



Defence and Space Innovation in India: Structural Change Imperatives

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Increased private sector involvement in the defence and space sector can catalyse a new innovation paradigm for India. Although the public sector has traditionally been the main player in defence production in India, private firms have the potential to bring in new technologies and approaches that can be a game changer for India. This essay examines the current defence and space landscape in India, the policy initiatives and reforms underway, the emergent defence and space startup ecosystem and draws attention to the various linkages that need to be strengthened between the private and public sector.

■ **Increasing Private Sector Involvement in Innovation and Production: Why does it Matter?**

The private sector, through innovation and production, has become the primary driver of defence and space innovation for many countries across the world. It has become crucial for countries to ensure a well developed synergy between the public and private sectors. For India, in particular, there are lessons to learn from these structures of defence and space innovation, particularly in how the private sector can catalyse innovation. The United States is often quoted as a shining example of the government funding defence and space R&D while the performance of R&D and innovation is largely carried out by the higher education sector and the private sector.

Traditionally, the direction of innovation was from the public sector to the private sector. The internet, GPS, voice assisted technology were all technologies developed by the public sector for military use initially, but later adapted to great success by the private sector (Mazzucato, 2015). Today the situation is reversed.

The changing nature of warfare has meant that several technologies developed in the private sector are now being adapted for defence use and spurring defence innovation (Howell, S. et. al 2021). These technologies include artificial intelligence, machine learning, autonomous systems, and communications networks. They have become fundamental to how countries wage war and tackle internal security (Jhonson et. al, 2019). The research and development related to these technologies is largely situated in the private sector. In other

words, the competitive advantage for countries lies in a booming private sector and its synergistic relationship with the public sector.

In India, as we shall see in the next section, currently production and R&D are both dominated by the public sector. This raises questions about the current structure on who should perform the research, who should develop the technology, what steps need to be taken to extract more value from overall R&D expenditure in defence and space and which ecosystem linkages need to be strengthened. The emerging defence and space startup ecosystem may just provide that fulcrum for greater private sector involvement.

■ **The Landscape of Defence and Space in India: Public Sector Dominance**

According to data from the Stockholm International Peace Research Institute (SIPRI), India was the third largest spender in terms of total defence spending after the US and China in 2021. The total defence spending by India was USD 73.5 billion compared to USD 767 billion by the US and USD 270 billion by China. India's defence expenditure as a share of GDP, as of 2021, was 2.5 percent and still below the 3 percent recommendation in the Standing Committee on Defence (2018) report.

Defence production in India is dominated by the public sector. Around 80 percent of the sales turnover can be attributed to the public sector, while the private sector accounts for the remaining 20 percent (see Table 1). Public sector firms like Hindustan Aeronautics Ltd. and Bharat Electronics Ltd. have a substantial share in the defence production of the country. These two firms alone account for close to 40 percent of the sales turnover of the defence sector. In the space sector, a Dassault survey of 281 space equipment manufacturers and service providers found the involvement of the private sector largely limited to the production of low value added products and services (PwC, 2021).

Table 1 Sales Turnover of Defence Firms by Sector

Year	Defence Public Sector Undertakings	Ordnance Factory Board	Other Public Sector Undertakings/ Joint Ventures)	Public Sector as a Share of Total	Defence Private Companies	Private Sector as a Share of Total	Total
	(US\$, Million)						
2017-18	6743	2301	804	80%	2381	20%	12228
2018-19	6491	1833	796	79%	2481	21%	11601
2019-20	6721	1301	888	80%	2242	20%	11152
2020-21	6293	1972	812	80%	2326	20%	11404
2021-22	7475	1596	859	79%	2642	21%	12572

Source: Department of Defence Production, https://ddpdashboard.gov.in/DefenceProduction/Defence_Production

The public sector dominates in terms of defence and space R&D too. In 2021, India spent close to USD 4 billion on defence and space related research according to the 22nd Standing Committee on Defence Report (2021). Almost 95 percent of this was performed in laboratories belonging to the Defence Research and Development Organisation (DRDO), the Department of Space (DoS) and the Department of Atomic Energy (DAE).

The funding allocated by the DRDO, DOS and DAE to support research in academic institutions is almost negligible. DRDO was reported to allocate around 1 percent of its total budget or USD 17.1 million towards academic institutions according to the 34th defence standing committee report. Compare this with the United States that spends USD 122 billion on defence R&D and USD 1.2 billion or 1 percent of its defence R&D budget on basic research in academic institutions alone. If one were to consider the allocation of funding for applied R&D and advanced technology development to academic institutions, the total US defence R&D allocation to academic institutions would be significantly higher (Congressional Research Service, 2022).

The same story, i.e. public sector dominance, repeats for industrial R&D in this sector. In 2021, the Aerospace & Defence¹ sector was among the top 10 sectors when it comes to industrial R&D in India, accounting for around 4 percent of total industrial R&D. The top Indian spenders on R&D include public sector enterprises like Hindustan Aeronautics Ltd, Bharat Electronics Ltd, Brahmos Aerospace Pvt. Ltd, and Mazagon Dock Shipbuilders Ltd. and private enterprises like Tata Advanced Systems Ltd. As can be seen in Table 2, Hindustan Aeronautics Ltd., Bharat Electronics Ltd., Tata Advanced Systems Ltd. have R&D intensity (R&D as percent of sales) levels well above the global average R&D intensity level.

Table 2 Comparison of Select Indian Firms' R&D Intensity with Global Average R&D Intensity

Select Aerospace and Defence Indian Firms	R&D Intensity (%)	Top 2500 Global Average R&D Intensity of Top Aerospace and Defence Firms (%)
Hindustan Aeronautics Ltd.	7.4	4
Bharat Electronics Ltd.	6.4	
Tata Advanced Systems Ltd.	8.6	
Brahmos Aerospace Pvt. Ltd.	3.4	
Mazagon Dock Shipbuilders Ltd.	2	

Source: Annual Reports (2020-21) of Indian companies; Prowess, data downloaded on 16 October 2022 from the platform; ACE Equity, data downloaded on 16 October 2022 from the platform; Ahmedabad University; EU Industrial R&D Investment Scoreboard (2022); Centre for Technology, Innovation and Economic Research (CTIER)

The patent output of the above mentioned Indian firms is low compared to the global top R&D spenders in this sector. Top firms like Airbus, Boeing and Lockheed Martin were granted 1,930 patents, 4,443 patents and 337 patents respectively in the same year. In comparison, only 11 patents were granted in FY2021 to the top Indian firms.

¹ Under the ICB classification, the aerospace and defence sector includes civilian aviation manufacturers, assemblers and distributors of aircraft and aircraft parts primarily used in commercial or private air transport besides defence manufacturing.

■ Policy Initiatives and Reforms

Recent policy announcements related to the defence sector have focused on boosting domestic production as well as trying to promote innovation within the sector. The Defence Acquisition Procedure (DAP) 2020 and the Defence Production and Export Promotion Policy (DPEPP) have been designed to boost production capabilities for self-reliance as well as defence exports from India. The Innovations for Defence Excellence (iDEX) scheme, introduced in 2018, focuses on building innovation capabilities by focusing on products and solutions. In the FY2023 budget, the government made a welcome announcement of allocating 25 percent of DRDO's budget to the private sector, higher education sector and startups (ThePrint,2022).

Within the space sector, the private sector is expected to play a role in production as well as testing of components and subsystems that will be used in launch vehicles and spacecrafts.² Two key agencies that are involved in implementing the space sector reforms are the New Space India Limited (NSIL) and the Indian National Space Promotion and Authorization Center (IN-SPACe). NSIL has been tasked with operating assets like launch vehicles and satellites that could be procured from the private sector or even the Indian Space Research Organisation (ISRO). It is also involved in aiding the transfer of technology developed by ISRO. IN-SPACe plays the role of regulator and is involved in awarding licences to private players.

Thus, both in defence and space, there is a definite policy intention to increase the involvement of the private sector with a focus on domestic firms. These policy initiatives and announcements may provide a roadmap for the public funding of research as well as a greater integration and involvement of the private sector in technology and product development in the work of public laboratories and departments.

² At the time of writing, the new Indian Space Policy 2023 has just been released and builds on the reform process started in 2020.

■ Emerging Defence and Space Startups: A Potential Game Changer for India

There have been examples of startups playing an increasingly prominent role in developing disruptive frontier technologies for the defence and space sector in the news recently. Sagar Defence Engineering, an unmanned system technologies startup, launched Varuna, the first human carrying drone to be inducted into the Indian Navy (Siddiqui, 2022). Tonbo Imaging, an imaging solutions startup, has developed thermal imaging binoculars and multi mission sight for the Indian Army (Phillip, 2021). Nyokas, a smart wearables startup and an iDEX winner, made a wearable T-shirt with sensors to track vitals and alert authorities in case the wearer was attacked (TOI, 2021). Agnikul Cosmos, a space startup working on 3D printed engines and launch vehicles set up its own private launchpad at the Satish Dhawan Space Centre (SDSC) at Sriharikota recently (Kandavel, 2022). Another space tech startup, Skyroot is all set to become the first private startup in South Asia to launch its rocket Vikram-II for an orbital flight (India Today, 2022).

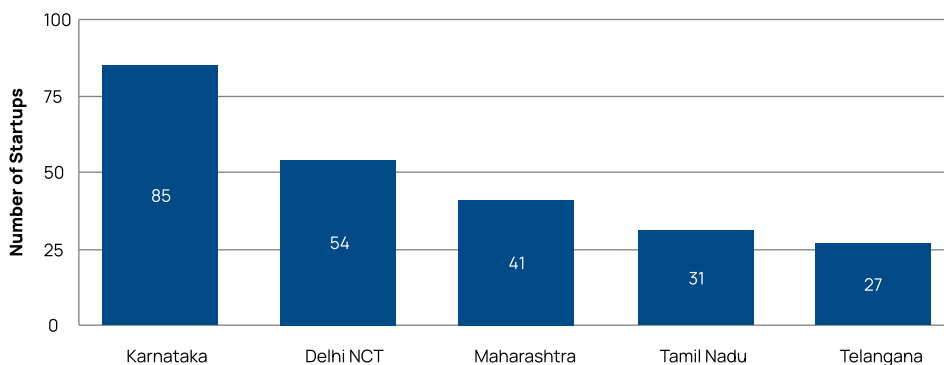
To explore if these are scattered individual efforts or signs of an emerging ecosystem, CTIER constructed a novel dataset of defence and space related startups established between 2011 and 2021. The CTIER database consists of defence and space startups in the country which are currently active and where information on their connection with the defence or space agencies is available in the public domain. This publicly available information includes the startup having won an award, a contract or has some other known offering in terms of goods or services. We identified 304 such startups currently in operation. We analysed startup information to look at the geographical distribution of the startups to identify hubs of startup activity, whether there are any dominant technologies that the startups are focused on and the educational profile of the founders and CxOs³ to identify if there were clusters of academic institutions from where founders and CxOs have graduated.

3 C-Suite Business Executive

■ Karnataka Leads in Defence and Space Startups

In terms of location, we found that 5 states formed the majority of defence and space startups. Karnataka had the highest number of defence startups at 85, followed by Delhi NCT at 54. This was followed by Maharashtra (41), Tamil Nadu (31) and Telangana (27). Bengaluru in Karnataka had the highest number of startups in a city (80) followed by Delhi (30), Chennai (26), Hyderabad (24) and then Mumbai (22). We also see startups emerging from newer hubs like Gurugram, Coimbatore, Aligarh, Ahmedabad, Kochi, Lucknow, Pune and Kanpur.

Figure 1 Geographical Distribution of Startups in the CTIER Database



Source: Authors Database

■ Unmanned Vehicles are the Dominant Technology Area

We analysed the dataset to determine the technology areas the startups were present in. The dominant technology area is unmanned vehicles, mainly drones and unmanned marine vehicles (UMVs) with 96 startups working in this area. This was followed by 71 startups in spacetech, 23 in IT & analytics and IoT infrastructure and 22 in aerospace. It should be noted a startup may have more than one technology area associated with it.

Within these technology areas, surveillance and software solutions dominate the solutions portfolio. This is a reflection of India's strength in the IT sector. Given the pace of technology development and the increasing linkages between software and hardware in products, these startups have the potential to change the rules of the game for manufacturers in India as well.

Table 3 Technologies across Different Defence Startups

Technology	Number of Startups
Drones & UMVs	96
SpaceTech	71
IT & Analytics, IOT infrastructure	23
Aerospace	22
Training and related services	13
Robotics	11
Security	10
Imaging	6
Others (Renewables, training, etc)	48

Source: Authors Database

There are a number of exciting startups working on hardware products too. These include Sagar Defence Engineering that produces drones, Big Bang Boom that produces military equipment and Agnikul Cosmos that produces 3D printed engines.

■ **Top-tier Academic Institutions are Not the Only Hubs of Talent**

When one considers the educational backgrounds of startup founders and CxOs in the CTIER database⁴, based on the bachelors, masters and PhD degrees attained, it is clear that talent in this sector is not limited to the traditional top ranked institutions and other known institutes of national importance (INIs).⁵ Of the 245 founders and CxOs for whom data on bachelor degrees was available, there were 98 that did not attend either a top 100 NIRF⁶ ranked institution or an INI, while 22 received their bachelors degrees overseas. For 168 masters degrees identified, there were 34 founders and CxOs who were neither from a top 100 NIRF

4 For the purpose of this essay, we considered founders and CxOs of 167 unmanned vehicles and spacetech startups, the top two technology areas as seen in Table 3.

5 Institutes of National Importance (INI) are premier public higher education institutions in India established by an act of parliament

6 The National Institutional Ranking Framework (NIRF) was launched in 2015 and outlines a methodology to rank academic institutions across the country

ranked institution or an INI while 54 founders and CxOs held international masters degrees. While the data on PhDs shows a preference towards top ranked institutions and other known INIs or even international institutions, of the 34 founders for whom we had information on doctoral degrees, there were 5 founders and CxOs who had earned their PhDs from institutes that were neither in the NIRF top 100 or an INI.

There are some interesting examples of founders and CxOs of startups who completed their undergraduate degrees from academic institutions in Gorakhpur, Burla, Dibrugarh and Kollam that do not feature in the NIRF top 100 or INI lists. This is a trend that needs to be encouraged. For example, Abyom Space Tech, whose founder graduated from Deendayal Upadhyay Gorakhpur University in Gorakhpur, is a budding startup currently based in Kushinagar, Uttar Pradesh. Abyom Space Tech is currently working on Reusable Launch Vehicles and recently showcased its work at the Aero India exhibition 2023 in Bangalore (Aero India 2023). Another interesting example is Spacefields, a defence and space startup whose founder studied at Burla in Odisha. The startup was recently declared as one of the winners of the Boeing University Innovation Leadership Development (BUILD) programme 2022-23 (The Hindu, 2023). Aadhya Aerospace, whose founders completed their education from Dibrugarh, Gorakhpur and Kollam, currently undertake contract work for DRDO and ISRO (Sachdev, 2020).

Looking at these examples from the CTIER database, we see a potential opportunity to nurture talent from academic institutions that do not feature in the top 100 NIRF or INI lists. Encouraging and promoting such talent can provide a big boost to the overall innovation ecosystem. The next section explores the current state of these linkages in India, keeping academic institutions at the centre.

■ **Academic Institutions as Locus Points for Innovation: Widening the Net**

Academic institutions contribute to the innovation ecosystem in terms of not only producing entrepreneurial talent but also in being active partners in performing collaborative research. Increasing investments in our academic institutions can strengthen ecosystem linkages and greatly accelerate innovation. Currently, the linkages between academia and the defence and space sectors are not well developed despite

stated intent. Moreover, most of these linkages are restricted to premier institutions.

The DRDO has 10 Defence Industry Academia Centre of Excellence (DIA-CoE) across premiere institutions across the country (PIB, 2022). The Centre of Excellence at IIT Delhi is a good example of a successful model that can be studied further with an intention to scale up. With an investment of approximately USD 39 million (INR 2.8 billion) over a span of four years, the centre has developed lightweight bulletproof jacket prototypes, anti mine boots, free space quantum key distribution etc. The development of these products across projects had active participation of 100 faculty members and 150 PhD students.⁷

In the space sector, the partnership announced between ISRO and the Indian Institute of Space Science & Technology (IIST) is another model to watch for. Similar to the partnership between Caltech and the Jet Propulsion Laboratory in the US, ISRO and IIST will undertake joint research to benefit various ISRO centres, and where the funding will be made available by ISRO (Firstpost, 2021). ISRO also runs several student satellite programs with higher education institutes to promote interest in technical careers related to space and space technology that can be scaled up.

Academic institutions are also becoming locus points for startup incubation. Tapping into the startups and ongoing research at these institutions can accelerate innovation. The Society for Innovation and Development (SID) at Indian Institute of Science (IISc) offers a good example of this. One of the startups incubated at IISc, Digantara, is developing a counter-space technology which can disable enemy satellites from space leveraging the incubation facilities and the academic expertise available at IISc (Chethan Kumar, 2020).

Policy efforts need to focus on increasing investments in academic institutions beyond the hallowed preferences of premier educational institutions.

7 Based on closed door roundtable discussion on India's Defence Sector and its potential for innovation as part of an ongoing Ananta Centre-CTIER roundtable series "India's R&D ambitions: Challenges and Imperatives" held in Septmber 2022. The investment amount of INR 2.8 billion was reported during the discussion and has been converted to USD 39 million using an average USD-INR exchange rate of 72.39 over the fiscal years 2018-19, 2019-20, 2020-21 and 2021-22

■ Newer Opportunities Opening Up for Private Sector in Manufacturing

Of late, there have been policy announcements in India geared towards encouraging domestic manufacturing, development of indigenous technologies, greater domestic procurement and increasing private sector participation in the defence and space sector. Domestic manufacturing stands to benefit from the innovations emerging from the defence and space startup ecosystem. The thrust towards domestic procurement opens up previously inaccessible spaces for defence manufacturing firms in India that include large firms like Tata, Larsen and Toubro, Mahindra and Mahindra, Bharat Forge and a growing MSME and startup sector. This can become a watershed moment for defence and space manufacturing in India.

While India has always purchased equipment from global firms there seems to be a shift in the offing with large firms in India entering technology partnerships with global firms like Airbus and Lockheed Martin to produce for domestic and international markets (Jayakumar, 2023). A recent example of this kind of a technology partnership is the collaboration between Tata Advanced Systems and Airbus which entails the production of military aircrafts by a private firm for the first time in India (ET, 2022).

There is a case to be made for large firms in India assuming the role of integrator of technologies developed by other stakeholders in the ecosystem. These linkages can result in a win-win solution for the ecosystem. The large firms get access to cutting edge innovations while the small firms (MSMEs and startups) get an opportunity to scale up. There is some evidence that this is already underway. Adani Defence acquired a 50 percent stake in General Aeronautics, an agri drone startup, to leverage capabilities for its own military drones with artificial intelligence and machine learning tech (Umarji, 2022). Similarly, Reliance acquired a 51 percent stake in Asteria Aerospace, a defence drone startup, to use Asteria's technology to test out its 5G networks for image analytics and drone delivery (ET, 2022).

We are also beginning to see startups that are scaling up or likely to scale up production as they win direct orders from the armed forces. India's defence modernisation drive has opened up manufacturing opportunities for startups like NewSpace Research and Technologies, a

Bengaluru based startup that has been supplying the Army with swarm drones and Sagar Defence Engineering, another drone startup that has received repeat orders from the Navy (Philip, 2023).

In discussions with industry members, the framework adopted by the Indian Navy to boost domestic manufacturing is often cited as an example that needs to be explored further. The Navy has taken steps to develop domestic capabilities as well as develop a domestic supply chain that involves private sector participants. According to a 2022 Defence Parliamentary Standing Committee report, 37 out of 39 ships and submarines are currently being built in India and there is a significant amount being invested in MSMEs as highlighted in the 27th Standing committee on defence.

■ **Catalysing a New Innovation Paradigm**

The public sector in India dominates innovation and production in defence and space. The emerging defence and space startup ecosystem coupled with policy announcements for greater private sector involvement can provide the much needed boost for increased involvement by the private players in the defence and space sector.

Our analysis using the CTIER defence and space startups database shows there are clear opportunities to invest significantly in academic institutions, for research as well as incubation activities. Several founders and CxOs of these startups were found to have studied at academic institutions that do not feature in the top 100 NIRF or INI lists. Identifying and investing in such institutions will help grow the talent base across the country. At the same time, every effort should be made to increase funding towards academic institutions, including the IITs and NITs that are already contributing to the defence and space ecosystem.

There are also early indications of the emergence of newer startup hubs in this sector like Coimbatore and Lucknow. Supporting the development of these hubs can provide an additional boost to the larger ecosystem. Taking such measures will enable wider diffusion of innovation through creating new linkages or improving existing linkages between the private sector and academic institutions.

In light of recent policy announcements, there is a unique opportunity for the private sector to scale up production. There are opportunities for increasing linkages between startups and the larger private firms. Corporate venture capital investments, for example, would need to be explored - this would also allow scaling up of new ideas while broadening the innovative capabilities of the larger firms. Government procurement and investment in developing the domestic supply chain as seen in the case of the Indian Navy too can play a crucial role here. Large orders can have a positive impact on the production ecosystem, providing a platform for domestic manufacturing.

While there have also been welcome announcements around increasing private sector participation in defence and space research, there is ambiguity around how some of these announcements will play out. For example, currently there is ambiguity around the announcement in the FY2023 budget regarding 25 percent of the DRDO budget being allocated to the private sector, higher education sector and startups. The ambiguity is whether it constitutes 25 percent of the total DRDO budget or whether it is 25 percent of the balance funding available once revenue expenditure and spending on existing items are considered.⁸

For India to have an increased competitive presence in defence and space globally, one would need to engineer a structural shift in public funding of R&D and production, with academic institutions and the private sector playing a dominant role. This would entail a significant increase in funding to academic institutions for research and the development while the production of technologies is increasingly undertaken by the private sector. This would help extract more value from overall R&D expenditure in defence and space and strengthen the ecosystem linkages between the public sector, academia, startups, MSMEs and large firms. It is imperative that there are continuous improvements in policy design to crowd in private investment when it comes to both R&D and production.

8 Based on closed door roundtable discussion on India's Defence Sector and its potential for innovation as part of an ongoing Ananta Centre-CTIER roundtable series "India's R&D ambitions: Challenges and Imperatives" held in September 2022. The investment amount of INR 2.8 billion was reported during the discussion and has been converted to USD 39 million using an average USD-INR exchange rate of 72.39 over the fiscal years 2018-19, 2019-20, 2020-21 and 2021-22

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