Web. https://www.geospatialworld.net/blogs/failure-isros-first-privately-built-satellite-blow-commercialization-efforts/.

their expansion of space related activities[60] has instead recently been capitalized by Adani Group (an Indian multinational conglomerate)[61]. Apart from local industry, foreign industries have also taken steps in exploring the potential of entering India for manufacturing their satellites. Berlin Space Technologies, a satellite manufacturer based in Germany has entered into a joint venture with Azista Aerospace to explore mass manufacturing of satellites in India[62]. Not all signs are positive for industry and investment in setting up of the space infrastructure in India. Given the positioning of ISRO/Department of Space (DoS) within the value chain as both a regulator and a satellite manufacturer, specific areas where ISRO has legacy investments and roadmaps may not be open to industry to independently pursue investments in such areas. One such example is the Hughes proposal to invest $500m in India as a part of Government of India's 'Digital India' campaign to provide broadband connectivity across the country[63]. This offer to investing into building and operating a KA-Band satellite to cater exclusively to India's connectivity needs was confounded by reluctance by the DoS[64]. Therefore the growth within the industry is mostly through the mandate provided by ISRO to the local industry rather than major local or Foreign Direct Investment (FDI) to be able to provide independent space-based services in the country.

## 1.3 Space Applications

Since the inception of the space agency, ISRO's goal has been to support the development of various space applications which can cater to the societal challenges in the country. 2015 saw one such unique exercise in the country with DoS conducting a National Meet on Promoting Space Technology based Tools and Applications in Governance and Development which saw the participation from 60 central government ministries/departments and was able to identify 170 projects across various stakeholders in the areas of natural resources management, energy & infrastructure, disaster & early warning, communication & navigation, e-governance & geo-spatial governance, societal services, and support to flagship programmes[65]. A combination of IRS, INSAT and IRNSS can be used to combine value propositions of imaging, communication, positioning, navigation and timing to provide a range of space-supported services. We would like to highlight some of the interesting examples from the recent past in this paper.

The roll out of services with NavIC which uses meteorological inputs is beginning with areas such as supporting the safety of fishermen. ISRO has integrated NavIC receivers into satellite phones to be fit into boats to lock their location, provide text and video messages on ocean weather forecasts and periodically update the location to the ground control room[66]. 200 such satellite phones were recently distributed in the State of Tamil Nadu to roll out of a pilot service[67]. Similarly, trials of a NavIC-based early warning system for trains approaching at unmanned level crossings has been completed by the Indian Railways and has been found satisfactory. According to report on railways crossing safety, around 40% of accidents of 5,792 unmanned railway crossing have had incidents, making it a priority to be addressed[68]. Data from the IRS satellites are being used in partnership with other government entities such as Indian Institute of Horticultural Research (IIHR) to conduct pilot studies on providing advisory to mango farmers in a comprehensive manner right from information from flowering of the crop to the estimated crop size in the concerned season,

60 Narasimhan, T. E. (2017). "Satellite Maker Alpha Design to Go Public in Six Months". Web. https://www.business-standard.com/article/companies/satellite-maker-alpha-design-to-go-public-in-six-months-117112101344_1.html.

61 Narasimhan, T.E. (2017). "Satellite Maker Alpha Design to Go Public in Six Months". Web. https://www.business-standard.com/article/companies/satellite-maker-alpha-design-to-go-public-in-six-months-117112101344_1.html.

62 ORF Kalpana Chawla Space Policy Dialogue (2018). "Small Satellites - Potential, Challenges and Risks". ORF Kalpana Chawla Space Policy Dialogue. Web. https://www.youtube.com/watch?v=e8g6bHWYo-s.

63 Alawadhi, Neha (2017). "Hughes India Looks to Invest $500M to Set up Satellite Systems". ETtech.Com. Web. http://tech.economictimes.indiatimes.com/news/corporate/hughes-india-looks-to-invest-500m-to-set-up-satellite-systems/57242998.

64 Arun, S. (2015). "Space Department Nixes Hughes Plan in Thumbs down to Digital India". The Financial Express. Web. https://www.financialexpress.com/economy/space-department-nixes-hughes-plan-in-thumbs-down-to-digital-india/30213/.

65 Press Information Bureau, Government of India (2015). "National Meet on Promoting Space Technology Based Tools and Applications in Governance and Development on 7th September 2015". Web. http://pib.nic.in/newsite/PrintRelease.aspx?relid=126670.

66 The New Indian Express (2017). "New ISRO Communication Gadget to Ensure Safety of Fishermen 1,500 Kms into Sea". Web. http://www.newindianexpress.com/cities/chennai/2017/dec/13/new-isro-communication-gadget-to-ensure-safety-of-fishermen-1500-kms-into-sea-1725864.html.

67 The New Indian Express (2018). "Tamil Nadu Fishermen given 200 Satellite Phones". Web. http://www.newindianexpress.com/states/tamil-nadu/2018/dec/18/fishermen-given-200-satellite-phones-1912916.html.

68 Singh, Surendra (2018). "Isro: Trial of Sat-Based Warning System at Unmanned Railway Crossings Satisfactory". The Times of India. Web. https://timesofindia.indiatimes.com/india/isro-trial-of-sat-based-warning-system-at-unmanned-railway-crossings-satisfactory/articleshow/64347014.cms.

which the government can also utilize to fix a base price for the crop[69].

ISRO backed services need other federal or state governments to act on them for mass adoption and some of the applications although are in demand by end users, they may not achieve mass adoption due to apathy from the federal or state government ministries/departments who are directly in charge of interfacing with the end users[70]. ISRO has recently setup an outreach facility for geospatial application at the National Remote Sensing Centre (NRSC)[71] and also announced a plan to setup 12 space technology incubation centres across the country to promote innovation and research[72]. Similarly, the state government of Kerala has also invested into developing a space technology park to support the development of space technology products and services[73]. Such initiatives also provide a pivot for international cooperation and provides an opportunity to stakeholders in Europe to promote the joint development of products/services which can use the combined capacities of both the regions (e.g. IRS and Copernicus).

## 1.4 Human Spaceflight

India has been making incremental steps towards human spaceflight by conducting limited experiments such as testing of crew module[74], escape systems[75] over the last decade. In a big move, Prime Minister Narendra Modi made an announcement a part of his 2018 Indian Independence Day speech to put an Indian in space by 2022. The mission named Gaganyaan will be India's first home-grown manned space flight attempt to send three humans into space for five to seven days in a spacecraft which will be placed in a low earth orbit of 300-400 k m from the earth's surface. The Government of India has sanctioned a budget of ₹ 9,023 Crore (~€ 1.1billion) towards the mission[76]. The budgetary allocation has allowed the space agency to create a dedicated Human Space Flight Centre in Bengaluru[77] and will be building a new campus to host all the facilities and infrastructure to train astronauts[78]. ISRO plans to conduct 2 unmanned missions before sending its astronauts on board the rocket[79]. These two flights are likely to establish the human rating of the GSLV MK III rocket, which will be used to haul the astronauts into orbit[80]. ISRO is planning to build three sets of crew and service modules that will be used within the two unmanned and one manned mission[81]. The space agency has also expressed its intent to fly women in the

69 Toppo, Abha (2019). "ISRO, IIHR Together to Provide Production Advisory for Mangoes". Krishi Jagran. Web. https://krishijagran.com/agriculture-world/isro-iihr-together-to-provide-production-advisory-for-mangoes/.

70 The Indian Express (2019). "No Plan to Provide Satellite Phones to Fishermen: Centre". The New Indian Express. Web. http://www.newindianexpress.com/states/tamil-nadu/2019/feb/12/no-plan-to-provide-satellite-phones-to-fishermen-centre-1937614.html.

71 Indian Space Research Organisation (n.d.). "Outreach Facility at NRSC Inaugurated". Web. https://www.isro.gov.in/outreach-facility-nrsc-inaugurated.

72 Singh, Surendra (2018). "Isro to Set up 12 Incubation, Research Centres to Promote Space R&D". The Times of India. Web. https://timesofindia.indiatimes.com/india/isro-to-set-up-12-incubation-research-centres-to-promote-space-rd/articleshow/66206451.cms.

73 Firstpost (2018). "ISRO's Space Tech Start-up Park in Kerala to Be up and Running by June 2019". Firstpost. Web. https://www.firstpost.com/tech/science/isros-space-tech-start-up-park-in-kerala-to-be-up-and-running-by-june-2019-5524201.html.

74 Valsan, Binoy (2014). "Isro Gets Closer to Manned Mission, Tests Crew Module". The Times of India. Web. https://timesofindia.indiatimes.com/home/science/Isro-gets-closer-to-manned-mission-tests-crew-module/articleshow/45568741.cms.

75 Vyawahare, Malavika (2018). "ISRO Conducts First Escape Test for India's Manned Mission to Space". Web. https://www.hindustantimes.com/india-news/isro-tests-crew-escape-system-for-human-spaceflight/story-a5XVUR4CRavn3ej68oJKMK.html.

76 PTI (2019)."Design Review of Gaganyaan Project to Be Completed in January". India Today. Web. https://www.indiatoday.in/science/story/design-review-of-gaganyaan-project-to-be-completed-in-january-1421767-2019-01-02.

77 PTI (2019). "Isro Sets up Human Space Flight Centre in Bengaluru for Manned Mission Programme". The Economic Times. Web. https://economictimes.indiatimes.com/news/science/isro-sets-up-human-space-flight-centre-in-bengaluru-for-manned-mission-programme/articleshow/67759655.cms.

78 Swarajya Magazinwe (2018). "Bengaluru Will Soon Turn Space Hub As ISRO Decides To Train Future Astronauts In The IT City". Web. https://swarajyamag.com/insta/bengaluru-will-soon-turn-space-hub-as-isro-decides-to-train-future-astronauts-in-the-it-city.

79 India Today (2019). "Will Conduct 2 Unmanned Missions before Gaganyaan: ISRO Chief K Sivan". India Today. Web. https://www.indiatoday.in/india/video/2-unmanned-missions-before-gaganyaan-isro-chief-k-sivan-1433974-2019-01-18.

80 Kumar, Ravi Prakash (2018). "GSLV-Mk III, India's 'Baahubali' Rocket for Gaganyaan, Chandrayaan II". Web. https://www.livemint.com/Politics/tBD0gjC3A5EF0msbcT14dK/GSLVMk-III-Indias-Bahubali-rocket-for-Gaganyaan-Chandr.html.

81 Tech2 (2019). "ISRO to Build Three Sets of GSLV Rockets, Crew and Service Modules for Gaganyaan". Web. https://www.firstpost.com/tech/science/isro-to-build-three-sets-of-gslv-rockets-crew-and-service-modules-for-gaganyaan-5834361.html.

maiden flight[82]. Three countries including Russia[83], France[84] and the U.S.[85] have expressed interest in supporting the Gaganyaan mission. The human spaceflight programme is yet another step in the diversification of the Indian space activities and provides an additional pivot for actors in Europe to collaborate.

## 1.5 Conclusion

India has been an early adopter of space-based applications for societal needs and has developed a foundation to conduct diverse range of missions with indigenous capacity. The Indian space programme has witnessed an unprecedented leap in the past decade with ISRO needing the taking forward the legacy programmes in remote sensing, meteorology and telecommunications and adding new missions in navigation, security and space sciences. India's space transportation efforts are taking a big leap forward with dedicated efforts in pushing to establish technologies for reusability as well as in cornering a market share in the global small satellite launch business. The ability to conduct interplanetary missions and engineer dedicated systems for defence use shows the maturity of the space programme to cater to emerging needs within the country. As for the challenges today, ISRO's biggest bottleneck is in building capacity to achieve the increased volumes of spacecraft and launch vehicles and this is this where the local industry also stands to benefit. The addition of the human spaceflight programme, new interplanetary missions and the pursuit to engineer space applications in new arenas adds a new facet into the Indian space program that provides an excellent opportunity for Europe to collaborate on a range of possible activities.

82 NDTV Gadgets 360 (2019). "India Keen to Fly a Woman in Maiden Manned Space Mission". Web. https://gadgets.ndtv.com/science/news/isro-keen-to-fly-a-woman-in-maiden-manned-space-mission-gaganyaan-1977290.
83 The Indian Express (2018). "Gaganyaan: Russia Has Committed Full Support to India's First Manned Space Mission, Says PM Modi". Web. https://indianexpress.com/article/india/russia-commits-full-support-to-indias-first-manned-space-mission-gaganyaan-pm-modi-5388790/.
84 PTI (2019). "ISRO Experts to Receive Training for Gaganyaan Project in France: CNES". Web. https://www.livemint.com/news/india/isro-experts-to-receive-training-for-gaganyaan-project-in-france-cnes-1551884273560.html.
85 India Today (2019). "Gaganyaan 2022: US Interested in Working with India for Manned Space Mission". Web. https://www.indiatoday.in/science/story/us-india-collaboration-gaganyaan-manned-space-mission-charles-bolden-1474207-2019-03-09.

# 2. G2G Space Cooperation between India and Europe: Assessing the Opportunities

By Vidya Sagar Reddy*

## *2.1 Introduction*

India collaborates with several external players, both governmental and non-governmental, for its space programme. In fact, foreign government collaboration was critical for launching the Indian space programme in the 1960s. France is a well-known European partner, which helped India with sounding rocket experiments then and launching geostationary satellites now. India's Vikas liquid engine development benefitted from the experience of Indian scientists participating in the French Viking engine project. Germany was the first European and international launch customer for India. Over the decades, India has launched several satellites for Europe on the Polar Satellite Launch Vehicle (PSLV). Recently, Spain became the latest European country willing to collaborate with the Indian space programme. In addition to the individual partnerships, India also collaborates with the European Union (EU), the European Space Agency (ESA) and other pan-European such as the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and European Centre for Medium Range Weather Forecasts (ECMWF).

The concurrent global geopolitical situation and the mutual recognition of space exploration benefitting economic development provide sound basis for strengthening India cooperation with European institutions in the space arena. However, before arriving at the synergies between India and Europe in outer space, it is pertinent to review the historical context and existing cooperation in the framework of bilateral relations. Therefore, the paper first focuses on the European countries with which the Indian Space Research Organisation (ISRO) has signed formal agreements. Whereas from an historical perspective, space cooperation did not receive much attention in India's bilateral relations with most of these countries, it has been gaining salience over the last few years by becoming a part of India's political and economic relations. Besides assessing these cooperation experiences, the paper discusses recent space policy developments in these European countries, with respect to the development of their private space industries. The objective is to assess the policy elements India could absorb from the European countries in developing a globally competitive space industry. Subsequently, the paper reviews the status of India's cooperative efforts with European institutions and finally provides considerations for future developments.

## *2.2 Assessing Cooperation with Individual European Countries*

The Indian space programme falls under the jurisdiction of Department of Space (DoS) and executed by the government controlled ISRO. Therefore, India's government-to-government (G2G) collaborations with European countries can be identified from ISRO's declared international cooperative agreements. This includes France, Germany, Italy, Norway, Spain, Sweden, Netherlands, Portugal, Luxembourg, Switzerland and United Kingdom[86]. Some of the remaining European countries such as Belgium, Denmark, and Austria have launched their satellites on the PSLV[87]. India and pan-European cooperative undertakings included joint missions and payload accommodation as well as data sharing and technology transfers (see Table 1 for an overview).

* Vidya Sagar Reddy is a Research Analyst at Jane's by IHS Markit.

[86] Indian Space Research Organisation (n.d.). "International Cooperation". Web. https://www.isro.gov.in/international-cooperation

[87] Antrix (n.d.). "International Customer Satellites Launched". Web. http://www.antrix.co.in/business/international-customer-satellites-launched

| Category | Country/Mission |
|---|---|
| **Joint Missions** | France (Megha Tropiques, SARAL) |
| **Payload Accommodation** | Italy (ROSA)<br>Germany (MEOSS, MOS, SIR-2)<br>UK (CIXS)<br>Sweden (SARA) |
| **Ground Station Support** | Norway (Svalbard, Tromso)<br>Germany (Neustrelitz) |
| **EO Experiments and Data Sharing** | Germany (Airborne Campaign, IRS data reception)<br>France (Ka-Band Propagation, SARAL, Megha Tropiques) |
| **Capacity Building /Tech Transfer** | France (Viking engine)<br>Germany (Scientists exchanges) |
| **Satellite Launch Services** | Italy (AGILE)<br>France (SPOT-6, SPOT-7, Hylas-1)<br>UK (STRAND-1, DMC-3, CBNT-1)<br>Austria (NLS-1,2)<br>Germany (BIRD, AISat, BIROS) |
| **Bilateral Meetings/Workshops** | Italy (ASI-ISRO Workshop on Space Research 2012)<br>Germany (ISRO-DLR Cooperation Workshop 2015)<br>France (Quality Workshop for ISRO at CNES 2016) |

Table 1: Overview of India's Bilateral Cooperation with European Countries[88]

### 2.2.1 France

India's collaboration with France in space technology is the most wide-ranging and in-depth compared to other European partners. India-France space relations began with the inception of the Indian space programme in the 1960s. More importantly, the impact of close association between Vikram Sarabhai, the father of India's space programme and then president of Centre National d'Etudes Spatiales (CNES) Jacques Blamont cannot be overlooked. The nascent Indian space programme started experimenting with sounding rockets with the help of France starting in 1963[89]. The collaboration was formalized in 1964 with an agreement between CNES and India's Department of Atomic Energy – then in charge of the Indian space programme. As a result, India obtained solid propulsion technology and licenses to build French Centaure sounding rockets. The Centaure was later indigenized, leading to the development of larger Rohini rockets. Currently, Rohini RH-560 can carry 100 kg payload to 470 km altitude[90].

India's development of liquid propulsion technology also benefitted from cooperation with France. In 1974, an ISRO team was set up to work alongside French engineers on the Viking liquid engine development for Ariane. This arrangement facilitated technology transfer to India in exchange for work-time from ISRO personnel. Later, India tested its first Vikas engine in France, which is critical for the success of PSLV. The PSLV had matured over the years launching foreign satellites including four French satellites and India-France joint

88 Aliberti, Marco (2018). "India in Space: Between Utility and Geopolitics". New York City: Springer. Pg. 26

89 Blamont, Jacques (2017). "Cooperation in Space between India and France". In Rajagopalan, Rajeswari and Prasad, Narayan (Eds.), "Space 2.0 India: Commerce, Policy, Security and Governance Perspectives". New Delhi: Observer Research Foundation. Pg. 215-233

90 Indian Space Research Organisation (n.d.). "Sounding Rockets". Web. https://www.isro.gov.in/launchers/sounding-rockets

satellites such as Megha-Tropiques in 2011 and SARAL in 2013[91].

The Vikas engines also powers different stages of Geosynchronous Satellite Launch Vehicles (GSLV) Mk II and Mk III. The GSLV rockets using cryogenic engine technology also could have benefitted from French technology. In the 1970s, a French company offered India cryogenic engine for about $1,500,000 (Rs. 1 crore then)[92]. ISRO declined the offer and the cost rose to approximately $5 million per engine (Rs. 33.5 crore) in the 1990s when a deal was being negotiated with Russia. However, despite the GSLV Mk II and Mk III trying to make their mark, India is still dependent on French Ariane 5 rocket for launching some of its geostationary satellites.

India's development of communications satellites also began with French assistance. The first experimental communications satellite Ariane Passenger Payload Experiment (APPLE) was launched on Ariane-1 in 1981. Later, INSAT-1C was launched on Ariane-3 in 1988 followed by five INSAT-2 series satellites in the 1990s[93]. Recently, India launched its first dedicated strategic communications satellite GSAT-7 meant for the Indian Navy on Ariane 5. It also launched the HYLAS satellite built on ISRO's I-2K satellite bus for a commercial joint project with EADS (European Aeronautics Defence and Space)/Astrium[94]. Similarly, ISRO provided the satellite bus for the W2M commercial satellite contracted to EADS/Astrium earning $40 million in profit[95].

In 2008, India and France signed three agreements in space cooperation covering G2G cooperation (research & development, small satellites, earth observation etc.), academic cooperation (MoU between IIST (Indian Institute of Space Science and Technology) and École Polytechnique of Paris) and industry cooperation enabling Astrium to deliver satellites in-orbit launched by PSLV[96]. In 2015, India and France signed an agreement for reinforced cooperation between ISRO and CNES followed by the signing of implementing agreements in 2016. The same year, ISRO and CNES led an initiative where more than 60 countries have agreed to coordinate their satellite data for monitoring human-induced greenhouse gas emissions[97]. Satellites can measure 26 out of the 50 essential climate variables for monitoring climate change.

In 2018, India-France Joint Vision for Space Cooperation was released addressing societal benefits from space exploration, high resolution earth observation, space situational awareness, climate change, cooperation in satellite navigation, joint development of reusable launch vehicles, outer space exploration etc.[98]. Accordingly, ISRO and CNES held discussions on various technologies such as aerobraking and navigation for planetary exploration[99]. The future Indian planetary missions will host French instruments and CNES will be involved from an early phase of project design. Simultaneously, India and France also released the Joint Strategic Vision of India-France Cooperation in the Indian Ocean Region, which welcomed a MoU between ISRO and CNES on co-developing a maritime surveillance system focused on the Indian Ocean and related data fusion mechanisms[100].

In 2017, CNES' engagement with the Indian space programme expanded further as it signed an agreement to fly two of its latest high technology cameras on-board Team Indus moon rover at no cost[101]. Meanwhile, CNES and ISRO also agreed to form a joint working group on reusable launch vehicles that could

91 No. 1

92 Narayanan, Nambi (2018). "Ready to Fire: How India and I Survived the ISRO Spy Case". New Delhi: Bloomsbury India. Pg. 160.

93 Embassy of India in the Republic of Ireland. "50 Years of Indo-French Space Cooperation". Web. http://www.indianembassydublin.in/docs/50-YEARS-OF-INDO-FRENCH-SPACE-COOPERATION.pdf

94 Indian Space Research Organisation (2010). "HYLAS Satellite Reaches Geostationary Orbit". Web. https://www.isro.gov.in/update/30-nov-2010/hylas-satellite-reaches-geostationary-orbit

95 LiveMint (2008). "ISRO makes $40 million profit out of W2M satellite". Web. https://www.livemint.com/Industry/wVmPLdPA759oFCHMmZYjvK/ISRO-makes-40-million-profit-out-of-W2M-satellite.html

96 Indian Space Research Organisation (2008). "India Signs Agreements with France on Cooperation in Space". Web. https://www.isro.gov.in/update/30-sep-2008/india-signs-agreements-with-france-cooperation-space

97 Press Information Bureau, Government of India (2016). "World's Space Agencies unite to face the Climate Challenge". Web. http://pib.nic.in/newsite/PrintRelease.aspx?relid=145974

98 Ministry of External Affairs, Government of India (2018). "India-France Joint Vision for Space Cooperation (New Delhi, 10 March 2018)". Web. http://mea.gov.in/bilateral-documents.htm?dtl/29597/IndiaFrance+Joint+Vision+for+Space+Cooperation+New+Delhi+10+March+2018

99 The Wire (2018). "India, France Hold Discussions for Inter-Planetary Missions to Mars, Venus". Web. https://thewire.in/space/india-france-hold-discussions-for-inter-planetary-missions-to-mars-venus

100 Ministry of External Affairs, Government of India (2018). "Joint Strategic Vision of India-France Cooperation in the Indian Ocean Region (New Delhi, 10 March 2018)". Web. http://www.mea.gov.in/bilateral-documents.htm?dtl/29598/Joint+Strategic+Vision+of+IndiaFrance+Cooperation+in+the+Indian+Ocean+Region+New+Delhi+10+March+2018

101 Consulate General of France in Bangalore, France in India (2017). "Signing of ISRO-CNES and CNES-Team Indus agreements". Web. https://in.ambafrance.org/Signing-of-ISRO-CNES-and-CNES-TeamIndus-agreements-14402

bring down the cost of space transportation[102]. This could be a significant area of cooperation since both Arianespace and ISRO intend to make their launch vehicles reusable. Another potential area of cooperation is the development of a small satellite launch vehicle given the depth of cooperation in launch vehicles between India and France. France could help India with the design and testing of this rocket and in return India can assure launches for the European small satellites at a low cost. Competition can be expected from the United Kingdom and Spain which are trying to establish spaceports and fly small satellite launch vehicles.

India-France space relations survived great odds such as India's detonation of a nuclear device in 1974 and weapons in 1998. France was the first country to recognize India's pressing security needs and initiate contact despite Western sanctions. These overarching positive political relations helped space cooperation to thrive. The dynamics of space transportation are changing and satellite technology is becoming increasingly available for more state and non-state actors. France and India with their respective strengths should cooperate to take advantage of these changes.

### 2.2.2 Germany

India-Germany space relations date back to Cold War period. Wernher von Braun, working in the U.S., visited ISRO facilities and instructed Abdul Kalam on India's Satellite Launch Vehicle (SLV-3)[103]. Sarabhai had maintained close relations with other German scientists as well forging a closer cooperation with Germany parallel to nurturing relations with France. Nambi Narayanan contends that Vikram Sarabhai was trying to put together the technology from World War II vanquished nations such as Germany (West Germany to be precise) for India's security[104]. Germany provided crucial wind tunnel testing for India's SLV-3 simulating pressures at various altitudes[105].

In 1971, India and West Germany signed an inter-governmental agreement, which was followed by an inter-agency agreement in 1974[106]. This facilitated the exchange of scientists, joint studies in space sciences and building applications for mission analysis, telemetry, tracking and command. In 1976, DLR started assisting India in rocket guidance by installing its interferometers on Indian sounding rockets[107]. In 1981, a major sounding rocket experiment included German on-board processors for navigation and guidance. These projects helped India to improve its launch vehicle designs. Cooperation continued in satellite design and instrumentation as well. In 1998, the then reunified Germany designed Ocular Electro-Optic Stereo Scanner for India's SROSS-2 satellite, which failed to reach the orbit[108]. Later, India's maiden moon mission Chandrayaan-1 launched in 2008 carried Near Infrared Spectrometer (SIR-2) from Germany[109].

Germany contributed an instrument for IRS-1E, the satellite launched on the first flight of the PSLV in 1993. In 1994, IRS-P2 was launched as a cooperative mission between ISRO and German Aerospace Centre (DLR) with the objective of acquiring remote sensing data[110]. Germany also hosts international ground stations for receiving India's RISAT-1, Resourcesat-2 and Oceansat-2 data[111]. Significantly, it was the first international customer for the PSLV when it launched DLR-TUBSAT in 1999[112]. It also launched from India other significant satellites such as BIRD which could detect forest fires early from space. Germany has been a steady customer over the years with the latest launch in 2017.

In 2013, the two space agencies organised a technical workshop to identify future areas of space cooperation – in particular regarding climate monitoring, commercial launch services,

[102] Henry, Caleb (2017). "CNES supplying cameras to Indian X Prize team, talks reusability with ISRO". Web. http://spacenews.com/cnes-supplying-cameras-to-indian-x-prize-team-talks-reusability-with-isro/

[103] Kalam, Abdul and Tiwari, Arun (1999). "Wings of Fire: An Autobiography of Abdul Kalam". Hyderabad: Universities Press. Pg. 87

[104] Narayanan, Nambi (2018). "Ready to Fire: How India and I Survived the ISRO Spy Case". New Delhi: Bloomsbury India. Pg. 105.

[105] Aliberti, Marco (2018). "India in Space: Between Utility and Geopolitics". New York City: Springer.

[106] Jochemich, Marc (2017). "Indo – German Cooperation in Space". Web. https://espi.or.at/files/news/documents/Indo-German-Cooperation-in-Space---Marc-Jochemich.compressed.pdf

[107] Milhollin, Gary (1989). "India's Missiles – With a Little Help from Our Friends". Web. https://www.wisconsinproject.org/indias-missiles-with-a-little-help-from-our-friends/

[108] Indian Space Research Organisation (1988). "SROSS-2". Web. https://www.isro.gov.in/Spacecraft/sross-2

[109] European Space Agency (n.d.). "Chandrayaan-1 Lunar Mission". Web. https://earth.esa.int/web/eoportal/satellite-missions/c-missions/chandrayaan-1

[110] Kramer, Herbert (2002). "Observation of the Earth and Its Environment: Survey of Missions and Sensors". New York City: Springer. Pg. 141

[111] Indian Space Research Organisation (2017). "Annual Report 2016-2017".Web. https://www.isro.gov.in/sites/default/files/flipping_book/annualreport-eng-2017/files/assets/common/downloads/Annual%20Report%202016-17.pdf

[112] No. 2

components procurement etc.[113]. In 2016, DLR helped an Indian power distributor to establish a research centre to develop solar power plants and components[114]. Given the historical and highly technical interactions between ISRO and DLR, space cooperation has been touted as an important area of bilateral relations. However, major future oriented proposals as seen in the case of France are yet to be formulated to keep the space relations viable for the future.

India-Germany space relations span decades but compared to France, they are not as wide ranging and do not attract the same level of enthusiasm. India certainly benefitted from cooperating with Germany by gaining valuable skill sets, components and instrument design. However, this relationship has more potential than realized as space start-ups can benefit from precision engineering skills and funding available in Germany. Germany and France are setting up a $1.1 billion fund for helping start-ups evolve beyond the seed stage[115]. The German start-ups witnessed an 88 percent increase in investments in 2017 totalling $5 billion bolstering Germany's start-up credentials[116]. The Indian government is working to facilitate exchanges between start-ups in Germany and South Asia as well as organise a meet-up for the start-ups to explore synergies[117]. This may help Indian start-ups gain easier access to the German market and investments[118].

Germany has also launched an initiative aiming to promote the business case for new ideas with support from DLR, ESA and Airbus. India could be a welcoming partner in this situation, combining its cheaper human resources with Germany's advanced manufacturing processes.

### 2.2.3 Italy

India and Italy signed an agreement on scientific and technical cooperation in 1998 prioritizing aerospace cooperation and ISRO-Italian Space Agency (ASI) framework agreement for cooperation in exploration and peaceful uses of outer space was signed in 2000[119]. In 2005, ISRO and ASI signed an agreement for conducting joint programmes in earth observation, space science and aeronautics[120]. Subsequently, India launched Italy's astronomy satellite AGILE in 2007, fulfilling a commercial contract won through an international competition[121] . Italy contributed the Radio Occultation Sounder for Atmosphere (ROSA) instrument to India's Oceansat-2 satellite in 2009[122]. Both ISRO and ASI ground stations can download the data using the processing software India received from Italy[123]. India's decision to adopt space technology for alerting road users at unmanned railway crossings followed a successful operation of similar technology by Italy[124]. In 2012, ISRO and ASI participated in a workshop to discuss space programmes on both sides and find synergies. Recently, India and Italy stressed ISRO-ASI cooperation in Earth observation and space exploration in a joint statement in 2017[125].

Relations with ASI could open collaborations on a range of space technologies and satellite

113 Indian Space Research Organisation (2014). "Annual Report 2013-2014". Web. https://www.isro.gov.in/sites/default/files/AnnualReports/2014/internationalcooperation.html

114 German Aerospace Agency (2016). "A model for energy providers in India – the DLR test and qualification laboratory for solar power plants". Web. https://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10081/151_read-16498/#/gallery/21772

115 Guerrini, Federico (2016). "Germany and France Plan to Set Up a 1 Billion Euro Fund for Start-ups". Web. https://www.forbes.com/sites/federicoguerrini/2016/12/19/germany-and-france-plan-to-set-up-a-1-billion-fund-for-start-ups/#31226cd73997

116 Dobush, Grace (2018). "German start-ups raise record €4.3 billion in funding". Web. https://global.handelsblatt.com/finance/german-start-ups-raise-record-e4-3-billion-in-funding-873012

117 Business Standard (2017). "India mulling start-ups exchanges with Germany, Saarc". Web. https://www.business-standard.com/article/news-ians/india-mulling-start-ups-exchanges-with-germany-saarc-117061900792_1.html

118 Chitravanshi, Ruchika (2017). "India, Germany plan pact to help start-ups thrive". Web. https://economictimes.indiatimes.com/small-biz/start-ups/india-germany-plan-pact-to-help-start-ups-thrive/articleshow/58990436.cms

119 Iacovoni, Sveva (2017). "ASI-ISRO Cooperation". Web. https://espi.or.at/files/news/documents/ASI-ISRO_Cooperation-_Sveva_Iacovoni.pdf

120 Space Daily (2005). "Agreement Between ISRO And Italian Space Agency". Web. http://www.spacedaily.com/news/india-05s.html

121 Indian Space Research Organisation (2007). "PSLV Successfully Launches Italian Satellite". Web. https://www.isro.gov.in/update/23-apr-2007/pslv-successfully-launches-italian-satellite

122 Indian Space Research Organisation (2009). "Oceansat-2". Web. http://resource.itschool.gov.in/physics-web/isro/www.isro.org/satellites/oceansat-2.html

123 Perona, Giovanni et al. (2007). "GPS radio occultation onboard the OCEANSAT-2 mission: an Indian (ISRO)—Italian (ASI) collaboration". Web. https://www.researchgate.net/publication/290013869_GPS_radio_occultation_onboard_the_OCEANSAT-2_mission_an_Indian_ISRO-Italian_ASI_collaboration.

124 Smart Rail World (2017). "India trials satellite-enabled warning system, following on from Italy ERTMS tests". Web. https://www.smartrailworld.com/signalling/india-trials-satellite-warning-system-after-italy-ertms-tests

125 Ministry of External Affairs, Government of India (2017). "India-Italy Joint Statement during the visit of Prime Minister of Italy to India (October 30, 2017)". Web. http://mea.gov.in/bilateral-documents.htm?dtl/29068/IndiaItaly_Joint_Statement_during_the_visit_of_Prime_Minister_of_Italy_to_India_October_30_2017

missions worldwide. Italy is instrumental in maintaining the Vega launch vehicle, which is fully designed in the country[126]. In fact, Italy's primary contracts awarded by ESA are in the areas of launch vehicles and human spaceflight[127]. ASI released a Strategic Vision Document 2016-2025 which details the promotion of the development of services and applications and the promotion of the development of infrastructure for space economy as first and second strategic goals respectively[128]. In this context, Italy has encouraged a local school of management on space economy evolution by adopting a holistic research methodology comprising of scientific, technical, financial and legal aspects of space exploration[129]. Italy has also setup Key Enabling Technologies Laboratory aimed at deriving marketable technologies and services from aerospace research[130]. Recently, NanoRacks has decided to cooperate with Italian companies and open its first European office in Italy[131].

Despite being the third largest contributor to ESA, Italy seems now more focused on developing the national space programme and expanding bilateral cooperation[132]. ASI already has extensive relations with major spacefaring countries around the world[133]. However, collaboration with India does not seem to be a priority. A major obstacle to reviving space relations is the lack of political enthusiasm after the so-called Erica Lexi case [134]. Also, as Italy reorients its space industry towards space economy pitching Vega for small satellite market, it could become a competitor to the PSLV, especially if it convinces European stakeholders to favour the use of Vega against non-European solutions. Also, since the space industry is primarily seen as driver for jobs creation and local economic development, Italy's interest in outsourcing satellite manufacturing to India appears very limited.

### 2.2.4 The Netherlands

The Netherlands has sent its satellites to space on the PSLV twice. The bilateral joint communique issued in 2017 calls for utilising space technology for climate modelling and air quality predictions[135]. In 2006, Netherlands declared India along with China and Russia as the three main priorities for its foreign policy. Netherlands is now the fifth largest investment partner of India, which has emerged as the third largest source of Foreign Direct Investment (FDI) in the last few years[136]. Netherlands is the entry point for at least 20 percent of India's exports to Europe. The bilateral trade has reached $6.9 billion in 2016-17 and various Indian trade related associations have opened offices in the Netherlands[137]. The Rotterdam port in Netherlands is the largest on the European continent and was the world's busiest from 1962 to 2004.

Netherlands has consolidated its space research activities under the Netherlands Space

126 Italian Space Agency (n.d.). "About ASI". Web. https://www.asi.it/en/agency/about-asi

127 Organisation for Economic Cooperation and Development (2007). "The Space Economy at a Glance 2007". Web. https://www.oecd-ilibrary.org/economics/the-space-economy-at-a-glance-2007_9789264040847-en

128 Italian Space Agency (n.d.). "Strategic Vision Document 2016-2025". Web. https://www.asi.it/sites/default/files/attach/dettaglio/dvs-ing_web.pdf

129 SDA Bocconi School of Management (2018). "A new agreement for the Space Economy between SDA Bocconi and the European Space Agency ESA". Web. https://www.sdabocconi.it/en/news/2018/06/new-agreement-space-economy-between-sda-bocconi-and-european-space-agency-esa

130 Campanale, Mark (n.d.). "The Economy that Came from Outer Space". Web. http://www.renewablematter.eu/en/art/675/The_Economy_that_Came_from_Outer_Space

131 Thales Alenia Space (2018). "Nanoracks, Altec and Thales Alenia Space Announce International Business Development Partnership". Web. https://www.thalesgroup.com/en/worldwide/space/press-release/nanoracks-altec-and-thales-alenia-space-announce-international

132 Organisation for Economic Cooperation and Development (2011). "The Space Economy at a Glance 2011". Web. https://www.oecd-ilibrary.org/economics/the-space-economy-at-a-glance-2011_9789264111790-en

133 ASI has strong linkages with NASA, including an agreement in 2017 to provide highly sensitive X-ray detectors and the use of its ground station in Kenya for the X-ray Polarimetry Explorer (IXPE) mission to be launched in 2020.[133] Italy and the U.S. are also in discussions about asteroid exploration. Italy has signed a MoU with the United Arab Emirates' space agency on various issues of space exploration and with China on human spaceflight. A Chinese earthquake detection satellite also has Italian instrument on-board. Italy is contributing four highly specialized instruments on the Europe-Japan joint mission to Mercury – Bepi Colombo.[133] The spacecraft is being integrated and tested at Thales Alenia facilities in Italy.

134 This was international dispute about two Indian fishermen killed off the coast of Kerala by two Italian marines on-board the Italian tanker Enrica Lexie. The case has caused serious diplomatic tensions between the two countries and has sparked a controversy over the legal jurisdiction and functional immunity between the two governments.

135 Ministry of External Affairs, Government of India (2017). "India-Netherlands Joint Communique The Hague, (June 27, 2017)". Web. http://www.mea.gov.in/bilateral-documents.htm?dtl/28562/IndiaNetherlands_Joint_Communique_The_Hague_June_27_2017

136 Hindustan Times (2017). "India, Netherlands sign three MoUs, Modi invites Dutch CEOs for investment". Web. https://www.hindustantimes.com/india-news/india-netherlands-sign-three-mous-modi-invites-dutch-ceos-for-investment/story-jcMU4pGgSB13mFmH8qtQIM.html

137 Embassy of India in The Netherlands (2018). "India-Netherlands Bilateral Brief". Web. http://www.indianembassy.nl/eoi.php?id=Bilateral

Office in 2009. The Dutch space policy stresses the use of space technology for scientific, societal and economic applications[138]. The Dutch has a space exploration lineage with Christiaan Huygens observing the Saturn and its moons. The Oort cloud and the Kuiper Belt were named after Dutch astronomers and Netherlands continues to be an active player in astronomy. Netherlands also showed interest in sounding rocket programme and was a participant in the International Geophysical Year 1957-58. The V-2 rocket programme of Nazi Germany influenced the Dutch researchers. They expanded the rocket research publishing theories on lunar orbits[139]. Netherlands was an avid supporter of the EU and was part of the basic treaties leading to the union. Netherlands became a founding member of ESRO and helped consolidate various European national efforts for developing launch vehicles by ELDO[140]. The Netherlands also hosts the European Space Research and Technology Centre, which is the main technology development and test centre for ESA.

The Dutch industry was active from the start and it even proposed building a satellite in 1966 for technology demonstration. The ground station envisioned as part of this plan eventually served as the first operational ground station for Intelsat-1. It had launched two astronomy satellites but the financial constraints and dwindling public interest in space exploration post Apollo led the Netherlands to shift focus from science to commercial applications. This also reoriented the country's space programme towards ESA. Thereafter, it received contracts from ESA developing advanced technology products by the local industry. The Dutch government will invest $164 million in the European space programmes that includes $41 million for earth observation considering the returns for Dutch businesses and the country's industrial competitiveness[141]. The Netherlands also pledged about $78 million to develop Ariane 6 and about $11 million for the ISS.

The Netherlands built a small scientific satellite weighing about 130 kg launched in 2005 to showcase the country's inherent interest in building such satellites. It has sent astronauts to the ISS and has contributed to terrestrial and space telescopes. In addition to the country's expertise in building solar panels, the Dutch government has created a national database of satellite images that is accessible by public and entrepreneurs[142]. Like other Nordic countries, the Netherlands is also a hotbed of start-up activity.

The main start-up centre is the capital Amsterdam but Delft and Rotterdam are also fast becoming start-up centres. In 2014, 75 major deals brought about $560 million worth of investments[143]. With the Netherlands supporting the European Union and the country being a gateway to Europe symbolized by the Rotterdam port, it draws investments from U.S. and China. It has started giving residence permits for non-EU based entrepreneurs to start a business in the Netherlands guided by an experienced Dutch mentor[144]. The Dutch government will be awarding $50 million annually to support the country's start-up enterprise[145].

The Netherlands has the highest digital infrastructure attracting global giants such as Google and Microsoft to open data centres, an investment worth $1.4 billion[146]. In fact, Netherlands is the gateway port connecting the American and European networks. Such a favourable climate is attracting foreign companies to open their European offices in the Netherlands. An Australian firm intending to launch small satellites for enabling internet of things has established its European office in the Netherlands. A Bangalore start-up is collaborating with a Netherlands based company to develop the first global search engine for the aerospace industry[147].

Three key activities attributed to the Netherlands gaining start-up capital are large scale marketing promising growth, a highly specialized bureaucratic team implementing key initiatives such as connecting the technology

138 Netherlands Space Office (n.d.). "Space policy". Web. https://www.spaceoffice.nl/en/about-nso/space-policy/

139 Kasteren, Joost (2002). "An Overview of Space Activities in the Netherlands". Web. http://www.esa.int/esapub/hsr/HSR_27.pdf

140 Ibid.

141 Government of the Netherlands (2014). "Netherlands Invests €140 million in European Space Programme". Web. https://www.government.nl/latest/news/2014/11/29/netherlands-invests-140-million-in-european-space-programme

142 Holland Trade and Investment Portal, Government of the Netherlands (n.d.). "From satellites to spin-offs, Dutch space industry is enterprising". Web. https://www.hollandtradeandinvest.com/feature-stories/dutch-space-industry

143 Cohen, Steven and Egusa, Conrad (2015). "The Netherlands: A Look at the World's High-Tech Start-up Capital". Web. https://techcrunch.com/2015/07/05/the-netherlands-a-look-at-the-worlds-high-tech-start-up-capital/

144 Netherlands Enterprise Agency (n.d.). "Residence permit for foreign start-ups". Web. https://english.rvo.nl/subsidies-programmes/residence-permit-foreign-start-ups

145 Government of the Netherlands (2017). "'The Dutch start-up climate', keynote speech by minister Kamp". Web. https://www.government.nl/documents/speeches/2017/01/10/the-dutch-start-up-climate-keynote-speech-by-minister-kamp

146 Ibid.

147 Putrevu, Sampath (2018). "Bengaluru goes to Netherlands to build the first global search engine for Aerospace". Web https://yourstory.com/2018/05/bengaluru-goes-netherlands-build-first-global-search-engine-aerospace/

hubs across the country and fostering collaboration between the start-ups and established companies[148]. India will be starting an initiative #Start-upLink to allow India and Netherlands explore each other's markets, exchange information and guide business opportunities[149].

### 2.2.5 Norway

The Norwegian space industry is a $780 million enterprise majorly dependent on telecommunications[150]. The country started communication services to remote Svalbard and the North Sea using satellites since the 1970s. The country's extensive maritime area compelled Norway to become a leader in maritime communications. It raised Telenor Company to be one of the world's five biggest communications services companies. The Norwegian space centre proclaims that its engineers are no more expensive than other countries. However, manufacturing costs are higher in Norway which countries like India can take advantage of. Norway boasts that each Krone (local currency) returned an average of 4.8 Krones from the contracts awarded by the Norwegian space centre to the industry[151].

Norway launched four small satellites for monitoring ship traffic with the latest satellites launched in 2017 having the capability to detect 60 percent more ships than the predecessors[152]. A next generation satellite in the series will be carrying an experimental navigational radar in addition to the AIS receiver to increase the accuracy and operate in contested domains where ships do not report AIS signal[153].

Norway has a space policy which declares space related activities are a tool for meeting national priorities in other sectors. The geographic realities that accords Norway with a sea area six times the land area, harsh climatic conditions and scattered population, dependency on marine resources, offshore drilling etc. makes it imperative for the country to invest in space technologies. This resulted in Norway seeking capacity on Intelsat and then become a critical player in the development of Inmarsat, which in turn promoted the telecommunications industry within the country[154]. The harsh weather conditions compelled it to join EUMETSAT which exploits meteorological data for weather forecasting. Norway was also quick to adopt the GPS technology for airport approach and landings, later as India did with GPS-aided GEO augmented navigation (GAGAN).

In 2011, Norway's space related goods and services amounted to $740 million of which 70 percent is export oriented. Norway uses technology advancement, market access and system insight to make space industry development possible[155]. Norway joined ESA in 1987 for technology advancement, particularly its telecommunications industry. Market access has been the motivation for Norway to join the Galileo and Copernicus programmes where Norwegian companies are able to secure supply contracts worth $152 million until 2013. The participation in these programmes also led to Norway gaining an insight into the financial and management practices of the ESA.

The geographic realities and resulting national needs led Norway to adopt a survivalist approach to space technology. It has developed a sophisticated but fundamentally realist strategy for gaining technology insights and repurpose the knowledge into creating world-class business entities. The sense of survivalism and local business growth is strong with Norway. Therefore, more than business opportunities, India could learn adopting space technology not only for economic and social development but also driving a business ecosystem as an inherent purpose.

Norway perceives India as a pioneer and supporter of globalization. India's Prime Minister Modi met the leaders of Nordic countries in April 2018. Modi has invited Norwegian State Pension Fund Global to invest in new sectors of India. The fund has already invested $11.7 billion in India by 2017, up $2.5 billion from 2016[156]. Achieving sustainable development

148 KPMG (2016). "Three keys to the Netherlands' rise as a European start-up hub". Web. https://home.kpmg.com/xx/en/home/insights/2016/03/netherlands-rise-as-european-start-up-hub.html

149 Press Information Bureau, Government of India (2018). "Indo-Dutch Start-up Initiative: #Start-upLink to be launched". Web. http://pib.nic.in/newsite/PrintRelease.aspx?relid=179472

150 Norwegian Space Centre (n.d.). "The Norwegian Space Industry". Web. https://www.romsenter.no/eng/Focus-Areas/Industry/The-Norwegian-Space-Industry

151 Ibid.

152 Norwegian Space Centre (n.d.). "Norwegian AIS-Satellites See Far More Ships". Web. https://www.romsenter.no/eng/News/News/Norwegian-AIS-satellites-see-far-more-ships2

153 Norwegian Space Centre (n.d.). "New Norwegian Satellite to Detect Radar Signals". Web. https://www.romsenter.no/eng/News/News/New-Norwegian-satellite-to-detect-radar-signals

154 Norway Government (n.d.). "Development of space activities in Norway". Web. https://www.regjeringen.no/en/dokumenter/meld.-st.-32-2012-2013/id723686/sec4

155 Ibid.

156 Hindustan Times (2018). "PM Modi invites Norway pension fund to invest in new sectors in India". Web. https://www.hindustantimes.com/india-news/pm-modi-invites-norway-pension-fund-to-invest-in-new-sectors-in-india/story-j7AcYrZYVRuEBX3Ca6cwZK.html

goals is a main priority where space technology can play a critical role. India-Norway bilateral trade rose from $974 million in 2013-14 to $1,265 million in 2014-15[157]. A governmental dialogue on trade and investment will facilitate including more sectors for cooperation, which will have a positive impact on bilateral trade. Space cooperation could be expanded along these lines given the increasing demand and the need for innovative business solutions.

### 2.2.6 Spain

Spanish space activity can be traced back to 1942, with the inception of its Instituto Nacional de Técnica Aerospacial (INTA). As a member of ESA, Spain hosts the European Space Astronomy Centre (ESAC) – the scientific operations centres for ESA's astronomy and planetary missions. In 2006, Spain established Spanish Strategic Plan providing the country with space industry guidelines. The focus rests on three pillars viz., strengthening the role of institutions on an international level and directing space policy in a user driven approach; support local space industry to make it globally competitive and increase industrial capacity and; develop infrastructure and support the use of it in international programmes.

Spain is trying to become a major player in small satellite launch market by encouraging local companies. Spain is also considering a space law to establish a spaceport in the country to consolidate its role space transportation business. The Spanish government has covered 25 percent of the costs associated with setting up a local company PLD Space in this regard[158]. In addition, the company received a $2.4 million grant from the European Commission[159]. It is designing Arion 1 that will launch 100-200 kg into suborbital altitudes and Arion 2 capable of launching 150 kg to a low Earth orbit. The Spanish space industry is primarily contracts based in the areas of development and operation of satellite systems as well as qualification of components. The total sales stands at $939 million in 2017[160]. Tecnalia Ventures manages ESA's space technology transfer programme to build non-space applications by the local industry[161].

Spain's space potential has been often diminished by the country's political and economic problems. Its space programme survives on its relations with NASA while ESA membership seems to have offered mixed benefits. Regardless, it is concentrating on utilising basic skills by encouraging small satellite launcher development. Whether this is an opportunity or a cause of competition remains to be seen as more European countries such as Italy and the UK are also betting on small satellite industry for economic development.

A notable step to increased cooperation between Spain and India was made through the establishment of the India-Spain Programme of Cooperation on Industrial Research and Development in March of 2018. This bilateral framework created by the Department of Science & Technology (DST) Government of India and the Centre for the Development of Industrial Technology (CDTI-E.P.E.) under the Secretariat of State for Research, Development and Innovation of Spain. This framework is meant to provide "financial support for collaborative R&D ventures between Indian and Spanish Industry and Academia" and will help pave the way for cooperation opportunities on space applications as well to further aid the implementation of the objectives of the agreement, particularly in the realm of agriculture, renewable energy, environmental sustainability, health and urban development.

### 2.2.7 Sweden

Sweden's space activities originate in the late 1950s. As a founding member of ESRO and later ESA, Sweden has pursued a multitude of space activities and is currently pursuing its 2018 national space strategy through the Swedish National Space Agency (SNSA), which was known as the Swedish National Space Board prior to its renaming in 2018. A notable space asset of the Swedish space programme is the Esrange Space Centre in the north of Sweden which functions as a rocket range and scientific centre used by the international scientific community for launching sounding rockets, high altitude balloons and drop tests of space and aerial vehicles[162]. Furthermore, Esrange also accommodates one of the world's

[157] Bhatia, Rajiv (2016). "India-Norway: burgeoning business synergy". Web. http://www.gatewayhouse.in/india-norway-burgeoning-business-synergy/

[158] Pultarova, Tereza (2017). "Spain's launch start-ups make a case for hosting a European spaceport". Web. http://spacenews.com/spains-launch-start-ups-make-a-case-for-hosting-a-european-spaceport/

[159] Henry, Caleb (2018). "Spain's PLD Space receives $2.4 million grant for smallsat launchers". Web. http://spacenews.com/spains-pld-space-receives-2-4-million-grant-for-smallsat-launcher/

[160] U.S. Department of Commerce (2017). "Spain - Aerospace and Defence". Web. https://www.export.gov/article?id=Spain-Aerospace-and-Defense

[161] European Space Agency (n.d.). "Tecnalia Ventures (Spain)". Web. http://www.esa-tec.eu/tecnalia-ventures/

[162] Swedish Space Corporation. "Esrange Space Centre". Web. https://www.sscspace.com/ssc-worldwide/esrange-space-center/

largest civilian satellite ground stations and acts as a hub in our satellite station network.

The ESA business incubation centre in Sweden opened in 2015 has supported more than 300 technology and innovation projects with support from local universities and industry. Seed funding is supporting at least 40 space start-ups so far[163]. The success of Sweden's start-up culture is attributed to government policy, infrastructure, social capital and presence of large corporate entities[164]. Stockholm attracts 15 percent of the total foreign direct investment destined for European technology sector. Sweden also subsidized 100 mbps fast internet via fibre optic cables to 60 percent of the country, which will rise to 90 percent by 2020[165]. Moreover, it has subsidized personal computers in the 1990s compelling the households to adopt new technology. The government also has taken steps to deregulate public monopolies and encourage private competition. The policy incentives coupled with infrastructure development led Sweden to reap the dividends by becoming the hub for digital entrepreneurs. In 2017, 442 start-ups received about $1.2 billion worth of investments, which is twice the capital infused in 2016[166].

Taking stock of this situation, in 2017 India and Sweden have signed a MoU to promote cooperation amongst the start-ups from both countries leading to an initiative called 'Start-up Sambandh,' that facilitates Swedish investors looking to invest in India[167]. On the political side, diplomatic relations were established in 1948. However, business relations started before independence and continued thereafter progressing through heavy industries and later information technology. Some of the Swedish companies are also establishing R&D centres in India. India and Sweden signed a MoU in 1986 to cooperate in space exploration including exchange of technology and personnel[168]. ISRO's Chandrayaan-1 mission carried instruments from Sweden. In April 2018, leaders of both countries agreed on a joint action plan which includes cooperation in earth observation, planetary exploration and ground station activities[169].

Sweden shows the significance of space sector as part of national economic and industrial ecosystem. The space industry is nurtured with investments and national basic infrastructure and human resources are allotted to it. The positive political climate between India and Sweden can support replicating Swedish success in technology start-ups in the space sector. India is a policy priority for Sweden, which can be translated into Indian space start-ups benefitting from this situation.

### 2.2.8 Portugal

India has a historical relationship with Portugal and established diplomatic relations in 1949. However, the relations soured over unification of Goa with the Union of India until the 1974 treaty recognized India's sovereignty over it. Since then, Modi has become India's first prime minister to pay a bilateral visit to Portugal in 2017, reciprocating an earlier visit by the Portuguese prime minister. Incidentally, Portugal's prime minister shares Indian ancestry and holds Overseas Citizen of India card. Cultivating such personal relationships could facilitate bilateral relations and R&D in both countries. In fact, science and technology cooperation and start-up partnership issues have received substantial attention during the visits.

During Modi's visit, MoUs for advancing research on space, marine sciences, weather and creating knowledge hubs to coordinate North-South cooperation have been signed. A space alliance has been envisioned for joint development of next generation nano- and micro-satellites[170]. The countries have resolved to establish a $4.5 million fund to support the research. Portugal invited India as a guest country to its annual science meeting where Antrix was represented. Portugal joined the ESA in 2000 creating an industry ecosystem and

163 European Space Agency (n.d.). "ESA Business Incubation Centre Sweden". Web. https://www.esa-bic.se/about/

164 University of Pennsylvania (2015). "How Stockholm Became a 'Unicorn Factory'". Web. http://knowledge.wharton.upenn.edu/article/how-stockholm-became-a-unicorn-factory/

165 McKenna, John (2017). "Why does Sweden produce so many start-ups?". Web. https://www.weforum.org/agenda/2017/10/why-does-sweden-produce-so-many-start-ups/

166 Turula, Tom (2018). "The Swedish tech scene had a golden year in 2017". Web. https://nordic.businessinsider.com/the-swedish-tech-scene-had-a-golden-year-in-2017--

167 Hindu Business Line (2017). "India, Sweden launch initiative for start-ups". Web. https://www.thehindubusinessline.com/companies/india-sweden-launch-initiative-for-start-ups/article9904760.ece

168 Government of India (n.d.). "Top 6 MoUs Signed by India-Sweden". Web. http://www.makeinindia.com/top-6-mous-signed-by-india-sweden

169 Government of Sweden (2018). "Sweden-India Joint Action Plan, agreed by Prime Minister Stefan Löfven and Prime Minister Narendra Modi". Web. https://www.government.se/statements/2018/04/sweden-india-joint-action-plan-agreed-by-prime-minister-stefan-lofven-and-prime-minister-narendra-modi/

170 Press Information Bureau (India) (2017). "India and Portugal: Cooperation from Outer Space to Deep Blue Seas". Web. http://pib.nic.in/newsite/PrintRelease.aspx?relid=166881

skilled personnel. However, considering the rapid changes in technology and business, it has evolved a strategy to support innovation through both domestic and international partnerships.

The 'Portugal Space 2030' has been drafted with the objectives of promoting economic growth, support NewSpace by leveraging international scientific and technical cooperation and share the benefits of space exploration with less developed countries especially Lusophone countries[171]. This strategy emphasises developing small satellites, extending satellite tracking activities and facilitating new opportunities in launcher services. The efforts to create a space agency could be part of this strategy and make Portugal as a serious space actor.

India could be a significant partner in executing this strategy. During Modi's visit, a MoU was signed to establish a research centre on the Azores archipelago to promote science and technology partnership. The Azores holds great potential for advancing India-Portugal space cooperation. It hosts one of the first Estrack stations which tracks the early ascent phase of Ariane 5 rockets launched from French Guyana[172]. The station will soon include an X-band radar that can track low earth orbit satellites. The local government is promoting the archipelago as a hub for space observation and launch services. The Azores International Research Center works on an integrated approach towards space, climate change and ocean science in the Atlantic and enable North-South cooperation[173]. This centre will build a spaceport on the Azores for low cost launches at a cost of about $350 million[174]. It already collaborates with diverse international partners from the north and south Atlantic areas.

The centre insists that the Portuguese space sector must collaborate with international partners and NewSpace players. The MoU between India and Portugal should act as the facilitator between Azores and Bangalore. A local company Tekever planning to launch Portuguese-made earth observation small satellite constellation already made a visit to India holding meetings with Antrix and local companies[175]. Therefore, India and Portugal should immediately draft a strategy to deepen space collaboration across the government, industry and entrepreneurs.

Space start-ups also should be promoted as part of Azores outreach and the bilateral start-up collaboration. Both countries agreed to facilitate collaboration between start-ups supported by Start-up India and Start-up Portugal. Portugal decided to expedite visas to Indian start-ups and businesses interested in setting up of Portuguese operations[176]. India-Portugal International Start-up Hub also has been established to facilitate cooperation between the start-up ecosystems of both countries[177]. Portugal is competing with the Nordic countries in emerging as the start-up hub. In 2016, a national network of start-ups and technology hubs has been created and about 400 entrepreneurs are given a one year fellowship to work on their ventures[178]. The Portuguese government has created a $233 million venture capital fund to promote foreign investment in the country's start-ups. The Moving to Portugal initiative has been attracting entrepreneurs and start-ups from competitive places like London. The impact is witnessed from the transformation of city neighbourhoods such as a former food factory turning into the world's largest campus for start-ups known as Hub Criativo do Beato. Moreover, Web Summit moving to Lisbon has raised the city's global profile.

India has rekindled relations with Portugal at the right moment when both countries are poised to take advantage of their respective strengths for economic development. How-

171 Foundation for Science and Technology (Spain). "Portugal Space 2030: A research, innovation and growth strategy for Portugal". Web. https://www.fct.pt/ptspace2030/docs/Portugal_Space_2030_(EN).pdf

172 European Space Agency (2015). "Santa Maria Station". Web. https://www.esa.int/Our_Activities/Operations/Estrack/Santa_Maria_station

173 Portugal Government (2016). "Towards a Science and Technology Agenda for an Integrative Approach to the Atlantic." Web. https://www.portugal.gov.pt/media/22048148/air-center-white_paper_v25oct2016_28102016-last.pdf

174 Carnegie Mellon University Portugal (2016). "AIR Centre will build Atlantic Spaceport in Azores". Web. http://www.cmuportugal.org/tiercontent.aspx?id=6685

175 Embassy of India in Portugal (2018). "India-Portugal Relations". Web. http://www.eoilisbon.gov.in/eoi.php?id=Bilateral

176 Ministry of External Affairs (India) (2017). "India-Portugal Joint Statement during the State visit of Prime Minister of Portugal to India". Web. https://www.mea.gov.in/bilateral-documents.htm?dtl/27905/IndiaPortugal+Joint+Statement+during+the+State+visit+of+Prime+Minister+of+Portugal+to+India+IndiaPortugal+relations+Historic+Ties+to+a+21st+Century+Partnership+Deepening+bilateral+relations

177 Indian Express (2017). "PM Modi launches India-Portugal International Start-up Hub in Lisbon". Web. https://indianexpress.com/article/business/economy/pm-modi-launches-india-portugal-international-start-up-hub-in-lisbon-4720352/

178 Forbes (2018). "Lisbon 2018: Why Start-ups Are Booming In The Portuguese Capital". Web. https://www.forbes.com/sites/heatherfarmbrough/2018/02/28/all-roads-lead-to-lisbon-why-start-ups-are-booming-in-the-portuguese-capital/#3e65465777ea

ever, the interest on space collaboration currently rests at the government level. The start-up cooperation led by the governments should take note of the synergies between space start-ups on both sides and facilitate collaboration.

### 2.2.9 Luxembourg

Luxembourg was a pioneer of commercial satellite communications now hosting offices of SES and Intelsat. It has attracted via tax instruments several American tech giants such as Apple, Microsoft etc. setup European offices in the country[179]. While most of the European countries are concentrating on small satellites and technology application start-ups deriving data from earth orbits, Luxembourg has set its goal on becoming a global hub for space resources. The Space Resources Initiative of the government has created a legal framework granting legal protection to rights of commercial entities to own, transport, use and sell mined space resources. The initiative had also setup an initial $233 million fund to promote research and development in space mining[180]. Moreover, Prince Guillaume, Hereditary Grand Duke of Luxembourg, paid a visit to the Silicon Valley visiting American space mining companies Deep Space Industries and Planetary Resources. These companies have decided to open offices in Luxembourg and the government will be a major partner in the mining missions. It has already bought a stake in Planetary Resources worth $28 million, which will be utilised to launch the company's first asteroid prospecting spacecraft by 2020[181]. Luxembourg is also planning to setup a space agency to coordinate financial, legal and technological issues related to space mining ventures[182].

Space mining is a foundational element of building human colonies in space. The proposed human settlements on the Moon and Mars will be costly endeavours without in-situ utilisation of resources and cheaper access to essential resources not found in the local environment. Moreover, there are plans to shift heavy manufacturing into outer space which could utilise space resources. The expansion of human activity including manufacturing into outer space establishes a space economy beyond the earth orbits. Therefore, Luxembourg is interested in becoming an early mover into this space economy as it did with space communications earlier. The space resources initiative promises to ensure peaceful utilisation of space resources which are gathered and used in a sustainable manner conforming to international law[183].

Nevertheless, the American and Luxembourg's passing of domestic laws on space mining has ensued a global debate on the international space law and the legal status of outer space bodies. This law is a result of negotiations during the Cold War to keep outer space free from conflict and to ensure passing of space exploration benefits to developing and underdeveloped countries. India is one of the countries that has been active at the United Nations to codify these objectives into a law. It also signed the Moon Agreement which discussed the legal aspects of space mining and utilisation of space resources. Recently, India's External Affairs Minister has become the first to visit Luxembourg and discuss outer space as one of the priority areas of cooperation[184]. Given the complexity of this issue and burgeoning interest in expanding the space economy, it is essential for India to engage with Luxembourg on this aspect.

In addition, Luxembourg also promotes a space applications-oriented industry. The Luxembourg Space Cluster has been established to research on space technologies and services. The cluster is comprised of 30 companies with a turnover of $2.3 billion[185]. The space policy adds the international dimension to the cluster. Luxembourg is an attractive destination for several global conglomerates including Tata and tech companies such as AOL, Amazon, eBay, Skype etc. which have established their European headquarters

179 Barker, Alex and Houlder, Vanessa. Forbes (2014). "How Juncker and Luxembourg landed Silicon Valley's biggest catch". Web. https://www.ft.com/content/78abd184-813c-11e4-896c-00144feabdc0

180 Reuters (2016). "Luxembourg sets aside 200 million euros to fund space mining ventures". Web. https://www.reuters.com/article/us-luxembourg-space-mining/luxembourg-sets-aside-200-million-euros-to-fund-space-mining-ventures-idUSKCN0YP22H

181 Jamasmie, Cecilia. Mining.com (2016). "Luxembourg shoots for the stars, invests $28 million in Planetary Resources". Web. http://www.mining.com/luxembourg-shoots-for-the-stars-invests-28-million-in-planetary-resources/

182 Schrieberg, David. Forbes (2017). "Space Industry in Luxembourg Set To Blast Off, Fuelled By Government Partnerships". Web. https://www.forbes.com/sites/davidschrieberg1/2017/04/30/space-industry-ready-to-blast-off-fueled-by-government-partnerships/#12f6e03555e2

183 Space Resources Initiative of the Government of the Grand Duchy of Luxembourg. (n.d.) Retrieved from http://www.spaceresources.public.lu/en.html

184 Hindustan Times (2018). "Swaraj calls on Luxembourg PM, discusses ways to bolster bilateral ties". Web. https://www.hindustantimes.com/india-news/swaraj-calls-on-luxembourg-pm-discusses-ways-to-bolster-bilateral-ties/story-1Un-aDVHRNmE1CZhFktdRMK.html

185 Luxembourg Space Cluster (n.d.) Web. http://clustermembers.luxinnovation.lu/space/about/

here[186]. The country has established a trade and investment office in Delhi alongside key financial centres such as San Francisco, Shanghai, Tokyo, Tel Aviv etc. Luxembourg's Ministry of Economy is in charge of the country's space policy and initiatives simplifying the bureaucratic structure bridging both sectors. This also helped make space innovation a significant government objective in its economic outlook. The ministry has been funding the NewSpace Europe since 2017, attracting NewSpace players discussing a wide array of topics. The government deal to fund Spire for $70 million in return for the company setting up its European headquarters in Luxembourg had been made prior at this event in 2017[187]. The Chamber of Commerce has opened a 'House of Start-ups' encouraging start-ups in finance, logistics etc.

Luxembourg is investing in NewSpace ventures that are more diverse than just space mining. Space technology, application and business development are part of the government's initiative to enhance the global profile of Luxembourg as it did in the past with steel, space and finance industries. The scale of resources invested in these ventures might be smaller than its European counterparts discussed in the paper. However, the 'whole of government' approach and the successful economic practices over the decades makes Luxembourg an engaging country for space entrepreneurs.

### 2.2.10 Switzerland

India-Switzerland political relations began soon after the former's independence, with a Treaty of Friendship in 1948 which culminated in a 'Privileged Partnership' in 2008. Switzerland showed interest to South Asia – even representing India's interests in Pakistan and vice versa between 1971 and 1976 which is marked by Bangladesh liberation[188]. The signing of a trade agreement between India and European Free Trade Association (consisting of Switzerland, Norway, Iceland and Liechtenstein) has been a major discussion point during the bilateral visits in the past few years. The business and strategic affairs also saw favourable developments resulting in mutual trust. Switzerland supports India's entry into the Nuclear Suppliers Group and a Bilateral Investment Treaty is being discussed. Switzerland is the 11$^{th}$ largest investor in India amounting to $7.7 billion as more than 250 Swiss companies operate in the country[189]. Nestle, ABB, Novartis etc. are some of the well-known names while the Indian companies TCS, Infosys, Tech Mahindra operate offices in Switzerland. Interestingly, Indian Ayurveda is set to become a legal medicine in Switzerland.

Outer space is not yet a major discussion point between India and Switzerland, although recent developments bode well for the future. Switzerland had sent one of its satellite on the record-breaking launch of 104 satellites by the PSLV. In fact, the first Swiss satellite SwissCube designed by university engineering teams was launched by India in 2009. This satellite will act as the target for CleanSpace One project designing debris removal technologies[190]. These projects are rooted in the Swiss space policy and space implementation plan within the education, research and innovation for 2014-2023. The space policy is aimed at developing space technologies and applications for societal benefits and economic progress. The space implementation plan offers a strategy in this regard by marking priority areas for research in academia and business. It cites small satellites and their clean-up as major emerging themes[191].

The space implementation plan builds on this experience and proposes establishing a space incubator initiative to help space start-ups overcome the entry barriers between laboratory and space. The plan envisages building the business potential of relevant space ventures and export the products within Europe and internationally, particularly India and China[192]. The Swiss global network Swissnex has organised 'Space Week in India' in 2016 to pursue collaboration between the Indian and

[186] Embassy of Luxembourg in New Delhi (n.d.) "Invest in Luxembourg - Your Gateway to Europe!". Web. http://newdelhi.mae.lu/en/Invest-in-Luxembourg-Your-Gateway-to-Europe

[187] Foust, Jeff. Space News (2017). "Luxembourg and European NewSpace". Web. https://spacenews.com/luxembourg-and-european-newspace/

[188] Ministry of External Affairs (2016). "India-Switzerland Relations". Web. http://mea.gov.in/Portal/ForeignRelation/Switzerland_Dec_2016.pdf

[189] Embassy of India in Berne (2018). "India-Switzerland Relations". Web. https://www.mea.gov.in/Portal/ForeignRelation/India-Switzerland_2018.pdf

[190] Space Engineering Centre, Swiss Federal Institute of Technology (n.d.) "CleanSpace One". Web. https://espace.epfl.ch/CleanSpaceOne_1

[191] Federal Department of Economic Affairs, Education and Research (2013). "Swiss Space Implementation Plan within Education, Research and Innovation for 2014-2023". Web. https://www.ethz.ch/content/dam/ethz/special-interest/dual/swiss-space-center-dam/homepage/documents/SwissSpaceImplementationPlanSSIP.pdf

[192] No. 160

Swiss space entities[193]. The space week included an information session on the Indian space start-ups and companies. The Swissnex already helped about 40 Swiss start-ups to open their offices in India and space start-ups could be a part of the collaboration. Switzerland is committing $5.19 million to space start-ups with support from ESA[194].

### 2.2.11 The United Kingdom

The United Kingdom (UK) has participated in India's Chandrayaan-1 mission by providing instruments. The UK has also been a customer for PSLV. However, the UK space industry is facing a crisis as it was excluded from ESA contract bidding which is open only for EU countries. This includes the Galileo project as the EU funds it[195]. However, the UK is assessing alternatives to the Galileo project and is betting on own space industrial strength to open new possibilities such as British Global Navigation Satellite System[196].

The UK has promulgated a space agency responsible for strategic decisions in its civil space programme ensuring sustainable economic growth, scientific advancement and societal benefits. It has a Space Innovation and Growth Strategy 2014-2030 aimed at capturing 10 percent of the global satellite market by 2030 and raise the space industry turnover by $25 billion by 2020[197]. The UK is investing about $200 million to develop advanced rocket engines, establish spaceports within the UK and build satellites[198]. It has recognized that 40 percent of the world's small satellites and one-fourth of total telecommunications satellites are built within the country[199]. It intends to become a global hub for small satellite launch activities by offering access to the most popular orbits used by about 80 percent of these satellites[200]. The UK is offering $67 million for development of new launchers and launch sites[201].

Reaction Engines Limited is working on a propulsion system which is part jet engine and part rocket engine. It has received investments from Boeing and Rolls-Royce amounting to $35 million while the British government has already allocated $80 million[202]. The start-up Effective Space is working on satellite servicing 'drones' to be launched by 2020 that will help expand the lives of satellites by taking over station keeping duty[203]. Another space start-up is aiming to reduce the entire satellite mission cost to less than $700,000[204]. It has won $2.3 million from the ESA. Britain has at least 15 space start-up clusters with the biggest one hosting about 80 companies[205]. It has also sponsored nine of the best space start-ups to travel to the U.S. for locating investors[206].

The positive investment climate has attracted the U.S. based Spire to open office in Glasgow with a $2 million Scottish government grant[207]. The UK space agency followed by investing about $5.3 million in the company for demonstrating advanced space technologies including parallel supercomputing[208]. Moreover, the UK space agency's international partnership

193 Swissnex India (2016). "Switzerland explores India's Space Industry". Web. https://www.swissnexindia.org/blog/switzerland-explores-indias-space-industry/

194 Swiss Broadcasting Corporation (2015). "Switzerland backs more space start-ups". Web. https://www.swissinfo.ch/eng/out-of-this-world-_switzerland-backs-more-space-start-ups/41354162

195 BBC News (2017). "UK firms 'excluded' from space contracts by Brexit". Web. https://www.bbc.com/news/business-42065836

196 UK Government (2018). "UK Space Agency leads work on options for independent satellite system". Web. https://www.gov.uk/government/news/uk-space-agency-leads-work-on-options-for-independent-satellite-system

197 UK Government (n.d.) "Space Innovation and Growth Strategy 2014-2030: Space Growth Action Plan". Web. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/298362/igs-action-plan.pdf

198 UK Government (2018). "UK space industry sets out vision for growth". Web. https://www.gov.uk/government/news/uk-space-industry-sets-out-vision-for-growth

199 No. 126

200 Sheetz, Michael (2018). "The British are coming — for the rocket-launching industry". Web. https://www.cnbc.com/2018/04/21/uk-space-agency-aims-100-billion-by-2030.html

201 Foust, Jeff (2017). "British government to offer funding for spaceports and launchers". Web. http://spacenews.com/british-government-to-offer-funding-for-spaceports-and-launchers/

202 Amos, Jonathan (2018). "Rolls-Royce and Boeing invest in UK space engine". Web. https://www.bbc.com/news/science-environment-43732035

203 Amos, Jonathan (2018). "UK 'space drones' look to Proton rocket ride". Web. https://www.bbc.com/news/science-environment-43374855

204 Open Cosmos (n.d.) "Open Cosmos raises $7 million on its mission to democratize the satellite industry". Web. https://open-cosmos.com/open-cosmos-raises-7-million-on-its-mission-to-democratise-the-satellite-industry/

205 Pultarova, Tereza (2017). "UK aims to become space start-up haven to achieve growth target". Web. http://spacenews.com/uk-aims-to-become-space-start-up-haven-to-achieve-growth-target/

206 UK Government (2015). "Nine UK companies get set for Space Mission to the United States". Web. https://www.gov.uk/government/news/nine-uk-companies-get-set-for-space-mission-to-the-united-states

207 BBC News (2015). "US satellite firm to create 50 jobs in Glasgow". Web. https://www.bbc.com/news/uk-scotland-scotland-business-33066479

208 Peakin, Will (2018). "Spire Global's UK base in Glasgow awarded £4m to demo cutting edge space technology". Web. http://futurescot.com/spire-global-glasgow-awarded-4m/

programme has announced $50 million investments in developing countries, which raises Britain's global profile while awarding more opportunities for the British space industry[209].

With the space sector tripling in value since 2010, the UK sees an opportunity to develop a comprehensive national space programme with related infrastructure to become an independent space player and boost economic growth. It is trying to promulgate user-friendly regulations that simplifies licensing processes instead of requesting permissions from multiple agencies/departments[210]. The seriousness of Britain's commitment to its space programme is well demonstrated by funding advanced technologies which have the capability to shape future space exploration and business.

India could be a part of this process. India is the second largest economy in the Commonwealth and is poised to become the largest by surpassing the UK this year[211]. India's Prime Minister Modi has attended the Commonwealth meeting in the UK recently and signed a bilateral agreement on high-end technologies such as nuclear energy, artificial intelligence and big data analytics. An UK-India Tech Partnership agreement also has been signed that will facilitate pairing businesses, universities and venture capital on both sides and enable market access for entrepreneurs[212]. India is also poised to sign a free trade agreement with Britain post Brexit. Given the political and historical legacy and Britain's thrust to create an independent space programme, ISRO as well as Indian entrepreneurs can foresee a multitude of opportunities in the UK.

## *2.3 Assessing Cooperation with European Institutions*

Besides cooperation with individual European countries, India entertains space relations with all major pan-European institutions involved in space matters. In this context, formal agreements have been signed with ESA, the EU, the EUMETSAT, and the ECMWF.

### 2.3.1 European Space Agency

India has a longstanding relation with the European Space Agency (ESA). The first consultation meetings date back to 1977, while the first cooperation agreement was signed in 1978. India's first telecommunication satellite, APPLE, was launched together with ESA's Meteosat 2 satellite on Ariane rocket in 1981. The launch paved the way for a strong Indo-European cooperation in the field of orbital launch service[213]. Indeed, since 1981, India has utilised Arianespace services more than 20 times for the launch of its heavier GEO satellites (including its first dedicated military satellite GSAT-7 in 2013), making ISRO one of Arianespace's most important clients[214]. ISRO reciprocated by launching ESA's PROBA satellite on board its PSLV in October 2001 in addition to a number of European small satellites. It is clear, however, that with the full operationalization of GSLV Mk III, this cooperation may be discontinued and even stimulate commercial competition in the future.

ESA and India's National Remote Sensing Agency signed an agreement in 1993 for the direct reception, processing archiving and distribution of ERS-1 SAR data in India. In the following years, cooperation in the field of remote sensing was further expanded, allowing exchange of data between Indian EO satellites (Resourcesat-1 and Risat-1) and ESA's Envisat and Soil Moisture and Ocean Salinity mission (SMOS) satellites. These data have become a useful tool for disaster relief and in 2002, India signed on the International Charter on 'space and major disasters' initiated by ESA and the French space agency[215].

In 2005, India and ESA signed a cooperation agreement on Chandrayaan-1. Through this

[209] UK Space Trade Association (2018). "New projects see UK space firms tackle global challenges". Web. http://www.ukspace.org/news-item/new-projects-see-uk-space-firms-tackle-global-challenges/

[210] Sheetz, Michael (2018). "The British are coming — for the rocket-launching industry". Web. https://www.cnbc.com/2018/04/21/uk-space-agency-aims-100-billion-by-2030.html

[211] McRae, Hamish (2018). "India is about to become the Commonwealth's largest economy – here are the challenges it will face on the way". Web. https://www.independent.co.uk/voices/india-commonwealth-largest-economy-challenges-uk-a8311031.html

[212] UK Government (2018). "UK and India agree ambitious new tech partnership". Web. https://www.gov.uk/government/news/uk-and-india-agree-ambitious-new-tech-partnership

[213] European Space Agency (2007). "ESA and India Tighten Relations at IAC 2007". Web. http://www.esa.int/About_Us/Welcome_to_ESA/ESA_and_India_tighten_relations_at_IAC_2007/(print)

[214] As noted by Lele, this specific arrangement "should not be viewed only as a commercial activity but also as one that demonstrates India's faith in the French administration, where they are depending on a foreign agency for the launch of a strategic system into space (Lele, Space Collaboration Beteen India and France - Towards a New Era, 2015).

[215] Aliberti, Marco (2018). "India in Space: Between Utility and Geopolitics". New York City: Springer. Pg. 212

agreement, ESA provided technical expertise in flight dynamics and mission analysis as well as three scientific instruments to be integrated on-board the Chandrayaan-1 spacecraft[216]. Incidentally, after the launch of Chandrayaan-1 in 2008, no additional cooperation efforts were pursued by both sides until January 2017, when the ESA-ISRO cooperation agreement was renewed for five additional years making it valid until January 2022[217]. The agreement identified several possible areas of cooperation to be formalised through mutual agreements. These include space sciences, telecommunications and remote sensing applications and corresponding data processing, meteorology, navigation, microgravity experiments and cooperation on satellite development. In addition, the agreement called for the establishment of joint working groups to identify new cooperation opportunities between ESA and ISRO.

Cooperation between the two agencies was further strengthened when ISRO chairman met ESA Director General in 2018 and requested a joint report identifying potential joint activities. As a result, four possible avenues of cooperation are now under consideration viz., EO applications, space sciences and exploration, human spaceflight and, space debris and safety of space operations. Multiple proposals put forward in 2018 by ISRO in Earth observation and remote sensing are currently under review. ESA's support to India's 2022 Indian human spaceflight mission is also being discussed.

### 2.3.2 European Union

Besides ESA, India has a long-standing cooperation and policy dialogue with the EU. Space technology cooperation was indeed mentioned as early as 1994 in the EU-India Cooperation Agreement and subsequently identified as a full-fledged component of the EU-India Strategic Partnership launched in November 2004 and included within the EU-India Joint Action Plan (JAP) endorsed at the Sixth EU-India Summit in[218]. The JAP opened cooperation space sciences, Earth observation and remote sensing for monitoring of natural resources and environment, communications, meteorology as well as navigation. India also negotiated an agreement to participate in the Galileo programme development by offering to invest $337 million (€300 million). This cooperation failed to materialise and remained limited to strengthening downstream GNSS industrial cooperation activities (see Chapter XX).

Compared to Galileo, both sides found the Copernicus programme as a more viable area of cooperation. An agreement was signed in 2018 between DoS and the European Commission to promote mutual access to the data from the European Union's Sentinel satellites and India's Earth observation satellites. The agreement includes a provision to access DoS in situ data as well as technical assistance to establish high bandwidth connections to ISRO sites. This agreement is expected to enable development of downstream sectors in both regions and also achieve broader policy objectives in tune with the EU-India Agenda for Action 2020.

This agenda is a vision document defining a common roadmap to jointly guide relations during 2016-2020. It was adopted at the 13th EU-India Summit of 2016 and is part of a broader effort to revitalise the EU-India strategic partnership announced at that summit by then President of the European Commission and India's Prime Minister. The agenda entails a list of joint objectives in a wide range of areas spanning foreign policy and security to trade, climate change, sustainable development and, research and innovation. With respect to space, the agenda recommends enhancing space cooperation including Earth observation and satellite navigation by strengthening interaction between Indian Regional Navigation Satellite System and EU's Galileo as well as joint scientific payloads.

Space cooperation between India and the EU has the potential to strengthen other areas of cooperation as well since climate change, urban development, information and communication technologies, energy and transport benefit from space derived data and applica-

[216] Indian Space Research Organisation (2005). "Agreement for Including European Instruments on Chandrayaan-1 Signed". Web. https://www.isro.gov.in/update/27-jun-2005/agreement-including-european-instruments-chandrayaan-1-signed

[217] European Space Agency (2017). "40 years of cooperation between ESA and ISRO". Web. https://espi.or.at/files/news/documents/40_years_of_cooperation_between_ESA_and_ISRO_-_Jean-Charles_Bigot.pdf

[218] In the joint Declaration released in conjunction with the launch of Strategic Partnership in 2004, the leaders emphasised space cooperation on Galileo: "We welcome the progress in the on-going discussion on the EU-India Draft Cooperation Agreement on the Galileo satellite navigation project. It will ensure India's equitable participation in Galileo space, ground and user segments and will guarantee the availability of highest quality signals over the Indian Territory." Considering that India has well proven capabilities in space, satellite and navigation related activities, the agreement will provide an important positive impulse for Indian and European industrial co-operation in many high-tech areas. The EU and India both have matured space programmes and a long history of cooperation in the peaceful exploration and uses of outer space.

tions. Therefore, space cooperation can be expected to play an increasingly active role in future India-EU relations.

### 2.3.3 EUMETSAT

Another pan-European agency India entertains cooperation with is the EUMETSAT. EUMETSAT was established to develop an operational meteorological programme for Europe after the success of ESA's Meteosat satellites in the 1970s[219]. ESA continues to be responsible for the space segment of EUMETSAT and both agencies collaborate on new programmes such as Copernicus. This collaboration facilitates exchange of satellite data for weather analysis and predictions. The data is gathered predominantly from IRSO's INSAT 3A, Kalpana and INSAT 3D satellite series and from EUMETSAT's polar orbiting satellites (Metop), geostationary satellites (Meteosat) and the Jason Altimetry Mission. However, this cooperation extends beyond the mere exchange of data, including data processing and reprocessing as well as calibration and validation. Building on existing cooperation, ISRO and EUMETSAT have expanded their cooperation to oceanography by using Meteosat-5 and Meteosat-7 satellite to provide imagery of the Indian Ocean area and later added ISRO's Oceansat-2 satellite. This proved valuable for monitoring of tropical cyclones and also contributed to growing partnership between EUMETSAT and ISRO.

This cooperation was reinforced through an agreement in 2014 that set to improve the existing mechanisms for data reciprocity and exchange of products as well as stressed regular bilateral meetings at technical and director-levels to review cooperation status and identify future cooperation plans. The core points of discussion during these meetings would include long-term cooperation plans, possibility of ISRO accessing data from the EU Copernicus Sentinels operated by EUMETSAT as well as the possibility of EUMETSAT obtaining access and data redistribution rights from ISRO's Scatsat-1 mission to complement its oceanography satellite programmes[220]. Eventually, EUMETSAT's access to India's scatterometer mission was agreed in 2016 while access to EU Copernicus Sentinels data was formalized through the above-mentioned 2018 agreement between ISRO and the European Commission. These developments are now expected to further consolidate ISRO-EUMESAT cooperation in a more fruitful partnership.

In addition to bilateral cooperation, ISRO and EUMETSAT entered into a tripartite agreement with CNES to enable data access to the Indo-French Megha-Tropiques and SARAL (Satellite with Argos and Altika) satellites. As reported by the EUMETSAT, this trilateral cooperation delivered its first benefits to users in 2013 with the start of real time dissemination of altimeter products from the SARAL satellite after full validation of the EUMETSAT ground segment elements. Ocean altimetry data from SARAL complements Jason-2 data as SARAL follows a different orbit and the combination of their data provides better coverage and sampling of global ocean circulation[221]. Subsequently, EUMETSAT and CNES implemented network connectivity and software needed to acquire and redistribute data from the SAPHIR humidity sounder on-board the ISRO-CNES Megha-Tropiques satellite. The data is now disseminated in near real-time to meteorological agencies. Moreover, ISRO and EUMETSAT have entered into multilateral agreements with the World Meteorological Organisation, the Committee on Earth Observation Satellites (CEOS), the Intergovernmental Group on Earth Observation (GEO) and the Coordination Group for Meteorological Satellites (CGMS). Another addition to India-Europe collaboration for weather forecasting is ECMWF, which is an independent intergovernmental organisation that monitors air quality, ocean circulations etc.[222].

## 2.4 Conclusion

India has a long-standing cooperation with Europe, be it at the individual national level or at the common European level bringing tangible benefits to both sides With India emerging as a capable spacefaring nation, the nature of cooperative efforts has evolved from capacity-building measures in early years of India's space programme to undertaking activities on a peer-to-peer basis at present. The analysis shows that both regions are well positioned to build on win-win cooperation in several areas

[219] European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) (n.d.). "International Cooperation: European Space Agency". Web. https://www.eumetsat.int/website/home/AboutUs/InternationalCooperation/EuropeanSpaceAgencyESA/index.html

[220] ISRO's Scatsat-1 mission was launched on 26 September 2016 by a PSLV-C35 rocket. The planned mission duration is of five years.

[221] EUMETSAT (2014, February). International Cooperation: Benefits for Global Users. Retrieved from http://www.eumetsat.int/website/home/InSight/NewsUpdates/DAT_2169186.html?lang=EN

[222] European Centre for Medium Range Weather Forecasts (ECMWF). "What we do". Retrieved from https://www.ecmwf.int/en/about/what-we-do

supported by deep political trust on either side. However, political uncertainties caused by Brexit is challenging the European space programme. The EU has decided to ban Britain from Galileo's military-grade signal system as it prepares to leave the Union. Britain has reacted by threatening delays in the Galileo procurement process using its membership capacity in the ESA Council[223]. As a result, the EU is contemplating a new space policy that would create an Agency of the Space Programmes allowing it to gain stricter control on the space programmes funded by the union[224]. However, ESA believes that the proposed agency would only duplicate the administrative processes while costing time and financial resources to become functional.

Amidst this political contention, EU has decided to increase its space programme budget to about $19 billion to be allocated between 2021-27, an increase of about $6 billion from the current budget[225]. Arguably, from ESA's perspective, the possible establishment of a rival agency under the jurisdiction of EU may cause further institutional misalignment threatening the efficacy of the European space programme and complicate international cooperation.

However, India is insulated from this process given the stronger bilateral space relations with European countries rather than ESA or the EU alone. The relationship with France is continuing stronger and new avenues of cooperation are being explored. France has demonstrated its inclination to engage with India's NewSpace industry by collaborating with Team Indus. Incidentally, the start-up culture is stronger in all the countries India has formal space agreements with. These countries are encouraging start-ups as the new baseline for economic development and some of them have captured global attention by emerging as space start-up hubs. Taking note of this, India has established mechanisms facilitating access to start-ups on either side, particularly with Nordic countries. The availability of capital, tax structures, high tech infrastructure and light-touch regulations encouraging the local space industries favour collaboration.

Another significant aspect to highlight is the growing effort on either side to capture shares of the burgeoning small satellite market. While synergies could exist between ISRO and its European partners on building small satellites owing to India's low manufacturing costs, attempts to jointly develop a dedicated launcher could turn into either an opportunity or competition. For example, France is interested in such a collaboration which is a positive development for India while the ongoing efforts in Italy and Spain could generate competition. It is impermissible to judge future collaboration with the UK in the current Brexit situation.

Nevertheless, a significant step that India should undertake is change its perception of the country's space programme as composed of different stakeholders rather than ISRO alone. India should take measures to build a globally competitive space industry, which is not possible without involving the private capital and industry players. An observation that is common to all the European countries discussed above is the apex decision to nurture local space industry and high technology skilled labour with the intent to develop non-space applications eventually. The encouragement to start-ups is the result of the later part of this strategy i.e. to build terrestrial applications using space technology and data. Such a policy should be replicated by India, along with the UK's experience that is encouraging also upstream oriented companies. India would greatly benefit from leveraging European partnerships beyond the realm of space technology and applications and should expand this cooperation to the space industry to build a well-rounded space programme composed of different stakeholders.

[223] Boffey, Daniel. The Guardian (2018). "European Space Agency boss warns EU of rival agency risks". Web. https://www.theguardian.com/science/2018/jun/06/european-space-agency-boss-warns-eu-over-star-wars

[224] Hollinger, Peggy et. al (2018). "European Space Agency proposes governance overhaul". Web. https://www.ft.com/content/84a5406c-67ff-11e8-8cf3-0c230fa67aec

[225] European Commission (2018). "EU budget: A €16 billion Space Programme to boost EU space leadership beyond 2020". Web. http://europa.eu/rapid/press-release_IP-18-4022_en.htm

# 3. Maximizing the Benefits of India-Europe Space Cooperation: Potentially Valuable Takeaways for India

By Ranjana Kaul*

## 3.1 Introduction

The India-EU diplomatic relationship spans four decades since the Cooperation Treaty of 17th December 1973. The 1994 EU-India Co-operation Agreement on partnership and development[226] set forth the legal framework enabling cooperation on political, economic and sectorial issues, including space. In November 2004 at the 5th EU-India Summit "*Space*" became a full element of the Strategic Partnership[227], specifically regarding satellite navigation – including India's participation in Galileo and cooperation between European Space Agency (ESA) – Indian Space Research Organization (ISRO)[228]. Space cooperation has since been reiterated and endorsed in all subsequent documents. Indeed, in March 2018 the EU and India signed a historic cooperation agreement to share Earth Observation Satellite Data to provide mutual benefits, particularly in the pursuit of the United Nations' Sustainable Development Goals and especially emphasizing long–term cooperation on data processing for common use in line with the EU-India Agenda for Action 2020. The March 2018 agreement also intends to promote the active development of downstream sectors in EU and India and facilitate the involvement of diverse users in the development of products and services[229].

Space cooperation has also been a reoccurring element, whether directly or indirectly, in India's deepening cooperation engagements with individual EU Member States. For example, the March 2018 India- France Space Cooperation Agreement, which covers almost every aspect of the peaceful uses of outer space including two joint space missions, was signed during the state visit of President Emmanuel Macron to New Delhi[230]. In contrast, the 2017 India-Germany bilateral agreements, which do not specially include a space cooperation agreement, encompass the promotion of security, stability, and sustainability contributing to a rules based global order. These agreements undeniably support the ubiquitous role space technology in realizing the objectives of the agreements. Global and national security issues, even if the national defence aspects are excluded from the list, necessarily include science & technology, climate change, natural disasters and response, the environment, urban development, water management, freedom of navigation, piracy, migrant flows and terrorism[231].

In sum, India has within its reach a dynamic platform consisting of cooperation agreements with the EU and with individual EU Member States. These collaborations can accrue a variety of opportunities and lead to the development of a more vibrant downstream sector in India. However, it can be argued that these opportunities will remain low hanging fruits if confined to a public-led effort. The synergistic involvement of the Indian private sector will

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226 European External Action Service (2013). "Cooperation Agreement between the European Community and the Republic of India on partnership and development" Web. http://ec.europa.eu/world/agreements/prepareCreateTreaties-Workspace/treatiesGeneralData.do?step=0&redirect=true&treatyId=352

227 Sourbès-Verger, I. (2016, December). EU-India Cooperation on Space and Security. *IAI Working Papers, 16|38*.

228 European Commission (2014). "Fifth India-EU Summit, The Hague, 8 November 2004 – Joint *Press Statement"*. Web. http://europa.eu/rapid/press-release_PRES-04-315_en.htm

229 European External Action Service (2018). "European Commission and Department of Space of India signed historic Cooperation Arrangement to share satellite Earth Observation data" Web. https://eeas.europa.eu/delegations/india/41583/european-commission-and-department-space-india-signed-historic-cooperation-arrangement-share_en

230 Ministry of External Affairs of India (2018). "India- France Joint Vision for Space Cooperation, New Delhi, March 2018". Web. http://mea.gov.in/bilateral-documents.htm?dtl/29597/IndiaFrance+Joint+Vision+for+Space+Cooperation+New+Delhi+10+March+2018

231 Sourbès-Verger, I. (2016, December). EU-India Cooperation on Space and Security. IAI Working Papers, 16|38.

be necessary to ensure a more efficient and robust development of products and services. Arguably, this is a target that can be best pursued by tasking the Niti Aayog (National Institution for Transforming India)[232] to design an ecosystem aimed at realizing the optimum potential of the national space industry and commercial space sectors. It is also suggested that such development is likely best rolled out through the enactment of a comprehensive National Space Policy and -roadmap for Implementation that will allow achieving the objectives identified by Niti Aayog. In fact, while India is one of the *Big Six in Space*[233], it has yet to unroll a national policy for the robust participation of the private industry in the space sector.

In this respect, the careful and systematic trajectory adopted by the EU in respect to its own space programme - starting with the development of Galileo and Copernicus and the subsequent promotion of commercial downstream services - offers many valuable takeaways for India. Consequently, this paper will look into the way in which India could take home some lessons from the EU experience and will offer some suggestions for short term and long-term policy interventions to support the active participation of private industry and maximize the benefits of EU-India cooperation. Towards this, the paper will first offer an overview of the most recent developments in India with regard to private sector involvement in space matters. Subsequently, the chapter will discuss the rationales and scope of a National Space Policy for India, and eventually provide key takeaways and suggestions.

## 3.2 Private Industry Participation in India: Recent Developments

In many countries, the commercial space sector has become the critical pillar to support and strengthen not just national space programmes, but the country's overall economy. Especially for the spacefaring nations, space activities are no longer an exclusive domain for governments: the private sector and new space companies have increasingly emerged across almost all verticals in the up-stream and down-stream space segments, well beyond satellite communications to into commercial space transportation and human space flights.

In India, the involvement of the private sector was for a long time marginal. This was primarily a consequence of the limited industrial base India could rely on during the early stage of its space programme. Consequently, the establishment of the required facilities and capabilities for the design, development, assembly, integration and testing of satellites and launch vehicles was entrusted to the Indian Space Research Organisation (ISRO). In terms of the statutory framework provided under the provisions of the *Government of India Allocation of Business Rules 1961 (as amended) for the Department of Space (Antariksha Vibhag)*[234], the implementation of space activities is placed under the jurisdiction of the Department of Space (DOS). The DOS reports to the Prime Minister, who is the minister in charge. The Business Allocation Rules contain a list of 15 main titles of space activities, which are implemented by DOS through ISRO and other entities under its jurisdiction in terms of the policies and programmes formulated by the Space Commission. This institutional mechanism has continued to receive the full support of the federal government, irrespective of the

232 Niti Aayog was established in 2015, replacing the 55 year old Planning Commission of India which followed the top-down approach. Niti Aayog serves as Government of India's policy think tank with the aim to achieve Sustainable Development Goals and to enhance cooperative federalism by fostering the involvements in economic policy making using a bottom up approach. The Prime Minister is the ex-officio Chairman of Niti Aayog. Its initiatives include "15 year road map", "7-year vision, strategy and action plan", AMRUT, Digital India, Atal Innovation Mission, Medical Education Reform, Agricultural Reforms (Model Land Leasing Law, Reforms of the Agricultural Produce Marketing Committee Act, Agricultural Marketing and Farmer Friendly Reforms Index for ranking states), Indices Measuring States' Performance in Health, Education and Water Management, Sub-Group of Chief Ministers on Rationalization of Centrally Sponsored Schemes, Sub-Group of Chief Ministers on Swachh Bharat Abhiyan, Sub-Group of Chief Ministers on Skill Development, Task Forces on Agriculture and Elimination of Poverty, and Transforming India Lecture Series.

233 Big Six in Space is a term used to indicate the six major space agencies worldwide. Each of them provides launch services (i.e. builds their own orbital-class rockets), builds their own satellites and scientific payloads, and has either achieved human spaceflight or interplanetary robotic science missions or both. In alphabetical order: (i) China: CNSA China National Space Agency ; (ii) EU: ESA European Space Agency, a consortium of national space agencies of several European countries; (iii) India: ISRO Indian Space Research Organisation; (iv) Japan: JAXA the Japanese national space agency; (v) USA: NASA National Aeronautics and Space Administration ; and (vi) Russia: ROSCOSMOS the Russian space agency

234 The Government of India (1961). "Government of India (Allocation of Business) Rules, 1961". Web. https://cabsec.gov.in/writereaddata/allocationbusinessrule/completeaobrules/english/1_Upload_1437.pdf

political party in government since its inception in 1972.

Historically, the private industry in India has been mainly built up by ISRO itself by providing technology transfer and buy-back agreements for several subsystems. This has enabled the creation of a local industry ecosystem of 500 Small and Medium Scale Enterprises (SMEs) that serves as a part of the supply chain of the space program which today works for the realization of space and ground infrastructure. Reports on industry participation in ISRO programmes suggest that 80% of the launch vehicle (PSLV) production being supported by industries. Similarly, over 120 industries are reported to have contributed to the Mars Orbiter Mission (MoM) which was the first attempt success in reaching Mars by any country in the world. The downstream application ecosystem in certain applications is almost entirely outsourced to industry.

It is, however, important to stress that the current supply chain for space infrastructure development and exploitation continues to be centred around ISRO (Figure **2**). A significant number of SMEs are involved as Tier-2/Tier-3 (subsystems components) suppliers to ISRO with only very few Tier-1 space companies (delivery of complete sub-systems). The relationship of suppliers mainly revolves around catering to several ISRO centres depending on their mandate and contribution to the development of space missions.

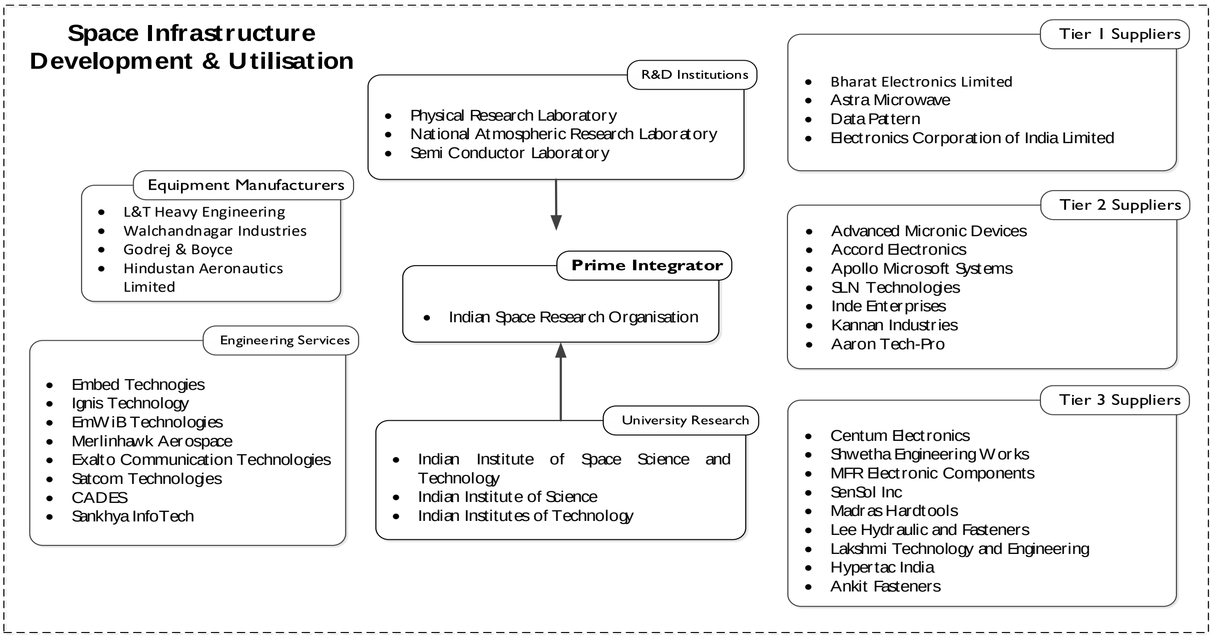


Figure 2: Role of Private Industry in the Indian Space Programme

The situation, however, is rapidly evolving. On 18th July 2018, the Government awarded three companies[235], each with a three-year contract for undertaking assembly, integration and testing of 9 small and medium satellites, aggregating in total 27 satellites. Arguably, this was a landmark moment. For the first time, the engagement between DoS and the private sector was catapulted beyond the range of the routine sub-contracts for sourcing specific products and services for the space programme. This was correspondingly the first time that the assembly, integration and testing of satellites functions was opened to the private sector.

Of the three awardees, Alpha Design Technologies Pvt. Ltd[236] with six consortium partners[237] and Tata Advanced Systems Ltd (TASL)[238] are private sector companies; while Bharat Electronics Ltd (BEL) is a public sector defence company. The task for each contractor in-

[235] U.R. Rao Satellite Centre, (Department of Space) executed the contracts with the companies.

[236] Alpha Design Technologies Pvt Ltd. (n.d.). “Alpha Design Technologies Pvt Ltd.”. Web. www.adtl.co.in/

[237] New Tech Solutions Pvt Ltd. (n.d.). Web. http://www.ntsblr.com/; Aidin Technologies Pvt.Ltd (n.d.). Web. www.aidintech.com/ ; Aniara Communications Pvt. Ltd (n.d.). Web. www.aniara.co.in/ ; Vinyas Innovative Technologies Pvt Ltd. (n.d.). Web. http://www.vinyasit.com/; DCX Cable Assemblies Pvt.Ltd (n.d.). Web. www.dcxindia.com/ and Exseed Space India Pvt Ltd (n.d.). Web. www.exseed.com/

[238] Tata Advanced Systems Ltd. (n.d.). Web. www.tataadvancedsystems.com/

volves producing three small to medium satellites each per year by July 2021[239]. The execution of the projects however requires the contractors to work with engineers at the three dedicated workstation facilities being setup at the U.R. Rao Satellite Centre (URSC) for the purpose.

It is important to note that the *Government of India Allocation of Business Rules 1961 (as amended) for the Department of Space (Antariksha Vibhag)*[240] provides the authority and regulatory underpinning for the Department of Space, for the three contracts with Alpha Design Technologies Pvt. Ltd, the Tata Advanced Systems Ltd (TASL) and Bharat Electronics Ltd (BEL), as well as for all other existing routine and limited subcontracting agreements with the private or public sector companies in India.

In other words, the Allocation of Business Rules and applicable normative laws already provide the foundation for the robust expansion of participation of private sector in manufacturing and related services, under the aegis of the Department of Space. Therefore, it could be argued that the impediment for the participation of the private sector in manufacturing and related activities for the downstream space sector does neither stem from the lack of applicable normative laws in force nor from the lack of interest on part of the private sector. Rather, it is the very posture of the government that can allow or prevent the private sector's participation. Arguably, countries make the best decisions when they have their backs to the wall[241].

Besides satellite manufacturing, in late 2017, Mr Kiran Kumar, then Chairman of ISRO, confirmed that the state-run space agency was planning to privatize the entire operations for the Polar Satellite Launch Vehicle (PSLV) by 2020[242] through industrial alliances routed through Antrix Corporation. During an interview on 12th August 2018, Dr. K Sivan, Chairman of ISRO informed us that India requires 45 additional satellites in orbit to augment the existing fleet of the 45 satellites presently in orbit[243]. The Chairman of ISRO and the Chairman of Antrix Corporation Limited followed up with an announcement on 29th August 2018, at the 6th Edition of the Bangalore Space Expo (BSX), saying that there was no hurdle in working with the private sector in the ₹ 1500–2000-crore annual Small Satellite Launch Vehicle (SSLV) launch business. This would include building single-vehicle launches, propellant vehicles in large numbers – a promising announcement for the country. At the occasion Vikram Kirloskar, Vice-President of CII, said that the "BSX was started with the intent to bring together Indian industries, ISRO and various other stake holders in the space domain for common benefit of improving productivity and commerce"[244]. At last, it appears that time has arrived for India to progress towards building capacity in the private sector as the first step towards establishing a national commercial space sector. As the only country, among the *Big Six in Space,* which does not derive strength from its own robust commercial space sector, the decision by the Government has not come a day too soon.

Arguably, rapid developments in the telecommunications and broadcasting sectors have had a bearing on the decision to open manufacturing and related activities in the space sector to the private sector. In the 20 years following the enactment of the *Policy Framework for Satellite Communications in India 1997*[245] and the New Telecom Policy 1999[246],

239 The Hindu (2018). "ISRO ropes in three partners to assemble 27 satellites". Web. https://www.thehindu.com/news/national/isro-ropes-in-three-partners/article24454488.ece

240 AOBR: *Supra* n. 19

241 Prime Minister of India Mr. PV Narsimha Rao was asked by a journalist in 1991 how he had found the courage to take the momentous decision to liberalize the Indian economy in a single stroke. The Prime Minister replied "*It is easy to be brave when you have your back against the wall!*" (The Prime Minister was referring to India's foreign debt cri sis which at the time stood at about $72 million, the third largest in the world at the time. A sharp decline in the country's foreign currency reserves had made the situation so grim that government had to mortgage about 20 tonnes of gold worth $240 million, just to keep the economy).

242 TECH News18.com (2017). "Why ISRO Plans to Privatize PSLV Manufacturing by 2020" Web. https://www.news18.com/news/tech/why-isro-plans-to-privatize-pslv-manufacturing-by-2020-1578105.html

243 Hindustan Times (2018). "India needs 45 more satellites in space: ISRO chairman". Web. https://www.hindustantimes.com/science/india-needs-45-more-satellites-in-space-isro-chairman/story-RmoIuyXz9rgFweZhu7Tp6N.html

244 The Hindu (2018). "ISRO, Antrix to involve private sector in SSLV biz" Web. https://www.thehindubusinessline.com/news/isro-antrix-to-involve-private-sector-in-sslv-biz/article24812998.ece

245 Policy Framework for Satellite Communications in India 1997: Permitted very operations in India by using foreign satellites was permitted in special cases that were notified. Web. https://www.isro.gov.in/sites/default/files/article-files/indias-space-policy-0/satcom-policy.pdf

246 New Telecom Policy 1999 (NTP 99). India's first Satcom Policy is stated at Para 3.9 of NTP 99 Web. http://www.nicf.gov.in/pdf/rules_policies/new_telecom_policies_1999.pdf

Briefly, the first attempt to liberalize country's telecom sector was made by Prime Minister Mrs Indira Gandhi in 1981, but withdrawn because of political opposition. The process was renewed Prime Minister Rajiv Gandhi. By 1985 India was manufacturing electronic telephone exchanges, got a new Department of Telecommunications (DOT). In 1986 the Mahanagar Telephone Nigam Limited (MTNL) were set up for providing telecom services to the metro cities Delhi & Mumbai; and the Videsh Sanchar Ni-

(which includes the '*Satcom Policy'* and the *Guidelines for Implementation of Satcom Policy 2000* by Department of Space[247]) India's satellite demand has burgeoned. However, this has been met by using transponder capacity on foreign satellites with the hope that INSAT capacity will be built up to the required levels. Both the sectors achieved phenomenal growth trajectory so that today India has emerged as the second largest telecommunications market[248]. The disconnect between demand and supply meant that the rate of expansion of the satellite telecom-broadcasting sectors raced far ahead of the rate at which INSAT capacity was built to fulfil the ever-expanding demands for transponder capacity. Recently, the Antrix Corporation Limited[249] acknowledged that 85% of the current transponder capacity requirements for the commercial telecommunications and broadcasting sectors is met by leasing capacity on foreign satellites. This has been common knowledge, not in the least because the subsisting ecosystem for obtaining transponder capacity continues to impose an avoidable additional burden of cost on the industry. Clearly, the present status cannot be a prescription for the future. Furthermore, the recent government initiative requiring broadcasting companies to migrate from using leased transponder capacity on foreign satellites to using capacity on INSAT satellites – though relaxed from its immediacy and concerns about subsisting long term lease contracts – makes it clear that the government intends the communications sectors in India to use INSAT capacity[250]. There is clearly urgency in the matters of manufacturing and launching communication satellites. Additionally, a plain reading of the Consultation Paper on Draft National Digital Communications Policy, 2018[251] (also known as Draft National Telecom Policy 2018) sets the ambitious Strategic Objective to be achieved by 2022. This objective is to be reached through public-private partnerships, including the Connect India; Propel India; and Secure India Missions, by timely deployment of implementation strategies, consisting of among others, a review of the satcom policy, spectrum access policy, universal broad band access, next generation access technologies and appropriate regulatory regimes. It is important to note that Satellite communications is the strategic objective focus area for India for the five years.

There are significant challenges for the DOS to scale up its infrastructure and one cannot expect an over-night and single-handed multiplication of ISRO's capacity to:

- build and launch the required number of communication satellites, including the replacement of satellites;
- subsume current and future demands of the telecommunication and broadcasting sectors;
- fulfil the Digital India mission;
- provide capacity required to fulfil identified goals under the National Digital Communication Policy, 2018;
- provide digital connectivity to the BIMSTEC countries, as part of regional co-operation, announced by Prime Minister recently[252].

gam Ltd (VSNL) for providing international long distance operations. In 1991, the severe financial crisis and resultant balance of payments issue led the government led by Prime Minister PV Narsimha Rao to liberalization of the Indian economy. GOI allowed partial liberalization by inviting private sector participation and foreign direct investment was permitted in several sectors including telecom.

247 Procedures for Satcom Policy Implementation, 2000 including therein : (i) Para 3 deals, inter alia, with conditions for Indian registered companies to establish & operate private satellite systems including allowing FDI not exceeding 74% with prior government approval ; (ii) at Para 3 also states that the Wireless & Planning Wing (WP&C) DoT is responsible for allocation of orbit-spectrum ; and (iii) Para 4 deals, inter alia, with lease of INSAT capacity to non-government users on commercial basis; and (iv) Para 5 deals with providing capacity on foreign satellites to accelerate roll out of satcom in India, until INSAT capacity can be provided. (https://www.isro.gov.in/update/08-aug-201 4/procedures-satcom-policy-implementation ). It may be noted that the Foreign Direct Investment Policy 2000 (FDI Policy) permitted FDI not exceeding 74% equity share capital with the prior government approval for Establishment and Operation of Satellite' .

248 Financial Express (2017). "Indian telecom sector second largest market in world; significant contribution to country's GDP growth". Web. https://www.financialexpress.com/economy/tapping-the-telecom-sector-for-next-phase-of-gdp-growth/980877/; Indian Brand Equity Foundation (2019) "Indian Telecom Industry Analysis". Web. https://www.ibef.org/industry/indian-telecommunications-industry-analysis-presentation

249 Antrix Corporation Ltd was incorporated in 1992 as the commercial arm of ISRO and functions under the aegis of the Department of Space.

250 Indian Television (2018). "MIB says ISRO upping capacity to facilitate migration from foreign satellites". Web. http://www.indiantelevision.com/regulators/ib-ministry/mib-says-isro-upping-capacity-to-facilitate-migration-from-foreign-satellites-180407 "The Indian government has admitted that inadequate capacity on Indian satellites has compelled domestic direct to home (DTH) operators to use a large number of transponders on foreign satellites and that India's space agency Indian Space Research Organisation (ISRO) is gearing up to meet growing demands owing to proliferation of HD TV channels."

251 Department of Telecommunications (2018). "Inviting Public comments on Draft National Digital Communications Policy – 2018". Web. http://dot.gov.in/sites/default/files/2018%2005%2025%20NDCP%202018%20Draft%20for%20Consultation_0.pdf

252 The Times of India (2018). "At BIMSTEC meet, PM Modi bats for better regional connectivity" Web. https://timesofindia.indiatimes.com/india/india-committed-to-work-with-bimstec-member-states-to-enhance-regional-connectivity-pm-modi/articleshow/65610689.cms

DoS/ISRO is also called upon to realise identified core national missions across various verticals, including the support of the Neighbourhood First foreign policy objectives since 2014[253]. Furthermore, there are on-going mandates to compete in the international commercial space launch market; to engage in R&D and innovation for newer technologies that allow for low cost access to outer space and applications required for national governance and security; and to meet the deadline of December 2021 set for India's first human spaceflight. The decision to invite private sector participation in manufacturing and related activities for new satellites and launch vehicles, some would argue, is driven by necessity. Whatever the impetus, the decision is most welcome.

It is a reiteration that when time is of the essence, the full potential of the private sector is available to the country for ensuring quick turnaround and timely achievement of government policies and objectives.

## 3.3 NITI Aayog: National Space Policy & Strategy for Implementation

The acceptance of the long-awaited invitation from the Department of Space/Antrix Corporation, by the private companies and start-ups, is a milestone event. With no doubt, the partnership will be successful. The Government's decision to open manufacturing for the space sector also simultaneously recognizes the potential of India's nascent New Space, along-side established companies – private and public sector. However, there is apprehension regarding the recent award of contracts to the private sector. In the absence of a national space policy that can systematically sustain the momentum, this development may well rather sustain a system of intermittent need-based decisions by the Department of Space[254].

A growing participation of the private sector in all verticals of space-enabled businesses, including manufacturing, can be certainly expected as a result of the recent push on the government side. However, it is argued that enabling the take-off of the **first vertical** (i.e. a national space industry complex) as a stand-alone development, will be akin to the proverbial *glass half full.* The *other half* can be filled only by rolling out the **conjoint second vertical**, that is, a careful designed policy ecosystem, including therein prescriptions for a regulatory-procedural-institutional framework. This would enable an Indian to establish a private communications satellite system launched by ISRO and registered as such. An accessible policy for granting experimental license (together with required frequency bands and permission for acquiring a sample consumer users) to the private sector for undertaking proof of concept trials, prior to commercial roll out of satellite communications services, will accelerate deriving benefit from new communications technologies. In other words, it will facilitate a level playing field to allow the emergence of Indian satellite operator companies to provide services within the country, the region and worldwide. It is understood that activities in outer space by non- government Indian entities can be permitted only when duly authorized and under continuing supervision of the designated regulator. The principle requirement to support such a development is a national law to regulate space activities in outer space by private entities in consonance with principles contained in the international space law treaties[255]. Needless to state that institutional mechanisms which provide for separation of functions of licensor, service provider and regulator will be cardinal to ensure transparent and efficient administration for on ground activities and for activities in outer space activities. It is important to recognize that of the *Big Six in Space,* India is the only country without such support.

Admittedly, India's civil space programme is being harnessed ever more in every aspect of national life, including citizen- focused efficient and transparent governance systems at the federal and in the state levels; rapid inclusive socio-economic development along all verticals and for assured robust national security. Satellites and the radio frequency spectrum used to connect with various technology driven tools have a pervasive and ubiquitous presence at every level across all governance institutional and governance verticals in the country. The principle technology platforms are provided by satellite telecommunications and broadcasting tools (voice-data-image)

[253] The Hindu (2017). "SAARC satellite to be launched on May 5". Web. https://www.thehindu.com/news/national/isro-to-launch-south-asia-satellite-on-may-5/article18332816.ece; DNA (2016). "IRNSS launch: PM Modi names new navigation system 'NAVIC'". Web. https://www.dnaindia.com/india/report-irnss-launch-pm-names-new-navigation-system-navic-2207221

[254] Government of India (Allocation of Business) Rules, 1961 for Department of Space (Antriksha Vibhag)

[255] Outer Space Treaty 1967; Rescue Agreement 1968; Liability Convention, 1972, Registration Convention 1976; and Moon Agreement 1979. In addition to the 5 Treaties are the UNGA Resolutions on specific space activities.

and the Internet; satellite imagery (images of the Earth provided by remote sensing satellites); and satellite navigation tools (GPS on mobile handsets and other receivers). Today, users are dependent on their hand set which provides them all three at the touch of a button. The following verticals are related to space enabled services.

**The third vertical** is related to the commercial use of NavIC satellite navigation[256] applications. This vertical is in a nascent stage and a policy for civil and commercial use of NavIC signals is awaited. The importance of the availability of inexpensive, user friendly receivers that are compatible and coordinated with NavIC signals does need not be overstated.

**The fourth vertical** is related to the already extensive commercial uses of remote sensing images or GIS and its prolific adaptations for different applications. The Indian geospatial industry has played pivotal role in facilitating adoption of geospatial technologies in India and have participated in implementation of large mission critical projects cutting across domains including disaster management, urban, natural resource management, utilities, land record modernization, security. Over the last several years, the industry has moved up the value chain in client engagement – from data conversion projects to large mission critical systems integration projects. Indian geospatial companies are also implementing large GIS projects successfully in other parts of the world. Indian users have, thus, benefited from this global exposure as best practices developed from international projects have been applied in domestic projects -- thereby enhancing value creation for our Indian customers. It has also led to the development of a world class technical workforce in India, capable of meeting the requirements of discerning customers globally. This has come about despite the restrictions and impediments inherent in the Indian regulatory framework consisting of 2011 Remote Sensing Data Distribution Policy[257]. There is no escaping the fact that Indian geospatial companies thrive outside India and start-ups by young Indians are preferring to set up their companies overseas.

Finally, **the fifth vertical**, encompassing innovations and development of cyber technology tools to ensure the safety and security of ground assets and conduct of the national space programme. Impetus for innovation includes new disruptive technologies for low cost access to outer space and low cost- low energy consuming solutions, the adoption of new age technology like 3D Printing into the space sector and space missions, including stronger protection for IPR are among the other possibilities.

## 3.4 Some Suggestions

The March 2018 EU-India cooperation agreement provides an excellent opportunity for provide mutual benefits, particularly in the pursuit of the United Nations' Sustainable Development Goals, to share Earth Observation Satellite Data[258], long –term cooperation on data processing for common use, and agreed intention for the active development of downstream sectors in EU and India. It is especially relevant and thus suggested to undertake a comprehensive review with a national perspective of the 2011 RSDP and 2005 Map Policy – in particular, to remove existing impediments and contradictions holding back the full potential of the Indian GIS sector, so that the policies are capable to be read together harmoniously and seamlessly. It is suggested that government facilitate a policy prescription with the objective to ensure that domestic GIS companies and start-ups benefit to the greatest extent possible as the EU-India cooperation agreement is rolled out.

Two decades after satellite telecommunication and broadcasting (e.g. Google Earth and GPS services), entered national lives, a new generation of government users, commercial users and ordinary citizen users have progressed from awe to creating innovative solutions. The policy framework, where each department or Ministry is the gate keeper and policies are often contradictory, cannot sustain balanced development. The recent opportunity for private sector to manufacture for the space sector needs to be built upon and domestic satellite operators encouraged. It is expected that India will not let itself to be left behind any longer.

There is scope to have continuous and timely reviews of all policies framed by individual Ministry /Department to serve their specific objectives. This will allow a much harmonious

256 Department of Space Indian Space Research Organisation (n.d.). "Indian Regional Navigation Satellite System (IRNSS): NavIC". Web. https://www.isro.gov.in/irnss-programme

257 Government of India (2011). "Remote Sensing Data Distribution Policy (RSDP – 2011)". Web. http://www.indiawaterportal.org/sites/indiawaterportal.org/files/Remote_sensing_data_policy_2011_released_by_ISRO.pdf

258 European ' Copernicus hub' and ISRO Oceansat-2, Megha-Tropiques, Scatsat-1, SARAL, INSAT-3D, INSAT-3DR, except high resolution data

development and integration of space technology applications in achieving their objectives as well as allowing the industry to flourish. Decision taken by individual government departments within their own limits may result in entry barriers that are restricting economic development for industries in some of the emerging sectors such as space. An example of this case is the imposition of General Sales Tax (GST) on an Indian company and start-up seeking to launch of a satellite on an ISRO launch vehicle, but none on a foreign company seeking to launch a satellite on an ISRO launch vehicle. Needless to say that the entry barrier for domestic companies in the commercial launch sector is evident.

Indeed, the "*space sector*" ought to be identified as a driver for national development for period 2018-2050. Indian space assets ought to be designated and included as '*National Critical Infrastructure*' and added to the list of '*Priority Sectors*[259]'. For a nation that seeks to achieve Prime Minister Narendra Modi's vision for '*Digital India'* and '*Make in India',* any delay could well lead to disastrous consequences. The ultimate objective should be to build strong and secure industrial space and commercial space sectors in the country to support and help expand the national programme as well as to drive innovations and technological developments

The Niti Aayog (National Institution for Transforming India) is allocated the business of designing an ecosystem aimed at realizing the optimum potential of a national commercial space sector, a phase-wise and balanced development - possible when the Indian private sector can realize its full potential. This will be possible only if "national space activities" as a specific area of economic activity is specifically referred to NITI Aayog for formulation of an umbrella national space policy – consisting of specific policy objectives/implementation strategy for each vertical together constituting "national space activities" - which incorporates national security within in the economic policy and strategy.

It is suggested that such development is likely best rolled out through the mechanism of a (i) National Space Policy for India - 2050; (ii) Roadmap for Implementation of the National Space Policy by 2030 – including (iii) carefully designed and appropriately drafted supporting frameworks for institutional and supporting regulations that will allow for timely roll out and implementation of policy and achieve delivery of objectives clearly identified by Niti Aayog. This will not only support the emergence of a strong private ecosystem, but fully seize the opportunities opened by EU-India cooperation.

[259] Priority Sector refers to a sector which the Government of India and Reserve Bank of India consider as important for the development of the basic needs of the country and are to be given priority over other sectors. The banks are mandated to encourage the growth of such sectors with adequate and timely credit.

# 4. Regulatory Framework: Upstream Sector in the Space Industry

By Pushan Dwivedi*

The space industry can be categorized into upstream and downstream sectors[260]. The upstream sector concerns itself with players such as "space prime contractor, contract R&D, space component supplier, and space subsystems". Conversely, the downstream sector includes the use of such technology by facilitating services for satellite broadcasting, "earth observation, financial services, and satellite communications"[260].

This note focuses on the international and domestic framework for the development of launch vehicles that fall under the upstream division of the space industry in India. International treaties form a comprehensive framework to identify and assign liability for space activities, of government agencies as well as private stakeholders, among sovereign countries. However, there is no comprehensive legislative framework to regulate the upstream sector of the space industry in India. In the absence of a comprehensive legislative framework, the development of launch vehicles may be subject to the layered regulatory framework under the Explosives Rules, 2008 enacted under the Explosives Act, 1882.

In recognition of the growing importance of private sector led space initiatives, the Draft Space Activities Bill, 2017 is an important step towards a comprehensive legislative framework in India to regulate the space industry. The proposed framework under the Draft Space Activities Bill, 2017 is indicative of the regulatory landscape that may be applicable on development of launch vehicles in India in future.

## 4.1 International Framework

The international regulatory framework, in the context of space activities, includes 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 (hereinafter "Outer Space Treaty"), the Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, 1967 (hereinafter "Astronaut Convention"), the Convention on International Liability for Damage Caused by Space Objects, 1972 (hereinafter "Liability Convention"); the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, 1979 (hereinafter "Moon Agreement") and the Convention on Registration of Objects Launched into Outer Space, 1974 (hereinafter "Registration Convention"). India is a party to all the five international treaties. The Outer Space Treaty, the Liability Convention and the Registration Convention are applicable in the context of upstream development of launch vehicles.

### 4.1.1 The Outer Space Treaty

India has ratified the Outer Space Treaty that provides the freedom of exploration and use of outer space, including the Moon and other celestial bodies, to all States without any discrimination. Further, it also assures the freedom of scientific investigation in outer space, including the Moon and other celestial bodies[261]. The Outer Space Treaty mandates that

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260 130, 7th Report, Select Committee on Science and Technology, House of Commons, United Kingdom (4th July, 2007). Web.https://publications.parliament.uk/pa/cm200607/cmselect/cmsctech/66/6608.htm.

261 Article I, Outer Space Treaty, 2002: The exploration and use of outer space, including the Moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind. Outer space, including the Moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies. There shall be freedom of scientific investigation in outer space, including the Moon and other celestial bodies, and States shall

"activities of non-governmental entities in outer space, including the Moon and other celestial bodies" are authorised and supervised by empowered government agencies[262]. Therefore, initiatives from the private sector in India in the upstream development of launch vehicles require compliance with the applicable legal and regulatory framework in India. The Indian State is obligated to ensure that the legal and regulatory framework permits the development and deployment of a launch vehicle only for the benefit and interests of all countries[263]; guided by the principle of cooperation and mutual assistance[264]; and in accordance with international law, including the Charter of the United Nations, 1945[265].

Further, the prohibited activities within the aforesaid legal and regulatory framework should include the placing in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction; installation of such weapons on celestial bodies; stationing such weapons in outer space in any other manner; establishment of military bases, installations and fortifications on celestial bodies; and testing of any type of weapons on celestial bodies and conduct of military manoeuvres on celestial bodies[266]. Permitted activities under the applicable framework should not result in damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the Moon and other celestial bodies[267].

### 4.1.2 The Liability Convention

The Liability Convention holds the launching state absolutely liable to compensate for any damage caused by its space objects on the surface of the Earth[268], or to an aircraft in flight[269], or elsewhere than on the surface of the Earth, to a space object of another launching state, or to persons or property on board such a space object[270].

facilitate and encourage international cooperation in such investigation.

[262] Article VI, Outer Space Treaty, 2002: States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the Moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental entities in outer space, including the Moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty. When activities are carried on in outer space, including the Moon and other celestial bodies, by an international organization, responsibility for compliance with this Treaty shall be borne both by the international organization and by the States Parties to the Treaty participating in such organization.

[263] Article I, Outer Space Treaty, 2002.

[264] Article IX, Outer Space Treaty, 2002: In the exploration and use of outer space, including the Moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of cooperation and mutual assistance and shall conduct all their activities in outer space, including the Moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty. States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them 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, shall adopt appropriate measures for this purpose. If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space, including the Moon and other celestial bodies, would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space, including the Moon and other celestial bodies, it shall undertake appropriate international consultations before proceeding with any such activity or experiment. A State Party to the Treaty which has reason to believe that an activity or experiment planned by another State Party in outer space, including the Moon and other celestial bodies, would cause potentially harmful interference with activities in the peaceful exploration and use of outer space, including the Moon and other celestial bodies, may request consultation concerning the activity or experiment.

[265] Article III, Outer Space Treaty, 2002: States Parties to the Treaty shall carry on activities in the exploration and use of outer space, including the Moon and other celestial bodies, in accordance with international law, including the Charter of the United Nations, in the interest of maintaining international peace and security and promoting international cooperation and understanding.

[266] Article IV, Outer Space Treaty, 2002: States Parties to the Treaty undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner. The Moon and other celestial bodies shall be used by all States Parties to the Treaty exclusively for peaceful purposes. The establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military manoeuvres on celestial bodies shall be forbidden. The use of military personnel for scientific research or for any other peaceful purposes shall not be prohibited. The use of any equipment or facility necessary for peaceful exploration of the Moon and other celestial bodies shall also not be prohibited.

[267] Article VII, Outer Space Treaty, 2002: Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the Moon and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in air space or in outer space, including the Moon and other celestial bodies.

[268] Article II, The Liability Convention, 1972: A launching State shall be absolutely liable to pay compensation for damage caused by its space object on the surface of the earth or to aircraft flight.

[269] Article II, The Liability Convention, 1972.

[270] Article III, The Liability Convention, 1972: In the event of damage being caused elsewhere than on the surface of the earth to a space object of one launching State or to persons or property on board such a space object by a space object of another launching State, the latter shall be liable only if the damage is due to its fault or the fault of persons for whom it is responsible.

Launching state refers to the state that launches or procures the launching of a space object or the state from whose territory or facility a space object is launched[271]. Therefore, a state is liable for launch related activities of private agencies as well. The term launching here includes attempted launches[272]. However, to the extent that a launching State establishes that the damage has resulted either wholly or partially from gross negligence, or from an act or omission done with intent to cause damage on the part of a claimant State, or of natural or juridical persons it represents, it will be exonerated from the liability, provided it can prove that the damage was not a result of activities that were not in conformity with international law[273].

### 4.1.3 The Registration Convention

The Registration Convention mandates the maintenance of registry of launching vehicles by the launching states, with contents and conditions as determined by it[274].

The Registration Convention also provides that the UN Secretary General is informed of the establishment of such a registry and furnished with the information concerning each space object carried on its registry[275]

## 4.2 Domestic Framework

International treaties or agreements entered into by India do not have the force of municipal law without legislation[276]. Currently there is no mechanism in place for authorization of private players. Instead, authorizations for the development of a launch vehicle are governed by contractual agreements between authorised space agencies and private players. An example of such an agreement includes the launching service agreement between Antrix (ISRO's commercial wing) and TeamIndus (that has now been called off)[277].

### 4.2.1 The Explosives Act, 1884

In conjunction with the contractual framework, the development of launch vehicles may also fall within the ambit of the Explosives Act, 1884. The main engine thrust of a launch vehicle is increased through the use of solid or liquid propellants[278]. Section 4(d) of the Explosives Act, 1884 read with Rule 2(42)[279] of the Explosives Rules, 2008 include both solid and liquid propellants within the definition of 'explosives'[280]. Therefore, the development of both solid and liquid propulsion systems may be subject to the Explosives Act, 1884 if any

[271] Article I(c), The Liability Convention, 1972: The term "launching State" means: (i) A State which launches or procures the launching of a space object; (ii) A State from whose territory or facility a space object is launched.

[272] Article I(b), The Liability Convention, 1972: The term "launching" includes attempted launching.

[273] Article VI, The Liability Convention, 1972: Subject to the provisions of paragraph 2 of this Article, exoneration from absolute liability shall be granted to the extent that a launching State establishes that the damage has resulted either wholly or partially from gross negligence or from an act or omission done with intent to cause damage on the part of a claimant State or of natural or juridical persons it represents. 2. No exoneration whatever shall be granted in cases where the damage has resulted from activities conducted by a launching State which are not in conformity with international law including, in particular, the Charter of the United Nations and the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies.

[274] Article II, The Registration Convention, 1974: 1. When a space object is launched into earth orbit or beyond, the launching State shall register the space object by means of an entry in an appropriate registry which it shall maintain. Each launching State shall inform the Secretary General of the United Nations of the establishment of such a registry. 2. Where there are two or more launching States in respect of any such space object, they shall jointly determine which one of them shall register the object in accordance with paragraph 1 of this article, bearing in mind the provisions of article VIII of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, and without prejudice to appropriate agreements concluded or to be concluded among the launching States on jurisdiction and control over the space object and over any personnel thereof. 3. The contents of each registry and the conditions under which it is maintained shall be determined by the State of registry concerned.

[275] Article II, The Registration Convention, 1974.

[276] Jolly George Verghese v. Bank of Cochin 1980 AIR 470; Civil Rights Vigilance Committee v. Union of India AIR 1983 Kant 85. Web. https://supremecourtofindia.nic.in/supremecourt/2012/35071/35071_2012_Judgement_24-Aug-2017.pdf

[277] Deccan Herald (2018). "Private Lunar Mission: Antrix, TeamIndus Terminate Deal". Web. https://www.deccanherald.com/content/655767/private-lunar-mission-antrix-teamindus.html.

[278] Salgado MCV, Belderrain MCN and Devezas TC (2018). "Space Propulsion: A Survey Study About Actual and Future Technologies, Journal of Aerospace Technology and Management", Volume 10, Web. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S2175-91462018000100201.

[279] Rule 2(42), The Explosives Rules, 2008:"propellant" means an explosive that normally functions by deflagration and is used for propulsion purposes.

[280] Section 4(d), The Explosives Act, 1884: "explosives" means gunpowder, nitrogycerine, nitroglycol, gun-cotton, di-nitro-toluenetri-nitrotoluene, picric acid, di-nitor-phenol, tri-nitor-resorcinol (styphnic act), cyclo-trimethylenetrinitramine, penta-erythritol-tetranitrate, tetry1, nitorguanidine, lead azide, lead styphynate, fulminate of mercury or any other metal, diazo-di-nitorphenol, coloured fires or any other substance whether a single chemical compound or a mixture of substances, whether solid or liquid or gaseous used or manufactured with a view to produce a practical effect by explosion or pyrotechnic effect; and includes fog-signals, fireworks, fuses, rockets, percussion caps, detonators, cartridges, ammunition of all descriptions and every adaptation or preparation of an explosive as defined in this clause.

of its constituents fall under the specified class of explosives[281] under the legislation[282].

In the aforesaid context, both solid and liquid propellants used in a launch vehicle will be required to comply with the regulatory regime under the Explosives Act, 1884 and the rules made thereunder as it regulates, inter alia, the manufacture, transport, storage, import and export of specified class of explosives.

### 4.2.2 Draft Space Activities Bill, 2017

In view of growing interest in space activities demonstrated by the private sector, the Draft Space Activities Bill, 2017 (hereinafter "DSAB") was drawn up. The DSAB seeks to enable further growth of space activities in India, rather than continuing with the restrictive regime, by facilitating private sector participation in space activities under authorization and supervision of the Government[283]. The DSAB, if legislated in the current form, will govern any entity incorporated in India which engages in any space activity[284], including the launch of any space object[285].

The DSAB mandates authorization of development of launch vehicles within the legislative scheme. The DSAB directs the Union Government to formulate, establish and notify the appropriate mechanism for licensing and other procedures, such as the eligibility criteria and fees for the license and conduct of any commercial space activity. Such a mechanism, along with the associated procedures must be compliant with the provisions of any international treaty to which India is a party[286]. The DSAB penalises the undertaking of commercial activity without any authorisation[287].

Further, the Union Government is indemnified by the licensee against claims in relation to any damage or loss on account of any commercial space activity by the licensee[288].

[281] Section 4(d), The Explosives Act, 1884.

[282] Section 5, Explosives Act, 1884: Power to make rules as to licensing of the manufacture, possession, use, sale, transport and Importation of explosives.
(1)The Central Government may, for any part of India, make rules consistent with this Act to regulate or prohibit, except under and in accordance with the conditions of a license granted as provided by those rules, the manufacture, possession, use sale, transport, import and export of explosives, or any specified class of explosives.

[283] 13, Draft Space Activities Bill, 2017: India's space activities are very unique towards delivering the results through various successful accomplishments. Today, the space technology and applications are used as enabling tools for national development and governance. Hence, it was considered that introduction of a space specific legal regime should only enable further growth of space activities in India, rather than merely a regulatory or restrictive regime. It needs to facilitate private sector participation in space activities under authorization and supervision by the Government.

[284] Section 1(3), Draft Space Activities Bill, 2017: The provisions of this Act shall apply to every citizen of India in India or outside India and every legal or juridical person, including Governmental, non-Governmental or private sector agency, company, corporate body registered or incorporated in India and engaged in any space activity in India or outside India.

[285] Section 2(f), Draft Space Activities Bill, 2017: "space activity" means the launch of any space object, use of space object, operation, guidance and entry of space object into and from outer space and all functions for performing the said activities including the procurement of the objects for the said purposes.

[286] Section 5(1), Draft Space Activities Bill, 2017: The Central Government shall formulate, establish and notify the appropriate mechanism for licensing and procedures including eligibility criteria, and fees for license and conduct of any commercial space activity in compliance with any international treaty on outer space activity, for which India is a State Party and the Central Government has obligation in the manner as may be prescribed.

[287] Section 13, Draft Space Activities Bill, 2017: Any person who undertakes any commercial space activity without authorization under section 6 or license under section 8, shall be punished with imprisonment for a term which shall not be less than one year but which may extend to three years or with fine which shall not be less than one crore rupees or with both and in case of continuing offence, with an additional fine which may extend to fifty lakh rupees for every day during which the offence continues.

[288] Section 10, Draft Space Activities Bill, 2017: (1) A licensee under this Act shall indemnify the Central Government against any claims brought against the Government in respect of any damage or loss arising out of a commercial space activity or in relation to a space object covered under the license.

# 5. Satcom and Access: The Final Frontier

By Kriti Trehan*

## 5.1 Introduction

According to recent assessments, approximately 7100 terabytes of data was consumed by roughly 7.5 million users at 370 (of 400) Wi-Fi hotspots at railway stations across India[289]. Rajan Anandan (from Google) projects that the total number of internet users in India shall be 650 million in 2020[290]. Compared with the 20 years it took to hit the milestone of bringing the first 100 million users online in India[291], IAMAI-IMRB's report pegged the number of internet users at a whopping 500 million in June 2018; December 2017 recorded 481 million internet users, which was an 11.34% rise since 2016[292].

India Inc. is at the precipice of revolutionary growth and opportunity. Prime Minister Modi identified the nation as being on the cusp of the fourth industrial revolution with technology being a tool to achieve prosperity and sustainability[293]. The role of the internet, and access to it, cannot be underscored in any economy, let alone a burgeoning one like India. As of March 2018, the Telecom Regulatory Authority of India (TRAI) logged a telecom subscriber base of more than 1.2 billion connections. The relevance of access is no longer limited to mere person-to-person communication; it is equally relevant across sectoral interests such as in energy, healthcare, disaster response, fintech, media and transportation. Importantly, it is visible across the economic foundation and imperatives of the nation.

Internet access, therefore, is a priority that guides a majority of government initiatives presently. This paper assesses the opportunity for the satellite industry in India to effectively participate in the access paradigm. In doing so, the paper analyses this opportunity from the lens of both the market and regulation. It finally provides some insight into potential means and methods, for interested members of the industry, of entering the Indian ecosystem and efficiently becoming part of this revolution.

## 5.2 Satellite Broadband – The Opportunity

### 5.2.1 The Public Policy Push

**Digital India**

The Indian government, in July 2015, launched the Digital India programme intended to improving governmental accountability and participation by connecting 1.3 billion Indians to the World Wide Web. The initiative seeks to connect Indians to the Internet

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289 Ray, Siladitya (2018)."7.5 million users consumed 7,100 terabytes over WiFi at 370 railway stations in April". Web. https://www.medianama.com/2018/06/223-7-5-million-users-consumed-7100-terabytes-over-wifi-at-370-railway-stations-in-april/; see also Mehrotra, Karishma (2018). "Data hunger growing, 4-fold spike in Wifi usage at 370 railway stations". Web. https://indianexpress.com/article/technology/tech-news-technology/data-hunger-growing-4-fold-spike-in-wifi-usage-at-370-railway-stations-5221825/

290 Ethiraj, Govindraj (2018). "India to hit 650 Million Internet Users by 2020, says Google's Rajan Anandan". Web. https://www.boomlive.in/india-to-hit-650-million-internet-users-by-2020-says-googles-rajan-anandan/

291 Satak, Putty & Bhat (2017). "Exploring the Potential of Satellite Connectivity for Digital India". In: Rajagopalan, Prasad (eds.) Space India 2.0 – Commerce, Policy, Security and Governance Perspectives. Observer Research Foundation, 2017

292 IAMAI-Kantar IMRB (2018). "Internet in India 2017".Web. http://www.iamai.in/research/reports_details/5001; http://www.iamai.in/node/4989

293 Financial Express (2018). "India at the cusp of digital revolution, says PM Narendra Modi". Web. https://www.financialexpress.com/industry/india-at-the-cusp-of-digital-revolution-says-pm-narendra-modi/1072211/

in the sphere of education, economics, agriculture, governance, and dissemination of information and technology. One of the greatest challenges this program has faced is the connectivity (or lack thereof) of India's tens of thousands of villages[294]. The IT Minister Mr. Ravi Shankar Prasad believes that the Indian digital sector will transform into a USD 1 trillion economy in itself over the next five years[295]. To him, the real vision of Digital India is to bridge the digital divide. In order to ensure the proliferation of digitally delivered services, the government is reportedly targeting the delivery of 10000 megabits per second in urban areas and 1000 megabits per second in rural areas[296].

**5G**

Internet access is widely accepted as a catalysing force for the economic development of a country. Today, 5G is being hailed as the next stage in digital transformation across the globe. The Organisation for Economic Cooperation and Development's Committee on Digital Economic Policy has found 5G technologies to be inherently linked with rising GDP, employment creation and digitizing the economy[297]. The next generation of products and services across the board include elements of M2M communication, Internet of Things and Artificial Intelligence. Additionally, government initiatives such as Make In India, Digital India, Smart Cities, a move towards a cashless economy, and subsets thereof all have one common component – seamless access.

**BharatNet**

In 2011, The National Optical Fibre Network (NOFN) project was set up under the Universal Service Obligation Fund (USOF) which was set up for improving telecommunications services in rural and remote areas of the country. It was later renamed BharatNet project. The goal of this project is to bring rural India onto the connectivity grid. In its first phase, 2.5 lakh villages were connected through optic fibre networks. Phase two aims at connecting another 1.5 lakh villages[298]. The second phase is also a symbol for Wi-Fi rollouts – the Finance Minister Mr. Arun Jaitley and the Telecom Secretary Dr. Aruna Sundararajan have both set the target of establishing five lakh Wi-Fi hotspots across the country by the end of 2018. The Department of Telecommunications (DoT) has specifically requested states to furnish a list of all unconnected villages, so that they may be connected by 2020.

**National Telecom Policy**

The DoT has specifically recognised 'new technologies' as a dedicated theme for the formulation of a new National Telecom Policy, which has, this time round, been named the National Digital Communications Policy (NDCP-18). With the underlying purpose of pushing socio-economic development through secure access and innovation, the draft policy states that "*it is necessary to explore and utilise the opportunities presented by next generation-networks like 5G and other pioneering network access technologies* ***including satellite communications***" (emphasis added)[299].

**TRAI**

In addition to these existing policy processes, TRAI has recommended[300], on various occasions in the past, to create a permissibility framework for the satellite industry to enter the foray for provision of internet access to areas where traditional infrastructure does not permeate because of tough geographical terrain or challenges with returns on investment.

The government has, therefore, evidently set the wheels in motion for several enabling policy imperatives, although gaps continue to exist and ought to be addressed on priority. There is no uncertainty in the acknowledgment that satellite communications infrastructure will be essential to the roll out of next generation networks, and indispensable to seamlessness of access.

[294] JDel Rosaria, Jose (2015). "Putting the Brakes on India's SATCOM growth". Northern Sky Research. Web. http://www.nsr.com/news-resources/the-bottom-line/putting-the-brakes-on-indias-satcom-growth/

[295] Economic Times (2019). "India could be a $3 trillion digi economy in the next 4-5 years: Ravi Shankar Prasad". Web. https://economictimes.indiatimes.com/news/economy/indicators/india-could-be-a-3-trillion-digi-economy-in-the-next-4-5-yearsravi-shankar-prasad/articleshow/68399392.cms

[296] DNA (2017). "Telecom ministry moves on 5G tech with research corpus". Web. http://www.dnaindia.com/business/report-telecom-ministry-moves-on-5g-tech-with-rs-500-crore-research-corpus-2548615

[297] D'Monte, Leslie (2017). "Why India has announced its 5G plans". Web. http://www.livemint.com/Opinion/I5fYDua2hKlQyKTbhQKjYO/Why-India-has-announced-its-5G-plans.html

[298] ETTelecom (2018). "Budget 2018: Government aiming to set up 5 lakh hotspots, allocates Rs 1000 cr". Web. https://telecom.economictimes.indiatimes.com/news/budget-2018-government-aiming-to-set-up-5-lakh-hotspots-allocates-rs-10000-cr/62738178

[299] Department of Telecommunications (2018). "National Digital Communications Policy – 2018".Web. http://dot.gov.in/sites/default/files/EnglishPolicy-NDCP.pdf.; also see National Digital Communications Policy 2018 – Draft for Consultation; http://dot.gov.in/sites/default/files/2018%2005%2025%20NDCP%202018%20Draft%20for%20Consultation_0.pdf

[300] Telecom Regulatory Authority of India (2015). "Recommendations on Delivering Broadband Quickly: What do we need to do?". Web. https://trai.gov.in/sites/default/files/Broadband%3D17.04.2015.pdf

### 5.2.2 The Numbers

TRAI released a press report on 23 May 2018, bearing information of Telecom Subscription Data in India as on 31 March 2018[301]. According to this document, the number of wireless and wireline telephone subscribers across the country was 1.206 billion at the end of March 2018, which implied a registered monthly growth rate of 2.24%. The total number of wired and wireless broadband subscribers amounted to under half a billion. The reported tele-density across the country was registered at 92.84 (increased from the recorded 90.89 in end of February 2018), with 56.51% being the urban subscriber base, and 43.49% being the rural subscriber base.

On 4 May 2018, TRAI published a report on "Yearly Performance Indicators of Telecom Sector" (Second Edition). The report stated that the total number of Wireless subscribers stood at 1167.44 million and Wireline subscribers stood at 23.23 million. There had been a -4.29% change in the amount of wireline subscribers from the previous year. The total number of Internet and Broadband subscribers had increased by 13.91% to 445.96 million subscribers[302].

According to the 8th Report on Technology, Media and Telecommunications report published by Deloitte India[303], due to challenges of deployment of fixed broadband networks, current rural internet penetration stands at 17%. In the future, the report states, the demand for fixed broadband would be limited to users with higher bandwidth/ quality of service (QOS) requirements with majority of home internet requirements catered through wireless networks.

### 5.2.3 The Market

The lack of adequate infrastructure for proliferation of the internet and the public policy push towards increasing internet access to the unserved and underserved parts of the country create a strong case for the satellite industry to bridge the gap. Despite a plethora of government initiatives, traditional telecommunications infrastructure is unable to fulfil all access requirements, and therefore is necessarily required to be buttressed by alternative technologies – satellites being a prime example.

As regards the satellites industry itself, the Northern Sky Research (NSR) released a report last year titled "Indian Satellite Markets"[304], which applauds the Indian Space Research Organisation's (ISRO) success and achievements on launches and R&D. However, the supply on the existing Indian National Satellite System (INSAT), ISRO's geo-stationary satellites meant to *inter alia* fulfil telecommunications, broadcasting, search and rescue operations requirements, is unable to meet domestic demands.

The government is attempting to address this by increasing capital flow to the Department of Space (DoS), which is the apex regulatory body (under the Prime Minister's Office) for all matters related to space and satellites. As was recently reported[305], the Central Government has allocated around INR 107.83 million in the union budget this year to the DoS. The report mentions that the allocation is slightly lower than expected, but that it should be viewed within the context of ISRO'S efforts to partner with private industries and augment the revenue of Antrix (ISRO's commercial arm).

The GSAT-11 was slated to be a feather in ISRO's cap – as a high-throughput satellite, which carries 40 transponders in Ku-band and Ka-band frequencies, it is capable of "providing high bandwidth connectivity" with up to 14 gigabit per second (GBPS) data transfer speed[306]. Unfortunately, ISRO reportedly recalled the GSAT-11 from Arianespace's spaceport in French Guiana for further tests, and has rescheduled it launch date.

It may be useful to recall the significant gap in internet penetration and access in rural and remote topographies – the present rate of internet penetration is roughly about 38%, and is much lower for rural and remote parts of the

301 Telecom Regulatory Authority of India *(2018). "*Highlights of Telecom Subscription Data". Web. http://www.trai.gov.in/sites/default/files/PRNo56Eng23052018.pdf

302 Telecom Regulatory Authority of India (2018). "*Yearly Performance Indicators of Indian Telecom Sector* (Second Edition)". Web. http://www.trai.gov.in/sites/default/files/YPIRReport04052018.pdf

303 Deloitte India (2018). "Deloitte India TMT Predictions 2018 report places lens on AI, Augmented Reality, Machine Learning and VOLTE". Web. https://www2.deloitte.com/in/en/pages/technology-media-and-telecommunications/articles/tmt-predictions-2018-press-release.html

304 Firstpost (2017). "Growth Period Ahead for Indian Satellite Market: NSR". Web. https://www.firstpost.com/biztech/growth-period-ahead-for-indian-satellite-market-nsr-1868825.html

305 Narasimhan, T E (2018). "Budget allocates Rs. 89.6 bn to Dept of Space for satellite launches". Business Standard, Web. http://www.business-standard.com/budget/article/budget-2018-allocates-rs-89-6-bn-to-dept-of-space-for-satellite-launches-118020200311_1.html

306 Singh, Surendra (2018). "G-SAT 11 launch delayed no glitch satellite needs more tests says ISRO". Times of India, Web. https://timesofindia.indiatimes.com/india/gsat-11-launch-delayed-no-glitch-satellite-needs-more-tests-says-isro/articleshow/63917999.cms

country. Therefore, there is a certainly a market opportunity for satellites to get added to the infrastructure layer for better proliferation of access.

## 5.3 Applicable Legal Framework

Space and satellites have historically been the prerogative of the government, with minimal private sector engagement. Telecommunications, as a sector, has had a similar past. However, when India underwent economic reform in the 1990s, the telecommunications industry was opened up to private investment and participation, and it became one of the largest sectoral success stories. Satellite communications (satcom), however, has not had a similar experience as yet. An overview of the regulation and corresponding government departments is available in the next sub-section.

### 5.3.1 The Regulatory Departments

**ISRO/ DoS**

The Indian Space Research Organisation was formed in the year 1969[307]. In 1972, the Government of India formed the Space Commission as well as the Department of Space[307]. This resulted in a restructure leading to ISRO being brought under the DoS[307]. The Space Commission is the authority responsible for formulating policies that further the objectives of the DoS[307]. The policies so formulated are implemented through ISRO and other research organisations regulated by the DoS including the Physical Research Laboratory (PRL), etc[307]. The objectives of the DoS have evolved over time, although its primary aim is to develop space technology to enable the growth and development of India[307]. As such, there are several programs that have been initiated by the DoS. This includes the INSAT program for telecommunications, broadcasting, etc[307].

**DoT**

The Department of Telecommunications under the Ministry of Communications is the government body that provides licenses and formulates policies in relation to modes of communication including data[308]**.** Thus, it also falls on the DoT to co-ordinate and co-operate with international bodies such as the International Telecommunication Satellite Organisation (INTELSAT) and the International Mobile Satellite Organisation (INMARSAT)[308].

**TRAI**

The Telecom Regulatory Authority of India was established in 1997 under the Telecom Regulatory Authority of India Act, 1997. The mandate of TRAI is to regulate the telecommunication services within India[309]. TRAI is the independent regulatory agency for all telecommunications, broadcasting and cable services.

**WPC**

The Wireless Planning and Coordination (WPC) wing of the DoT is the authority responsible for Frequency Spectrum Management[310]. Its responsibilities include issuance of licenses for establishing, operating and maintaining wireless stations[310].

**CAISS**

The Committee for Authorizing the establishment and operation of Indian Satellite Systems (CAISS) is the single window clearance committee for authorization to be obtained by Indian Satellite Systems in relation to compliance with the UN Outer Space Treaty and existent government space policy and requisite permissions to operate a space station in consonance with International Telecommunication Union (ITU) Radio Regulations[311].

**DPIIT**

The erstwhile Department of Industrial Policy and Promotion, recently rechristened as the Department for Promotion of Industry and Internal Trade (DPIIT) is the key body for all foreign investment related matters. The body drafts and implements the FDI Policy, which is modified each year, and ascertains the sectors, caps for FDI (as a percentage of total investment), and routes of obtaining FDI (automatic or government approval routes). For instance, in telecommunications services, FDI of up to 49% is permissible under the automatic

[307] Department of Space Indian Space Research Organisation *(2018).* "Department of Space and ISRO HQ". Web. https://www.isro.gov.in/about-isro/department-of-space-and-isro-hq.

[308] Department of Telecommunications (2018). "Functions of DoT" ". Web. http://www.dot.gov.in/objectives.

[309] Government of India (1997). "Telecom Regulatory Authority of India Act, 1997". Web http://ijlt.in/wp-content/uploads/2015/09/TRAI-Act-1997.pdf.

[310] Department of Telecommunications (2018). "Wireless planning and coordination wing overview". Web. http://wpc.dot.gov.in/content/12_1_Overview.aspx.

[311] Department of Space (2018). "The norms, guidelines and procedures for implementation of the policy frame-work for satellite communications in India as approved by Government in 2000".Web. https://www.dos.gov.in/sites/default/files/article-files/indias-space-policy-0/satcom-ngp.pdf.

route, and 100% under the government approval route[312]. In the establishment and operation of satellites, 100% FDI is permissible under the government approval route[312].

### 5.3.2 The Evolution of Policy

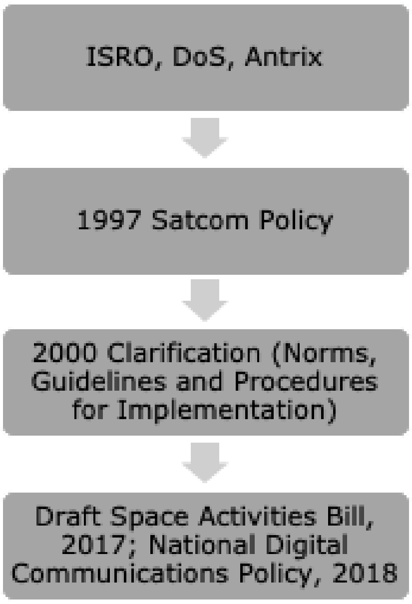


Figure 3: Evolution of India's Space Policy Framework

**1997 SATCOM Policy[313]**

In 1997, the Government of India approved and published "A policy framework for satellite communication in India" (Satcom Policy)[313]. The main objective of the Satcom Policy as formulated by the DoS was the development of the communication satellite and ground equipment industry as also the satellite communication service industry[313]. The policy also aimed at making available the infrastructure built through INSAT to a wider section of the economy as well as the public[313]. The Satcom Policy also, in some ways, can be thought of as having laid the foundation for the make-in India policy in relation to satellite infrastructure[313]. The stated aim of the Satcom Policy was the attraction of private sector funding and the encouragement of foreign investment in the sector[313].

The scope of the policy included the following[313]:

- Leasing of INSAT capacity to both Indian and foreign private parties on the basis of defined norms.
- TV uplinking through Indian Satellites by Indian parties and provision of services thereon.
- Authorization of the Indian administration in consultation with the DoS and other regulatory authorities for registration of Indian Satellite Systems by and for private Indian parties.
- Specifying the circumstances in which foreign satellites could be operated from Indian soil including Satellite Systems owned by Indian parties and registered in a foreign country prior to rules for registering having been formulated in India, or where the Satellite System has considerable Indian contribution by way of equity or otherwise and in case of reciprocal arrangements with foreign countries.
- Provision for licensing of Direct to Home (DTH) broadcasting on Indian Satellite Systems and others (provided they are not specifically prohibited). However, if such licenses are provided for operation on foreign systems, at the time of renewal of such license, the authority may require the licensee to opt for Indian Satellite systems subject to availability.

From a brief overview of the Satcom Policy, it is clear that the policy was intended to make provisions for leasing of INSAT capacity to private parties and thus, it was the intention of the policy makers to allow private parties to participate in the satellite sector [313]. A particularly instructive bit in the policy is where the Satcom Policy authorises "*Indian Administration in consultation with DoS… **to inform, notify, co-ordinate and register satellite systems and networks by and for Indian private parties** following certain well defined and transparent norms…*"

Most significantly, the policy was only meant to be the initial enabling guidance document, which was supposed to be succeeded by a clear registration framework. Therefore, the policy, like any other, clarified the intention of the policy makers, although it did little to establish a clear and predictable registration process for private Indian Satellite Systems, including those with foreign investment.

**Norms, Guidelines and Procedures for Implementation of the Policy Framework for Satellite Communications in**

[312] Consolidated FDI Policy, 2017

[313] Department of Space (1997). "A policy framework for satellite communication in India, 1997". Web. https://www.dos.gov.in/sites/default/files/article-files/indias-space-policy-0/satcom-policy.pdf.

**India as approved by Government in 2000[314]**

The Satcom Policy was a short document which, effectively, laid out the intent and vision of the government with respect to involving the private sector in space. The absence of clarity on procedures, licenses, registrations and permissions gave rise to a clarification document in the year 2000 – "The norms, guidelines and procedures for implementation of the policy frame-work for satellite communications in India as approved by Government in 2000" (clarification) [314]. The aim of the clarification was to specify and provide guidelines for the establishment and operation of Indian Satellite Systems[314]. Interestingly, this (relatively more comprehensive) document outlined the permissions mechanisms from across a wide array of governmental agencies from the DoS, DoT, and the relevant permissions with respect to foreign investment from the appropriate department. Broadly speaking, the clarification required that the entity requesting to be registered as an Indian Satellite System be an Indian company, with Foreign Direct Investment (FDI) (if any) limited to 74%, and with ownership, management and control of the company in the hands of Indian persons. The DoS could potentially provide a dispensation permitting 100% FDI provided that within the next five years (of obtaining the license), this FDI would be rolled back to at least 74%.

The clarification provided that the Global Mobile Personal Communication by Satellite (GMPCS) Policy formulated by the DoT would be applicable in case of GMPCS and for establishment and operation of the satellite systems themselves, the clarification would apply[314]. It further crystallised the intention of according preference to domestic Indian Satellite Systems over foreign satellite systems[314].

The clarification sought to deal with the norms on the basis of which INSAT capacity could be leased and the provision of services such as TV uplinking through Indian satellite systems[314]. The clarification itself provided that INSAT capacity was limited to satellite systems built by DoS or procured[314]. It also included the transponders leased for the purpose of augmenting existing capacity[314]. The base guidelines provided in this regard were that the INSAT capacity should be provided on a "for profit" basis to commercial entities and the policies in relation to the INSAT capacity would be formulated by the INSAT Coordination Committee (ICC)[314].

The uses for which such leasing would be provided were defined to be[314]:

- Telecommunications
- Broadcasting
- Education and Development Communications
- Security Communications

Of the above specified uses, both education and security communications were singled out on the basis of future growth potential in these sectors, and it was clarified that the regular licensing procedure may not be applicable to these sectors[314]. It was further provided that a percentage of the INSAT capacity would be earmarked for telecommunication purposes, apart from the existing use by All India Radio (AIR) and Doordarshan[314]. The clarification also stated that the DoS could build capacity for a private party subject to feasibility and approved budgets[314]. Such capacity would not be considered a part of the INSAT capacity unless specified to be so by the ICC[314].

The clarification also authorised the DoS as the authority to register Indian Satellite Systems[314]. The licenses that would be required were three-fold including[314]:

- Authorization to own and operate an Indian Satellite System which also included the spacecraft control centre from the DoS. CAISS would be responsible for provision of the licenses in this respect prior to DoS authorization.
- Authorisation by the WPC for operation of a Space Station in accordance with ITU Radio Regulations. CAISS would be responsible for provision of the licenses in this respect prior to WPC authorisation.
- Authorisation from the respective system/network for the services themselves. In respect of telecommunication services, the licenses are to be provided by DoT, etc.

The clarification further stated that foreign satellite systems could be used for purposes of international and domestic communication services[314]. The Domestic Communication Services include broadcasting, public switched telephone network (PSTN), land mobile satellite devices and value added services[314]. Value Added services include provision of Very Small Aperture Terminals (VSAT) for closed user groups, private VSAT service with shared hub, data broadcasting, internet services, etc[314]. Thus, the Domestic Communication Services

[314] Department of Space (2018). "The norms, guidelines and procedures for implementation of the policy frame-work for satellite communications in India as approved by Government in 2000".*Web.* https://www.dos.gov.in/sites/default/files/article-files/indias-space-policy-0/satcom-ngp.pdf.

so defined clearly make provision for internet service as well as data broadcasting as well as provision of data through VSATs[314].

**The Space Activities Bill, 2017[315]**

The progress of public policy narrative on satcom, between the years 2000 and 2017, was, at best, at a snail's pace. While discussions on private commercial interests emerged and policies around foreign investment advanced, there was no dedicated regulation around private investment in the space and satcom industry (other the guidance provided by the 1997 and 2000 documents). The draft Space Activities Bill, 2017 (Bill), in that sense, was a refreshing development.

The Bill was published around November 2017 and provided further insight on the intention of the law makers in relation to the aforementioned policies[315].

The most important aspect of the Bill is the definition of the terms "space activity" and "commercial space activity[315]. The Bill defines space activity to include the launch of any space object, use of space object, and the operation thereof and commercial space activity to be any space activity that generates profit[315]. The Bill further provided for the licenses to be granted (and the processes to be followed thereon) to persons (defined to include individuals etc.) for commercial space activity[315].

Although the Bill is merely a draft, it encapsulates the intention of the legislature/ policy makers to provide a seamless mechanism for the launch, maintenance and operation of private satellite systems for commercial space activities which would also include within its ambit the provision of data and internet services.

Unfortunately, the Bill is not without its own inherent challenges. The licensing framework that the Bill identifies is applicable to "space objects" and "space activities". Space activity is defined as one that involves launch, use, operation, guidance and entry of space objects into and from outer space, and all related functions including procurement. Space object is one that is launched or intended to be launched, a device that helps the launch, and any constituent element of both. The wide ambit of the definition is certainly a concern, and has the potential to transform this purported step of liberalisation of the sector into an extremely regulation heavy ecosystem.

**The Closed User Group ("CUG") VSAT License[316]**

The CUG VSAT license is presently provided for the purpose of provision of domestic data services through the INSAT capacity[316]. The license does not include provision of PSTN services[316].

Presently, there are two types of CUG VSAT license that are provided by the DoT, namely, the Commercial CUG VSAT license and the Captive CUG VSAT license[316]. The differentiation of the two licenses is based on the number of CUGs that can be set up. While on a commercial license, several CUGs may be set up for provision of services to its subscribers, whereas in the case of a captive license only a single CUG is set up for the purpose of utilising the services[316]. At present, the licenses are only provided to entities registered under the (Indian) Companies Act, 1956 or 2013 and the Foreign investment in such companies is not to exceed the FDI capping as fixed by the Reserve Bank of India[316] (in this case up to 100 per cent)[317].

This may imply the existence of an enabling framework for provision of satellite broadband through the existing INSAT capacity[316]. If appropriate amendments are made to regulation generally, it may be useful for the government to consider modifying this license in order to permit satellite broadband provided over private satellites under this license itself.

**INMARSAT Satellite Phone Service[318]**

INMARSAT operates geo-stationary satellites that extend phone, fax and data services[318]. In India, Tata Communications Limited (TCL) has been allowed the requisite licenses to provide INMARSAT operations[318].

TCL provides different levels of services through various INMARSAT terminals including INMARSAT B, C, M, Mini M, Mini M4. Through all these terminals, TCL provides telex, fax and data services[318]. The speed of the data varies upon the INMARSAT terminals[318]. However, the scope of this service is limited to marine vessels, although it may potentially be inter-

[315] Department of Space, ISRO (2017) "*Seeking comments on Draft 'Space Activities Bill, 2017'from the stakeholders/public- regarding.".* *Web.* https://www.isro.gov.in/update/21-nov-2017/seeking-comments-draft-space-activities-bill-2017-stakeholders-public-regarding.

[316] Department of Telecommunications (2018). "VSAT & Satellite Communication". Web. http://www.dot.gov.in/data-services/2575.

[317] Department of Industrial Policy and Promotion, Ministry of Commerce and Industry, Government of India (2018). "Consolidated FDI Policy (Effective from August 28, 2017)". W*eb.* http://www.makeinindia.com/documents/10281/0/Consolidated+FDI+Policy+2017.pdf.

[318] Department of Telecommunications (2018). "INMARSAT*". Web.* http://www.dot.gov.in/inmarsat.

preted as an enabling factor to elicit the government's interest to perhaps extend such services on land as well.

**Frequencies and Spectrum**

The National Frequency Allocation Plan 2018 (NFAP-18) provides a broad regulatory framework, identifying which frequency bands are available for cellular mobile service, Wi-Fi, sound and television broadcasting, radio-navigation for aircrafts and ships, defence and security communications, disaster relief and emergency communications, satellite communications and satellite-broadcasting, and amateur service, to name just a few. Frequency allocation is the first step towards ensuring efficient, rational, and interference-free use of the radio-frequency spectrum and satellite orbits [319].

The Frequency Allocation Tables mentioned in the NFAP-18 provide with the spectrum range of frequency for use by geostationary and non-geostationary satellite systems for various services such as radio communication services, broadcasting services, etc. A frequency allocation to a service is categorised as a primary or a secondary allocation. A service which is shown in "capitals" (example: FIXED) is a primary service for that allocation. A service the name of which is printed in "normal characters" (example: Mobile) is a secondary service. Additional remarks, qualifying a service in a frequency allocation, is printed in normal characters (example: MOBILE except aeronautical mobile). The Government of India, through the WPC, formulates detailed guidelines for the auction and allotment of spectrum for the required services involving use of satellite communication systems. The process of auction is the same for both geostationary satellites as well as non-geostationary satellites.

Earlier in 2019, the DoT was reported as being in conversation with ISRO and DoS to set up a network of low and medium earth orbit satellites in order to propel telecommunications services across India[320]. Reports also suggest that the DoT is bearing the cost of the project, and ownership of these satellites therefore shall vest in the DoT. At present, the largest challenges associated with communications services provided over satellites relate to costs and latency. To address the issues, Low Earth Orbit (LEO) satellites, at roughly at a 2000 km distance in orbit, are expected to be launched.

Spectrum licensing is the responsibility of the WPC, and permissions are awarded on the basis of auctions. The Radio Regulations[321], an international treaty signed by India and other member states of the International Telecommunication Union (ITU), governs the use of radio-frequency spectrum and satellite-orbits (geostationary and non-geostationary) at the global level. Accordingly, the Radio Regulations (2016) is the foundational text used for drawing up the NFAP-18. Spectrum licensing falls squarely within the domain of the telecommunications authorities. However, the additional interface of using satellites to provide telecommunications connectivity increases the regulatory interface owing to permissions and approvals required from ISRO/ DoS.

**National Digital Communications Policy – 2018 [299]**

The National Digital Communications Policy (NDCP-18) aims to enable the provision of broadband for the entirety of India and to meet the citizens' requirement for affordable digital connectivity and infrastructure [299,322].

The aim of the NDCP-18 is to be realized through the following strategies: The National Broadband Mission (which provides for Broadband to be provided through Optical Fibres), recognition of spectrum as a key national source, *strengthening of Satellite Communication Technologies* in India, inclusion of uncovered areas and digitally deprived segments of society by leveraging the USOF, and ensuring Quality of Service standards and appropriate grievance redressal processes[299] (emphasis added).

The NDCP-18 aims at reviewing the existing regulatory regime in relation to satellite systems, including (i) revising licensing conditions that limit the use the satellite communications like barriers to speed, band allocation etc., (ii) easing compliance processes, and (iii) expanding on the services to be provided under the Unified Licensing regime (formulated under National Telecom Policy, 2012) using high throughput satellite communication systems.

The NDCP-18 also aims to optimise satellite systems and create an ecosystem of satellite systems[299]. This, it aims to achieve, by push-

[319] Department of Telecommunications (2019). "National Frequency Allocation Plan, 2018". Web. http://wpc.dot.gov.in/WriteReadData/userfiles/NFAP%202018.pdf

[320] Srivastava, Prasoon (2019). "DoT in talks with ISRO to set up network of telecom satellites". Web. https://www.livemint.com/Industry/b0DofD5jmxzKRMxGe6nBYJ/DoT-in-talks-with-ISRO-to-set-up-network-of-telecom-satellit.html

321 International Telecommunications Union (2016). "The Radio Regulations (Edition of 2016)". Web. http://search.itu.int/history/HistoryDigitalCollectionDocLibrary/1.43.48.en.101.pdf

[322] *see* Department of Telecommunications (2018) "Inviting Public comments on Draft National Digital Communications Policy – 2018*"*. Web. http://www.dot.gov.in/sites/default/files/DNDCP2018.pdf.

ing a technology neutral, competitive and flexible regime, in close consultation with the DoS. The NDCP-18 also highlights the importance of creating spectrum band availability for commercial satcom services (including the use of the Ku band), rationalising costs associated with transponders, spectrum and other charges, streamlining administrative processes for allocations, clearances and permissions related to satcom systems, promoting domestic manufacturing, and encouraging participation from private stakeholders.

Although the NDCP-18 focuses on provision of data and internet services through Optical Fibres, it recognizes the potential of Satellite Systems in this regard. It especially notes the positive role that satellite based mobile communications could play in enhancing public protection and disaster relief imperatives.

The NDCP-18, in its draft form, underwent a robust process of public discussion and consultation. As a result of this, it has translated into a policy that, for the first time in nearly two decades, creates a push for the private satcom industry to become an irreplaceable cog in the wheel of provision of access across the Indian subcontinent.

## 5.4 Conclusion – Satellite Broadband: Going Where India has Barely Gone Before

It is clear that the government's discourse is currently focussed on making data available to all its citizens including the rural and remote areas. However, the policy focus thus far, on provision of data/ internet services, has been skewed in favour of access penetration through cables and optical fibres.

Increasingly, however, we note that the potential of satellite systems in this regard is being recognised. Examples of application presently are fairly small scale, and are seen as being limited to VSAT CUG licenses and the provision of data through INMARSAT satellites. In case of the latter, the focus is on the provision of telecommunication facilities and the provision of data is on a very limited scale.

There are, of course, challenges – administrative uncertainty due to a multiplicity of bodies allocating licenses, permissions and authorisations requires a reassessment. TRAI has recently published recommendations on making the conduct of business[323] in the telecommunications sector easier, in which it pushes for changing permissions mechanisms (including those to be obtained from the WPC) and adds a 30 day timeframe for all permissions. A similar process within the DoS would certainly be helpful as well. There is also an urgent need to transform all authorisation processes into single-window clearances.

However, this note of caution does give way to optimism as well – the increasing reference to reliance on satellites for expanding access to the internet is definitely a positive sign. The current TRAI chairman, Mr. RS Sharma, has spoken about the importance of leveraging satellite services to provide access and bandwidth especially to rural areas, without geographical or economic constraints[324]. The government's plans for digital empowerment and access, most significantly, create a foothold for the first time, for creation of an enabling framework for satellites and their services in the telecommunications (specifically on broadband) sector, and therefore, it is all the more important for industry, academia and civil society to engage with and participate in public consultative processes a

round the emerging policies. Because access is a government priority, the satellite industry has the unique opportunity to be part of the next stage of the great Indian story – to be the object of desire for achieving seamless access.

[323] Telecom Regulatory Authority of India (2017). "Recommendations on Ease of Doing Telecom Business". Web.http://www.trai.gov.in/sites/default/files/Recommendations_EDB_30112017.pdf

[324] Jha, Vaibhav (2017). "Need for policy change for deeper internet penetration: TRAI head in Noida". Web. https://www.hindustantimes.com/noida/need-for-policy-change-for-deeper-internet-penetration-trai-head-in-noida/story-HQe0YXiQ48KG11zOazwz9M.html

| Cheat Sheet: Quick pointers for private entities seeking permission in India |
|---|
| Required to be registered as a company in India under applicable laws. |
| FDI permissible up to 100% under the government approval route, as per the FDI Policy, 2016. |
| Read with the (2000) clarification, FDI must be rolled back to 74% within 5 years of obtaining license. |
| Permissions needed from DoT, WPC on the telecommunications side; DoS, CAISS (ISRO, Antrix are involved as well in practice) on the space side; DPIIT for FDI related permissions. |
| Preference given to Indian Satellite Systems, as opposed to foreign satellites. |
| Track closely ongoing policy discussions the Space Activities Bill, 2017 – clarity will emerge once it is finalised |

# 6. The Remote Sensing Context in India: Policy Perspectives

By Ashok G.V.*

## 6.1 Introduction

Despite the overwhelming growth of India's urban landscapes, agriculture remains a significant part of India's overall socio-economic context and picture. Roughly 58% of India's population is dependent on agriculture for employment and it contributes roughly Rs. 17.67 trillion to India's Gross Domestic Product (GDP). Furthermore, industries dependant on agriculture such as the food and beverage sector represent 8.39 percent of the GDP of the country and represents 13% of India's overall exports[325].

India produces 95 minerals – 4 fuel-related minerals, 10 metallic minerals, 23 non-metallic minerals, 3 atomic minerals and 55 minor minerals (including building and other minerals). Rise in infrastructure development and automotive production are driving growth in the sector. Power and cement industries are also aiding growth in the metals and mining sector. Demand for iron and steel is set to continue, given the strong growth expectations for the residential and commercial building industry[326]. The construction and infrastructure sector in India is worth US$ 24.87 billion[327].

Though the context of the agricultural, mining and construction sector cited above should represent a thriving economy, the fact remains that farmer suicides remain a huge problem, losses from illegal mining activities are estimated at Rs. 4,000/- crore[328] in just the state of Goa alone, besides inflicting severe environmental damage in Kerala[329]. Litigation related to land encroachment, among other things, constitute 76% of the infamous judicial backlog in the country[330]. Problems in claims verification[331], real time monitoring of unauthorised mining activities and evidentiary issues in land encroachment have frustrated agricultural insurance, regulatory enforcement and expeditious disposal of land encroachment cases, which in turn have become hurdles for the sustainable growth of agriculture, mining and construction and infrastructure development sectors.

India has a history of launching and operating close to 18 remote sensing satellites. Its present arsenal of remote sensing satellites boast of imaging sensors which provide spatial resolution ranging from 1 km to better than 1m;

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325 India Brand Equity Foundation (2018). "Agriculture in India: Industry Overview, Market Size, Role in Development...| IBEF". Ibef.org. Web. https://www.ibef.org/industry/agriculture-india.aspx Accessed 16 Jan. 2019.

326 India Brand Equity Foundation (2018). "Metals & Mining Industry in India: Overview, Market Size & Growth | IBEF". Ibef.org. Web. https://www.ibef.org/industry/metals-and-mining.aspx Accessed 16 Jan. 2019.

327 India Brand Equity Foundation (2018). "Infrastructure Development in India: Market Size, Investments, Govt Initiatives | IBEF". Ibef.org. Web. https://www.ibef.org/industry/infrastructure-sector-india.aspx Accessed 16 Jan. 2019.

328 United News of India (2018). "Mining loss caused due to illegal mining is Rs. 3,000-Rs. 4000 Cr: Goa CM", Web. http://www.uniindia.com/~/mining-loss-caused-due-to-illegal-mining-was-rs-3000-rs-4000-cr-goa-cm/States/news/1299332.html.

329 Times of India (2018). "Kerala floods: Environmentalist Gadgil says it is also a man-made disaster - Times of India". The Times of India. Web. https://timesofindia.indiatimes.com/india/kerala-floods-environmentalist-gadgil-says-it-is-also-a-man-made-disaster/articleshow/65468351.cms Accessed 16 Jan. 2019.

330 Reuters (2016). "Millions of cases stuck in courts show need for 'urgent' land reform" Web. https://in.reuters.com/article/india-landrights-court/millions-of-cases-stuck-in-courts-show-need-for-urgent-land-reform-advocacy-idINKCN10J1GE Accessed 16 Jan. 2019.

331 Raju, S. and Chand, R. (2008). "Agricultural Insurance in India Problems and Prospect". National Centre for Agricultural Economics and Policy Research (Indian Council of Agricultural Research), p.47. Web. http://www.ncap.res.in/upload_files/others/oth_15.pdf.

"The processing of claims in NAIS begins only after the harvesting of the crop. Further, claim payments have to wait for the results of Crop Cutting Experiments (CCE"s) and also for the release of requisite funds from the central and state governments. Consequently, there is a gap of 8-10 months between the occurrence of loss and actual claim payment. To expedite the settlement of claims in the case of adverse seasonal conditions, and to ensure that at least part payment of the likely claims is paid to the farmer, before the end of the season, it is suggested to introduce 'on-account' settlement of claims, without waiting for the receipt of yield data, to the extent of 50 per cent of likely claims, subject to adjustment against the claims assessed on the yield basis."

repeat observation (temporal imaging) from 22 days to every 15 minutes and radiometric ranging from 7 bit to 12 bit, which has significantly helped in several applications at national level[332]. With such a rich resource of earth observation satellites, there are precedents in disaster management[333] , land record management[334] and land encroachment monitoring[335] and enforcement of mining regulations[336] that show that remote sensing satellites can be effectively leveraged to solve problems of national significance.

While India as a state is slowly embracing the full extent of possibilities through its earth observation satellites, the remote sensing satellites are yet to translate into a full-fledged economy on to itself. In this paper, I analyse the policy governing the launch and operation of remote sensing and earth observation satellites in India and reflect on some policy reforms that could potentially unleash the full potential of the remote sensing data industry.

## 6.2 Basis for Space Law in India

Before dwelling into the specific laws governing space activities and more specifically remote sensing data, it is important to understand the structure of the Indian state and how law is made and enforced in India. India has a federal structure, with the rule making powers distributed between the Central Legislature, comprising of the House of the People (Lok Sabha) and the Council of States (Rajya Sabha) and the State Legislature, comprising of the Legislative Assembly and Legislative Council. The powers of the Central and State Legislature are almost evenly divided between the Centre and the State in terms of List-I, List-II and List-III of the Seventh Schedule to the Constitution of India. The responsibility and the mandate to forge international relations, enter into International obligations, ratify the same and enforce them in the domestic territory of India, however, is vested exclusively with the Central Legislature[337].

The federal character of the Indian state has been held to be an integral part of the basic structure of the constitution[338] and therefore remains immune to alteration. Indian administrative law also provides for delegation of powers by the Legislature to executive authorities, provided such delegation of powers is reasonable and non-arbitrary and further provides a policy framework for exercise of powers by the authority to whom it is delegated.

The Indian Constitutional culture also permits a limited scope for judicial review and activism, as a result of which the High Courts and Supreme Court of India are vested with the power to pass appropriate writs under Articles 32 and 221 of the Constitution, where it is found that such writs are necessary to a) remedy a violation of fundamental rights, b) to remedy an exercise of power by the Centre or State that is not granted under the Constitution and c) to remedy the improper exercise of power by the state.

The powers of judicial review, though limited, have resulted in the High Courts and Supreme Court of India occupying a unique role in which the Supreme Court or the High Court can make a law to advance international obligations if such obligations are necessary to give effect to the fundamental rights under the Indian Constitution, provided that the legislature itself has failed to pass a law in respect of such international obligations[339]. In fact, closer to the topic at hand, the Supreme Court in the case of *Union of India v. Centre,* in Writ Petition No. 423/2010, in which, the Supreme Court not only declared the allocation of Licenses for 2G spectrum by the Ministry of Telecommunications as being arbitrary, but went ahead to cancel the licenses already granted. Thus, the law in India, as defined by Article 12 of the Constitution includes not just legislations of the state, but also executive policies and court verdicts.

[332] Isro.gov.in (2019). "The Saga of Indian Remote Sensing Satellite System – ISRO". Web. https://www.isro.gov.in/saga-of-indian-remote-sensing-satellite-system Accessed 16 Jan. 2019.

[333] Geospatial World (2019). "Geospatial intelligence – key to disaster relief - Geospatial World". Web. https://www.geospatialworld.net/blogs/geospatial-intelligence-key-to-disaster-relief/ Accessed 16 Jan. 2019.

[334] Esri (2016). „ArcGIS® for Land Records". Web. https://www.esri.com/library/brochures/pdfs/arcgis-for-land-records.pdf.

[335] Hindustan Times (2019). "Satellite imagery to track city land encroachment". Web. https://www.hindustantimes.com/pune-news/satellite-imagery-to-track-city-land-encroachment/story-BbMMGGUNJx0d23eolOHQsJ.html Accessed 16 Jan. 2019.

[336] Suresh, M. and Jain, K. (2013). "Change Detection and Estimation of Illegal Mining using Satellite Images". [ebook] Proceedings of 2nd International Conference on Innovations in Electronics and Communication Engineering (ICIECE-2013). Web. https://www.researchgate.net/publication/260790890 Accessed 16 Jan. 2019.

[337] See Article 51 of the Constitution of India

[338] See Kesavananda Bharati v. State of Kerala, (1973) 4 SCC 225

[339] See Vishaka v. State of Rajasthan, (1997) 6 SCC 241

## 6.3 Regulations on Remote Sensing

International law on the subject is not specific. With the foundation of most international space policy being the Outer Space Treaty, some clarity emerged on International law governing remote sensing with the passing of the General Assembly Resolution (GAR) 41/65. Though non-binding per se, state practice suggests that there is wide-spread endorsement of the GAR 41/65[340]. Underlining principles spelt out by GAR 41/65 includes,

- "Remote sensing activities shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic, social or scientific and technological development, and taking into particular consideration the needs of the developing countries."
- "Remote Sensing activities is to be pursued in accordance with the spirit of the Outer Space Treaty, thus requiring remote sensing activities to be undertaken for the benefit of all mankind with the state operating remote sensing satellites remaining liable for their actions."
- "Remote Sensing activities are to be utilised for the protection of Earth's natural environment. States having information that could prevent harm to Earth's environment remain obligated to disclose such information to the states concerned."

Domestically, the principal policy guidelines governing remote sensing data is the Remote Sensing Data Policy (RSDP) of 2011. The RSDP principally deals with a) Data generated by Indian Remote Sensing Satellites, b) Acquisition and distribution of remote sensing data within India and c) Acquisition and distribution of Indian Remote Sensing Satellite data for use in countries other than India.

To summarise the policy,

- All data generated from Indian Remote Sensing Satellite Program (IRS) are exclusively owned and distributed by the Department of Space within the Government of India.
- Any person engaged in the acquisition and distribution of remote sensing data requires a license from the Department of Space. Curiously enough as per sub clause (b) of Clause 2 of the Policy, the National Remote Sensing Centre (NRSC) of the Indian Space Research Organisation (ISRO) is vested with the authority (though the question of whether this authority is exclusive or non-exclusive is unanswered), to acquire and disseminate remote sensing data from Indian and foreign sources in consultations with Antrix Corporation Limited, the commercial arm of the ISRO.
- Export of IRS data is undertaken through Antrix Corporation Limited.
- Data up to 1 m resolution is to be distributed on a non-discriminatory basis and on "as requested basis", but data with resolution better than 1 m ("restricted data") attracts stricter regulatory oversight for distribution. The policy prescribes liberal sharing of such restricted data for Governmental users. However private sector players will require clearances and will likely be subject to confidentiality obligations, to access restricted data.

In addition to the Remote Sensing Data Policy, the Satellite Communication (SATCOM) Policy 2000, governs upstream activities such as launch of Earth Observation satellites and National Map Policy governs the manner in which maps of India are prepared and showcased. In addition, specific states are now passing laws relevant to geospatial information with the Nation's capital taking the lead by promulgating the *Delhi Geo Spatial Data Infrastructure (Management, Control, Security and Safety Act, 2011)*, which mandates making public geospatial information relevant to public utilities, leverage such data for governance and keep such information continuously updated. However, the custodian of the entire project remains a Government owned company i.e., Geo-Spatial Delhi Limited.

## 6.4 The Policy Guidelines in Practice

On the upstream front, the two principal policies that govern launch of satellites are the Framework for Satellite Communication in India ('SATCOM Policy') and The Norms, Guidelines and Procedures for implementation of the Policy framework for satellite communications in India ('SATCOM Norms'). On a perusal of the policy and norms, a committee for author-

340 Von Der Dunk, F. (2009). "European Satellite Earth Observation: Law, Regulations, Policies, Projects, and Programmes". Creighton Law Review, p.416. Web. http://digitalcommons.unl.edu/spacelaw.

ising the establishment and operation of Indian Satellite Systems (CAISS), comprising of 6 ministries and advisors, is constituted to review and approve applications for launch of satellites. However, as per Section 3.6.7 of the Norms, the CAISS is empowered to primarily approve launch of satellites for providing satcom services and there remains no mention about the procedure for securing approval for launch of Earth Observation Satellites[341]. This perhaps can be attributed to the fact that Indian earth observation satellites are primarily state owned and operated – thus the question of a private sector enterprise launching or operating one from within India remains unprecedented. Though the norms and the policy prescribe a strict approach to compliance of India's international obligations under the Outer Space Treaty, the overall underdevelopment of international space law has also revealed how vulnerable India's own domestic regulations are[342].

The policy guidelines for remote sensing pose fundamental questions, the first of which is whether the RSDP is even a law. If we assume that a law is a set of rules objectively defined by the State, which, if violated, results in sanctions, this question about the RSDP becomes even more complicated to answer. While the RSDP is no doubt formulated and passed by the State i.e., the department of space pursuant to the Allocation of Business Rules under Article 77 (3) of the Constitution, the policy does not specify any sanctions if any of its provisions are violated.

The Hon'ble Madras High Court in the case of *J. Mohanraj v. Secretary to the Government,* in W.P. 29713/2018, while dealing with a public interest litigation seeking a ban on *google earth*, observed that the Petitioner had failed to provide a law dealing with geospatial information despite discussing the National Map Policy of 2005. This judgement suggests that policies such as National Map Policy, 2005 which lack inherent schemes for enforcement of its provisions, may not even qualify as a law in the first place.

The RSDP shares this in common with the National Map Policy, 2005, as the RSDP also fails to specify the consequences of breach of its guidelines. Consequently, it is anybody's guess on what could be the consequences if the RSDP is, in fact, breached. That, earth observation data from space agencies worldwide are freely available on the internet[343], both in India and abroad, raise legitimate concerns on how India would enforce its national security objectives involving the breach of RSDP, when the enforceability of RSDP remains suspect.

## 6.5 The Impact of Policy on Investment

The lack of clarity on regulations has not mitigated or deterred the growth of business and commerce in the domain of remote sensing activity. In GAR 41/65, remote sensing activity was defined as follows:

"'remote sensing' means the sensing of the Earth's surface from space by making use of the properties of electromagnetic waves emitted, reflected or diffracted by the sensed objects, for the purpose of improving natural resources management, land use and the protection of the environment"[344].

However that definition covers an enormous variety of businesses which may make regulating each kind of business with a single policy impossible. After all, the remote sensing and geospatial industry is pervasive in our lives in today's world. From Uber and Ola, employing remote sensing data to facilitate their cab aggregator platforms in India, to Google Maps becoming a premiere provider of navigation services, remote sensing data and geospatial information have become a part of our everyday life. From public health and disaster management to supply chain management, geospatial data aided by Earth observation satellites are all around us and are continuously in use to improve our day to day lives[345]. This therefore begs the questions, who should be regulated by remote sensing regulations and what comprises of a remote sensing activity that requires regulation?

India has not been able to answer these questions easily, nor is there a ready answer available. Based on the experiences with Google

341 Gabrynowicz, Joanne I. (2010). "A Brief Survey of Remote Sensing Law Around the World" Web. http://www.unoosa.org/pdf/pres/2010/SLW2010/02-13.pdf

342 G.V., Ashok (2018). "A Swarm of Legal Issues Launched by First Rogue Satellites". *Space Alert ORF Quarterly on Space Affairs*, Volume VI (Issue No. 2), pp.2-6. Web. https://www.orfonline.org/wp-content/uploads/2018/04/Space-Alert-V6-I2-April-2018-.pdf

343 Earth.esa.int. (2019). "Data Access - Earth Online – ESA". Web. https://earth.esa.int/web/guest/data-access Accessed 16 Jan. 2019.

344 UNGA Res. 41/65 "Principles relating to remote sensing of the Earth from space"

345 Trajectory Magazine (2018). "The Past, Present, and Future of Geospatial Data Use | Trajectory Magazine". http://trajectorymagazine.com/past-present-future-geospatial-data-use/ Accessed 16 Jan. 2019.

Street View[346], the Indian Government appears to be treading with caution, carefully balancing the inevitable presence of geospatial data in day to day lives with considerations of national security. That earth observation satellites have privacy implications[347], only justify the caution of the Indian government in approaching remote sensing data.

That being said, the law of the land plays a significant role in impacting investments. A clear coherent and stable policy that is capable of enforcement not only benefits the world of business, but provides the state with means to enforce its welfare objectives. An investment friendly law must result in the government's approach to investments, both foreign and domestic, becoming predictable. It must also explicitly provide for the rights and obligations of the investor, minimise the cost of the investment transaction by balancing national interests with freedom of commerce, direct and control the flow of capital and provide for expeditious resolution of investment disputes. In short, it must be predictable, reasonable and enable freedom of contract and commerce[348].

As a matter of practice and to the credit of the Indian Government, an increasingly investment and business friendly practice has emerged. Antrix has forged meaningful relationships with Indian start-ups[349], enabling domestic remote sensing business activities. The announcement of a more private sector friendly policy and practice by the ISRO[350] is being regarded as a new era in the history of the Indian Space Program. Therefore, whatever may be the criticism of the RSDP or the SATCOM Policy, these instances involving the ISRO and Antrix reveal a pro-business shift in the thinking of the Government. Not only has this yielded rich returns for businesses, but this has also allowed an entire generation of Indians to give back to the country, in critical areas such as national security[351].

However, as executive practices are susceptible to changes, depending upon the priorities of the relevant government, they do not score well on the parameters of an investment friendly law namely, predictability, reasonableness and enabling freedom of contract and commerce. Therefore, reflecting the investment friendly practices of the Government in its policies especially the SATCOM Policy, Norms and the RSDP would greatly enable the industry to attract domestic and foreign capital, sustain and grow in the country.

Of course, with the announcement of the space activities bill, the RSDP may not remain in its present form for too long. However, even the draft of the space activities bill does not answer critical questions around freedom of access to remote sensing data, whether applications for such access or applications for launch of remote sensing satellites will be decided in a time bound manner and what, if any, will be the criterion based on which businesses involved in remote sensing upstream or downstream activities will be cleared by the Government. If these issues remain unanswered, businesses would continue to be wary of governmental clearances lacking procedural integrity and constitutional sanction, resulting in outcomes similar to the cancellation of the 2G spectrum licenses by the Supreme Court of India.

## 6.6 The Way Forward

In order to give effect to the government's intention of facilitating a robust space industry within the country, policy reforms will remain inevitable. To begin with, the SATCOM Policy must expand beyond authorising satellites for SATCOM Services and must contemplate and regulate launch and operation of remote sensing satellites as well. The CAISS must truly become a single window clearance platform and must be mandated to act within a clearly defined policy framework and in a time bound manner, the net result of which should enable applications to estimate the outcome and the time within the outcome of their application would be achieved.

On the subject of the Remote Sensing Data Policy, firstly it is time to define who qualifies as a person engaged in a regulated remote sensing data activity. Under the RSDP, it

[346] The Economic Times (2018). "'Google Street View' proposal rejected by govt". Web. https://economictimes.indiatimes.com/news/politics-and-nation/google-street-view-proposal-rejected-by-govt/articleshow/63482412.cms Accessed 16 Jan. 2019.

[347] O'Leary, A. (2018). "Husband divorces 'cheating' wife after spotting her cuddling man on Google Maps". mirror. Web. https://www.mirror.co.uk/news/weird-news/google-maps-causes-divorce-after-13396055.

[348] Salacuse, J. (2013). "The three laws of international investment". UK: Oxford University Press

[349] Via Satellite (2018). "Antrix, SatSure to Further Geospatial Big Data Analytics - Via Satellite". Web. https://www.satellitetoday.com/innovation/2018/06/05/antrix-satsure-to-further-geospatial-big-data-analytics/ Accessed 16 Jan. 2019.

[350] The Hindu (2017). "ISRO opens doors to private sector". Web. https://www.thehindu.com/news/national/isro-opens-doors-to-private-sector/article20603113.ece

[351] The Economic Times (2017). "New frontier opens for Indian techies: Fighting for the nation with data". Web. https://economictimes.indiatimes.com/news/defence/new-frontier-opens-for-indian-techies-fighting-for-the-nation-with-data/articleshow/60749458.cms Accessed 16 Jan. 2019.

would be impractical for the Department of Space to regulate even the Ola and Ubers of the world who employ geospatial information to provide the cab aggregator platform. It is time to fundamentally revisit the dichotomy of restricted data and unrestricted data. The threshold of 1m though well founded for the sake of national security, could be impractical and unrealistic in today's world when superior quality satellite images are available in public domain. The process of granting licenses to persons engaged in acquisition, processing and distribution of data must become transparent and well defined on the following parameters,

- Persons eligible to apply.
- The considerations based on which licenses will be granted.
- The regulatory oversight on the activities of the licensee and the conditions of grant of such licenses.
- Consequences of breach of the license terms.

In addition with the Indian Supreme Court acknowledging the right of privacy within the fundamental right to life and personal liberty under Article 21 of the Indian Constitution, appropriate privacy regulations will have to be imposed on remote sensing data activities[352]. Though informed consent in the context of a satellite clicking pictures several kilometres in space is difficult to comprehend, let alone to implement, regulations could define data anonymisation standards that would enable the objective of remote sensing activities to be realised without violating the right of privacy of individuals.

## 6.7 Conclusions

Pending and independent of these regulatory reforms, businesses across the world must recognise and accept the well-founded practice of the Indian state to place ISRO and its commercial arm, Antrix Corporation at the centre of its regulatory and operational roles so far as space activities are concerned. Given the history and legacy of both these organisations, they are likely to remain key to ensuring India's sustainable growth in the space sector in the 21st century. Therefore, as demonstrated by the success of companies like SatSure[353], the entry to the Indian market must begin with earning the trust and relationship of the ISRO and Antrix. Businesses would be well advised to collaborate with instead of competing with these organisations.

Though the present policies of the Indian state may give rise to apprehensions around predictability, reasonableness and freedom of contract, the size of the Indian market, the availability of highly skilled labour and the overall legacy of the Indian space program, renders India a highly lucrative destination for remote sensing data industries.

The right kind of regulatory reforms would greatly enhance the legacy of the Indian space program, inspire confidence among investors, make the space program more relevant to the common man and help enable a space economy. If India can balance its concerns around private sector enterprises entering into the domain of remote sensing with its objective of enabling businesses to grow in the country, the resulting atmosphere would not only advance national interests by nurturing domestic innovation, but would also enable space entrepreneurs find success within the nation.

[352] See Justice Puttaswamy v. Union of India, Writ Petition No. 494 OF 2012, and Hindustan Times (2018). "Geospatial data too may be regulated by data protection bill: Officials". Web. https://www.hindustantimes.com/india-news/geospatial-data-too-may-be-regulated-by-data-protection-bill-officials/story-4XIW3ThVdWigwKfm1eqeLN.html Accessed 16 Jan. 2019.

[353] YourStory.com (2017). "Big data analytics makes its way into the Indian agriculture sector through SatSure". Web. https://yourstory.com/2017/05/satsure/ Accessed 16 Jan. 2019.

# 7. A Review of India's Navigation Programme and its Future Potential

By Narayan Prasad*

The Indian Regional Navigation Satellite System (IRNSS) is a programme by the Indian Space Research Organisation (ISRO) to establish a regional navigation system using a combination of 7 Geostationary Earth Orbit (GEO) and Geostationary Synchronous Orbit (GSO) spacecraft to achieve self-reliance in navigation within the Indian subcontinent[354]. The IRNSS complements the existing Indian Remote Sensing (IRS) and the Indian National Satellite System (INSAT) series of satellites which focus on providing remote sensing and communication services in India.

Figure 4355 provides an overview of the IIRNSS system which now has all 7 spacecraft in orbit[356]. The system provides a position accuracy of better than 20 m over the Indian landmass and additionally is able to provide services extending about 1500 sq. km around India[357]. The present work explores the historical context, the bottlenecks in the operationalization and the strategies being used to catalyse the downstream adoption of India's indigenous navigation satellite system. We also underpin some of the similarities in the nature of the challenges in the development and operationalization of the navigation systems of India and Europe to provide a context for further cooperation between the two sides.

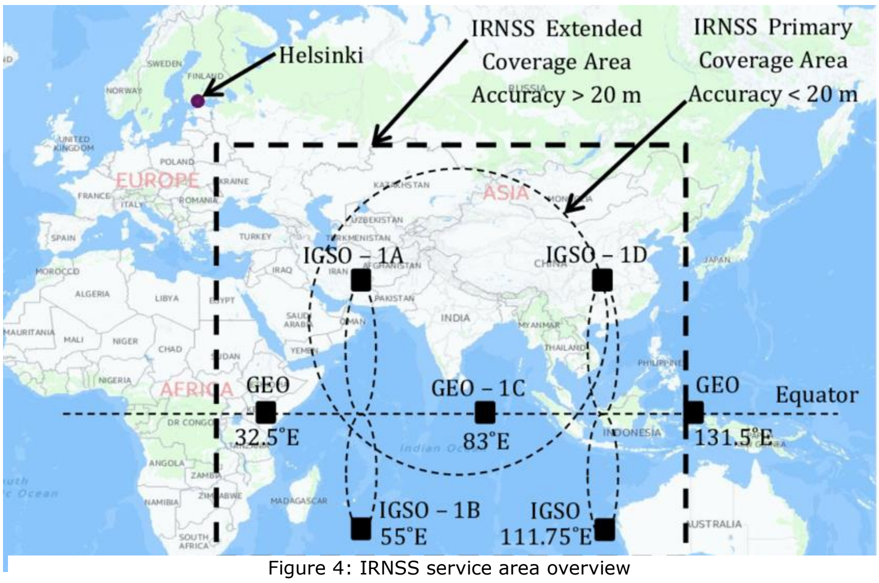


Figure 4: IRNSS service area overview

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354 Indian Space Research Organisation (n.d.). "Towards Self Reliance in Navigation-IRNSS". Web. https://www.isro.gov.in/towards-self-reliance-navigation-irnss.

355 Thombre, Sarang, et. al. (2016). "A Software Multi-GNSS Receiver Implementation for the Indian Regional Navigation Satellite System". *IETE Journal of Research*, 62.2: 246–56. Web. https://doi.org/10.1080/03772063.2015.1093968.

356 Thombre, Sarang, et. al. (2016). "A Software Multi-GNSS Receiver Implementation for the Indian Regional Navigation Satellite System". *IETE Journal of Research*, 62.2: 246–56. Web. https://doi.org/10.1080/03772063.2015.1093968.

357 Thoelert, Steffen; Montenbruck, Oliver and Meurer, Michael (2014). "IRNSS-1A: Signal and Clock Characterization of the Indian Regional Navigation System". *GPS Solutions*, 18.1:147–52. Web. https://doi.org/10.1007/s10291-013-0351-7.

## 7.1 The Development of IRNSS between Autonomy and Cooperation

The reason behind India's choice of having an independent navigation system can be traced back to its experience of being denied access to the U.S. run Global Positioning System (GPS) during the 1999 military operations in Kargil[358]. The Government of India took a decision in 2006 to establish a regional navigation constellation at a cost of INR 14.20 billion (€ 181 million) with the 7-satellite constellation to be operational by 2011[359]. There are no publicly available official sources that provide a holistic substantiation on the decision to invest into creating an independent system. However, experts believe that the investment made to have an independent navigation capability is owing to the need to liberate the country from its dependence on the U.S.' GPS, Russia's Glonass and other such foreign systems, which may threaten the use of navigation, positioning and timing capabilities during potentially dangerous during conflicts[360].

Interestingly, the European Union (EU) and India had negotiations in 2003 about the possibility of India investing into the EU's Galileo navigation constellation and reports suggest that there was initial interest from India to invest € 300 million in Galileo[361]. However, the negotiations did not lead to fruitful realisation of India's participation in Galileo with a 2005 agreement between EU and India being watered down to only ensure the availability of highest quality Galileo services in India as well as cooperation to establish regional augmentation systems based on European Geostationary Navigation Overlay Service (EGNOS) and Galileo[362]. The fundamental disagreement seems to be pinned to the perception of the Indian side of not being treated as an equal partner in the project and the potential denial of services in times of war[363]. Eventually New Delhi decided to withdraw from the project. At the time, such decision was primarily imputed to its intention to acquire an indigenous RNSS. However, there also appears to have been other, and perhaps more important motivations. These certainly include India's concerns about being caught between the cross fires of EU-U.S. discussions on Galileo-GPS interoperability and hence the risk of compromising its blossoming cooperation with Washington, which had always expressed an evident opposition to the Galileo project, as well as New Delhi's frustration in dealing with the complex instructional structures set-up for Galileo[364]. However, more importantly, there appears to have been India's disappointment in being rejected as a full partner and "co-decision-maker in the Galileo project, especially after it had been asked to invest 300 million euros in the project"[365].

In the interim period, India chose to implement a parallel navigation service based on Satellite Based Augmentation System (SBAS) using GPS under a program called GPS Aided Geo Augmented Navigation system (GAGAN) to provide additional accuracy, availability, and integrity to civilian air traffic[366]. This was mainly done through an agreement between the Airports Authority of India (AAI) and ISRO executed in August 2001[367]. In what can be deemed as a diplomatic recovery, the U.S. government through the Federal Aviation Administration (FAA) supported the realisation of the GAGAN by providing training to ISRO and AAI in realising GAGAN[368]. In 2009, ISRO

358 Srivastava, Ishan (2014). "How Kargil Spurred India to Design Own GPS". *The Times of India.* Web. https://timesofindia.indiatimes.com/home/science/How-Kargil-spurred-India-to-design-own-GPS/articleshow/33254691.cms.

359 Datta, Anusuya (2018). "CAG Pulls up ISRO on NavIC Delays, Cost Overruns". *Geospatial World*.Web.https://www.geospatialworld.net/blogs/cag-pulls-up-isro-on-navic-delays-cost-overruns/.

360 The Economic Times (2016). "IRNSS: Desi GPS to Liberate India from Dependence on U.S., Russia". The Economic Times. Web. https://economictimes.indiatimes.com/news/science/irnss-desi-gps-to-liberate-india-from-dependence-on-us-russia/articleshow/52058262.cms.

361 Agence France-Presse (2003). "India to Invest in Galileo Satellite Project: EU". Web. http://www.spacedaily.com/2003/031030141843.79tqo71o.html.

362 European Commission (2005). "The GALILEO Family Is Further Expanding: EU and India Seal Their Agreement". Web. http://europa.eu/rapid/press-release_IP-05-1105_en.htm?locale=en.

363 Winand, Pascaline; Vicziany, Marika; and Datar, Poonam (2015). *The European Union and India: Rhetoric or Meaningful Partnership?* (Edward Elgar Publishing, 2015).

364 Aliberti, M. (2018). India in Space Between Utility and Geopolitics. Springer: Vienna

365 Vicziany, M. (2015). EU-India security issues: fundamental incompatibilities. In P. Winand, M. Wicziany, & P. Datar, The European Union and India: Rethoric or Meaningful Partnership. Cheltenham: Edward Elgar Publishing.

366 Airports Authority of India (n.d.). "What Is GAGAN?". Web. https://www.aai.aero/en/content/what-gagan.

367 Jerzy Mikulski (2018). "Management Perspective for Transport Telematics: 18th International Conference on Transport System Telematics" TST 2018, Krakow, Poland, March 20-23, 2018, Selected Papers (Springer, 2018).

368 Mathur, Navin ; McLaughlin, Heather (2002). "GAGAN: The FAA and India Take Initial Steps". *SatNav News*, 16:6.

awarded an $82 million contract to U.S.-company Raytheon[369] to build eight reference stations in various cities, as well as a Master Control Centre and an uplink station[370]. ISRO's GSAT-10 geostationary communications satellite flown by Ariane in September 2012 carried a transponder for GAGAN[371]. The Indian aviation regulator Directorate General of Civil Aviation (DGCA) certified GAGAN for use on 30th of December, 2013[372] and made it mandatory for all India-registered aircraft to install GAGAN equipment from January 1, 2019 as a part of India's National Civil Aviation Policy[373]. GAGAN is facing adoption challenges with airlines citing the Indian civil aviation market to be still premature and not being able to afford $200,000 for equipment and training per aircraft and an additional 10 to 14 days grounding of the aircraft for any retrofits[374]. Following the lack of preparedness on the part of the domestic airlines, the Government of India has pushed the deadline for GAGAN system-equipped aircraft to June 2020[375].

## 7.2 Utilization of IRNSS in India

Given the adoption and economies of scale the GPS has already achieved world over, it is an uphill challenge for any new independent navigation systems to compete over possible adoption. ISRO has been helping support the adoption of IRNSS by piloting several applications for stakeholders within the country who may be able to leverage the IRNSS service for the services they provide. Some of the examples of these include messaging receivers for fishermen, warning systems for unmanned level crossings, railway line mapping, tracking of its own launch vehicle, etc.[376].

The Government of India through its Ministry of Electronics and Information Technology (MeitY) is planning to roll out immediate applications for an operational IRNSS system in areas such as railway wagon tracking, vehicle tracking system for state transport buses, taxis and all public service vehicles, tracking of fishing vessels, tracking and geo-fencing of mechanised vehicles in service[377].

Experts in India suggest that the primary use of IRNSS shall be for the defence forces and in short and medium-range missiles[378]. However, ISRO remains hopeful that the mobile phone industry will integrate IRNSS and it is rumoured that a Taiwanese company is working on building a chip that has IRNSS integrated into it[379]. The first global adoption of IRNSS comes from Telit, an Italian wireless machine to machine modules maker who has announced the world's first IRNSS-enabled GNSS Module[380]. The new positioning module from Telit combines GPS, IRNSS, and GAGAN and complies with Automotive Industry Standard 140.

Similarly, U.S. based semiconductor company Broadcom has created a chip that supports IRNSS and the Chinese smartphone manufacturer Xiaomi is expected to implement Broad-

369 Raytheon (n.d.). "Raytheon Selected to Deliver GPS-Aided Indian Air Navigation System". Web. http://investor.raytheon.com/phoenix.zhtml?c=84193&p=irol-newsArticle&ID=1309030.

370 Geospatial Today (2004). "GAGAN Project Contract to Raytheon". Web. http://library.nic.in/fulltextjournals/geospatial/Nov-Dec2004/pdf/pdf/8_9.pdf.

371 GPS World (2012). "Update on EGNOS and GAGAN SBAS Satellites". Web. https://www.gpsworld.com/gnss-systemaugmentation-assistancenewsupdate-egnos-and-gagan-sbas-satellites-13286/.

372 Radhakrishnan, S. Anil (2014). "GAGAN System Ready for Operations". *The Hindu*. Web. https://www.thehindu.com/news/national/kerala/gagan-system-ready-for-operations/article5565700.ece.

373 Anand, Aditya (2016). "Government to Airlines: Use GAGAN GPS or Face Consequences". *Mumbai Mirror*. Web. https://mumbaimirror.indiatimes.com/mumbai/other/government-to-airlines-use-gagan-gps-or-face-consequences/articleshow/56177266.cms.

374 Mathews, Neelam (2019). "Ailing Indian Airlines Get Relief from Gagan Delay". *Aviation International News*. Web. https://www.ainonline.com/aviation-news/air-transport/2019-01-03/ailing-indian-airlines-get-relief-gagan-delay.

375 PTI (2019). "Govt Delays Gagan-Equipped Aircraft Commissioning to June 2020". Web. https://www.livemint.com/Politics/z0xciJ3iK3VKbKkMe5fZON/Govt-delays-Gaganequipped-aircraft-commissioning-to-June-20.html.

376 Reddy, Akhileshwar (2018). "NavCom and Other Novel Applications of NavIC/GAGAN". Web. http://www.unoosa.org/documents/pdf/icg/2018/icg13/wgb/wgb_21.pdf.

377 Ministry of Electronics and Information Technology (2016). "Development of NavIC Chip for Commercial/Civilian Purposes". Web. https://meity.gov.in/development-navic-chip-commercialcivilian-purposes.

378 Dasgupta, Arup (2018). "Will NAVIC Be a Commercial Success? Let's Ponder Upon". *Geospatial World*. Web. https://www.geospatialworld.net/blogs/will-navic-be-a-commercial-success/.

379 PTI (2018). "Mobile Phones May Have NaVIC System as Early as next Year: ISRO Scientist". *The Economic Times*. Web. https://economictimes.indiatimes.com/news/science/mobile-phones-may-have-navic-system-as-early-as-next-year-isro-scientist/articleshow/65724520.cms.

380 Telit (n.d.). "Telit Announces the First NavIC-Enabled GNSS Module on the SL869 Form Factor". Web. https://www.telit.com/press-release/telit-announces-the-first-navic-enabled-gnss-module-on-the-sl869-form-factor/.

com's IRNSS chip for smart phone-based navigation[381]. This may be early evidence of the potential adoption of IRNSS by global navigation-based technology and service providers to be able to stand out in entering or accessing the Indian market. The Government of India is also providing stimulus to the expansion of the IRNSS-based services by initiating bids from the industry to produce 1 million integrated IRNSS and GPS receivers to promote the commercialisation of India's indigenous positioning technology[382].

## 7.3 Common Bottlenecks in EU and India

Establishing an independent navigation satellite system is technically, financially and operationally challenging. Both Europe and India have faced problems in the realisation of their respective navigation satellite constellations. The major issue on both the sides have been the cost and timeline overruns. Galileo had a budget of some €3bn and was originally planned to be operational in 2008[383] and IRNSS had a budget of some € 181 million and was originally planned to be operational in 2011[384]. The 24-satellite system for Galileo was completed only in 2018 with a three-fold budget overrun[385] and the 7-satellite system for IRNSS was completed in 2018 with a 2-fold budget overrun[386].

Both EU and India have also faced bottlenecks in completing their respective satellite navigation systems due to failures in space transportation. Galileo faced problems with its 5 and 6 satellites being placed in wrong orbits in 2014 due to malfunction of the Soyuz ST-Fregat vehicle carrying these satellites and had to conduct recovery operations to be able to use the satellites[387]. Similarly, ISRO lost one of IRNSS satellites in 2017 due to heat shield not separating from the rocket which was carrying the satellite[388]. Once the spacecraft were in orbit, both the constellations have faced problems with the clocks being used on the satellite failing. In January 2017, ISRO reported three atomic clock failures around the same time that the European Space Agency (ESA) reported that three rubidium atomic clocks and six hydrogen maser clocks on-board Galileo satellites having failed[389]. It is reported that ESA's investigation narrowed down the rubidium clocks failure to a faulty component that could cause a short circuit and is resolved[390]. Similarly, ISRO also rectified the problems with clocks it has procured from European sources[391], but has invested into developing indigenous clocks to potentially replace the imported clocks in future satellites[392].

## 8.4 Opportunities for Cooperation

As both the EU and India have made fiscal and space transportation decisions for their respective navigation satellite systems, there are few avenues of upstream cooperation. It also may be challenging to find common inter-

381 Chaturvedi, Aditya (2018). "IRNSS Compatible Smartphones Likely to Be Launched in 2019, Xiaomi to Lead the Way". *Geospatial World*. Web. https://www.geospatialworld.net/blogs/irnss-compatible-smartphones-likely-to-be-launched-in-2019-xiaomi-to-lead-the-way/.

382 Hasan, Abid (2017). "MeitY Initiates Bids for 1 Million NavIC and GPS Receivers". *ElectronicsB2B*. Web. https://www.electronicsb2b.com/industry-buzz/meity-initiates-bids-1-million-navic-gps-receivers/.

383 BBC (2016). "EU's Galileo Satellite System Goes Live". Web. https://www.bbc.com/news/science-environment-38329341.

384 Baruah, Sanjib Kr (2018). "India's Own GPS 7 Years Late despite 90 per Cent of Funds Allocated Spent". *The Asian Age*. Web. http://www.asianage.com/india/all-india/140318/indias-own-gps-7-years-late-despite-90-per-cent-of-funds-allocated-spent.html.

385 Galileo GNSS (2016). "Galileo to Go Live on Thursday". Web. https://galileognss.eu/galileo-to-go-live-on-thursday/.

386 The Wire (2018). "India's GPS' Delayed by Deadline Overruns, ISRO's 'Administrative Laxity': CAG", *The Wire.* Web. https://thewire.in/space/indias-gps-delayed-by-deadline-overruns-isros-administrative-laxity-cag.

387 Inside GNSS (2018). "Galileo 5 and 6 Satellites: Mission Recovery and Exploitation Part 1". Web. https://insidegnss.com/galileo-5-and-6-eccentric-satellites-mission-recovery-and-exploitation-part-i/.

388 PTI (2007). "Setback for ISRO: Launch of Navigation Satellite IRNSS-1H Unsuccessful". *The Economic Times*. Web. https://economictimes.indiatimes.com/news/science/setback-for-isro-launch-of-navigation-satellite-irnss-1h-unsuccessful/articleshow/60311374.cms.

389 Mukunth, Vasudevan (2017). "Three Atomic Clocks Have Failed On-board India's 'Regional GPS' Constellation" *The Wire*. Web. https://thewire.in/science/atomic-clock-rubidium-irnss.

390 Agence France-Presse (2017). "Europe's Galileo Satnav Identifies Problems Behind Failing Clocks". *NDTV Gadgets 360.* Web. https://gadgets.ndtv.com/science/news/galileo-satnav-atomic-clock-failure-esa-investigation-1720170.

391 Madhumathi, D.S (2017). "ISRO Set to Launch Satellite with Corrected Clocks". *The Hindu.* Web. https://www.thehindu.com/sci-tech/science/isro-set-to-launch-satellite-with-corrected-clocks/article19429289.ece.

392 Singh, Surendra (2018). "Isro Develops Desi Atomic Clock, to Be Used in Navigation Satellites". *The Times of India.* Web. https://timesofindia.indiatimes.com/india/isro-develops-desi-atomic-clock-to-be-used-in-navigation-satellites/articleshow/64056352.cms.

ests in such high-level decisions at the moment owing to the fact that both EU and India have already made decisions to operationalize the adoption of their own constellations within their respective areas of interest. However, there are several upstream-related areas where there are opportunities for collaboration between India and the EU. These include potentially working on collaborative development of future clocks for navigation satellites as well as new generation quantum communication-based positioning technologies. India has announced a Memorandum of Understanding (MoU) with Israel, which is one of the world's leading nations for space-based technologies to develop atomic clocks[393]. Israel-based Accubeat is already providing atomic clocks to the U.S. Air Force, Boeing among others[394]. There is potential to explore areas such as cold atomic clocks within the EU India collaboration framework to establish joint technology competence in areas where other countries such as China have already made in roads through investments[395]. Similarly, quantum positioning is touted to complement the problems with the usage of satellite-based navigation such as positioning under water and can provide critical backup to application areas such as autonomous vehicles, where a loss of satellite navigation signal can be dangerous[396]. Scientists in the United Kingdom have recently demonstrated a standalone quantum "compass," which will allow highly accurate navigation without the need for navigation satellites[397]. This could be another such area where EU and India can look to share resources and benefit from joint investment and collaboration.

From a downstream adoption perspective, the EU is using its Horizon 2020 Framework Programme for Research and Innovation to fund a cooperation effort called GNSS.asia. Initially launched under the EU 7th Framework Programme (FP7) and then continued under Horizon 2020, the GNSS-Asia project aims at identifying and implementing downstream GNSS industrial cooperation activities between Europe and the Asia-Pacific region[398]. GNSS.asia plans to provide concrete recommendations for a sustainable adoption of Galileo in the downstream sector of five Asian countries, namely India, China, Taiwan, Korea and Japan. The project offers cost-free support services (including market analyses, identification of key opportunities, networking, etc.) with the overarching objectives of:

- a) Supporting industrial cooperation between European and Asian GNSS companies, with a special focus on applications and receivers/chipsets,
- b) Promoting European GNSS Galileo solutions, and
- c) Raising awareness of Galileo's applications and benefits

In India, the project is led by the European Business Group India (EBGI). Key objectives include the promotion of GNSS applications for infrastructure modernisation, most specifically road and rail improvements throughout the country, the compatibility of GAGAN with Europe's EGNOS system, and the opportunity to leverage European expertise in satellite-based augmentation systems (SBAS) to support the expansion of GAGAN to sectors beyond its application in aviation. The focus is also engaging local stakeholders and raising awareness on Galileo and EGNOS in particular through workshops and seminars[399]. Recently, one such hackathon was organised in Bangalore to promote the use of Galileo in addressing different challenges in smart cities & urban mobility, safety and health in India[400]. GNSS.asia is a good example of EU showing interest to promote the integration of Galileo into concrete cases of industrial cooperation between European and Indian companies to ensuring the utility of Galileo-enabled receivers and chipsets outside of Europe. However, there is still scope to explore potential for exploring downstream proliferation of navigation products and services-based harmonisation of IRNSS

393 Somasekhar, M. (2017). "India-Israel Space Ties to Get a Boost". *The Hindu Business Line*. Web. https://www.thehindubusinessline.com/news/indiaisrael-space-ties-to-get-a-boost/article9758381.ece.

394 Goh, Deyana (2017). "ISRO Wastes No Time in Fixing Atomic Clock Issues". *SpaceTech Asia.* Web. http://www.spacetechasia.com/isro-wastes-no-time-in-fixing-atomic-clock-issues/.

395 Chen, Stephen (2016). "China to Launch World's First 'Cold' Atomic Clock in Space ... and It'll Stay Accurate for a Billion Years". *South China Morning Post*. Web. https://www.scmp.com/news/china/article/2019276/china-launch-worlds-first-cold-atomic-clock-space-and-itll-stay-accurate.

396 Marks, Paul (2014). "Quantum Positioning System Steps in When GPS Fails". *New Scientist*. Web. https://www.newscientist.com/article/mg22229694-000-quantum-positioning-system-steps-in-when-gps-fails/.

397 Cuthbertson, Anthony (2018). "The World's First Quantum 'compass' Could Make Sat-Nav Obsolete". *The Independent*. Web. https://www.independent.co.uk/life-style/gadgets-and-tech/news/quantum-compass-atoms-satellite-navigation-gps-m-squared-imperial-college-london-a8625556.html.

398 European Global Navigation Satellite Systems Agency (2017). "Two Awards Promote European GNSS in Asia". *European Global Navigation Satellite Systems Agency*. Web. https://www.gsa.europa.eu/newsroom/news/two-awards-promote-european-gnss-asia.

399 GNSS.asia (n.d.). "Objective of GNSS.Asia". *GNSS Asia*. Web. https://india.gnss.asia/.

400 PES University (n.d.). "Galileo Hackthon by GNSS.Asia". *PES University*. Web. https://www.pes.edu/events/galileo-hackthon-by-gnss-asia/.

and Galileo by establishing cooperation between European Global Navigation Satellite Systems Agency and ISRO. One possible avenue in promoting such harmonised use of IRNSS with Galileo can also be the extension of navigation focused accelerators such as Galileo Masters[401] to have an India-focused vertical which can promote the creation of navigation products and services based on both the navigation satellite systems. It is important to note that any applications developed using IRNSS that caters to local socio-economic problems within India has the potential to be scaled into other developing countries. The limited geographical coverage of IRNSS provides an opportunity for EU policymakers to leverage the global coverage of Galileo to help any such solutions to be scaled into other developing markets. Such complementary aspects of cooperation need to be apart from the current strategy that focusses mainly on promoting the utilisation of Galileo within India.

## 8.5 Conclusion

India's navigation satellite system is one of the unique efforts by a developing country to establish self-sustenance in positioning, navigation and timings (PNT) applications. Having spent over a decade in establishing the necessary upstream and ground segment infrastructure, India is now looking to create applications that will use its own indigenous navigation satellite system. Both India and Europe have faced several bottlenecks in the process of establishing independent capacity in navigation and there are several potential areas within the technology development realm for the next generation navigation systems that are still available for collaborative cooperation. Policymakers in India seem to be creating catalytic instruments that shall allow plausible volume creation in the downstream of the PNT applications. The current European interaction with the Indian subcontinent in the downstream of navigation applications seem to be limited to promoting the adoption of Galileo alone. The EU should not view India as a mere customer or adopter of its navigation system but harvest peer-to-peer opportunities as an integral part of the EU-India cooperation agenda. India is known for frugal innovation solutions for several socio-economic problems present in the developing world. The services built on up of IRNSS can also be viewed as a geography where pilots are being done to solve challenges specific to developing countries. Given the geographical limitations of coverage of IRNSS, policymakers in the EU should consider providing a platform for the potential expansion of such unique services to other parts of the developing world where Galileo can provide the foundation for the services. One way to explore this may be through embedding GNSS downstream cooperation in the overall cooperation framework the EU-India Agenda for Action 2020. Such initiatives will not only move forward the yardstick on India being treated as an equal by EU, but will also provide leverage for EU to deepen the usage of Galileo in several parts of the developing world.

[401] European GNSS Agency (n.d.). "Galileo Masters". *Anwendungszentrum GmbH Oberpfaffenhofen*. Web. https://www.galileo-masters.eu/.

# 8. India-Europe Space Security Cooperation

By Rajeswari Pillai Rajagopalan*

Space has become crowded, congested and contested. Even though it sounds clichéd, it happens to be true as well. From a time when outer space was dominated by two or three major powers, there are around 80 players active in space today. It is also to be noted that this includes no longer just state actors but commercial players, educational institutions and other non-governmental organisations who are pursuing a role in space for several different applications. The growing number of objects in outer space including space debris and the early indicators of weaponisation are among key concerns for the long-term sustainability of outer space. With the increasing number of actors, radio frequency interference could become a bigger problem in the coming years. While much of the developing world is looking at space from an economic and developmental perspective, there are others who are approaching space from a national security angle. There are also a growing number of counter-space threats that have made access to outer space a lot more challenging.

Space has been gaining centrality in the India-Europe security discourse as well. A decade and half ago, in 2004, at the fifth EU-India Summit, space was identified as a key element in the bilateral cooperation.[402] This found further purposeful mention in *The India-EU Strategic Partnership Joint Action Plan* of 2005 which highlighted outer space as a key area in the first section on "Economic Sectoral Dialogues and Co-operation," indicative of the importance of outer space to both sides.[403] A cursory look at the India-EU Summit documents even over the past few years clearly underscore the importance of outer space cooperation in the bilateral context.[404] In 2018, the European Commission and India's Department of Space signed a major cooperation agreement in the area of Earth Observation data. The agreement seeks to enhance data sharing arrangement between the Copernicus Sentinel family of satellites and ISRO's Earth Observation satellites that could lead to the establishment of an active downstream sector in the European Union and India. The areas of focus under this agreement include long-term management of natural resources, monitoring of marine and coastal areas, water resource management, impact of climate variability, food security and infrastructure for territorial development.[405] This agreement also has a broader bearing in meeting the UN Sustainable Development Goals (SDGs).[406]

Given the broader commonality of approaches and the growing space profile of India and Europe in the outer space domain, there have been concerted efforts from both sides to cultivate and nurture strong bilateral and multilateral cooperation with each other. While most of these engagements so far have been on the civilian aspects of space, this is beginning to change gradually. The two sides have begun to acknowledge the longer-term of implications of ignoring some of the security-related developments that are staring both India and Europe in the face. But this is somewhat more pronounced in India's bilateral engagement with some individual European countries. This is particularly true of the India-France and India-Germany bilateral space cooperation. This is because the EU is "a large monetary contributor to the trans-governmental ESA", which is primarily focused on peace-

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402 European Commission (2004). "An EU-India Strategic Partnership (COM/2004/430)". Web. http://eur-lex.europa.eu/legal-content/en/TXT/?uri=celex:52004DC0430; Council of the European Union (2004). "Fifth India-EU Summit (14431/04 Presse 315)". Web. http://europa.eu/rapid/press-release_PRES-04-315_en.htm

403 Council of the European Union (2005). "The India-EU Strategic Partnership Joint Action Plan (11984/05 Presse 223)". Web. http://europa.eu/rapid/press-release_PRES-05-223_en.htm

404 Endorsement of "EU-India Agenda for Action-2020," in European Parliament, Web. http://www.europarl.europa.eu/cmsdata/122862/20160330-agenda-action-eu-india.pdf; European Parliament (2016). "Joint Statement 14th India-EU Summit,". Web . http://www.europarl.europa.eu/cmsdata/122861/20160330-joint-statement-eu-india.pdf; European Commission, "Roadmap for EU-India S&T cooperation," 2018. Web. https://ec.europa.eu/research/iscp/pdf/policy/in_roadmap_2018.pdf

405 European External Action Service (2018). "European Commission and Department of Space of India Signed Historic Cooperation Agreement to Share Satellite Earth Observation Data".Web. https://eeas.europa.eu/delegations/india/41583/european-commission-and-department-space-india-signed-historic-cooperation-arrangement-share_en

406 UN SPIDER (2018). "European Commission and India to share satellite data". Web. http://www.un-spider.org/news-and-events/news/european-commission-and-india-share-satellite-data

ful applications of space technology and utilization, compared to national European space programs, which have a security component also.[407]

This chapter will discuss the major imperatives for India and Europe to join hands on space security, the strengths and weaknesses of this partnership and possible way forward for further development of this cooperation. The driving imperatives for India and Europe to combine their efforts in the area of space security include several security challenges which will have the impact of making sustainable access to space problematic. While the two sides, independently, have often highlighted these challenges, the efforts at combining their strategies, efforts and resources have not been as forthcoming until now. The lack of clear institutional architecture and the absence of a strategic framework has possibly impeded progress in the bilateral context. The concluding section will identify a few measures that could be taken up by India and Europe in this regard.

## 8.1 Space in the India-Europe Context

Both India and Europe have traditionally looked at space from the perspective of its utility for civilian and peaceful uses, which makes both somewhat uncomfortable with the current trends in outer space. Both sides emphasize the large-scale use of satellites for civilian developmental needs, mapping of natural resources, predicting weather patterns with important implications for the agriculture sector, disaster preparedness and mitigation. For vast regions such as India and Europe, the relevance of satellites in enhancing communication also needs to be underscored.

India and Europe have pursued their space programmes with three key focus areas: Earth observation (EO), communication and navigation. Each of these areas has also gained salience in the context of national security. Given the extensive dependence on space assets for these functions, the security of these assets has become significant. Both India and Europe have been against the growing trend toward weaponisation of outer space and perceive a strong interest in preserving the peaceful uses of outer space. This should drive both sides to work together in curbing some of the emerging negative trends in space while emphasising the need to strengthen the existing outer space regimes and mechanisms and/or to establish new initiatives. The fact that both India and Europe have a strong affinity for engaging in normative rule-making exercise should be prove to be an ideal area to kick-start the India-Europe space conversations. So far, this has not seen any concrete joint discussions or action-oriented plans.

There are several factors that drive India and Europe to increase space security cooperation. In the face of new strategic competition and rivalry that increasingly includes the space domain, both have a natural interest in augmenting their competitiveness through mutual cooperation. While Europe treated India with benign neglect for several decades, this changed with the US-India nuclear deal of 2005. The nuclear deal (and the NSG waiver in 2008) created regional and global dynamics and prompted Europe to approach India afresh, examining the large potential in the relationship across economic and strategic sectors. The shifting balance of power from trans-Atlantic to Asia also provided a useful stimulus to re-energise this relationship. Further, the military balance in Asia, increasing militarisation, the competitive dynamics including in space, the re-emergence of anti-satellite (ASAT) tests are all driving Europe to engage India and the broader Asian region.

## 8.2 Key Drivers for India and Europe Space Security Cooperation

This section will analyse key motivating factors that will shape the Indian and European approach to create meaningful conversations on space security.

### 8.2.1 Changing Geopolitics as an Influencer:

India's space trajectory is increasingly shaped by its geopolitics. Ignoring those realities will cost India in economic and security terms and therefore New Delhi has had to tweak its space programme in consonance with the changing geopolitical realities in Asia and beyond. The recent anti-satellite (ASAT) test conducted by India was also in recognition of the growing security threats and challenges and what it needs to do to establish its own deterrence

[407] Gateway House: Indian Council on Global Relations in partnership with Istituto Affari Internazionali (2016). "Moving forward the EU-India Security Dialogue: Traditional and emerging issues: Potential and challenges of India-EU space cooperation". Web. https://www.gatewayhouse.in/wp-content/uploads/2017/01/EU-India-Security-Dialogue-Space-Commentary.pdf

mechanism in outer space. The Chinese ASAT test of January 2007 pushed India to take cognisance of the emerging military uses of space including the development of different counter-space capabilities. The Chinese ASAT test demonstrated the growing prowess of China in the military space domain, something India could not afford to ignore.[408] But for more than a decade, India wavered on whether to conduct an ASAT or not. India is clearly a reluctant ASAT power, finally forced to reckon with the emerging realities. Whether China is responding to its own perception of threat from the far superior US space capabilities or not, Beijing's growing muscle power in space will have a multiplier effect in its dealings with India and other key spacefaring powers such as Japan. Thus, India has also come to the recognition that "space may not remain a purely civilian domain."[409] This implies that space gets increasingly weaponised and India choosing to ignore such developments would mean that New Delhi will be lagging in a vital national security area. This is where the lack of a political vision in India's space programme and policy come in. India's space programme has been by and large shaped by its scientific community but ideally the space programme should be part of the larger national strategy of India, which in turn should dictate the Indian space trajectory.

This re-orientation in India's space programme towards security purposes has not come easily for India. India has traditionally been opposed to using space for security-related functions. In fact, from the beginning of its space program, India played an active role in pushing to keep outer space beyond interstate conflicts. The changed focus of India's space programme has also led India to pursue collaborative ventures in space with a number of other key space powers such as the US, Japan and France.[410] But this bilateral framework of cooperation can be expanded to a regional one as well that could bring in other key European space powers.

### 8.2.2 Sustainable Use of Outer Space[411]:

For both India and Europe, the long-term sustainability of outer space is a declared matter of importance. According to the Committee on the Peaceful Uses of Outer Space (COPUOS)' Guidelines, long-term sustainability of outer space is "the ability to maintain the conduct of space activities indefinitely into the future in a manner that realizes the objectives of equitable access to the benefits of the exploration and use of outer space for peaceful purposes, in order to meet the needs of the present generations while preserving the outer space environment for future generations."[412] This faces a number of challenges: A crowded space with growing amount of space debris, dual use nature of space technology that makes it difficult to determine the nature of space activities, radio-frequency interference, and electronic and cyber warfare in outer space are all threatening the sustainable use of outer space. Space assets are also important in the context of achieving the Sustainable Development Goals. Therefore, continued, safe, secure and uninterrupted access to outer space would require all states and multilateral organisations to commit to debating ways to avoid irresponsible behaviour by any actor. Both the established and emerging space players have responsibilities in this regard. But the crowded and congested nature of outer space should not however mean that the aspirations of the emerging players can anyway be constrained by the existing or new regimes. On the other hand, capacity building and transfer of technology should be explicitly identified as important areas of focus in any emerging regime and practical measures in this regard should be identified.

### 8.2.3 Space Debris and Space Situational Awareness (SSA):

Space debris has continued to remain a serious problem in ensuring safe and secure access to outer space. There are more than 21,000 pieces of space debris larger than 10 cms, approximately 500,000 pieces of debris

408 Harsh V Pant and Ajey Lele (2010). "India in Space: Factors Shaping the Indian Trajectory," *Space and Defense*, United States Air Force Academy, vol. 4 no. 2, p. 52; Rajeswari Pillai Rajagopalan (2011). "India's Changing Policy on Space Militarization: The Impact of China's ASAT Test," *India Review*, 10:4, pp. 354-378.

409 Rajeswari Pillai Rajagopalan (2018). "India Changing Tack on Space Policy," *Asia Global Online*. Web. https://www.asiaglobalonline.hku.hk/india-changing-tack-on-space-policy/

410 Rajeswari Pillai Rajagopalan (2018). "From Sea to Space: India and France Deepen Security Cooperation," The Diplomat, Web. https://thediplomat.com/2018/03/from-sea-to-space-india-and-france-deepen-security-cooperation/

411 Strictly speaking, sustainability of outer space is construed as an area within the peaceful uses of outer space under the COPUOS mandate, however, the growing number of threats in outer space has tended to cast a gloomy shadow in how states are able to perform their functions, be it for peaceful purposes or security-related functions. Hence, this chapter considers sustainable use of outer space as an important contextualizing factor setting the tone for India-Europe space security cooperation.

412 UN Committee on the Peaceful Uses of Outer Space (2018). "Guidelines for the Long-term Sustainability of Outer Space Activities," Vienna, Web. http://www.unoosa.org/res/oosadoc/data/documents/2018/aac_1052018crp/aac_1052018crp_20_0_html/AC105_2018_CRP20E.pdf

between 1 cm and 10 cm, and the number of pieces smaller than 1 cm is estimated to be more than 100 million. Irrespective of who is responsible for creating space debris, it will affect everyone who has a stake in space. Space debris does not distinguish between assets of different states and different types of assets. Therefore, space debris offers an important opportunity for states and private sector players to collaborate and find possible ways to mitigate the threats caused by space debris, especially because this threat becomes more severe given the crowded and congested state of outer space. In order to ensure continued, safe and secure access to outer space and keep it sustainable for future generations, states have to come together and agree to avoid certain activities that might lead to creation of more space debris. However, the bigger problem with cleaning space debris comes from the fact that technologies to clean up space debris are yet to be proven, and these technologies are available only to a handful of countries. The risky aspects of these technologies come from the fact if a particular technology can be used to remove a piece of debris, it can also be used for other nefarious purposes, such as attacking satellites. In addition, the legal and regulatory aspects of space debris are yet to be debated.

One of the most effective means to monitor the space environment is to have an effective space situational awareness (SSA) system. An effective SSA would help in tracking of space objects, debris, space weather, detect launches of new space objects, threats and attacks on spacecraft and include the ability to predict collisions in orbit and predict re-entry of space objects into the atmosphere.[413] As of today, the US has the largest SSA network with a number of radars and sensors, followed by Russia and the EU. While the US' SSA network is quite comprehensive, it does not provide a good coverage of the southern hemisphere. This gap can be addressed by Russia, EU as well as the emerging capabilities and networks in countries such as China, Japan and India.

The limited capabilities that India and Europe have developed in this regard need to be combined to develop a more holistic picture of the space environment. The two can further collaborate with other like-minded countries to formalise cooperation in this area which will go a long way in having a better SSA. This could also contribute to instituting better space traffic management measures.

### 8.2.4 Electronic and Cyber Warfare in Space:

The growing reliance on space for national security and military purposes has given rise to development of counter-space capabilities, making outer space more competitive and contested. Countries today are investing on a range of capabilities to "deceive, disrupt, deny, degrade or destroy space systems." While counter-space technologies are not entirely new, the prevalent geopolitical conditions are quite different from that of the Cold War. Countries today appear to be a lot more willing to develop and use these capabilities, even if these acts have not yet resulted in the permanent damage or destruction of space assets. Counter-space capabilities could involve kinetic capabilities which results in physical destruction of a space object as well as electronic and cyber-attacks where the effects of the attack are temporary in nature. Electronic means involve the use of radiofrequency energy to interfere with or jam communications to or from satellites causing temporary damage and disruption. Electronic and cyber means of attack are a lot more challenging because these capabilities can be developed and used with others being in the dark as to who is responsible for such attacks. The deniability and the difficulties associated with attribution, in addition to these being easier technologies and cost-effective to develop, make them attractive options. Another issue that complicates efforts to counter electronic and cyber warfare in space is the fact that it is extremely difficult to distinguish between an intentional attack and non-intentional failure or malfunction. Other issues that complicate matters are the dual-use nature of many space assets as well as private sector participation in space.

### 8.2.5 Militarisation and Weaponisation of Outer Space:

One can say that outer space has been militarized from the time Sputnik was launched in 1957, though all the major powers have emphasised the peaceful uses of outer space, at least in their declaratory policies and statements. At least in the initial decades, this meant non-military uses of outer space but over the years, this has come to mean different things to different actors. The US began to have a broader interpretation of peaceful use

413 Isabelle Sourbès-Verger (2016). "EU-India Cooperation on Space and Security," IAI Working Papers 16, Istituto Affari Internazionali, Web. https://www.frstrategie.org/web/documents/publications/autres/2017/2017-sourbes-iai-eu-india-cooperation.pdf

to mean "non-aggressive" than "non-military" and gradually the Soviet Union too came to accept this broader understanding.[414] From the 1960s onwards, the two major players in space were operating satellites that had direct military applications and the broader understanding of the concept of peaceful uses of outer space gained greater acceptability. Thereafter, the first Gulf War in the early 1990s demonstrated the military utilisation of outer space in the entire spectrum of war, leaving no doubt about the militarisation of outer space.

In the meantime, the growing distinction between the terms militarisation and weaponisation of outer space, has made the debates a lot more vague and trickier and states approach these terms as per their national interests. In the absence of clear understanding on what constitutes a space weapon, weaponisation has been limited to "destructive" activities in outer space. What this means is that while treaties such as the OST have prohibited the placement of weapons of mass destruction (WMD) in outer space, the development of counter-space capabilities with "non-destructive" means is seen as acceptable. Lack of definitional clarity and a common understanding can only accentuate further insecurities in future. Recent trends in space weaponisation have far-reaching consequences in terms of regional military balance, national and international security. These developments, if unchecked, could give way to an arms race in outer space.

### 8.2.6 Global Rules of the Road:

The re-appearance of old challenges like ASAT missiles and new ones such as electronic and cyber warfare as well as the growing trend towards weaponization call for developing a more holistic and global perspective on rules of the road for outer space activities. Outer space activities have so far been guided by the Outer Space Treaty (OST) of 1967 and its four associated agreements.[415] OST has remained quite sufficient so far to keep the space safe and secure but there are gaps in the OST that have made it ineffective in addressing counter-space security challenges. The fact that it does not explicitly prohibit states from placing weapons in outer space is a major lacuna. The insufficiency and ambiguities in the existing regime including in the OST is widely acknowledged and there is a renewed call for proactive engagements in reviewing the existing mechanisms and/ or creating new measures that would further regulate activities in outer space.

First and foremost, Europe and India should acknowledge that no comprehensive international mechanisms have been developed since the OST came in 1967. The need for an overarching mechanism is real and several measures have been debated within various UN bodies but they have floundered in the absence of consensus among the key spacefaring powers. In fact, the lack of consensus among major powers has become the biggest stumbling block in developing an effective outer space regime. There are also issues relating to the mandate and functioning of key UN institutions. The UN Committee on the Peaceful Uses of Outer Space (COPUOS) has a fair amount of international acceptance and is also a fairly representative body in terms of the number of countries present but the shortfall of the UN COPUOS is that it has a limited mandate and does not cover an entire array of activities that fall within the security and military domain. The Geneva-based Conference on Disarmament (CD), the forum where nuclear and space-related arms control issues are debated, has remained stalemated for more than two decades. While many countries assert the importance of CD as the sole venue where arms control and security-related space issues must be debated, the reality is that there has not been an agreement among states even on a programme of action for many years. Developing a treaty on the Prevention of Arms Race in Outer Space (PAROS) has been debated but it has been met with several challenges. Since early 1980s, a resolution on PAROS has been passed in the UN General Assembly but differences among major powers have hindered any progress on such a treaty measure. PAROS has also been criticised for the fact it has an excessive focus on arms race in outer space.

Some of the other recent initiatives include the EU-proposed international code of conduct for outer space activities (ICoC)[416], the draft Treaty on the Prevention of the Placement of

[414] For a detailed analysis on the debate between weaponisation and militarisation, see Kiran
Nair (2007). "Putting Current Space Militarization and Weaponization Dynamics in
Perspective: An Approach to Space Security," in United Nations Institute for
Disarmament Research (2007). "Celebrating the Space Age: 50 Years of Space Technology, 40 Years of the Outer Space Treaty," *Conference Report*,, p. 102.

[415] Rajeswari Pillai Rajagopalan (2018). "Space Governance," Oxford Research Encyclopedia of Planetary Science, Web. http://oxfordre.com/planetaryscience/view/10.1093/acrefore/9780190647926.001.0001/acrefore-9780190647926-e-107?print=pdf

[416] Ajey Lele (2012). "Space code of conduct: the challenges ahead," *Space Review*, July 16, Web. http://www.thespacereview.com/article/2119/1;%20Rajeswari%20Pillai%20Rajagopalan

Weapons in Outer Space, the Threat or Use of Force against Outer Space Objects (PPWT)[417], No First Placement, and Transparency and Confidence Building Measures (TCBMs).

The ICoC was a comprehensive political proposal with a goal of establishing norms of responsible behaviour in space, pertaining to both civilian and military domains of outer space activities but it ran into problems primarily because of the process by which the EU developed this initiative. Many countries felt that they were not part of the initial phases of developing this Code and that they could not sign onto something finalised by the EU. Countries across Asia, Africa, and Latin America observed that the EU exercise was rather an "exclusionary" one, with the EU determining what is good for the world.[418] The EU came to appreciate the problem and undertook three rounds of Open-ended Consultations as part of their outreach efforts but the political hindrances that came in the way post-Ukraine crisis became too difficult to cross. Given the overall comprehensive nature of the Code and that the opposition to the Code was primarily not related to its content but rather to the manner in which it was developed, there is hope for Europe and India to work together and develop a new Code or a similar political initiative.

## 8.3 Way Forward

India and Europe are heavily invested in outer space and both have important economic stakes in keeping the outer space environment safe, secure and clean. India's investments are worth $37 billion, including the ground-based infrastructure and value-added services. Therefore, the protection of its space assets is a high priority. There has also been a commonality of approaches between India and Europe in approaching space. Both see enormous benefits that space can bring for social and economic development of their people and accordingly emphasize the use of space for developmental and peaceful purposes. The two have also feel, to their credit, that all states must be assured independent and equitable access to space.

In recent years, India and Europe have focused their attention to many practical areas of cooperation including environmental intelligence and disaster warning, imagery and communications to support humanitarian relief operations, maritime domain awareness (MDA), air domain awareness (ADA), space exploration and space-based solar power. While some of these ideas have found quite a bit of traction, others are lagging. Areas such as mitigating climate change and environmental challenges using space assets have made tremendous progress. The Indian space agency, Indian Space Research Organisation and the French National Space Agency (CNES) have been undertaking joint missions such as Megha-Tropiques and Saral-Altika. The two also have ongoing initiatives such as the Trishna satellite for land Infrared monitoring and the Oceansat-3 Argos mission.[419] MDA and ADA have also received fair amount of attention in space cooperation between India and some of the European powers. India and France, for instance, are involved in designing and developing products and techniques including for Automatic Identification System (AIS), to keep an eye on and protect assets in land and sea. The two sides are also developing a constellation of satellites for strengthening maritime surveillance.

Another important area for India and Europe to come together would be for extending space development assistance to a number of emerging space players in Asia, Africa and Latin America. Both Europe and India have their own capacities in the areas of earth observation and communication satellites. India has one of the largest remote sensing satellite systems in place with the launch of CARTOSAT 1, 2, 2A and 2B, RISAT-2, RISAT-1, Megha-Tropiques and SARAL and European Union's Copernicus Earth Observation and Monitoring programme can also do a great deal in meeting the requirements of the emerging space players in different regions.

Another important area that both India and Europe must find ways to cooperate on is with regard to global governance. Both have an inherent interest in strengthening the existing rules as well as formulating new ones in line with the contemporary challenges. The EU-proposed Code of Conduct for instance was potentially a good area to work on but India had its own difficulties given that the EU Code was a voluntary measure. India was of the view that a voluntary measure will have no

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417 Michael Listner and Rajeswari Pillai Rajagopalan (2014). "The 2014 PPWT: a new draft but with the same and different problems," *Space Review*, August 11, Web. http://www.thespacereview.com/article/2575/1

418 Rajeswari Pillai Rajagopalan (2012). "Writing the Rules on Space: Why Inclusion Matters," *Space News*, January 23, Web. https://spacenews.com/writing-rules-space-why-inclusion-matters/

419 Ministry of External Affairs (2018). "India-France Joint Vision for Space Cooperation," New Delhi, March 10, Web. https://mea.gov.in/bilateral-documents.htm?dtl/29597/IndiaFrance+Joint+Vision+for+Space+Cooperation+New+Delhi+10+March+2018

teeth to enforce it, potentially making the instrument ineffective from the start. But India could have worked with Europe on the Code because the Code at the global level was a loose initiative binding states to develop more binding measures at the national level. Therefore, states that endorse the Code would be required to comply with national measures and those could be monitored through certain verification measures. Issues of verification add further complexities because there is no good way to verify space technologies, given that they are inherently dual-use in nature.

New Delhi has become pragmatic enough in the past decade to understand and appreciate the utility of working on TCBMs first and gradually move to develop a treaty-like legal instrument.

Finally, as mentioned before, both India and Europe have made significant investments in outer space. Both sides need to protect these investments from the growing number of challenges as a priority. Both also recognise that space assets come under multiple threats and are not limited to space weather and meteorites. In fact, in the years to come, a bulk of the challenges could come from intentional attacks as also space debris. Both India and Europe need to prioritize space security in their bilateral agenda if the two want to ensure safe, secure and uninterrupted access to outer space. Strengthening their SSA capabilities could be an important agenda in this regard. Further, changing geopolitics dictates that India and Europe pursue space cooperation for strengthening their eyes on international waters. There are thus a number of areas that the two sides can find to cooperate on in the outer space domain.

# 9. Cyber Security and Space Cooperation

By Rajaram Nagappa, PM Soundar Rajan & Mrunalini Deshpande*

## 9.1 Introduction

The number of countries using space for enhancement of societal services, communication, weather, resource management, positioning, navigation and timing (PNT) and disaster management is constantly increasing. Space plays an important role in supplementing and supporting the goals set out in the 2030 UN Agenda for Sustainable Development. In fact, the vision document of the UN Economic and Social Commission for Asia Pacific (UN-ESCAP) states that by 2030 all countries in the Asia-Pacific region will be able to access and use space science, technology and their applications to the fullest extent to meet their individual and regional needs to achieving the sustainable development goals. Similar vision exists for other regions/groupings around the world and one can imagine the assets that need to be in space for meeting the goals worldwide. The fact that 382[420] objects were launched into space on board launch vehicles in 114 launches[421] in 2018 mirrors the magnitude of the effort needed. In this statistic it must be noted that China with 39 launches, USA with 31 launches and Russia with 21 launches were the lead space launch countries. For Russia, discounting the Progress launches to ISS, the number of launches stands at 17. Many of the launches of these three countries have a military bearing – the Atlas launched satellites of the US and SS-20 launched satellites of Russia are an obvious give away and the Chinese satellites can be deciphered with some effort. The exponential increase in micro, cube and nanosatellites has further contributed to the overcrowding of space. Demands for space resources like frequency will increase, which along with the overcrowding could lead to situation of conflicts in space.

Space is adequately militarized, and this role has come to be accepted. While weaponization has not happened in the true sense and in all dimensions, such trends are potent and visible. During the Gulf War, especially the 2003 Operation Iraqi Freedom, space assets were used by the allied forces as major capability enhancement tools. Space assets were used in locating targets, providing warning of impending threats, relaying commands, aiding navigation and providing weather forecasts. From a technology point of view, this was a highly asymmetric war, with all the technological advantages including those accruing from space technology being in favour of the United States and its allies. If the adversary was stronger, the space assets of the allied forces would have been prime targets.

The inevitability of weaponization of space is in some fashion accepted, though to be fair no operational system has been deployed so far. Many concepts have been talked about; some technologies have been developed and demonstrated. The Rumsfeld Space Commission Report published in 2001, besides other findings had concluded that *conflict in space is inevitable; it said that every medium – air, land and sea – has become an arena for conflict, space will be no different*[422]*.* Development of kinetic kill weapons, coorbital weapons, directed energy weapons have reached different stages of development and maturation with some countries. The Outer Space Treaty codified in 1967 has been the bellwether to protect the rights of all spacefaring nations and assuring the rights of access to space. The treaty specifically prohibits the placement of weapons of mass destruction in orbit and also prohibits the use of celestial bodies for any military purpose. The treaty does not specifically place restrictions on placing conventional

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[420] Aditya Chaturvedi (2019). "Do you know how many satellites are currently orbiting around the Earth?". Geospatial World, Web. https://www.geospatialworld.net/blogs/do-you-know-how-many-satellites-earth/

[421] Space Launch Report (2018). "2018 Launch Stats". Web. https://www.spacelaunchreport.com/log2018.html

[422] Federation of American Scientists (2005). "Ensuring America's Space Security – Report of the FAS Panel on Weapons in Space". Federation of American Scientists, October 2005, page 36-37.

weapons in orbit or transit of ballistic missiles with nuclear warheads through space or ASAT weapons. At the time when the Outer Space Treaty was drafted, ICT and cyber technologies had not made much headway and nation states had not anticipated and taken into account a) the rapid growth of cyber technology, b) system vulnerabilities and c) cyber attacks and its consequences.

Hybrid Attacks **-** the current scenario in the counter satellite technologies is spread across five categories: Direct-Ascent, Co-Orbital, Electronic Warfare, Directed Energy, and Cyber. A threat, in the form of a co-orbiting satellite, could maneuver itself to come close enough to the target and use relatively little power to damage the bus. It could use a few hundred watts of Directed Laser energy to permanently damage critical E/O sensors, solar panels etc. Using co-orbital KKVs as a delivery vehicle for EW capabilities, or using pre-installed back doors to deactivate sensors or countermeasures in advance of a kinetic operation.

## 9.2 Cyber Threats and Vulnerabilities[423]

Cyber attacks can be engineered to be of destructive nature, i.e., they can be used to cripple a process or a system. This could be achieved through modifying or utilizing a bug in the application software, altering the functionality of the Operating System, altering the function of the Firmware through malware. An example is the *Stuxnet* malware and the damage it did to the Iranian enrichment centrifuge facility.

The cyber system could be infected with malware even at the stage of development or production. On board electronics use processors, memories and FPGAs which are very vulnerable to malware as they come through a very susceptible supply chain. Even Real Time Operating Systems which are imported are a potential source of malware.

For example, Hidden services, or back doors, in an Actel ProASIC3 chip, are difficult to find, and once installed may prove difficult to mitigate. Boeing 787 used Actel ProASIC3 chip, but the Generator Control Units (GCU) were found to have a software overflow that would cause them to go into fail-safe mode after being powered up for 248 days.

An attack vector that has come to the attention of cyber security professionals in the past few years is what is collectively known as, the "supply chain", which is a general term for malicious activities in the design, construction or on-going support of systems. If an attacker is completely rebuffed by the physical and cyber security measures, and willing to invest in a longer-term attack strategy, then the vendors could be used to attack one's critical systems.

By either compromising one's vendor or actually going to work for them (especially in product support or field service where they can abuse the 'trust relationship'), an attacker could potentially achieve any of the following:

- Including hidden functions in the original product software/firmware
- Producing/providing updates that contain a logic bomb, hidden function or a backdoor
- Providing security patches that are ineffective or that increase vulnerabilities
- Making malicious alteration of security policy settings (degrading protections)
- Malicious tampering to create vulnerabilities or implant malware
- Abusing poor end-point security for remote diagnostic support/access
- Use of infected test equipment and/or removable media in support activities
- Reinstallation of removed vulnerable applications (un-do the 'hardening')
- Creation of an unauthorized admin account

In early 2014, the US security agencies took up the task of planning cyber attacks[424] on North Korean missile launches. Their objective was to target North Korea's Musudan missiles with a series of cyber and electronic warfare strikes. According to David Sanger, author of The Perfect Weapon, "the hope was to sabotage them (missiles) before they got into air, or to send them off-course moments after launch. The further hope was that the North Koreans, like the Iranians before them, would blame themselves for manufacturing errors". In a span of six months starting April 2016, North Korea[425] launched eight Musudan missiles of which seven failed. Consequent to the failures North Korea suspended further Musudan launches. It is not difficult to imagine the extension of such cyber and electronic warfare into the space domain also. Sabotage, deception and deniability are three prime features of

[423] Consultative Committee for Space Data Systems (2019). "The Application Of Security To CCSDS Protocols, CCSDS 350.0-G-3", March, Web. https://public.ccsds.org/Pubs/350x0g3.pdf

[424] David E Sanger (2018). "The Perfect Weapon", Crown, New York, page133

[425] Ibid, page 259

cyber attacks. And these attributes therefore make it difficult to plan and execute counter action. The capability of certain players to carry out persistent cyber attacks renders most systems vulnerable. It becomes necessary to design systems with hardened elements and resilience.

The advantage of cyber attacks is its relatively low cost, though they require some level of technological sophistication. The focus of cyber attacks is the data and the systems which use the data. Consequently, both the ground and space segments could be targeted and used as intrusion points. Cyber attacks can be used for eavesdropping and monitoring data and data traffic. An example of this would be the close approach and probable communication intercept carried out by the, Russian satellite Louch-Olymp[426] in 2017. This satellite, which is known to possess advanced listening capabilities, had carried out an approach maneuver towards the Franco-Italian Athena Fidus satellite used by the French and Italian militaries for providing secure communication. The Russian craft could have or had intention to intercept communication from Athena Fidus.

Cyber attack can also manifest as deliberate corruption of data input or even take control of the satellite command and control system. A cyber attack on space systems can even lead to the permanent loss of a satellite. In an extreme scenario, a cyber attack on the command and control system of a satellite can result in the takeover of the satellite. An adversary can thus control the satellite and cripple any of the major subsystems like communication, sensors or propulsion system. Some examples can be seen below:

- In 1998, German-US ROSAT space telescope inexplicably turned towards the sun, irreversibly damaging a critical optical sensor following a cyber-intrusion at the Goddard Space Flight Center.
- On October 20, 2007, Landsat 7 experienced 12 or more minutes of interference. Again, on July 23, 2008, it experienced other 12 minutes of interference. The responsible party did not achieve all steps required to command the satellite, but the service was disturbed.
- In 2008, NASA EOS AM–1 satellite experienced two events of disrupted control: in both cases, the attacker achieved all steps required to command the satellite, but stopped short of issuing commands.
- In October 2014 a cyber attack on the US weather satellites system demonstrated the cyber vulnerabilities of strategic space-based assets.
- During March 2014, Russian state-controlled news agency, Interfax, reported that the Ukrainians attempted to "decay" the orbit of the communications satellite. No details were provided.
- Kaspersky Labs discovered that the Russia-based cyber-espionage group, Turla, hacked their way into a satellite internet provider to hide cyber-espionage operations against countries ranging from the US to the former Eastern Bloc. By using a ground antenna, Turla could detect IP addresses from satellite internet users and then initiate a TCP/IP connection from the stolen IP address. The attack is not easily detectable because the espionage operation does not need to perceivably impact the innocent user's performance; it depends on whether the hacker and the legitimate user are using the IP address simultaneously. Because both the victim and attacker's machines would have the same IP address, the attack will be stealthy and unlikely to be flagged by *intrusion detection systems.*[427]
- In 2017, the US Maritime Administration reported the first GPS spoofing attack against over 20 ships in the Black Sea. Correspondence between one of the impacted vessels and their command center reflects that over the course of the attack, the GPS position displayed on their navigation tool sometimes showed "lost GPS fixing position." At one point during the attack, the spoofed location showed the ship was located near the Gelendzhik airport, but was in fact 25 nautical miles from the reported location. Another attack of this type was used by the Iranians to capture a US drone in December 2011. In September 2011, Iranians claimed they mastered a new technique to compromise aircrafts via GPS spoofing. This technique was demonstrated when they successfully captured an American RQ-170 Sentinel drone by reconfiguring the coordinates of the GPS signal to make the drone land in Iran instead of its base in Afghanistan. The US military blamed the capture on a malfunction but were unable to explain

[426] Radio Free Europe (2018). "France accuses Russia of spying on military satellite". Radio Free Europe, 08 September, Web. https://www.rferl.org/a/france-accuses-russia-spying-military-communications-satellite-in-space/29478427.html

[427] Kapersky Lab (2014). "The Epic Turla Operation". August 7th, Web. https://securelist.com/the-epic-turla-operation/65545/

> how the Iranians hijacked the drone intact.[428]

An individual hacker can now intercept, e.g., Iridium satellite traffic, with a homemade, software-defined radio, which could be assembled for less than one-hundred dollars using instructions freely-available on YouTube. Moreover, many satellites were orbited prior to cyber-security considerations being taken seriously to the extent that we take for granted today.

## 9.3 Cyber Security Approaches

In the past, civil space missions relied on their uniqueness to deny unauthorized access to the space and ground-mission data systems, whereas military missions have implemented mission-specific security measures to protect the spacecraft command and telemetry data. This situation has changed with the advent of open systems for mission control and data distribution, increased Internet connectivity, and cross support activities. Civil space mission and ground system developers must consider security as part of their system architecture and design process.

Space missions require a level of data-system security to protect the spacecraft and ground systems from unauthorized access. This is particularly evident as space mission control activities make more use of public networks, such as the Internet, for ground network connectivity. Some missions will require increasingly higher levels of security for a variety of operational and commercial reasons.

### 9.3.1 Information Security

Information Security can be described as the effect or process of minimizing the vulnerabilities of assets or resources. The key elements of information security for a data communications system are access control, authentication, availability, confidentiality, integrity, and accountability. Access control results in limiting system access to specified individuals or groups (or processes acting on their behalf). Authentication is the assurance that the claimed identity of the source of information is not forged. *Availability* is the assurance that a system will be available for use. *Confidentiality* is protection against unauthorized disclosure of information, and *integrity* is protection against unauthorized modification of data.

Data transmitted to and received from spacecraft are sent over Radio Frequency (RF) communications links. All RF communications are subject to interception by listening to the specific allocated frequencies. However, RF used for spacecraft communication are potentially less susceptible to interception than common radio because of the large ground antennas and narrow beam widths used to communicate between the ground and space and, conversely, the low power and narrow beam widths used from space to ground. But this is mission dependent since all missions are different.

For example, Geo-Transfer Orbit (GTO) and Geostationary Earth Orbit (GEO) would have a relatively large downlink beam width resulting in a much more easily intercepted signal. For a low-Earth orbiter, smaller dishes and power are needed, but because of short passes, tracking creates an obstacle for an interceptor. As spacecraft move towards optical communications, data interception will become more difficult, but not impossible. Someone trying to intercept optical communication would have to be very close to the narrow optical beam width.

If ground system communications are operating over public networks (e.g., the Internet) they are susceptible to interception since the data is routed through many uncontrolled resources which could be tapped.

### 9.3.2 Security Mechanisms

The security mechanism that provides a confidentiality service for communications is ***encryption*.** Encryption may also contribute to the achievement of other security services such as data integrity and authentication. Encryption, when used for confidentiality, transforms sensitive data to a non-sensitive form. When used for integrity or authentication, cryptographic techniques are used to generate unforgeable functions such as a *digital signature.*

Encryption is performed on *plaintext* to produce *ciphertext*. The reverse process is known as decryption. A key is used during both encryption and decryption to direct specific transformations as part of the cryptographic process. When a key is changed, different ciphertext is obtained for the same plaintext input. The security of the encryption process is

[428] Scott Peterson (2011). "Exclusive: Iran Hijacked US Drone, Says Iranian Engineer". 15 December, Web. https://www.csmonitor.com/World/Middle-East/2011/1215/Exclusive-Iran-hijacked-US-drone-says-Iranian-engineer

dependent on the strength of the cryptographic algorithm being used, the length of the cryptographic keys, and maintaining the secrecy of the keys. Often the details of the cryptographic algorithm being used are publicly known, as is the case with the Advanced Encryption Standard (AES). In this case, because the details of the algorithms are known, security of the system is designed to be dependent on the secure handling of the cryptographic keys: their management, distribution, use, and destruction.

### 9.3.3 Key Management

In an asymmetric (or public-key) system, each communicating end system possesses a key pair: a *public* key and a *private* key. The private key is kept secret, but the public key is made available to anyone who wants it. It may be posted to a publicly available server (e.g., a key server). An asymmetric system relies on the fact that it is practically impossible to obtain knowledge of the decryption key from knowledge of the encryption (public) key. For example, the Rivest-Shamir-Adleman (RSA) public key system, the best known and most commercialized public key system in use, is based on the difficulty of finding factors of large prime numbers. The public key does not need to remain secure, which implies that no prior secret key exchange is required, and which in-turn leads to reduced security-development and operations costs. However, in practice RSA uses a combination of asymmetric and symmetric key systems (hybrid encryption) to improve efficiency. A public key exchange is used between the communicating assets in order to agree on a shared key (the traffic or session encryption key), which is then used with a symmetric algorithm to provide data confidentiality.

### 9.3.4 Data Integrity

Data integrity can be considered as having two different functions: the integrity of the individual data units and the integrity of a stream of data units. Different mechanisms are generally used to provide these different integrity functions. Integrity of individual data units is achieved by appending an Integrity Check Value (ICV) to the data structure in a manner similar to the way a digital signature is appended. However, the ICV is always a function of the data itself. A Cyclic Redundancy Check (CRC) is a simple example of such a function. A stronger function is provided in the Secure Hash Algorithm (SHA-2). The receiver generates a corresponding check value by performing an operation on the data and compares the result to a received value to determine if the data has been modified in transit. In some applications, both authentication and individual data-unit integrity can be provided by one mechanism. Coding specifications, such as Reed-Solomon and Turbo Codes, provide data integrity by virtue of their error detection and correction capabilities. To provide integrity of a stream of data units, a sequence number is employed to protect against replay attacks. Alternatively, time stamping of data may be used to provide limited replay protection.

### 9.3.5 Access Control

Access Control is to ensure that data or information-technology resources are available only for authorized users or processes. As a result of ensuring data availability, access-control mechanisms may provide limited confidentiality and integrity. It should be noted, however, that access control is not a fundamental technique for providing these other two security services; it is purely a barrier in the path of a potential intruder. Access control requires the use of a number of techniques, including the establishment of access-control information bases in which the access rights of users or processes are maintained securely. Authentication information such as identification, cryptographic credentials (e.g., X.509 certificate, Kerberos ticket), and passwords provide management and control of access to the system. Audit trails are an important mechanism in security management. They are used to monitor system usage and password changes, and should contain as much information regarding the system details and previous accesses as possible.

### 9.3.6 Availability

Availability is the assurance that a system will be usable when it is required to function. Although not entirely a security matter, it is a security concern from the perspective of an attacker attempting to deny access to a system, either by denial-of-service attacks or by crashing the system. In a space environment, there are Radio Frequency (RF) communications links. Unlike wire-line communications, RF communications can be jammed by devices emitting high power levels on the same (or nearby) frequency. When a frequency is jammed, communication over that RF link is interrupted. This impedes telemetry and telecommand to/from a spacecraft. This also impedes the collection of data from a spacecraft, potentially resulting in total, unrecoverable data loss. It can also result in the loss of the spacecraft if housekeeping data is not received on the ground and there is an emergency situation that must be dealt with immediately. Likewise, a spacecraft can be lost if telemetry is received but the telecommand uplink is jammed so that no commands can be sent. **Spread spectrum and frequency hopping** are techniques used to counter jamming.

### 9.3.7 Security Implementation

Implementation is best done in four out of the seven ISO Layers: Application, Network, Data Link, and Physical Layers.

**Bulk encryption** provides confidentiality to the communication system data structure. It is implemented at the Physical Layer and provides the highest possible level of data confidentiality available on a point-to-point basis; often this is termed 'link encryption'. However, this is not to imply encryption at the Data Link Layer but rather over the physical link. No separate integrity, authentication, or access-control services are implied other than those implicitly provided by encryption. For example, if symmetric key encryption is used, authentication is implicitly achieved because the receiving end must have the correct key, which has been distributed by an assured key distribution system in order to decipher the data. Bulk encryption would result in encryption of the full Physical Layer data structure. Similarly, to prevent jamming of the Physical Layer, techniques such as *spread spectrum* using *direct sequence* and *frequency hopping* can be employed. This technology is known as TRANsmission SECurity (TRANSEC). When data is transmitted using spread spectrum techniques, the information is transmitted over a wide range of frequencies and then collected by a receiver onto a single frequency. In direct sequence spread spectrum, the stream of information to be transmitted is divided into small pieces, each of which is allocated to a frequency channel across the spectrum. This technique spreads the signal so that it appears to be noise rather than data and therefore is hard to intercept and jam. Using frequency-hopping techniques, data is transmitted over a single frequency, but the frequency changes over time during the transmission. The receiver must be synchronized in order to change frequencies, as is being done by the transmitter. Data Link Layer and Application Layers have been discussed in detail at Reference.

### 9.3.8 Network Layer Security—Internet Protocol Security (Ipsec)

Developed by the Internet Engineering Task Force (IETF), IPSec provides end-to-end security for internet protocol packet payloads. That is, IPSec provides confidentiality and authentication for all data contained in an Internet Protocol (IP) datagram. This includes the Transmission Control Protocol (TCP) header and the information payload. The primary benefit of IPSec is its ability to provide end-to-end security, that is, from the source of the data to its final destination. Any non-security-related intermediate systems and networks will not have access to the data unless explicitly authorized and therefore insecure networks may be utilized to transmit sensitive data. The communication end points are implementation specific and are defined by the implementing system. IPSec does not mandate any specific security algorithm but defines the protocol framework to provide Network Layer data confidentiality, integrity, and authentication services for space communications systems.

## *9.4 Cybersecurity Approach for Space Systems*

A system approach best serves the objective of space cybersecurity. There are commonalities between defence and cybersecurity defence. The principal elements of both physical defence and cybersecurity defence include elements of deterrence, detection, delaying, denial and response. The three attributes of cybersecurity, viz confidentiality, availability and integrity are practiced in space systems also. Launch vehicle missions per se, are of short durations, typically of the order of twenty to thirty minutes; during this period a large number of sensors provide information which aids the steering of the vehicle in the appropriate path and injection of the satellite at the correct orbit and inclination. Once the satellite is injected in orbit, it has to carry out its design functions (Earth observation, communication, weather or navigation) over its lifetime. Satellite life time could vary from a few months in very low orbits to 12-15 years in GEO.

Security risks will always be present and approach requires strategies to minimize them and manage them. Just like reliability is built into system design, security features also should be addressed in the design phase itself. The system verification is part of the quality check and this should specifically address security vulnerabilities. Intended and unintended insider threats should be specifically considered. Unintended insider threats could include incorporation of software updates/modifications without due process of verification and authorization. Intended threats are difficult to model, especially with the pace of technological changes, but some level of gaming and ethical hacking should be considered as part of the development process. The operating environment is equally important and appropriate methodology depending upon the level of autonomy of stand-alone systems should be a factor during the development and verification phase. Specifically, consideration of issues of the devices employed (given the concerns regarding the pedigree of some procured devices) and connectivity/isolation with internet should be addressed.

Cybersecurity is essentially a risk management approach, where adequate safeguards are built in along with mitigation and recovery strategies.  It must also be remembered that cybersecurity is not a static process. The system design should allow for updation as and when new vulnerabilities get exposed. Needless to say, the personnel training is an important requirement. In short, protection of space assets will call for the following capabilities:

- **Detect cyber attacks**: one must have sensors capable of detecting attacks by constantly looking for anomalous and suspicious events or occurrences. Environmental phenomenon (cause and effect, for example) that can impact the normal operation of systems need to be identified.
- **Identify, locate and classify threats**: Accurate determination of the cyber threat or attack source is necessary to decide on appropriate response and retaliation. This is quite complicated and calls for capability to receive, process, correlate, fuse and disseminate information rapidly and unambiguously for execution. (The challenge is in the accurate determination of the threat, while the other attributes are anyway essential in respect of other types of threats to space assets)
- **Withstand and defend**: System requirements to counter cyber attacks. Key system vulnerability and active/passive systems needed to preserve the functionality of such systems.
- **Reconstitute and Repair**: Redundant schemes to recover lost functionality
- **Assess Mission Impact**: Proper assessment of performance anomalies caused by the cyber threat for planning corrective action.

Power projection and deterrence are important tools. Any attacker will carefully weigh the options and risks before triggering a cyber attack. Factors governing the nature and quantum of a cyber attack could include the victim's technological as well as political and economic response; the strength of deniability; and the attacker's own vulnerabilities. In cyber attack like in any other form of attack, a quick response will be the most effective one. However, in international relations, credible evidence is necessary in order to retaliate and impose costs on an attacker. In responding to attacks on cyber and space systems, a report of the National Academies[429], in the context of the United States examines the many sources of uncertainty for adversaries mounting an attack and for the US to respond to such an attack. The report infers that the "primary challenge will be a lack of understanding of an adversary's motives and values – an understanding that is also necessary to the effective creation of deterrence in the adversary's mind". According to the report, response to space attacks goes beyond the technical capabilities and needs better insight into adversary thinking. The report further adds that in addition to understanding an adversary's doctrine, organization and war plans, insight is needed as to what the adversary desires and fears. The summing up reads "this allows for a better understanding of an adversary's internal political calculations, so as to better tailor US deterrence and capabilities". The political makeup is as important as the technical capability for execution of cyber attack and in retaliation.

## 9.5 India-Europe Cooperation

The platform for the EU Cyber Dialogue with India was provided at the EU-India summit in 2010. The first meeting was held at the EU Joint Research Centre in Ispra in November 2011 and was followed by a meeting in New Delhi in 2012. After a three-year break, the issue was placed on the agenda of the EU-India Summit in 2015 and subsequently included within the EU-India Agenda for Action 2020 at the EU-India Summit of 2016[430]. The Agenda acknowledges cyber security as a topic of policy dialogue and cooperation in the broader areas of security and ICT cooperation and recommends exchanging expertise and best practices. The most recent Dialogue took place on 12 December 2018. However, aspects of space cyber security still need to be highlighted and discussed.

Individual countries and space agencies are bound to have their own cybersecurity protocols, approaches and practices. Bilateral and multilateral agreements may also be in vogue.

429 National Academies of Science, Engineering and Medicine (2016). "National Security Space Defence and Protection: Public Report", National Academies Press 2016.

430 European Parliament (2016). "EU-India Agenda for Action 2020". Web. http://www.europarl.europa.eu/cmsdata/122862/20160330-agenda-action-eu-india.pdf

It is still worthwhile to consider how bodies like the National Institute of Advanced Studies and the European Space Policy Institute could catalyze some cooperative thoughts and actions. Some of the possibilities are:

- Sharing of experience of experts including case studies
- Sharing information on intrusions, modus operandi, threat vectors and malware
- Sharing information on Supply Chain
- Sharing information on trusted components (both hardware and software) leading to Trusted Computing Systems for both satellite and ground station applications
- Taking up collaborative studies/projects including exchange of scholars
- Preparing database of known cyber attacks, effects, response and resolution. The technical and political fixes
- Joint studies relating to defence-in-depth
- Joint workshops and seminars
- Sharing of Space Situational Awareness data.

## *9.6 Conclusion*

Space systems, originally, lacked the software and technology with vulnerabilities and were therefore immune to cyber attacks. However, with the progress in technology, satellite systems are now digitized and can be intruded from the ground. While the technology progresses were readily incorporated in the satellite systems, cybersecurity of these systems was generally overlooked, rendering them vulnerable to attacks. It is evident that space assets are central to smooth functioning of a number of critical infrastructures on Earth. Attacks on these systems have the potential to cause physical damage, financial losses of significant proportions and pose consequences to the public.

Cyber-attacks can either be carried out by nation states against an adversary state, by non-state actors against the states or by individuals. One of the major features of a cyber-attack is the problem of attribution. Due to the inherent stealthy nature of the attack, it becomes challenging to identify the adversary. The happenings in space have the potential to trigger conflicts on Earth. It therefore becomes important to determine the intent of actions in space and attribute a mishap to avoid misunderstandings. Greater uncertainty leads to greater level of misperception and misunderstanding at a strategic level, inflating the threat perception. It is therefore cardinal to identify the cyber security risks and vulnerabilities to these space assets and develop standard regulations.

The Space Industry today is largely driven by the commercial sector and therefore, apart from spacefaring nations, the commercial sector should also be an important stakeholder in the formulation of regulations. The stakeholders can develop cooperation between university researchers and ethical hackers to test penetrate their systems. Apart from this, cyber security training exercises for space domain between nations should be promoted.

As space technology continues to develop and evolve cyber security challenges will continue to grow as well. It therefore becomes important for both, the technologists and the policymakers to actively engage to simultaneously evolve policy and regulatory issues. Cyber security of space assets is a global issue. It therefore becomes important to develop common mechanisms to promote best practices and identify vulnerabilities that would arise in the software and hardware. Similarly, it is important to share exploits and countermeasures between all the stake holders. The possibility of a common global cyber security regime that promotes and regulates these mechanisms for all stakeholders in space can be explored. While bilateral and multilateral cooperative agreements are valuable, research institutions and think tanks should play an active role in promoting security policy and regulations.

# 10. NewSpace in India: Assessing its Potential and Engagement Opportunities with Europe

By Narayan Prasad*

## 10.1 Introduction

The global landscape for space activities is currently undergoing dramatic changes in its structure, with the historical *status quo* progressively being challenged by new business-driven endeavours. Whereas the vast majority of space activities today are still led by governments with private industries acting as suppliers for public programmes and relying massively on public funding, a disruptive, commercially-driven approach to space has emerged, marked by ambitious undertakings aiming to capture space markets with innovative schemes and business models. In this new ecosystem, private actors are playing a more prominent role, pursuing the eventual goal of conducting space business independently from governments.

This new dynamic, usually referred to as New Space, is gradually – yet steadily – emerging across the globe. Whereas still primarily concentrated in the U.S., and to a lesser extent in Europe and Japan, over the past few years India too has started to witness a New Space phenomenon. Partly inspired by the undertakings of U.S. companies such as Space X, Planet and Blue Origins, and partly prompted by the growing private dynamism in the country, several Indian entrepreneurs have seen opportunities to do space businesses in either the upstream or downstream segments of the space value chain. Companies like SatSure, Earth2Orbit, Bellatrix Aerospace, Astrome Technologies, among several others, are now positioning their offerings within the national and international market and promise not only to disrupt the way space activities are conducted in India, but also to exercise a relevant influence on the future space economy.

Drawing on extensive research and discussions with India-based space companies and stakeholders, this Chapter provides an assessment of the current outlook and future trajectory of the New Space ecosystem taking shape in India. The paper first offers a mapping of this emergent commercial ecosystem and then reviews its weaknesses and strengths – also in relation to the traditional space industry – and finally disentangle its growth potential and implications at international level. The chapter, more specifically, demonstrates that there is an inherent growth potential for New Space in India and that such growth will create both challenges and opportunities for the global space industry, especially by that of Europe. In this final part, the chapter also shows that there is much scope to nurture mutually beneficial B2B solutions between Indian and foreign space companies in a variety of fields.

## 10.2 Understanding the Difference between Traditional Space and NewSpace

To fully understand the potential of NewSpace, it is important to understand the nature of the phenomenon and how it is different from that of the legacy approaches to space activities. NewSpace is a global movement of entrepreneurs targeting the creation of innovative space products/services that can target other businesses or non-governmental customers. Largely driven by the U.S, this movement has been making waves around the world with other regions being inspired by the approach.

NewSpace in India is driven by private entrepreneurs who are looking to establish innovative services that can help address local demands of the country or are building products through which they can secure a piece of the pie of the global space market. There is still no comprehensive mapping of the New Space dynamic taking shape in India, and no collection of relevant economic data to perform thorough quantitative assessments. The Indian community of astropreneurs has, however, become more and more active in providing insight on this nascent ecosystem and in voicing their efforts, primarily as a result of their need to raise awareness among public institutions and private investors in and outside of India. Drawing on the collection of available sources and interviews with several Indian entrepreneurs, an overview of New Space start-ups that have been formally incorporated in India and their respective offerings is provided in Table 2.

| Name | Incorporation | Segment | Mission/Offering |
|---|---|---|---|
| **Aeolus Aerotech** | 2012, Chennai | Education | Development of smallsat hardware and training kits |

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| | | | |
|---|---|---|---|
| **Aniara Space** | n.d, Bangalore | Engineering | Satellite services (VSAT connectivity, capacity leasing, IoT, etc.) |
| **Astrome Technologies** | 2015, Bangalore | Internet | Satellite constellation-based Internet connectivity |
| **Bellatrix Aerospace** | 2015, Bangalore | Propulsion | R&D company; Launch vehicle & electric propulsion systems |
| **Dhruva Space** | 2012, Bangalore | Satellites | Development of small satellite platforms with a focus on AIT |
| **Earth2Orbit** | 2009, Mumbai | Engineering | Provision-of remote sensing value-added products, Technology consulting |
| **Naika Statlogic** | 2015, Bangalore | Consulting | Space-based statistical data analysis |
| **SatSure** | 2014, Bangalore | GIS | Crop yield risk assessment for Insurance companies and banks |
| **SPACE India** | n.d. | Education | Astronomy education and space-tourism services |
| **Team Indus** | 2012, Hyderabad | Lander | Indian contender at the Google Lunar X-Prize competition |
| **Xovian** | 2014, Kanpur | Satellites | Low-cost, sustainable satellite fabrication solutions, sounding rockets & HAPS |
| **Exseed Space** | 2016, Bangalore | Satellites | CubeSat based satellites services |
| **Rocketeers** | 2013, Bangalore | Education | Model rocketry and human resource development |
| **Agnikul Cosmos** | 2018, Chennai | Propulsion | Small satellite launch vehicle development |
| **Skyroot Aerospace** | 2018, Hyderabad | Propulsion | Small satellite launch vehicle development |
| **Manastu Space** | 2018, Mumbai | Propulsion | Green propellant thruster |
| **Kawa Space** | 2019, Mumbai | Satellites | CubeSat based satellites services |
| **NoPo Technologies** | 2013, Bangalore | Materials | Carbon nanotubes for space applications |
| **Astrogate Labs** | 2017, Bangalore | Communication | Optical communications |

Table 2: India's New Space Companies

As evident from Table 2, the emergence of a New Space entrepreneurship in India is at a very embryonic stage and hence understandably centred on start-up companies that are yet to consolidate their offerings in the domestic market. Admittedly, India can already boast an industrial base of more than 500 small, medium and large enterprises that are seizing commercial opportunities by supplying capacity to the Indian Space Research Organisation (ISRO).

Hence, the key question is how are these start-ups different from those 500 odd SMEs that serve ISRO? The answer lies in a rather simple fact that these companies are the ones that plan to either build 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. Another strong distinction from the traditional business models that exist so far in the country is their vision to majorly focus on the possibility of exporting their offerings.

Thus, the approach of NewSpace in India is different from the legacy of entrepreneurial approaches working with government-driven space activities. In order to understand the possible growth trajectories for NewSpace in India and its potential in developing a scalable space economy in the country, it is important to understand additional key underlying differences between the traditional and NewSpace approaches. The following are the key highlights to the differences between the approaches:

- **Customer Landscape** – Traditional space industry approach majorly depends on tax-payer funded requirements within the national demand framework administered by a space agency. This is a process that several countries have pursued in upgrading the capacity in the industry. 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 while 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 requirements at Tier-2/Tier-3 levels with the initial technology and knowhow itself has also been mostly borrowed from ISRO. Therefore, the traditional space industry will tend to gain more traction by working towards establishing a larger share in manufacturing/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 upgradation are based on performance/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 and 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 duly noted that there are a large number of failures associated with the start-up nature of NewSpace as well.
- **Exit Landscape** – Traditional space industry in India is driven by SMEs or one division of large corporations working with the space agency alone which makes it difficult for them to attain scale or find high-velocity reasonable exits. NewSpace brings along the possibility of Mergers & Acquisitions (M&As), public listings and other positive liquidation events for investors and entrepreneurs. A mature ecosystem is necessary for such exit scenarios.

From an Indian context, the argument is not a race between traditional vs NewSpace, it is rather a matter of enabling 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 pre-mature in the ability to design, development, deliver a complete end-to-end space system or a space-based service. Policy makers should look to draw a long-term roadmap to create an environment of multiple industry players or industry consortiums who have the ability to deliver end-to-end systems so that there is room for competition in the national ecosystem. The traditional space industry ecosystem will certainly benefit from long-term perspective planning by policy makers. 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 not only help meet the growing requirements in volumes nationally but will help integrate the Indian industry base globally. NewSpace too holds the potential of creating a multiplier effect on the space economy unlike the circulation of tax money that normally happens within traditional space industry approaches. Policy makers in the country need to support NewSpace in India to further catalyse the multiplier effect while steps are being taken to upgrade the capacity of the traditional space industry in the country.

## *10.3 New Space in India: a Still Challenging Dynamic*

When observing the amount of India's New Space companies and the general landscape of ventures in the sector, one will clearly notice how niche the sector really is, especially when compared to other Indian technology areas, such as IT, or to the New Space dynamics in other countries, particularly in the United States.

If compared to the U.S. and European private space sectors, it has to be also noted that India's space start-up ecosystem not only lags behind in terms of entrepreneurs, but also in terms of venture capitalists, mentors, accelerators, and incubators. Despite various success stories that are progressively emerging, the overall enterprise readiness level of India´s New Space companies remains rather low, with an extremely small number of companies having reached technological and operational maturity.

A number of elements can be identified as the major causes for the limited emergence of new private actors in India.

First, involvement and capabilities of private industries in the Indian space programme remain rather marginal in comparison to the U.S. and Europe. As a country, India is one of the most successful nations to have 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 built up in the private industry as 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 is due to the fact that in both the upstream and downstream segments of India's space industry, the role of the public actor has remained predominant, with ISRO acting as the main manufacturer and Antrix as the main operator for the commercialisation of space-related services, including remote sensing data imagery, transponder leases on Indian telecommunication satellites, ground station services, satellites launches, and exports of satellite components and other products. Whereas over the past forty years ISRO has been outsourcing to industry an increasingly large part of its satellites and launch vehicles' manufacturing, its *modus operandi* has not entailed procurement of turn-key products and services. Most of the private industry in India has remained involved in supplying ISRO with Tier-2/Tier-3 products and services. As a result, there are only a handful of Tier-1 space companies in the industrial ecosystem, a role that is still in the hands of ISRO. The final assembly, integration and testing (AIT) of spacecraft and launch vehicles are also within the remit of ISRO. Clearly, this specific relationship between Indian SMEs and ISRO has prevented industry to gain key competences in the development and provision of end-to-end solutions. This creates bottleneck effects in the possible expansion of industry to the global supply chain, especially from an export perspective.

Second, the private investment base to support the growth of Indian start-ups remains very small compared to the U.S. and European ecosystems. Most of them have been self-funded or sponsored by grants from high net-worth individuals like Tata, Mohandas Pai, and Rajan Anandan. Interestingly, this is in stark contrast to India's broader start up ecosystem (particularly in the IT sector), which has a well-organized community of venture capitalists (see next section).

Third, unlike New Space companies in the U.S. or Europe, Indian astropreneurs cannot count on any dedicated start-up support programme such as the Small Business Innovation Research fund offered by NASA or the Business Incubation Programme of the European Space Agency (ESA). There is no real case of institutional capital investment for these companies and no dedicated support structure like incubators or accelerators. More broadly, the level of institutional sponsorship, which has proved key in the emergence of New Space companies in the U.S., has been thus far negligible. Support for private industries has been limited to a policy of "transfer and buy back", in which ISRO has been procuring products manufactured by industry as a result of a technology transfer enabled by ISRO itself,[431] and to the execution of some consultancy projects in high technology areas to provide support to various industries.

Fourth, India is yet to adopt transparent and comprehensive regulatory mechanisms that are supportive of private space business in the country. A sound policy, legal and procedural framework is quintessential for any industry in any geographic location, and has been instrumental also for the emergence of New Space in the U.S. and Europe. However, in the case of India's space sector governmental policies and practices have been unsupportive, not to say obstructive, of private sector undertakings. Indeed, while such policies acknowledge

[431] ISRO reports that 300 technologies have been transferred to industries in the fields of electronic and computer based systems, speciality polymer chemicals and materials, electro optical instruments, mechanical equipment and ground systems related to satellite communications, broadcasting and meteorology.

the existence of commercial activities, they are not by any measure comparable to the pro-business legislations earmarked by the U.S. or Luxembourg. They are rather loosely defined and government-centred frameworks that do not fully ensure predictability, transparency, responsiveness, efficiency; in short what the private sectors demands [432] ,[433]. It suffices to highlight the cumbersome procedures for establishing satellite systems or for accessing and using space-based information and data from Indian satellites. From an overall perspective, these policies not only hinder potential foreign investment but also prevent "the acceleration of new technology applications by indigenous innovations and start-up enterprises to assist in the timely achievement of national economic development goals"[434].

Despite these serious obstacles – or exactly because of them – the emergence of a New Space dynamic in India appears rather remarkable and requires an assessment of its possible growth trajectory.

## 10.4 Appreciating the Inherent Potential of New Space in India

While the emergence of a New Space dynamic in India is still at its infancy and, if compared to the U.S. or Europe, much slower and more burdensome, there are many indications about its inherent growth potential and, possibly, about the eventual success of Indian astropreneurs in the national and international space markets. As detailed below, three macro-factors underpinning this projection can be identified. These factors are respectively related to India´s surging market demand for space products and services, its remarkable assets on the supply side, and the growing number of externalities to be leveraged by Indian New Space companies.

### 10.4.1 India's Surging Market Demand

One of the most relevant factors that could possibly boost and ensure the success of New Space in India is related to the conditions of the country's market demand. Given its size and scale, India already has a very large market for space-based products that highlight high potential for the development of a space-based services private economy in the country. Taking the space telecommunications and TV broadcasting's market as an example, in 2016, India recorded close to 80 million connected DTH subscribers, 160 million broadband subscribers and more than a billion mobile phone subscribers. The demand for pay-tv alone is estimated to be to reach US$18 billion in the next few years and "there are expectations that the number of TV channels (currently more than 800) will grow further in the near future to an impressive 1300[435],[436]. Clearly, there are huge opportunities for satellite-based communication services in India. Similarly, the market for Geographic Information System (GIS)-based services and for Positioning, Navigation and Timing (PNT)-based applications have a huge user and consumer base.[437]

What is perhaps more remarkable than this already huge demand is that the projections associated with Indian demographic and economic growth – both of which are expected to generate a large-scale middle-income population of working age – highlight an even higher potential for growth in demand for satellite capacity and for new downstream services. In this respect, it has been noted that "space-based services in India have reached a stage where demand is outpacing supply and is creating a unique opportunity for developing space industry"[436] . It is here sufficient to highlight that less than 30% of India's transponder capacity is being served by Indian satellites

[432] Government of India. (1997). "Policy Framework for Satellite Communications in India". New Delhi: Department of Space; Government of India. (2000). "Norms, guidelines and procedures for implementation of the policy frame-work for satellite communications in India". New Delhi: Government of India; Government of India. (2012). "National Data Sharing and Accessibility Policy". New Delhi: Government of India.

[433] PwC. (2016). "Capacity crunch continues Assessment of satellite transponders' capacity for the Indian broadcast and broadband market". Hong Kong: Casbaa.

[434] Kaul, R. (2017). "A Review of India's Geospatial Policy". In R. P. Rajagopalan, & N. Prasad, *Space India 2.0 Commerce, Policy, Security and Governance Perspectives* (pp. 141-150). New Delhi.

[435] G.V., A., & D'Souza, R. (2017). "SATCOM Policy: Bridging the Present and the Future". In R. P. Rajagopalan, & N. Prasad, *Space India 2.0 Commerce, Policy, Security and Governance Perspectives* (pp. 119-139). New Delhi: Observer Research Foundation.

[436] Murthi, S., Start-Up Europe (2017). "Start-Up Europe India Network. Retrieved from Start-Up Europe India Network". Web. https://start-upeuropeindia.net.
& Rao, M. (2016). "Privatising Space Missions: The Critical Route to Boost Indian Space Economy". *New Space*.

[437] According to the GNSS Market Report published by the GSA, India (and more broadly Asia) is the 'hot spot' for GNSS services. "In fact, it is currently the primary region of global market growth in terms of in-use GNSS devices. The region is forecasted to grow 11% per year, from 1.7 billion in 2014 to 4.2 billion devices in 2023 – more than the EU and North America combined". Web. https://www.gsa.europa.eu/galileo/international-co-operation#asia

while the rest is leased from foreign satellites via three-year deals made by Antrix Corporation, which subsequently sub-lets foreign transponders to Indian DTH operators through back-to-back agreements[433] . By the same token, "the market for satellite remote sensing data is also inadequately covered by domestic systems and industry, particularly in the high-resolution data segment"[436] , while the market for PNT applications remains yet to be fully exploited.[438] Clearly, there is not only an opportunity but also a necessity for more private sector engagement. This is because ISRO is unlikely to have the resources and means to manage the explosive growth in demand for space assets on its own. After all, up to 150 missions are estimated to be scheduled for the next five to ten years[439] ; a major increase as opposed to the 58 missions undertaken during the 12th Five-Year Plan (2012-2017). In a turn of events, 2015 also saw a mandate by the Prime Minister himself to identify and integrate space-based applications into all spheres of governance, with the Department of Space (DOS) organising perhaps the biggest user meet for space technology and applications in the country inviting over 1500 Central and State Ministers, officials from the Prime Minister's Office (PMO) and Cabinet Secretariat, Secretaries and Senior Officials of all the Ministries/Departments, Chief Secretaries and Senior Officials of all States/Union Territories to identify new applications for space-based services[440] . The user meet seems to have identified over 170 new projects where the relevant stakeholders within the government would like to use space technology or space-based services or better governance[441] . It remains unclear as to how this demand translates into the number of additional space assets needed to fulfil them and keeping with the already set roadmap between 2012 and 2017. Assuming the accuracy of these projections and taking into consideration the fact that ISRO's workforce has remained fairly constant at 16,000 with little change as of recently, leads to the assumption that – even with a more substantial budget increase – ISRO simply lacks the capacity to face these sizeable but needed increases in space activity. In short, there is an evident need to take the necessary steps to accommodate a more prominent involvement of the private sector.

When assessing demand conditions, it is also important to stress that India proves a fertile ecosystem for entrepreneurship in space not only because there is significant unsatisfied demand and a larger potential market propelled by its demographic and economic growth projections, but also because the specificities of the country and state of development in the adoption of space-based services make space solutions particularly apposite. More specifically, India's still-present developmental challenges (e.g. in terms of access to education services, healthcare and government services), the concentration of its population in rural areas and the sheer number of locations involved given the size of this country, all underscore a strong case for the development of private space-based solutions. The connectivity issue and the solution proposed by Indian start-up Astrome Technologies is a clear case in point. With its 375 million internet users, India already has the largest number of internet users in the world after China, though it still faces the challenge of connecting roughly 70% of the country's population, the majority of which resides in semi-urban and rural areas. Considering that standard approaches using underground optical cables are not the best options to tackle this gap,[442] and that ISRO is still coping with a large supply gap in its telecommunications satellites, there is immense scope for private space companies to step-up with their solutions. Towards this, Astrome Technologies plans to launch 150 small satellites into LEO by the early 2020s providing high-speed affordable internet to remote locations across the country[443],[444].

An analogous line of reasoning can be certainly made for meeting the requirements of other upstream systems or downstream services. For instance, there is a clear need to further

438 It can be for instance highlighted that vehicle navigation systems still have a very poor presence in India with less than 40 cities having been mapped.

439 Rao, M. K. (2015). "Indian Space - Towards a "National Eco-System" for Future Space Activities". 66th International Astronautical Congress, 12 – 16 October 2015.Jerusalem: International Astronautical Federation.

440 The Hindu Business Line (2015). "Modi to address meet on space technology on Monday". Web. https://www.thehindubusinessline.com/news/science/modi-to-address-meet-on-space-technology-on-monday/article7622125.ece

441 Mohan, V. (2015). "Isro to align with 170 government projects to benefit aam aadmi". Web. https://timesofindia.indiatimes.com/india/Isro-to-align-with-170-government-projects-to-benefit-aam-aadmi/articleshow/48877910.cms

442 It is estimated that the cost to cover a square Km for space solutions vary between $3 to $6 as compared to ground solutions which require at least $3000 to cover the same area .

443 Satak, N., Putty, M., & Bhat, P. (2017). "Exploring the Potential of Satellite Connectivity for Digital India". New Delhi. In N. Prasad, & R. P. Rajagopalan, *Space India 2.0 Commerce, Policy, Security, and Governance Perspectives.* New Delhi.

444 It is important to highlight that thanks to satellite Internet, many highly valuable services contemplated in the *Digital India* flagship programme can finally reach every corner of the country, while also opening up a myriad of space commerce opportunities for start-ups to develop new citizen-centred products and services.

develop GIS and PNT-based systems to support food security and water management efforts through the provision of precision farming solutions (guide planting and irrigation; yield monitoring; variable rate technology to fine-tune inputs, improve yields, water, and fertiliser efficiency) and through the creation so called "technology-enabled supply chains" [445] to reduce wastage and ensure quality throughout the agricultural supply chain Such applications are particularly relevant for India, because - as a recent report by PwC duly noted - "one of the biggest challenges in the Indian agriculture and food sector is post-harvest crop losses. Some 30% of fruits and vegetables (40 million tonnes per year) are lost to spoilage on the way through the distribution system. This adds up to losses of about $4 billion per year in the Indian food distribution system and contributes to food scarcity. Using Internet of Things (IoT) tagging and tracking technologies, Indian farmers and food distributors could monitor the progress of crops from farm to market and cut down on the amount of food spoiled in transit because of avoidable delays"[446] . Towards meeting these requirements, New Space companies like SatSure, for instance, have been developing analytics tools and predictive models that make use of Earth observation satellites, big data, cloud computing, machine learning and IoT technology to deliver insurance companies, pesticide and seed companies, etc. with clear decision solutions in the field of crop damage assessment, crop health monitoring, and precision farming[447]

There is also an imminent possibility of the creation of a Defence Space Agency in India with the Government of India currently finalising approval for such a specialised agency that shall leverage and integrate space as an active asset of the military by training and equipping units in the army, navy and the air force. Latest reports suggest that the proposed Defence Space Agency shall have over 200 personnel with its headquarters in Delhi but shall closely work with ISRO and Defence Research and Development Organisation (DRDO)[448] .

Overall, there appears to be important market requirements for the development of a private space industry in India. Arguably, such requirements can not only support the economic viability of several Indian New Space companies, but may also likely empower small businesses to achieve economies of scale that may eventually position their products/services offerings into the global space markets.

### 10.4.2 Relevant Supply Assets and Competences

In addition to the favourable conditions of India´s market demand, a second important factor that can potentially boost the future growth of New Space in India is given by the valuable assets and talent the country can boast on the supply side. As inter alia noted by the Observer Research Foundation (ORF), India has "inherent advantages such as the availability of skilled workforce, a stable and business-friendly government, positive investor climate, and low cost of labour and operations". In addition, India's demographic dividend[449] and standing as the premier economy in Central and Southern Asia along with superb innovation skills, R&D expertise, academic/scientific excellence including outstanding tertiary education, its strong engineering services backbone, particularly in terms of IT-enabled services and software developments and the global top rank in ICT service exports, speak volumes[450]. Moreover, the commitment of India to innovation is strong and growing, gradually lifting the country closer to other top-ranked innovation economies".[451]

Whereas innovation inputs (such as education and R&D expenses)[452] lag behind those of the advanced economies of the OECD world, it should be also highlighted that thanks to the availability of highly skilled employees at low prices (budget-conserving talent), as well as the need to serve a market with low purchasing power (budget-constrained customers),

445 Technology-enable supply chain refers to the use of information technology (in particular advanced GIS/PNT technologies) to track food across the distribution system in order to improve demand and supply matching across markets and locations and also reduce waste, while helping farmers capture more value from the sale of their output.

446 McKinsey Global Institute. (2014). "India's technology opportunity: Transforming work, empowering people". New Delhi: McKinsey.

447 SatSure. (2017). "Solutions". Web. http://www.satsure.in/#partner

448 Singh, S. (2017, October 16). Coming soon: Ministry of Defence's cyber, space, special operations divisions. Web. http://indianexpress.com/article/india/coming-soon-ministry-of-defence-mods-cyber-space-special-operations-divisions-4892404/

449 By 2020, India is set to become the youngest country in the world, with two thirds of its population in working age. With such a young population, it will be the one country with the strongest demographic dividend in the first half of the 21st century. According to some estimations, the number of Indian graduates of working age – i.e. the most economically productive segment of society – will reach 117 million by 2030 and a 208 million by 2050.

450 Dutta, S., & Lanvin, B. a.-V. (2016). "The Global Innovation Index Report 2016." *Web.* https://www.globalinnovationindex.org/gii-2016-report

451 It is for instance worth to highlight that in 2016 India's rank in the Global Innovation Index grew considerably, passing from the 81st position in 2015 to the 66th position.

452 OECD (2014). "India - Addressing Economic and Social Challenges through Innovation". Paris: OECD.

the country has emerged as a hub of so-called grassroots and frugal innovation. As the name frugal alludes, this kind of innovation essentially implies "achieving more with less", an idea that is largely inspired by the Indian tradition of *jugaad* or *jugaar*. This colloquial Hindi and Punjabi word, (which literally means a hack), is generally used to indicate a context-sensitive solution to a problem through resourcefulness. Whereas *jugaad* solutions are generally enabled by the need to serve markets with low purchasing power, frugal innovation is much more than making things cheaper. Authors Navi Radjou and Jaideep Prabhu have in their volume *Jugaad Innovation* and their follow-up study *Frugal Innovation* demonstrated how working under a resource-constrained context can actually help force more innovative solutions. If necessity is the mother of creation, the underlying argument is that India's lack of resources can actually lead to very innovative outcomes. According to the authors, this no-thrill approach can even result in disruptive innovation, as for instance shown by the Tata Nano and the famous General Eclectic´s ECG machine[453].

All in all, the specific approach of India to innovation dynamics clearly come into the fore when considering the growth potential of Indian New Space companies. Indeed, there is little doubt that India's astropreneurs can leverage this inherent talent pool, (prompted by the availability of highly skilled yet low cost employees and by the need to serve budget-constrained customers), to offer highly competitive industrial approaches or innovative market solution offerings that can be scaled up to international space markets.

### 10.4.3 Unfolding Externalities and Government Support

Closely related to this aspect, a third macro factor underpinning positive projections about India's New Space growth is offered the unfolding possibilities for India´s new space companies to leverage relevant externalities that can help this nascent ecosystem to move towards long-term growth. Four major types of externalities can be identified.

First, Indian astropreneurs have increasing opportunities to create synergies and cross-fertilisation with other industrial sectors such as Information Technology (IT), This is related to the fact that New Space is typically characterized by a shift of innovation toward downstream exploitation of space infrastructures and in particular data processing and analytics, an area where India is significantly thriving. SatSure, for instance, is cross-pollinating satellite Earth observation with big data, cloud computing, machine learning and IoT technology to deliver crop management related services. Towards this, it has created partnership with software solutions providers and companies operating in the field of precision farming[447].

By the same token, there are also clear possibilities to link and team-up with India´s broader start-up ecosystem, which is the second fastest growing start-up ecosystem in the world. According to the 2015 NASCOM Industry Report, India now has over 4,000 start-ups, well on its way to reaching its goal of 10,000 by 2020[454] . This makes India the third largest home for start-ups, behind only the United States and the United Kingdom, ahead of countries like Israel and China[455] . India is best known for its B2C start-ups and big unicorn companies (i.e. start-ups that are valued among $1 billion), mostly in the e-commerce and Ed-Tech sector, but the important point to highlight is the ecosystem itself. India now has a very impressive community of venture capitalists, business angels, mentors, incubators, accelerators, clusters, all of which can be ideally leveraged by Indian astropreneurs not only to access growing capital investment, but more importantly to improve the overall conditions of the space industry ecosystem and support the viability of their business model.

Second, India's NewSpace entrepreneurs can possibly leverage the already established capacity to deliver highly reliable technology products and services, including the infrastructure created over five decades of investments into the space sector by the Government. For instance, Earth2Orbit has been using remote sensing data from ISRO's IRS constellation to provide its customers with "actionable intelligence" applications. As also argued by Dhruva space co-founder Narayan Prasad, "with the backbone technology know-how foundation in place mainly by the efforts of ISRO and its vendor base, there is immense scope for New Space enterprises to leverage these cluster-based externalities such as technologies, infrastructure and manpower to build space-based services"[456].

[453] Radjou, N., & Prabhu, J. (2012). "Jugaad Innovation". New Delhi: Jossey-Bass.

[454] NASSCOM. (2016). "Start-Up Report - Momentous Rise of the Indian Start-Up Ecosystem". Web. http://www.nasscom.in/knowledge-center/publications/start-report-momentous-rise-indian-start-ecosystem

[455] Mehrotra, S. (2015). "Realising the Demographic Dividend Policies to Achieve Inclusive Growth in India". Harvard University Press.

[456] Prasad, N. (2017). "Traditional Space and New Space in Industry in India: Current Outlook and Perspectives for the Future". In

Third, there are growing prospects for Indian SMEs and New Space companies to attract attention for potential B2B solutions with international partners to realise end-to-end upstream and downstream systems offerings. For instance, in 2014 the Indian start-up Dhruva Space had signed a MoU with the German start-up Berlin Space Technologies (a company specialised in small satellite systems and technology) for the joint development and manufacturing of Earth observation micro-satellite in India[457] . Another possible involvement of foreign partners lies in investment opportunities through Foreign Direct Investments (FDI), Mergers & Acquisitions (M&A) or Joint Ventures (JV). Indeed, with the recently introduced relaxation of the FDI threshold in the aerospace sector from 49% to 100%, as well as the prospected surge in Indian demand for space products and services, there are stronger incentives for international firms to invest in (and create B2B alliances with) Indian New Space companies. In addition, the same market conditions (e.g. the availability of skilled workforce, low cost of labour and operations, engineering services backbone, a positive investor climate, etc.) that MNCs have already exploited successfully in technology sectors such as aerospace and IT continue to make India an attractive destination for foreign companies looking for replicating outsourcing innovation paradigm in the space sector through innovative industrial approaches and/or disruptive market solutions for space manufacturing/applications[456]. Some signs of this is already showing with U.S.-based companies such as ViatSat and Gogo both opening their offshore development centres in India working on supporting operations of the satellite service providers. ViaSat already has over 110 employees in Chennai while Gogo recently reported that it plans to hire over a 100 people in its development centre in Chennai too[458]. One cannot write off such possibilities by NewSpace ventures from outside of India to use India their offshore development centres as they scale or collaborate with Indian counterparts.

The possibilities for India to attract foreign investment and to leverage the already present infrastructure base put in place by ISRO relates to a fourth type of externality that will prove of utmost importance in nurturing the growth potential of New Space initiatives in India: the emerging encouragement and support from the public sector. The importance of governments' role in supporting space industry's competitiveness has been widely articulated in a number of studies. Even for a country like the U.S., which certainly has the most vibrant space industry in the world, the reality is that without the U.S. government as either an anchor tenant or a major customer, very little of the still small but growing private activity that we now see would exist. As inter alia pointed out by innovation economist Mariana Mazzucato, the current mythmaking about Silicon Valley's wildcatting entrepreneurs often forgets that many of the seeds were planted by public sector agencies through a series of institutional, financial and legislative tools[459]. An invaluable role has been in particular played by such public institutions like NASA or DARPA, which for instance have been key in backing the competitiveness of companies like SpaceX. Even today, it can be expected that "the future of the New Space dynamic, although commercially driven, will be highly dependent on the success of implementation of new public strategies"[460].

In light of the burgeoning national demand for space services and of ISRO´s purported inability to manage this demand, policy makers in India are becoming aware of the need to support private industry in India to complement efforts of ISRO in the provision of new and innovative services and are coming to realise that "there is immense scope for the bringing a change in the commercial space landscape and achieve economies of scale in space-based services if New Space is enabled. Parallels can be drawn to the rise of IT industry which enabled the creation of an environment that today is one of the pillars of export activity in the country"[456].

As a demonstration of this increased awareness about the role of private space industry in India, it is important to highlight the structural reforms IRSO is introducing in the organisation/execution of its space activities and the impact these will have on the growth trajectory of India's space industry, both in the local and international markets.

With the increase in demand for space-based services in the country, ISRO has been moving

N. Prasad, & R. P. Rajagopalan, *Space India 2.0 Commerce, Policy, Security, and Governance Perspectives.* New Delhi.

457 Murali, M. (2015). "Dhruva Space, German start-up Berlin Space Technologies ink MoU on satellites". Web. http://economictimes.indiatimes.com/small-biz/start-ups/dhruva-space-german-start-up-berlin-space-technologies-ink-mou-on-satellites/articleshow/46015590.cms

458 Simhan, T. (2018). "Inflight connectivity provider Gogo to open tech centre in Chennai". Web. https://www.thehindubusinessline.com/info-tech/inflight-connectivity-provider-gogo-to-open-tech-centre-in-chennai/article10049932.ece

459 Mazzucato, Mariana. (2015). "The Innovative State". *Foreign Affairs*.

460 Vernile, A. (2017). "The Rise of the Private Actor in the Space Sector". Vienna: European Space Policy Institute.

towards a new industrial participation strategy aiming to redefine the private sector role from mere supplier of Tier-2, 3, and 4 level work to that of integrator and owner of launch vehicles and satellites[461]. Towards this, the creation of industry consortiums for the production of both the PSLV and satellite systems are currently under implementation. This approach is expected not only to allow ISRO to focus completely on novel technology development over a longer horizon period, but also to "bring along a unique opportunity in the Indian industry ecosystem to build up systemic capacity to be able to deliver end-to-end space systems for the first time in the country"[456].

It can be anticipated that once these institutional reforms in the organisation of space activities in India will enter in full swing, their impact will not be limited to ISRO´s relations with the two industry consortia, but more broadly have a double positive spill-over effect on India space commercial ecosystem. More specifically, on the one hand it is likely that these reforms will indirectly contribute to the enhancement of the overall level India´s space industrial base, and on the other hand to the enhancement of India´s role in the global commercial markets. Taking launch services as an example, the success of Indian rockets on the commercial market has been so far limited by the fact that ISRO has been able to offer excess capacity only to foreign customers. With industry taking over the launcher manufacturing, it can be anticipated the ensuing increase in production rates will not only allow to meet domestic demand but also to offer competitive launch solutions in the global space market, with the future competitiveness of Indian also backed by India's burgeoning internal demand, which will allow to generate economies of scale and keep competitive prices.

In addition to the above-mentioned institutional reforms, when considering the role of public institutions in boosting the growth of a new space dynamic, it is also important to stress that the government of India has already launched several key initiatives such as, for instance, *Make in India* and *Digital India* (a long-term flagship initiative focusing on empowerment of Indian citizen through ICT services), which provide Indian "traditional" and the "New Space" industry with important opportunities of engagement. Prime Minister Narendra Modi's government has also launched a *Start-up India Initiative* in January 2016 which seeks to foster, entrepreneurship and promote innovation, including in the space sector, with the ultimate goal of turning India into a homeland of job creators, instead of job seekers.

Given the importance of a dynamic and strong private space industry for India, it can be expected that in the coming years dedicated initiatives to support the rise and long-term competitiveness of Indian private industry more strongly will be launched. These initiatives may include the creation of a space start-up incubator similar to the ones successfully put in place by ESA or the setting-up of a national fund for the promotion of space entrepreneurship[462].

In parallel to this, there are indications about the forthcoming adoption of a new space legislation to define a comprehensive regulatory, legal and procedural regime for conducting private space activities in the country. This would be a particularly encouraging move for both Indian and foreign space companies, which have thus far been affected by unsupportive – if not obstructive – regulations with respect to licensing, technology certification, insurance, liability, and dispute resolutions amongst others. A sound legal framework for astropreneurs, especially if catalysed by a sound and long-term national strategy for the promotion of Indian space industry, will indeed prove the most important tool to support a steady and sustainable growth of Indian space companies.

In November 2017, a draft bill aiming to regulate public and private space activities in India was posted by ISRO on its website. The Bill, which was open to comments by all stakeholders and the public, is now pending before the Parliament. While the Bill will certainly require further adjustments and is yet to be put in place, should the government start to back the private sector through a series of institutional, financial and legal tools along the line of the U.S. government, New Space India will have all the ingredients to become a very active industry, exercising a great impact on Indian and the global space economies alike.

461 Murthi, S., & Rao, M. (2015). "Future Indian (New) Space – Contours Of A National Space Policy That Positions A New Public-Private Regime". *3rd Manfred Lachs International Conference on NewSpace Commercialisation and the Law.* Montreal: NIAS.

462 Prasad, N. (2017). "Developing a Space Start-up Incubator to Build a New Space Ecosystem in India". In N. Prasad, & R. P. Rajagopalan, *Space India 2.0 Commerce, Policy, Security, and Governance Perspectives.* New Delhi.

## 10.5 Discussing Implications and Cooperation Prospects with Europe

Despite many shortcomings are still to be overcome, the three macro-economic factors outlined in the previous section (favourable conditions on the demand side, valuable assets on the supply side, and growing externalities to be leveraged) not only make India a fertile environment for space entrepreneurship, but also point to a progressive growth and consolidation of the New Space dynamic.

Several success stories are progressively emerging and the overall ecosystem is likewise consolidating, helping to turn the solutions proposed by Indian astropreneurs into a viable business case. Were the current growth trajectory to solidify, also as a result of an increased level of sponsorship by Indian public institutions, it can be argued that India´s New Space companies promise not only to disrupt the way space activities are conducted in the country, but also to an exercise an increased influence in the global space economy, at least from a medium- to long-term standpoint.

Whereas the exact positing of India´s New Space companies in the future space economy are certainly hard to disentangle and no conclusive projections on what their growth will mean for the global space industry can be drawn at this point, it is essential for European institutions and industries (both small and large) to monitor these developments closely. Broadly speaking, it can be expected that the rise of New Space in India inherently entails a Janus-faced implication for the international space industry, and more specifically that of Europe.

On the one hand, the emergence and growth of new private actors in the international space markets promise to turn itself into a rising threat for the historical European industry position as major competitor for both upstream space systems and downstream applications on the global space scene. Backed by the ability to provide innovative and super low-cost solutions and by a huge domestic demand that enables the creation of economies of scale, Indian New Space companies will certainly have inherent competitive advantage when positioning their solutions internationally. Their emergence will hence create new challenges for well-established industry players, who will be likely forced to adapt their strategy to take into account this new competition, in addition to the one already posed by the U.S. companies.

However, alongside *long-term* competition scenarios, the emergence of the New Space dynamic in India is creating valuable cooperation opportunities for European industrial players; opportunities that are already open in the *short term*. The rationales and drivers behind such cooperation opportunities are to a large extent the same ones pinpointing to their long-term growth, and hence primarily associated with India´s favourable market demand and supply conditions.

First of all, India´s market has a largely untapped potential when it comes to space products and services. Whereas this market has typically been rather restrictive for private actors' involvement, the Indian government has adopted business-friendly policies under its recent flagship initiatives that can ease the doing-of-business for foreign space industries, such as raising the cap on FDI in the space sector from 49% to 100%, as part of a broader initiative (*Make in India*) that seeks to position India as a global manufacturing hub. With India now encouraging more FDI in the space sector, there is a clear case for European firms to either outsource production (e.g. low-cost components) or "gain a market entry into India by positioning their offerings independently or by integrating their market strategies via partnerships with Indian SMEs and start-ups to produce satellite components and subsystems or even realise end-to-end upstream and downstream systems offerings"[456].

Given that the Indian demand for space-related products and services is expected to increase dramatically over the coming years in several domains, there will be more opportunities for European stakeholders to access this market, especially if cooperation is pursued with domestic industries through the creation of B2B alliances such as JVs, M&As or Special Purpose Entities (SPEs).

In addition to the size of the market, India's market conditions, including low labour costs, talent pool, and an engineering services backbone, particularly in terms of information technology enabled services and software developments, provide European companies with non-negligible incentives to invest in India. Thanks to its large educated English-speaking population and wealth of skilled low-cost labour, a cooperation with Indian space industries could be ideal in pursuing a cost leadership competitive advantage, where European manufacturers trade market access for low-cost labour[463]. Furthermore, European satellite integrators like Thales Alenia Space and Airbus Defence & Space still have an advantage compared to U.S. integrators in potentially benefitting from India's low-cost labour, or in utilising low-cost Indian satellite components and subsystems, because of the partial limitations still imposed by the export-control regulations on the U.S. space competitors.

India's creativity and capacity to innovate are likewise important drivers that European private sector could size[453],[464]. As highlighted before, India has not only proven to be a hot-bed of so-called *jugaad* engineering and grassroots innovation; it has also shown an innate ability to innovate in a plethora of ways that are invisible to the Western consumers – from revolutionary B2B solutions to novel programme management models and reverse engineering.[465] The budget conserving talent and budget-constrained customers that catalysed Indian reverse and frugal engineering skills create a strong "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"[456].

European firms could capitalise on these local market conditions "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 […] Based on the long-term strategy, global firms can typically benefit of exploiting India as a foundation for devising growth strategy under competitive pressures by developing expansion plans, increasing time to market, improving service levels, business process redesign, adopting an industry practice, testing differentiation strategy, access to new markets, enhancing system redundancy"[456] .

To sum up, there are several drivers and opportunities for European industries to engage India's. What is important to note, however, is that closer B2B ties would not only profit Europe's space industries, but rather nurture win-win solutions with India's, since operations by European companies could likely spur the growth of an investment ecosystem in India and, in turn, also contribute to addressing India's increasing demand of space products and services.

Indeed, one of the crucial necessities for the for most of the start-ups and SMEs in the country is to access substantial capital that can enable them to scale their business by moving from the proof-of-the-concept phase to the actual provision of products and services. Considering that India has a rather undeveloped private investment landscape in the space sector, Indian SMEs and New Space companies would greatly benefit from possible FDI, M&As or JVs with international partners.

In addition, it is also clear that the resources Indian partners would tap into through cooperation would not just be financial, but also technical and technological. By contributing to the marketability of European technologies, cooperation with India could also embed the use of related standards, which is essential for Europe's industry, given that it would strengthen the positioning of the European space sector in the global market for space technologies and services. For Indian partners, achieving collaborative partnerships with 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 a practice can "spread the capacity within the industry to replicate the success achieved in the auto-industry within the country"[456]. At the same time, it is undeniable that, by enabling an expansion of Indian industry's capacity to realise and deliver end-to-end upstream and downstream systems India might over time gain a considerable benefit from the know-how provided by European partners, thus allowing its industry to enhance its own market position at Europe's expense[463].

When considering potential B2B cooperation opportunities, it is also important to highlight that such opportunities can be sized not only by well-established space industry players like Airbus DS and TAS, but also by the emerging New Space players in Europe. There are already some partnership cases between Indian and European astropreneurs. In the downstream segment, for instance, Indian start-up Earth2Orbit start-up has been cooperating with Climate City, a Toulouse-based start-up in the provision of actionable intelligence data on cities' air quality based on Earth observation big data, while in the upstream, Dhruva Space and Berlin Space Technologies have

[463] Al-Ekabi, C. (2016). "The Future of European Commercial Spacecraft Manufacturing". Vienna: European Space Policy Institute.

[464] Zinnov (2015). "The Indian Promise". Web. http://zinnov.com/the-indian-promise/

[465] The classic example of reverse engineering is offered by General Electric's ultra-low-cost ECG machines, which was developed in India, initially for use in this country, but with inputs from local and foreign subsidiaries.

been cooperating on the joint development of EO micro-satellites in India, as mentioned before. Whilst these specific cases have hitherto been somewhat negligible, the important point to consider is that concrete cooperation opportunities are opening up in a number of fields, particularly in the downstream segment (e.g. integrated applications for mobility, smart cities, agriculture, etc.). Irrespective of the variety of specific projects that could be implemented, what is also important to underline is that the creation of B2B solutions between European and Indian space start-ups – especially if a stronger backing by such frameworks as the "Start-up Europe India Network" is provided[466] – could enable both ecosystems to reach a higher degree of maturity in a shorter amount of time, and build a strong, mutually beneficial alliance that can help both partners compete in the U.S.-dominated New Space marketplace.

There are currently no specific frameworks or studies related to the analysis and the political, economic, social and technological extent to which European players engage with India at G2G, B2B and B2C levels. The most prominent European player engaged in several levels of cooperation with India remains France. Industries from France have especially developed a close relationship with India in space with French companies such as Arianespace have serviced ISRO for over 50 years now and the likes of Airbus have built satellites in cooperation with Antrix. In order to support a more holistic foundation for cooperation between several other European actors, it is important understand the current landscape of fertile areas of cooperation which leads to a win-win on both the sides. It is also important to recognise that the dialogue so far between European players and India has been mostly at the G2G level and there is substantial work needed in creating a transparent perspective for industry players to view each other's ecosystem to enable the trickling down of the engagement deeper into B2B and B2C levels. Crafting a framework that can review ties on a year-on-year basis can help stakeholders on both the sides to gain systematic reference to taking joint measures that can lead to better trade and economic gains.

## 10.6 Conclusions

New Space is an unfolding and complex phenomenon encompassing various trends, including technological, political, and commercial trends that are together contributing to an increasingly more prominent role for private actors' involvement in space. Whereas still primarily concentrated in the U.S. and in Europe, India has also been in recent years witnessing the emergence of a New Space dynamic, with several Indian entrepreneurs kick-starting space ventures to provide innovative end-to-end B2B and B2C solutions in both the upstream and downstream segments.

The mapping and analysis provided in this paper has shown that whilst the overall enterprise readiness level of these New Space companies remains low, cumbered by a number of shortcomings (including the shortage of a private investment, the lack of a comprehensive and pro-business regulatory system), there is also a wealth of factors that underpin an inherent growth potential for such a New Space dynamic. From an aggregate macro-economic perspective, these factors are respectively related to India´s surging market demand for space products and services, its remarkable assets on the supply side, and the growing number of positive externalities to be leveraged by Indian New Space companies. Taken together, these factors substantiate the fact that the country can emerge as a fertile ecosystem for New Space entrepreneurship.

It is important to understand that enabling NewSpace in India shall have an effect not only on young start-ups with but will also give an opportunity to existing 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.

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 home-grown industries as a recognition of producing world-class products and services. Therefore, NewSpace offers the potential of diversification of customer base for Indian industry in the space sector at the global level. There is immense scope for 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.

While these transformations are still to be put in place in India, the paper argues that if the Indian government eventually choses to back the private sector in a similar fashion to what

[466] Start-Up Europe (2017). "Start-Up Europe India Network". Web. https://start-upeuropeindia.net.

the U.S. government has been doing vis-à-vis its private industry, Indian New Space companies have the potential to exercise a great impact on domestic and the global space economies alike.

Finally, in discussing their possible footprint in the future space economy, the paper put the spotlight on the fact that there are not only long-term challenges to be faced by the European space industries, but also clear opportunities to nurture mutually beneficial B2B solutions between Indian and European space companies. It will hence be important for them to keep a close eye on New Space developments in India.

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Prof. P M Soundar Rajan commenced his professional career in 1973 with Electronics and Radar Development Establishment (LRDE), Bangalore, DRDO. During his tenure at LRDE he designed and developed digital communication systems. From 1978-1996, he served in the Aeronautical Development Establishment. He joined Defence Avionics Research Establishment (DARE, erstwhile ASIEO) in 1996 and assumed charge as the Director of DARE, Bangalore in 2011. During his tenure he guided and progressed the development of advanced Digital Electronic Warfare systems for the IAF aircraft. He retired from DRDO after 40 years of eventful and fruitful service in 2014. He is the recipient of AGNI Award for excellence in Self Reliance for the year 2003 and DRDO Performance Excellence Award for the year 2008.

## Vidya Sagar Reddy

Vidya Sagar Reddy is a Research Analyst at Jane’s by IHS Markit. Previously, he was an Associate Fellow in the Nuclear and Space Policy Initiative at Observer Research Foundation (ORF). His papers and articles appeared in Astropolitics and NewSpace journals as well as in The Space Review, E-International Relations, Georgetown Journal of International Affairs etc. He holds Master's degrees in Space Systems Engineering from the University of Michigan, Ann Arbor and in Geopolitics and International Relations from Manipal University.

## Kriti Trehan

Kriti Trehan leads the technology laws & policy advisory practice at the Law Offices of Panag & Babu, and is based in the firm’s New Delhi office. She works across a wide range of issues in the information and communications technology sector where regulatory frameworks are still evolving. She advises leading technology innovators across the globe on seamless rollout of products and services with innovations untested by Indian law.

Kriti focuses on regulation around privacy, data protection, net neutrality, localisation, and encryption, cloud computing, internet intermediaries, devices, IoT, network infrastructure, new technologies, satellite communications and fintech. She also interfaces with policy professionals to clarify evolving tech law frameworks, and assists multinational companies in assessing risks associated with a changing, multi-tiered regulatory landscape.

Previously, Kriti has researched for a women’s rights organisation, participated in the international discourse on climate change and worked with the UN International Criminal Tribunal for Yugoslavia. She tweets at @krititrehan.

# About ESPI

The European Space Policy Institute (ESPI) is an association ruled by Austrian Law, based in Vienna, funded at its inception (2003) by the Austrian Space Agency and ESA, and now supported by 17 members that include European national space agencies, the European Commission, and main European space services companies and manufacturers.

The Institute provides decision-makers with an informed view on mid-to-long-term issues relevant to Europe's space activities. In this context, ESPI acts as an independent platform for developing positions and strategies.

ESPI fulfils its objectives through various multidisciplinary research activities leading to the publication of books, reports, papers, articles, executive briefs, proceedings and position papers, and to the organisation of conferences and events including the annual ESPI Autumn Conference. Located in the heart of Vienna, the Institute has developed a privileged relationship with the United Nations Office for Outer Space Affairs and with a network of researchers and experts in Europe and across the globe.

More information on ESPI is available on our website: www.espi.or.at

# About the Observer Research Foundation (ORF)

Set up in 1990, ORF seeks to lead and aid policy thinking towards building a strong and prosperous India in a fair and equitable world. It helps discover and inform India's choices, and carries Indian voices and ideas to forums shaping global debates. ORF provides non-partisan, independent analyses and inputs on matters of security, strategy, economy, development, energy, resources and global governance to diverse decision-makers (governments, business communities, academia, and civil society). ORF's mandate is to conduct in-depth research, provide inclusive platforms and invest in tomorrow's thought leaders today

More information on ORF can be found on our website: https://www.orfonline.org

# List of Acronyms

| **Acronym** | Explanation |
|---|---|
| AEC | Atomic Energy Commission |
| AIR | All India Radio |
| AIT | Assembly, Integration & Testing |
| ASI | Italian Space Agency |
| B2B | Business-to-Business |
| B2C | Business-to-Customer |
| BEL | Bharat Electronics Ltd |
| BIMSTEC | Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation |
| CAISS | Indian Satellite Systems |
| CNES | Centre National d'Études Spatiales |
| COSPAR | Committee for Space Research |
| CUG | Closed User Group |
| DAE | Department of Atomic Energy |
| DLR | German Aerospace Centre |
| DOS | Department of Space |
| DoT | Department of Telecommunications |
| DPIIT | Department for Promotion of Industry and Internal Trade |
| DRDO | Defence Research and Development Organisation |
| DSAB | Draft Space Activities Bill |
| DTH | Direct to Home |
| EADS | European aeronautics Defence and Space |
| ECMWF | European Centre for Medium Range Weather Forecasts |
| ELDO | European Launcher Development Organisation |
| ERSO | European Space Research Organisation |
| ESA | European Space Agency |

| **Acronym** | Explanation |
|---|---|
| ESPI | European Space Policy Institute |
| ESRO | European Space Research Organization |
| EU | European Union |
| EUMESTAT | European Organisation for the Exploitation of Meteorological Satellites |
| FDI | Foreign Direct Investment |
| G2G | Government-to-Government |
| GAGAN | GPS-aided GEO augmented navigation |
| GAR | General Assembly Resolution |
| GBPS | Gigabit per second |
| GDP | Gross Domestic Product |
| GIS | Geographic Information System |
| GMPCS | Global Mobile Personal Communication by Satellite |
| GPS | Global Positioning System |
| GSAT | Geostationary communication satellite |
| GSLV | Geosynchronous Launch Vehicle |
| GST | General Sales Tax |
| IAMAI | Internet and Mobile Association of India |
| ICC | INSAT Coordination Committee |
| ICT | Information and Communication Technology |
| IIST | Indian Institute for Space Science and Technology |
| IMRB | Kantar IMRB |
| INCOSPAR | Indian National Committee for Space Research |
| INMARSAT | International Mobile Satellite Organisation |
| INSAT | Indian National Satellite System |
| IRNSS | Indian Regional Navigation Satellite System |
| IRS | Indian Remote Sensing Satellite Program |
| ISRO | Indian Space Research Organisation |
| IT | Information Technology |
| ITU | International Telecommunications Union |

| **Acronym** | Explanation |
|---|---|
| IXPE | X-ray Polarimetry Explorer |
| M&A | Merger and Acquisition |
| M2M | Machine to machine |
| MNC | Multinational Corporations |
| MoU | Memorandum of Understanding |
| NASA | National Aeronautics and Space Administration |
| NDCP-18 | National Digital Communications Policy 2018 |
| NFAP-18 | National Frequency Allocation Plan 2018 |
| NITI Aayog | National Institution for Transforming India |
| NOFN | National Optical Fibre Network |
| NRSC | National Remote Sensing Centre |
| NSR | Northern Sky Research |
| NTP 1999 | New Telecom Policy 1999 |
| PNT | Positioning, Navigation and Timing |
| PRL | Physical Research Laboratory |
| PSLV | Polar Satellite Launch Vehicle |
| PSTN | Public switched telephone network |
| QOS | Quality of service |
| R&D | Research and Development |
| ROSA | Radio Occultation Sounder for Atmosphere |
| RSDP | Remote Sensing Data Policy |
| SARAL | Satellite with Argos and Altika |
| SATCOM | Satellite Communication |
| SMEs | Small and Medium Enterprises |
| SSLV | Small Satellite Launch Vehicles |
| TAS | Thales Alenia Space |
| TASL | Tata Advanced Systems Ltd |
| TCL | Tata Communications Limited |
| TERLS | Thumba Equatorial Rocket Launching Station |

| **Acronym** | Explanation |
|---|---|
| TIFR | Tata Institute of Fundamental Research |
| TRAI | Telecom Regulatory Authority of India |
| UAE | United Arab Emirates |
| UK | United Kingdom |
| URSC | U.R. Rao Satellite Centre |
| U.S. | United States of America |
| USD/US$ | U.S. dollars |
| USOF | Universal Service Obligation Fund |
| VSAT | Very small aperture terminals |
| WPC | Wireless Planning and Coordination |
| AEC | Atomic Energy Commission |
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| SARAL | Satellite with Argos and Altika |
| SATCOM | Satellite Communication |

| **Acronym** | Explanation |
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| SMEs | Small and Medium Enterprises |

## Mission Statement of ESPI

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