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Potential Role of Academia-Industry Interface for Space Economy: Emerging Policy Options Before India

Chaitanya Giri*

Abstract: Before 2020, India's space activities were largely government-financed, and its research and development, testing, and evaluation (RDTE) were confined to the Department of Space (DoS) institutions. DoS institutions, including the Indian Space Research Organization (ISRO), have separate liaisons with academia and industry, leaving narrow scope for a tripartite DoS-academia-industry partnership. By 2040, the global space economy is estimated to grow massively from nearly US$ 450 billion, at present, to around US$ 3 trillion. Therefore, cultivating a robust tripartite partnership is crucial for India to raise its strategic stakes in the global space economy. The Indian National Space Promotion and Authorisation Centre (IN-SPACe) is an industry-facilitating agency recently created under DoS. This paper discusses rational for stronger academic-industry partnership for Indian space economy and emerging options before it. A TRL-based task allocation between ISRO and IN-SPACe is necessary for achieving the entire life-cycle of space technology RDTE, from ideation to commercialization, which would contribute to the 'sunrise' of India's space economy.

Keywords: Academia-Industry Interface, IN-SPACe, ISRO, Space Economy, Technology Readiness Level

Introduction

The Indian Space Research Organization (ISRO) has been a workhorse space agency, one of its kind globally. Over the years, it assumed multitasking roles of an R&D institution, an industry-ecosystem progenitor, commercial space services provider, an assembler of industrial

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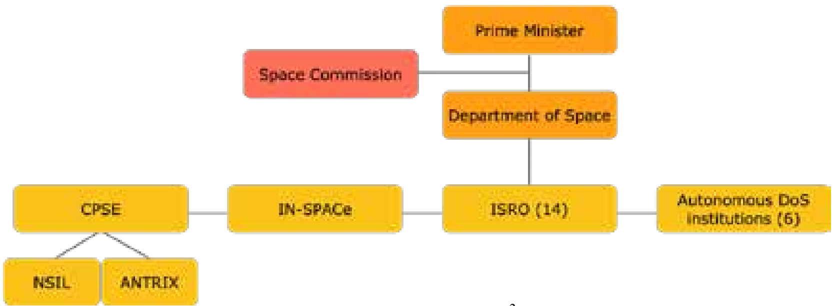
subsystems into large and complex space systems, and a source for multi-disciplinary scientific space research (Goswami & Garretson, 2022).[1] Despite this, reducing its multitasking abilities and delegating its responsibilities were crucial to enhance its performance as a 21st-century civilian space agency, helping the sunrise of the 'space economy' in India.

The Government of India's space sector reforms of 2020 was to delegate tasks burdensome to ISRO among newly-established cooperative 'sister' agencies. Unburdening was crucial because, given the limited resource bandwidth with ISRO, it is in the national interest to let it focus on risky and avant-garde RDTE that the commercial sector usually refrains from pursuing. It was equally crucial for ISRO to pass non-RDTE tasks to other newly-formed entities within its parent government body, the Department of Space's (DoS) organogram (Figure 1). As an outcome of the space sector reforms, the DoS now has a new sister agency for ISRO, the Indian National Space Promotion and Authorization Centre (IN-SPACe).[2] In its initial months, IN-SPACe has successfully assumed the role of a private-sector authorizing agency. Nevertheless, its role as a promoter of commercial RDTE, especially in India's ecosystem where non-governmental private entities (NGPEs) were for long only manufacturing vendors, is yet to grow well. In this regard, this discussion paper also discusses rational for stronger academic-industry interface for Indian space economy.

Figure 1: Department of Space Organogram and Relation between ISRO and IN-SPACe as Sister Concerns



Source: Adapted from Indian Space Research Organization[3]

India has witnessed a steady growth in space-sector NGPEs over the last eight years (MoF, 2022a).[4] This ecosystem enrichment has happened concomitant to the committed governmental efforts to bring business-friendly national regulations, policies, norms, and guidelines for satellite communications,[5] remote sensing data,[6] geospatial data (GoI, 2022),[7] civil aviation (MoCA, 2016),[8] and drones (GoI, 2021).[9] The Union Budget of 2022 highlights artificial intelligence, geospatial drones and systems, semi-conductor and its ecosystems, pharmaceuticals and genomics, green energy, clean mobility systems, and Space Economy, as 'sunrise opportunities' and the central government pledges to support R&D in these 'sunrise sectors' (MoF, 2022b).[10] As part of these governmental efforts, new business-friendly regulations are being designed to prepare Indian space-sector NGPEs for emerging opportunities in the space economy.

Assured of business-friendliness, Indian space-sector NGPEs now, for the first time, have access to high-end technology RDTE infrastructure, which ISRO painstakingly built over the years. Such access will help NGPEs develop novel space-tech products without spending exorbitant sums of their investors to raise an already available RDTE infrastructure. Prior to 2020, there was no governmental modality allowing Indian space-sector NGPEs access to ISRO's RDTE infrastructure. The Indian government has given IN-SPACe the role of a facilitator.

Besides being the private sector's access provider to ISRO's RDTE infrastructure, IN-SPACe will also help space-sector NGPEs set up temporary infrastructure within ISRO's premises and offer necessary clearances, statutory guidelines, and safety norms for NGPEs to set up their infrastructure outside ISRO's remit. IN-SPACe is also creating an integrated launch manifest, where it would develop a mechanism to gauge the readiness of launch vehicles, spacecraft, ground segments, and end-users. This manifest will help IN-SPACe develop mechanisms for on-demand spacecraft launches. It will also register satellites built, operated, and controlled by Indian NGPEs and promote the usage of spacecraft data for downstream space-based services. However, this paper emphasis that keeping IN-SPACe merely as a facilitator and authorizer will not prove helpful if India aims to catapult its space economy on a growth trajectory. IN-SPACe must promote space RDTE in industry and create an academia-industry interface relevant to the 'sunrise' of the space economy in India. This article discusses the rationale for defining IN-SPACe's academia-industry linking role, justifying the 'space promotion' in its name.

Growing Significance of Academia-Industry Interface

Strong linkages between the academic and industrial domains are hallmarks of RDTE ecosystems of advanced economies (Young, 2013).[11] A robust academia-industry interface is vital for completing the development life cycle of any technology carried with imminent or distant economic goals in sight. At times, such interfaces also assume the role of a trouble-shooting mechanism whenever any technology's RDTE path gets jammed.

In the United States, the RDTE collaborations between academia and industries are guided by several legal provisions, including the National Cooperative Research and Production Act (FTC, 1993).[12] This Act provides legal protections for any joint RDTE or production ventures notified with the Attorney General and the Federal Trade Commission. The law prevents potential antitrust liabilities, ensuring a vibrant and competitive R&D ecosystem. In the case of China, the top-down diktat created by the Military-Civil Fusion programme has created synergies between the Central Military Commission, the state-controlled laboratories, universities, startups, and industries governed by the State Council (Stone & Wood, 2020).[13]

The Indian government, too, realizes the growing significance of the academia-industry interface and is taking constructive steps. The National Institutional Ranking Framework of the Ministry of Education (MHRD, 2015),[14] Intellectual Property Annual Reports published by the Office of Controller General of Patents (Borkar & Paturkar, 2012),[15] Atal Ranking of Institutions on Innovation Achievements also by the Ministry of Education (MoE, 2021),[16] call attention to spawning commercially-motivated innovation in academic institutions. The Indian government's

New Education Policy 2020 has also commanded universities to set up startup incubation centers, centers in frontier research areas, and technology development centers, and likewise promote academia-industry linkages (MHRD, 2020).[17]

The academia-industry interface appears vibrant, especially in the Indian Institutes of Technology (IIT), National Institutes of Technology (NIT), Indian Institutes for Science Education and Research (IISER), central and private universities, and national laboratories. These interfaces operate in the form of S&T consultancy, contractual R&D, mentoring startups and incubating them, and transfer of intellectual property to interested NGPEs (DSIR, 2019).[18] The state universities are far behind the others in building such interfaces. A strategic domain like space, which is crucial from India's comprehensive security – including economic security - standpoint, needs a dedicated academia-industry interface that works meticulously on the evolving needs of the space economy. Unfortunately, there are substantial deficiencies within India's space academia-industry interface. These deficiencies are becoming apparent as space activities globally become more economy- and security-oriented than ever before. The growing international footprints in earth's orbits and deep space are already triggering tremendous 'astroeconomic' competition (Giri, 2021a). For India to have an edge in this competition, it becomes imperative to make the role of the academia-industry interface in the space domain second to none in criticality.

ISRO's Detached Interfaces with Industry and Academia

Over the years, ISRO has maintained two separate interfaces with Indian industries and academic institutions. ISRO's interface with the Indian industry began by seeking vendor-assistance from Indian NGPEs. The NGPEs have been manufacturing satellites and their components, launch vehicles and their components, payloads, electronic and mechanical systems and subsystems, satellite applications, testing and evaluation infrastructure, specialty chemicals and fuels, alloys, metals and materials, and other ancillary outputs (Murthi & Rao, 2015). These manufacturing contracts were limited to products developed according to ISRO's specifications and design (Giri, 2021b). Space-sector NGPEs did not undertake novel space RDTE, nor have they participated in space operations, as in any typical Government Owned Contractor Operated (GOCO) model. They were vendors dependent on ISRO hires and manufacturing according to ISRO's stringent specifications.

The space reforms of 2020 have set free the vendor-buyer-only relation between ISRO and the Indian space-sector NGPEs. Nevertheless, since this is a recent episode, ISRO and space-sector NGPEs are yet to remould their business according to the goals of the space reforms. The Indian government created two precise supply-side and demand-side liaising mechanisms as an outcome of the space sector reforms. The DoS' newly established public-sector enterprise, the New Space India Limited (NSIL), is now responsible for supply-side interactions with the space-sector NGPEs.[19] NSIL will primarily deal with technology transfers from ISRO to domestic space companies. It will be the commercial arm of ISRO that provides the latter transponder capacities, remote sensing services, space launch services, and commercial manufacturing of ISRO-developed launch vehicles to domestic end users. IN-SPACe will operate on the demand side.

NSIL and IN-SPACe, both outcomes of space reforms, have come against the backdrop of the initial successes of the GOCO model experienced in the defence sector (Krishnan, 2009).[20] A similar GOCO and commercially-owned-commercially-operated (COCO) model can be executed in India's space domain if IN-SPACe promotes RDTE interests of Indian space-sector NGPEs and does not remain a gatekeeper of ISRO.

IN-SPACe can facilitate commercially-motivated and novel RDTE in Indian space-sector NGPEs. Their commercial focus will help ISRO focus on its core mandate of high-risk-high-reward space exploration, human spaceflight, high-end astronomy projects, and avant-garde space technology development. IN-SPACe should assist Indian space-sector NGPEs in carrying out RDTE of commercially viable space technology prototypes, and manufacturing and assembly of space-proven technologies.

On the academic front ISRO, for the past five decades, has been running the RESPOND (an anagram for Sponsored Research) programme specifically for liaison with universities and public and not-for-profit laboratories outside the DoS organogram.[21] ISRO catalogues research problems gathered from an internal survey within ISRO and DoS institutions through the RESPOND programme. The research co-principal investigator (Co-PI), working out of an ISRO or DoS laboratory, identifies the research problem and seeks collaboration from the scientific faculty residing in non-DoS and non-ISRO institutions. The non-DoS and non-ISRO faculty on peer-reviewed selection become the principal investigator (PI) of the research problem. The institution where the selected non-DoS and non-ISRO faculty belongs receives the RESPOND research grant for the same project. So far, this programme is working very well for ISRO.

Along with RESPOND (refer to Table 1), ISRO has been collaborating with a few universities through the ISRO Chairs and Space Technology Cells (STCs).[22] The ISRO Chairs[23] are ISRO-endowed professorships for many years. Highly accomplished space domain professionals take a leadership role in shaping various aspects of space research in their universities. The ISRO Chairs provide the necessary direction to faculty, research scholars, and students of the universities in cultivating the competence necessary for carrying out cutting-edge space research. The STCs are joint initiatives of the host universities and ISRO that carry out R&D in space technology and applications.

Recently, ISRO has established two new types of institutions, the Regional Academic Centres for Space (RAC-S)[24] and the Space Technology Incubation Centres (STICS),[25] on various university campuses. A RAC-S is in every region – eastern, central, western, northern, and southern – of the country. The task of RAC-S is to carry out futuristic R&D of relevance to the Indian space program and promote space research activities in the region. However, on this matter, one recommendation for the ISRO Headquarters would be not to locate RAC-S in arbitrary regions. They can consider locating them according to the Zonal Councils, set up vide III of the State Reorganization Act, 1956 (MHA, 2010).[26]

Two of the four main objectives of these Zonal Councils, all chaired by the Union Home Minister, are "Enabling the Centre and the States to co-operate and exchange ideas and experiences" and "Establishing a climate of cooperation amongst the States for successful and speedy execution of development projects." These objectives fit well with the purpose of RAC-S' establishment. In that scenario, there are two RAC-S in the Northern Zonal Council based at NIT Kurukshetra and MNIT Jaipur and none in the Western Zonal Council. A new RAC-S could come up in a suitable academic institution in the Western Zonal Council.

The STICS aims to support university faculties and students to realize their innovative research targets into space-grade components that can be utilized for space applications and incubate start-ups on university campuses. In the past 2-3 years, ISRO has also begun to sign a stand-alone memorandum of agreements (MoUs) with public and private universities setting new centers of excellence and space research institutions.[27]

Inadequacies in DoS's Academia-Industry Interface

The foremost inadequacy of DoS's academia-industry interface is that it has not had a tripartite interface but two independent liaisons, each with academia and industry. Tripartite industry-academia collaborations are imperative with the increasing strategic significance of cultivating an Indian space economy. Implementing a defence sector-like GOCO model or an entirely new COCO model in DoS would demand equipping space companies to operate India's space assets on the government's behalf. The GOCO model has been efficiently demonstrated in the U.S. Prime examples being its dedicated Commercial Resupply Services, Commercial Crew Development Programme,[29] and the more recent Lunar Catalyst programmes (NASA, 2017).[30] The U.S. government has moved one step ahead of GOCO. It has now has pledged to encourage the private sector to carry out these contracted operations through a (COCO) model, which has multiplied U.S space capacities (Jones, 2018),[31] and U.S.' competitors, especially Europe and China are taking notice.

Table 1: Distribution of Department of Space institutions across Zonal Councils of India

	Northern Zonal Council	Western Zonal Council	Southern Zonal Council	Central Zonal Council	Eastern Zonal Council	North Eastern Zonal Council
ISRO Centres	ISRO Branch Office, New Delhi Delhi Earth Station, New Delhi	Space Applications Centre, Ahmedabad ISRO Liaison Office	Master Control Facility, Hassan Space Commission, Bengaluru ISRO Headquarters, Bengaluru Antrix Corporation, Bengaluru New Space India Limited, Bengaluru Human Space Flight Centre, Bengaluru Liquid Propulsion Systems Centre, Bengaluru. Valiamala ISRO Telemetry, Tracking and Command Network, Bengaluru Laboratory for Electrooptical Systems, Bengaluru	Master Control Facility, Bhopal Indian Institute of Remote Sensing, Dehradun		North Eastern Space Applications Centre, Shillong

Table 1 Continued...

Table 1 Continued...

			UR Rao Satellite Centre, Bengaluru National Remote Sensing Centre, Hyderabad Satish Dhawan Space Centre, Sriharikota ISRO Propulsion Complex, Mahendragiri Vikram Sarabhai Space Centre, Trivandrum ISRO Inertial Systems Unit, IISU		-	
DoS Autonomous Bodies	DoS Branch Secretariat, New Delhi Western Regional Remote Sensing Centre, Jodhpur Udaipur Solar Observatory, Udaipur Infrared Observatory, Mount Abu Semi-Conductor Laboratory, Chandigarh	Physical Research Laboratory, Ahmedabad Development and Educational Communication Unit, Ahmedabad	National Atmospheric Research Laboratory, Gadanki Down Range Station, Port Blair Indian Institute of Space Science and Technology, Trivandrum	-		Eastern Regional Remote Sensing Centre, Kolkata

Table 1 Continued...

Table 1 Continued...

ISRO Chair	-	Savitribai Phule Pune University		-	IIT Kharagpur	-
Space Technology Cells	IIT Delhi	Savitribai Phule Pune University IIT Bombay	IISc Bengaluru IIT Madras	IIT Kanpur IIT Roorkee	-	-
Regional Academic Centres for Space (RAC-S)	NIT Kurukshetra MNIT Jaipur	-	NITK Surathkal	IIT BHU Varanasi	NIT Patna	Gauhati University, Guwahati
Space Technology Incubation Centres	NIT Jalandhar	NIT Nagpur	NIT Trichy	NIT Bhopal	NIT Rourkela	NIT Agartala
Stand-alone ISRO academic centres	Satish Dhawan Centre for Space Science, Central University of Jammu	-	Centre of Excellence, Centre for Nano Science and Engineering, IISc Bengaluru Centre of Excellence, Advanced Mechanics of Materials, IISc Bengaluru		Veer Surendra Sai Space Innovation Centre, Veer Surendra Sai University of Technology	-

Source: Adapted from Indian Space Research Organization[28]

Typically, COCO and GOCO models compel space companies to carry out in-house RDTE to make the technology development and its commercial operations financially viable and profitable. India's prominent space-sector NGPEs have seldom performed commercially-motivated R&D, have not generated voluminous amounts of intellectual property in space domains, or invested in original design or original equipment manufacturing. Additionally, India's low gross expenditure on research and development (GERD) has been a chronic issue. The Economic Survey of 2021-22 identifies India's low share – about 2 percent - of the global space economy (MoF, 2022). Most of the space RDTE in India gets financed by the Indian government's expenditures on the national space program (refer to Table 2). The substantially profit-making commercial NGPEs, particularly from the telecommunications sector, have long been purchasing or leasing space technologies from overseas space hardware companies and have not innovated hardware competencies domestically.[32]

Table 2: Ranking of Government Expenditure on National Space Programs (2021)

R&D Ranking	Country	Expenditure (billion USD)
1	United States	54,589
2	China	10,286
3	Japan	4,214
4	France	3,952
5	Russia	3,567
6	European Union	2,574
7	Germany	2,377
8	India	1,963
9	Italy	1,481
10	United Kingdom	1,464
Total	Including all space programs	92,400

Source: Euroconsult 'Government Space Programs' Report, 2021[33]

The space reforms of 2020 have paved the way for space-sector NGPEs to fill the RDTE gaps in India's space ecosystem. However,to tread that path, the DoS must strategically employ IN-SPACe for equitably enabling R&D activities in all space-sector NGPEs – large conglomerates, MSMEs, and startups – and plug their RDTE output for building the national space economy.

Currently, the DoS finances ISRO's RESPOND programme through budgetary allocations and curates low-technology readiness level (low TRL) R&D activities (Table 3) in universities and not-for-profit scientific laboratories. However, Indian space-sector NGPEs are not habitual in sponsoring high TRL and commercial-readiness-level (CRL) space R&D activities in similar institutions. This inability creates hindrances in smoothly transitioning low-TRL technologies to higher-TRLs and eventually getting them the space-proven and commercial-readiness tags.

Consequently, many space technologies in India find it difficult to evolve from space laboratories, get the necessary support for prototyping, testing, and evaluation, and eventually enter the global commercial space market on time. Judicious employment of IN-SPACe as an enabler of academia-industry partnerships in the space domain can help fill these lacunae crucial for India's strategic needs.

IN-SPACe together with ISRO can Sustain End-to-End Life Cycle of Space RDTE

Estimates show that the global space economy will grow from the current US$ 450 billion to US$ 3 trillion by 2040.[34] India must attain a significant share in this 'sunrise' economic sector. To achieve a substantial share in the global space economy and sustain it later throughout the 21st century, ISRO and IN-SPACe must create a tripartite interface with academia and industry. Along with an ISRO-led RESPOND, the DoS should consider IN-SPACe to steer an Indian space industry-sponsored research (IND-RESPOND) programme.

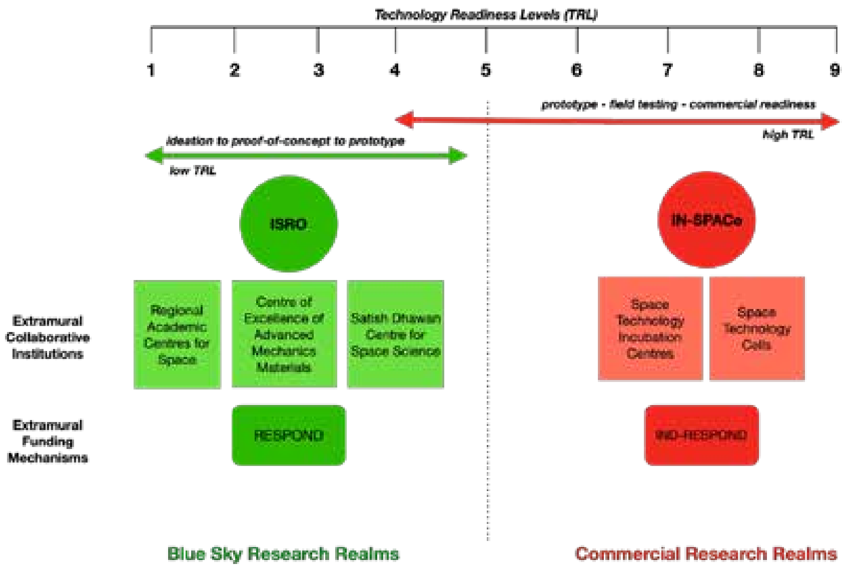
Under the IND-RESPOND, the Indian space-sector NGPEs may enlist with IN-SPACe RDTE projects of value to them. ISRO's RESPOND primarily supports projects between TRL 0 and TRL 5. Given any industry's inherent interest in furthering RDTE on proven proofs-of-concept and prototypes, IND-RESPOND can enlist industry-sponsored RDTE projects from TRL 4 to TRL 9 (Table 3). Like RESPOND, the IND-RESPOND can have an industry-based scientist as the Co-PI and the grant-receiving scientist in academic and not-for-profit scientific institutions as PI. Such an arrangement will allow ISRO and IN-SPACe to be collaboratively take charge of India's space innovation ecosystem and build the 'missing bridges' between academic and industrial space RDTE.

Table 3: Proposed Responsibility Sharing on Completion of space RDTE Life Cycle between ISRO and IN-SPACe based on Technology Readiness Levels

<table>
<tr><th>Technology Readiness Level</th><th>Description of TRL</th><th>Stage in TRL</th><th>RESPOND under ISRO</th><th>Proposed IND-RESPOND under IN-SPACe</th></tr>
<tr><td>0</td><td>Unproven concept</td><td rowspan="4">Ideation</td><td rowspan="6"></td><td rowspan="4"></td></tr>
<tr><td>1</td><td>Basic research</td></tr>
<tr><td>2</td><td>Concept formulation</td></tr>
<tr><td>3</td><td>Concept Validation</td></tr>
<tr><td>4</td><td>Prototype testing in simulated environment</td><td rowspan="2">Prototyping</td><td rowspan="6"></td></tr>
<tr><td>5</td><td>Prototype testing in real environment</td></tr>
<tr><td>6</td><td>Full system demonstration in simulated environment</td><td rowspan="2">Validation</td><td rowspan="4"></td></tr>
<tr><td>7</td><td>Full system demonstration in real environment</td></tr>
<tr><td>8</td><td>Full system testing qualification in real environment</td><td rowspan="2">Commercial Production</td></tr>
<tr><td>9</td><td>Full system 'proven' through mission operations</td></tr>
</table>

Source: Adapted from National Aeronautics and Research Administration[35]

Figure 2: Potential R&D Life Cycle Completion between ISRO and IN-SPACe efforts

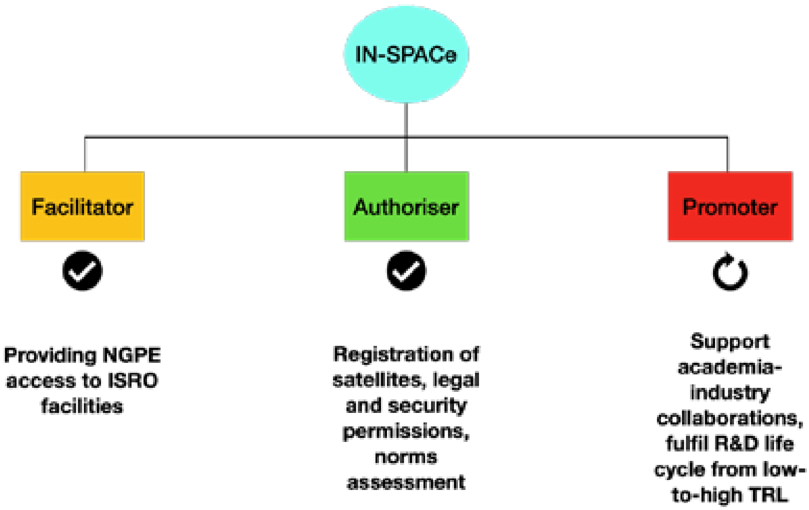


Source: Adapted from Indian Space Research Organization[36]

There is also a need to give IN-SPACe a charge equal to ISRO in the STCs and STICS. The university-based RAC-S, centers of excellence, and space science centers being academic and focusing on novel concepts and low-TRL high-risk-high-reward research, could be kept entirely with ISRO. However, if a TRL 5 and above R&D project is to happen on their premises, the IN-SPACe could monitor them through IND-RESPOND. Given the charge of STCs and STICS, IN-SPACe can connect scientists in host universities and space-sector NGPEs and command over R&D from TRL 5 to TRL 9 (Figure 2).

Unlike ISRO, which has space laboratories under its umbrella, IN-SPACe is bereft of laboratories, nor are there any plans for them. Besides, IN-SPACe, if it has to make the strategic impact on the nation's 'sunrise' space economy in the next 1-2 decades, does not have the time and liberty to build such laboratories as ISRO has over decades. Giving IN-SPACe hands-on management of space R&D, much more than a facilitator, is of utmost importance. To make it effective quickly, the DoS can consider giving IN-SPACe complete charge of managing STCs and STICS and deriving high-TRL output from them. The IN-SPACe can consider nurturing STCs and STICS depending on the host university's inherent research strengths and the research ecosystem existing in its vicinity. Where IND-RESPOND would create the industry's extramural interface between universities and national laboratories, giving IN-SPACe the charge of STICS and STCs will create dedicated research centers for the needs of space-sector NGPEs in India. IN-SPACe-run STCs and STICS could provide R&D services and consultancies to its NGPE sponsors (refer to Figure 3).

Figure 3: IN-SPACe' role as facilitator and authoriser is defined; it can be given an additional role as a promoter



Source: Adapted from Indian Space Promotion and Authorization Centre[37]

Giving IN-SPACe charge of STCs and STICS will necessarily not modify their mandates already given by ISRO. Under IN-SPACe's charge, STCs can continue working closely with the talent (faculty and students) pool residing in the host universities. Similarly, STIC's mandate of incubating faculty- and student-led startups can also continue. In the case of RAC-S's, with whom IN-SPACe would be related only through IND-RESPOND, they could assist their core mandate of proliferating the social, economic, and technological impact of R&D activities into their respective zonal jurisdictions.

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The IN-SPACe-administered STCs and STICS must be autonomously administered, with business rules different from fully ISRO and DoS-governed R&D institutions. The STCs will flourish if they keep host universities as business stakeholders in a corporatized not-for-profit model. Nevertheless, these joint centers must not depend on the host universities apart from sharing real estate, intellectual property on a case-by-case basis, and utility services. At the same time, the other stakes would belong to IN-SPACe, with research sponsorship coming from various space-sector NGPEs. Such corporatized IN-SPACe-run institutions will positively have a constructive multiplier effect on the Indian space program. They will generate tremendous R&D output for the consumption of academia, industry, startups, and governmental institutions.

Setting Priority Areas for Growing India's Space Economy

As IN-SPACe operationalizes its mandate, it will need to incessantly examine the international space economy landscape and have the tactical agility to make the Indian space ecosystem globally competitive. IN-SPACe will need to assess the vast amount of technological, financial, and human resource pooling initiated by the US under the Artemis Accords (Giri, 2021) it is leading, or a similar resource concentration led by China, as it comprehends the broad scope for India's space economy. In such a scenario, the indigenous space technologies cultivated under the RESPOND and IND-RESPOND must deliver strategic returns for India's space economy. Again, such agility will need a competitive tripartite DoS (ISRO and IN-SPACe), industry, and academia partnership working on cost-effective, time-bound, and strategically impactful deliverables.

Indian space-sector NGPEs, among many technologies, will continue to focus on miniaturizing satellites, creating on-demand and quick-reaction space launch platforms, and building better space-based telecommunication and remote sensing systems. Together RESPOND and IND-RESPOND can support the complete RDTE cycle of systems, subsystems, and components crucial to these technologies. However, given the growing human footprint, the emphasis on sustainable development in outer space will increase. This emphasis should be taken seriously as international or domestic financing for space industries may soon begin to use sustainable development in space as a qualifier.

The fourth edition of the Paris Peace Forum, held in November 2021, took a pledge for *Net Zero Space*.[38] The *Net Zero Space* pledge calls stakeholders of the global space economy – space agencies, academic institutions, satellite operators, space launch entities, and not-for-profit institutions - to contribute to eliminating space debris by 2030 and keep it that way. This initiative has the backing of the United Nations Office for Outer Space Affairs. It comes from the backdrop of rapid advances in space situational awareness, in-orbit servicing, de-orbiting, space debris removal, and satellite and space component recycling companies [Table 4].

Table 4: Private and Governmental Entities pledging commitment to Net Zero Space

Entities committed to Net-Zero Space of Paris Peace Forum	**Business domain of entities**
Viasat; SpaceAble; Kall Morris; Darkstar Aerospace; Clutch Space Systems	Quantitative evaluation of LEO environment; Space Situational Awareness
ShareMySpace; SCOUT; GMV; Chang Guan Satellite	Space debris detection; autonomous satellite navigation
OrbitX; Skyroot Aerospace; Arianespace	Clean launch vehicle fuels; rocket-stage reusability
Planet; NorthStar; Inmarsat; Hispasat; Eutelsat	High-fidelity space-based services
ISISSpace; EUSST; Exotrail; E-Space; ClearSpace; Avanti Space; Astroscale; Astrocast	Debris reduction; mitigation; debris removal; satellite de-orbiting; automated satellite maneuvering; on-orbit servicing
International Institute of Air and Space Law; International Association for the Advancement of Space Safety	Policy and legal education on Space debris mitigation and remediation
CNES; EgSA; GISTDA	Committed space agencies

Source: Paris Peace Forum [38]

There are chances that the global space industry stakeholders will aim to make efficient and clean propulsion for launch vehicles, satellites, and spacecraft mandatory. Similarly, national net zero-emission goals will utilize space-based assets in a big way.[39] The quantification of emissions and emission reductions possible using high-resolution (pin-pointed) space-based datasets will be vital for calculating carbon taxation and emission trading schemes. Therefore, beyond the simplistic necessities of the space economy, the RESPOND and IND-RESPOND should spawn technologies crucial for India's geoeconomic and geopolitical obligations.

Conclusion

The formation of IN-SPACe is a constructive step towards facilitating the needs of space-sector NGPEs and authorizing their participation in space activities. However, IN-SPACe should not be merely kept as single-window facilitation and authorizing window for NGPEs. IN-SPACe should also promote RDTE relevant to India's space-sector NGPEs by establishing an extra-mural innovation financing mechanism and a dedicated academia-industry interface. Consequently, ISRO and IN-SPACe could operate a relay mechanism where ISRO curates space RDTE from TRL 0 to TRL 5 and IN-SPACe, in coordination with Indian space-sector NGPEs, take these technologies to space qualification and commercial readiness levels from TRL 4 to TRL 9.

Giving IN-SPACe charge of STICS and STCs can spawn space industry-relevant RDTE activities on university campuses. While ISRO strengthens its outreach to academia through RAC-S, the centers of excellence and space science centers, together with IN-SPACe, will ensure making of futuristic space innovations relevant to India's space economy requirements and ambitions. Considering IN-SPACe's recent origin, it should emerge as promoter of India's 'sunrise' space economy ambitions and a tool of statecraft considering the changing global geo-economic order.

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