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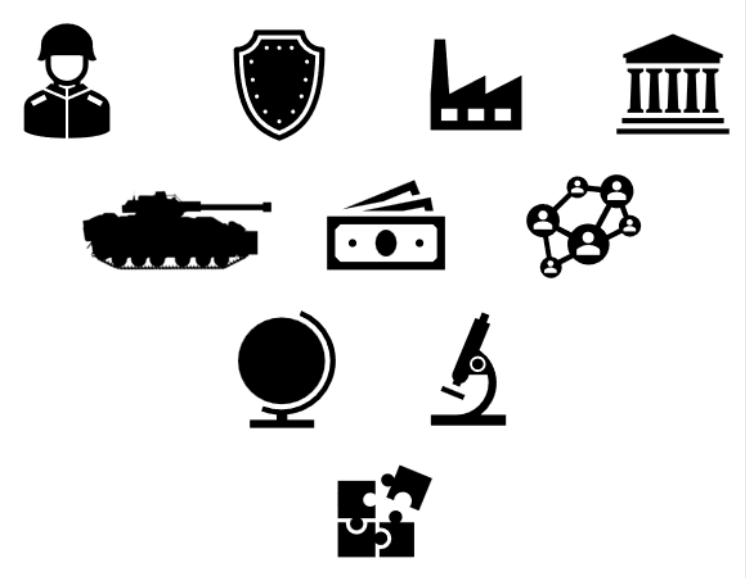
Defence Research and Development:

A case for change in India



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This brief working paper by Foundation for Advancing Science and Technology-India (FAST-India) contains an overview of the Indian defence research and development setup. The focus of this paper is to suggest changes in the Indian defence R&D ecosystem that encourage stakeholder participation with the ultimate goal of self reliance. This working paper is a part of the ongoing effort by FAST-India to stimulate thought and action in the science and technology ecosystem of the country. The paper will be updated as more insights and recommendations are gathered through further research and consultations. Send feedback/ inputs for this paper to chetandeep@fast-india.org

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1. About the working paper

This paper aims to provide an overview of the Indian defence sector's research and development activities. Additionally, the idea is to compare statistics with major global military spenders, identify some key trends in India's defence R&D ecosystem, and finally suggest a few recommendations to enable major shifts in the sector's domestic R&D set-up leading to enhanced outcomes.

2. Executive Summary

2.1 Introduction

The Defence research ecosystem in India has not achieved high levels of scientific capability as compared to other developed and developing countries despite being the third largest military spender in the world after the USA and China. A major portion of this expenditure has been spent on imports of arms and technology as well as routine operational expenses but a commensurate elevation in standards has not been achieved in domestic research and development of defence systems. India accounted for almost 11% of the world's share of arms trade (global leader) between the years 2017-2021[1]. In comparison, China held only about 4.8% share in the arms trade in the same timeframe[1].

While the Ministry of Defence has been allocated the lion's share of the Union Budget in every financial year, one of the principal recipients of those funds: Defence Research and Development Organisation (DRDO), has not fully succeeded to create adequate technological advancements for the Armed forces to utilise. DRDO projects have often been marred by exorbitant costs, mismanagement, delayed timelines and suboptimal end-products. DRDO's stature of being the sole Defence R&D authority in the country has led to a lack of competitiveness in the market with the private industry engaging mostly as licensed manufacturers and not researchers. There has also been a limited involvement of academic partners. This year, Rs. 1200 crore has been earmarked for defence research through academia[2]. In comparison, the USA allocates more than double the amount (~$3500 million)[3] to academia for defence research.

The latest union budget (FY 2022-23) has provisions to open up defence R&D and procurement for private industry through an allocation of 68% of the capital acquisition budget for procurement from the domestic industry in addition to earmarking 25% of the defence R&D budget for the private industry including startups[4]. It is clear though that the Indian government plans to reduce its dependence on foreign defence imports and encourage domestic industry participation.

2.2 Scope

For the purpose of this study, the following aspects were explored in detail:

1. Indian defence R&D structure including relevant stakeholders such as Defence Research and Development Organisation (DRDO), Defence Public Sector Units (DPSUs), Private industry and Academia.

2. The current state of defence research in the country by examining the performance of domestic R&D entities over the years and their effect on the larger defence ecosystem.

3. Defence R&D structures of some technologically advanced nations so as to compare and contrast practices with the Indian landscape and perhaps utilise elements of a few in recommending potential changes to the defence R&D setup.

2.3 Findings and Analysis

Research has shed light on the lack of synergy existing between relevant stakeholders, with much of research activity scattered across the sectors despite active collaborations existing on paper. Collaborative research efforts by agencies such as DARPA in the USA have yielded cutting edge technologies like the Global Positioning System (GPS). Agencies such as AID in France and FPI in Russia have been modelled to encourage similar partnerships between stakeholders.

Further, DRDO's monopolised stance over Indian defence R&D coupled with high levels of government regulations drove the private industry away from this space for the longest time. The defence R&D setup, which should have been a thriving ecosystem with competitive players from the industry and academia joining hands with the government to create world class research, currently sits on a strategy dependent on import of foreign technology to stay abreast in a globally superior market. While the government is making efforts to attract industry and academia to contribute to defence R&D through policies such as the Defence Acquisition Procedure (DAP) 2020 and provisions in the Union Budget 2022-23, the operational clarity on some of the moving parts continues to elude us.

Given the current geo-political threats facing the country, it is absolutely imperative that the Indian defence system is adequately equipped to counter hazards in a technologically advanced world.

2.4 Recommendations

Defence R&D activities in the country need to be shaken up from the grassroot level. A framework is needed to engage with multiple stakeholders and to even assess India's

technology adoption readiness. Based on global best practices, a summary of the said framework has been provided in Figure A. The goal of this structure is to make India self-reliant in defence technologies with a subsequent reduction of dependency on imports.

	Mission Centric Projects	Long Range Projects	Existing	Proposed
Industry			★ Industry role limited to licensed manufacturer ★ Very few incentives to participate in R&D	★ Industry to drive collaborations in mission centric projects ★ Long-term, open-ended research through an independent, DARPA analogous agency formed as a SPV under GoI's allotment of 25% of R&D budget to private industry and academia
Academia			★ Partnerships exist but notable R&D activities non existent	★ Academic CoE's to participate in long range projects involving fundamental and applied research ★ Government labs to be used by academicians to collaborate with industry for mission centric projects
Government			★ Government is the primary funder of defence R&D ★ DRDO the sole defence R&D performer	★ Government to act as a facilitator in bridging gaps and providing common ground to industry and academia for furthering defence R&D ★ Government to rework technology transfer policy to receive as much 'know-why' as possible on imports ★ Assessment of technology needed for developing R&D capability for the future
Services (Army, Navy, Air Force)			★ Current role of an end user/ consumer of products only	★ Services to have individual R&D units to focus primarily on mission centric outcomes ★ Active involvement in testing and feedback of research outputs
International partners			★ Import of foreign technology without adequate technology transfer	★ Basic research projects to be sought with international defence production giants ★ Arrangements for IPR ownership needed to provide benefit to Indian defence R&D ecosystem

Figure A: Framework for stakeholder engagement. ***Note: Shaded area represents share of involvement***

1. It is proposed that the Government of India views Defence Projects through two lenses: **Mission centric projects** and **Long range projects**. The Long range projects should be helmed by an industry-driven, independent agency sitting parallel to the DRDO and reporting to the Ministry of Defence. GoI's allotment of 25% of defence R&D budget to be channelled through the proposed DARPA-like independent agency.
2. An **assessment of technologies** is needed to ascertain their domestic development readiness. The technology will be assessed on the basis of resources available in India, cost to develop v/s import and eagerness to acquire among other factors. The goal of the exercise is to move from 'Make in India' towards '**Develop & Make in India**' in defence R&D.
3. Involvement of the Armed forces (Army, Navy, Air Force) in R&D activities is of utmost importance to synergise the biggest stakeholder in the defence industry. It is proposed that the **Armed Forces should have R&D units** of their own to foster tactical project development that is not capital or resource intensive. Role of the Armed Forces needs to change from merely a 'user' to 'user and contributor to the development' of technology.
4. Undertaking **basic research through international collaborations** with defence companies to build domestic R&D capacity is another way forward. Research programs can be opened up to students of Centres of Excellence (CoE) and researchers of DRDO labs. Ownership of IPR needs to be resolved on priority to keep learnings, licences and profits stemming from any research within the country.

5. Extensive involvement of **private industry in defence R&D** activities is needed to drive up competition in addition to opening up collaborative ventures with research labs. Not only does private industry bring in funding opportunities, but also helps scale up new technology absorption.

3. Overview of the Indian national defence sector

India's Ministry of Defence (MoD) is primarily responsible for coordinating and overseeing the Indian Armed Forces (Army, Navy, and Air Force) and the Indian Coast Guard. The MoD also provides policy frameworks on national security-related issues. Budgets of other ministries in the Indian ecosystem feel pale compared to the Indian defence sector budget year on year. The FY 2021-22 allocation to the Defence ministry was INR 4.8 lakh crore, accounting for about 14% of the total budget[1].

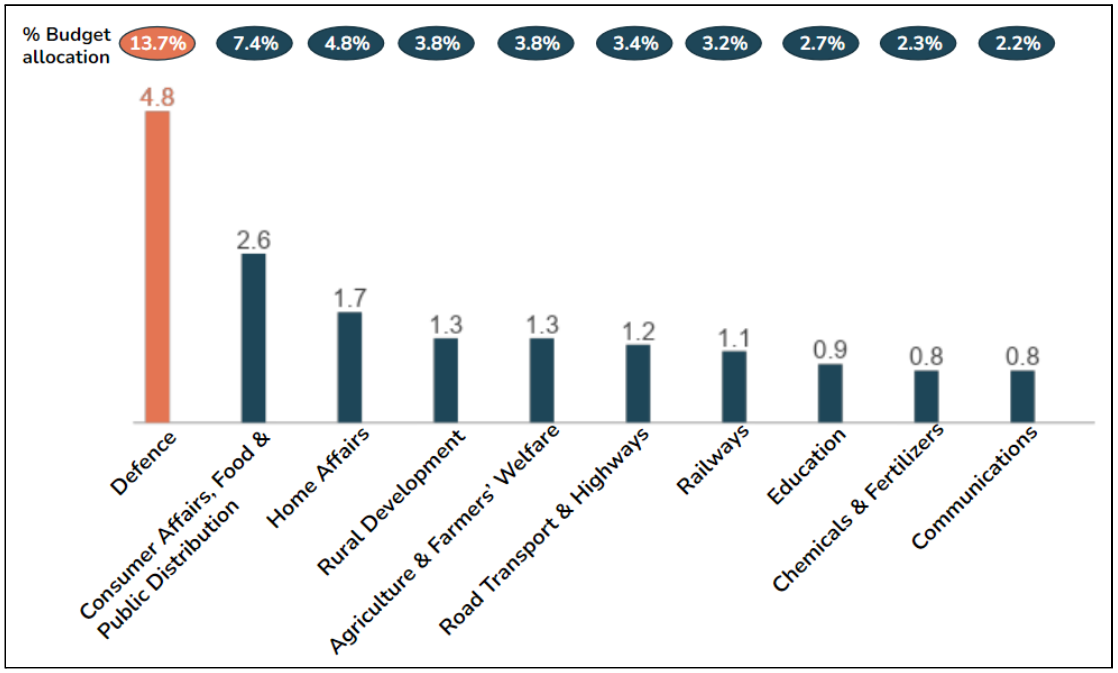

Figure 1: Top 10 Ministry Allocated Budgets in FY 2021-22 (INR Lakh Crore)[2]

The Defence budget consists of components such as Salaries, Pension and Capital outlay among other expenditures. The Capital expenditure includes outlays on procurement of machinery and equipment, and construction work. It is directly related to modernisation and development of infrastructure within the Armed Forces. A major component of the defence budget is spent on salaries and pensions (52-53%) as seen over the last two financial years. **It can be seen from Table 1 that of the total defence budget, only 1-2% is being spent on research and development related activities. This represents by far an extremely low figure as compared to global statistics where countries like the USA and China spend more than 10% of their defence budget on R&D related activities.**

Table 1: R&D Budget[3]

R&D Budget	Actual 2020-21	Budget 2021-22	Revised 2021-22	Budget 2022-23
Defence services (revenue)	7,983	9,082	8,462	9,348
Capital outlay	7,724	11,376	9,876	11,982
Total Budget	**15,707**	**20,457**	**18,337**	**21,330**
R&D as % of total budget	***1.6%***	***2.4%***	***2.0%***	***2.3%***

4. Research and Development: Indian Defence sector

The Defence Research and Development Organisation (DRDO) is the R&D wing of the Ministry of Defence and is also tasked with advising the Government on the scientific aspects of military equipment. DRDO does so by aiming to design, develop and produce state-of-the-art weapon systems and allied equipment and develop infrastructure to build a strong home-grown technology base.

The DRDO has been consistently working with an outlay of approximately 5-6% of the total Defence budget[4]. In comparison, the US Department of Defence spent approximately 13% of its Defence budget on R&D alone. A comparison of the actual numbers reveals the true picture and a stark contrast. In 2018-19, DRDO functioned with a budget of Rs. 17,861 crore while USA's Department of Defence spent approximately Rs. 7,13,200 crore on Defence R&D. The following table summarises the Defence R&D expenditure in the global context. Table 2 presents a case of global defence expenditure.

Table 2: Defence R&D expenditure[1][4]

Country	Defence R&D expenditure in 2019 (Rs. crore)	Percentage of Defence budget spent on R&D (2017-2019)
USA	7,20,067	13-15%
China	1,90,339	9-10%
France	71,300	18-20%
Russia	29,600	10-12.5%
South Korea	26,553	8-9%
India	17,861	1-2%

India's defence R&D, led by DRDO, has a network of more than 50 laboratories and additionally works in partnership with a number of academic institutions (through Centres of Excellence spread across the country), Defence Public Sector Units (HAL, BEL, BDL, etc), Ordnance Factories (now converted to DPSU), national S&T establishments (CSIR, DAE, DoS, etc), Private sector industries (L&T, Tata group, Mahindra group, etc.) and even international collaborations.

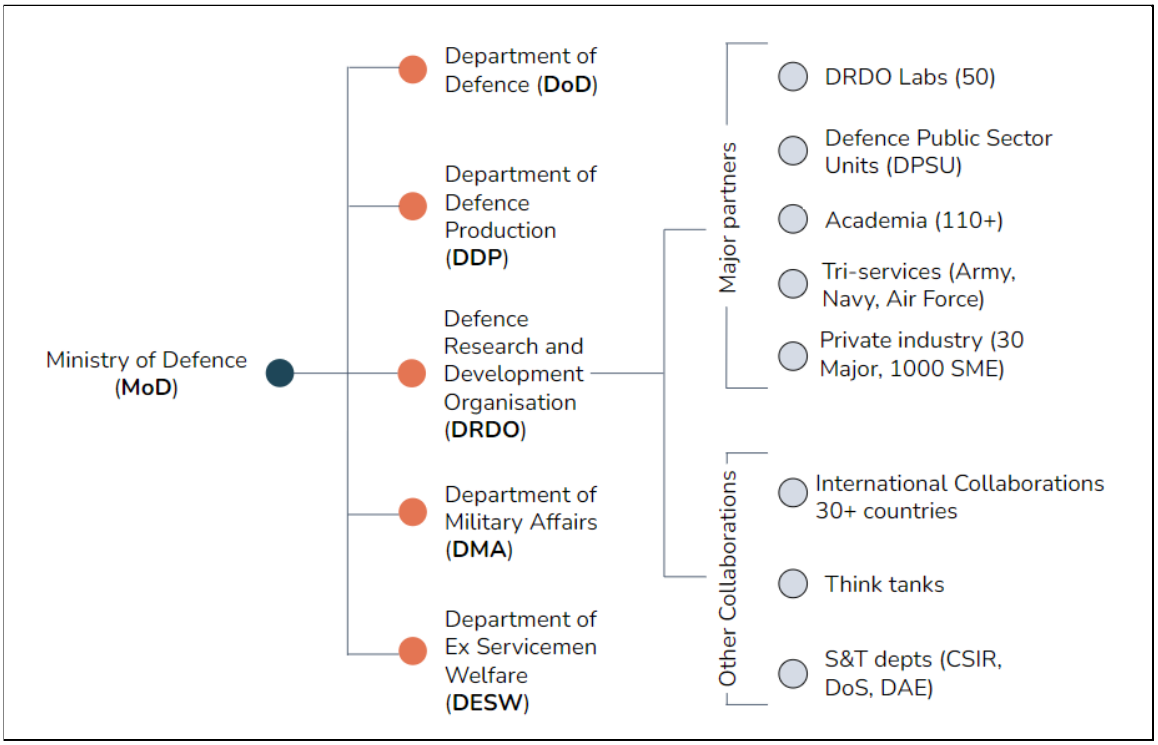

Figure 3: DRDO partnerships[5]

Basic and applied research is done at DRDO laboratories, Academic Centres of Excellence and national S&T laboratories whereas development and production of military equipment is done by both Defence PSUs and private industry through licensed partnerships. The following illustration details the various modes of engagement DRDO has with industry and academia.

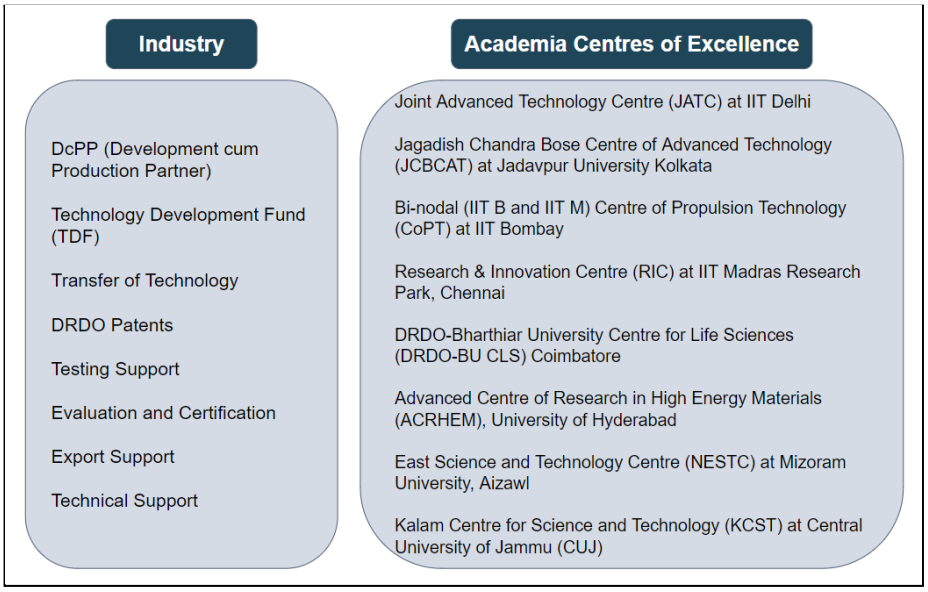

Figure 4: DRDO Interactions with industry and academia[6][7]

DRDO interacts with the industry in various ways such as providing technical support, export support, assisting in evaluation and certification and even providing testing support at their test

facilities. Interestingly, DRDO patents are open for the industry and can be used free of cost. DRDO also provides technical know-how through the technology transfer route to industry entities at specific rates. **It is important to note here that industry primarily engages with the DRDO as a Development cum Production Partner (DcPP) wherein they primarily act as Licensed Manufacturers.** Currently, Tata group, Kalyani group, Mahindra Defence Systems and Larsen & Toubro are some of the active defence manufacturers for DRDO in addition to the DPSUs. In an effort to engage the MSME's and Startups, DRDO has set up a corpus fund[8] of Rs. 100 Crore for indigenisation of defence products. This fund has been set up to be utilised for new technology development and each project will be funded upto 90% of the total cost if it is an amount under Rs. 10 Crore. Additionally, the formation of Defence Innovation Organisation (DIO)[9] to manage Innovation for Defence Excellence (iDEX) by the DPSUs HAL and BEL to promote engagement with MSMEs, startups, individual innovators and even academia incubators has opened up avenues for better collaborations. As far as academia is concerned, DRDO engages with premier institutes across the country such as IIT Delhi, IIT Bombay, IIT Madras and others for active research collaborations. These were established as Centres of Excellence (CoE) but currently perform only a tertiary role in the defence R&D landscape.

5. Issues in the Indian Defence R&D sector:

While India's arms imports have decreased in recent years[13], the fact that it still remains one of the largest importers of defence equipment in the world warrants a few questions: Is Indian defence R&D not up to the mark in developing state-of-the-art military equipment? Despite having the best scientists working in modern laboratories in tandem with industry giants, why does the Indian defence industry need to rely so heavily on imports? There is perhaps a simpler answer to these questions and a more thought provoking one as well. The simple answer would be that India needs to increase its defence budget and consequently its defence R&D budget as well while reducing its reliance on foreign imports. In the larger scheme of things though, one also needs to analyse the current state of defence R&D in India and the current geopolitical situation.

DRDO's shortcomings: DRDO's failures have been well documented in a variety of reports. Unviable projects, exorbitant project costs, extended delays in delivery and sub-par quality of end products are some of the phrases that have consistently defined DRDO's performance over the years[10][11]. DRDO has often indulged in futile projects such as development of assault rifles, sub-machine guns and sniper rifles that lingered on for decades, causing not only delays in delivery, but also monetary losses. Another example of DRDO's lack of project planning is clearly visible in the development of the Kaveri turbofan engine project; commissioned in 1986 but 34 years later, the project is stuck in limbo but DRDO has still not pulled the plug. A test audit report by the Comptroller and Auditor General (CAG) examined the working of Aeronautical Development Establishment (ADE), revealing that the lab took up projects aimlessly without any focus and priority[10]. Furthermore, even for completed projects, there were no buyers, pointing to a clear case of not designing products according to user needs[10].

Mismanagement of projects: It is visible that DRDO has not succeeded in its mission to indigenise the defence sector, a theme that the organisation initially aimed to create. Needless spending on

unviable projects has amounted to a case of throwing good money after bad. Rather than accepting its failure with projects like the Kaveri turbofan engine, the DRDO has doggedly stuck to it. Had this persistence resulted in completion of the project, it would still have made sense but at this point, having already spent Rs. 2035.56 crore and 3217 hours of engine testing, the project is nowhere near completion[12]. The Light Combat Aircraft Tejas, for which this engine was originally developed, is currently using an imported engine due to mismatched configuration demands[12].

High rejection rates of domestic products: Additionally, it has been found that the Armed forces have rejected 70% of the products developed at the Armament Research and Development Establishment (ARDE), Pune in the past 15 years[10]. The reason for such high rejection rates has been attributed to non conformance to the required standards. Not only does this indicate a violation of the basic design principles but also goes to show a lack of synergy between users and the technology development centre.

High percentage of imports without full technology transfer: It is worth noting that India is one of the biggest importers of military arms in the world accounting for approximately 11% of share in global imports between 2017-2021[13].

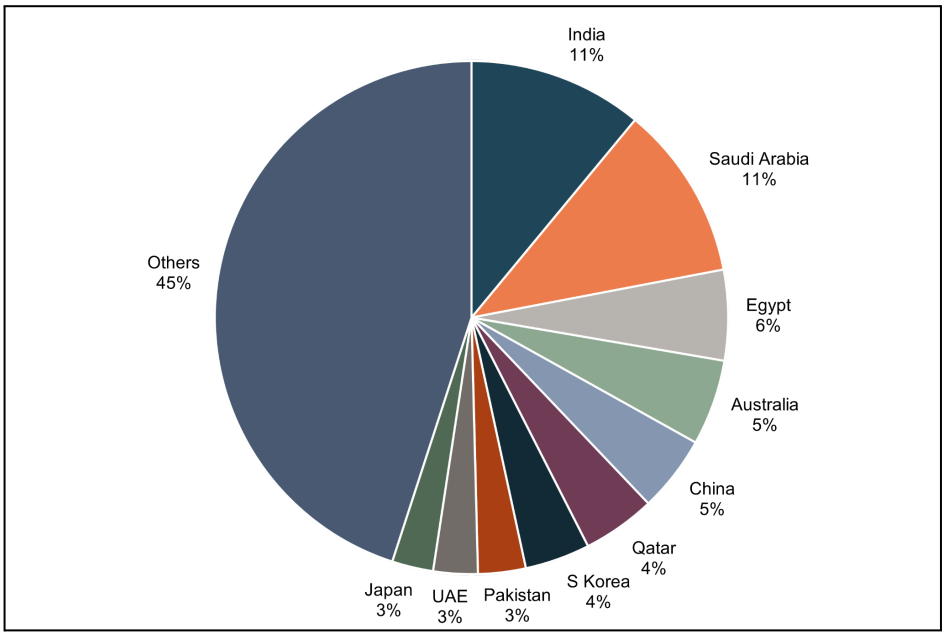

Figure 5: Share of Global arms imports (2017-2021)[13]

Table 3 throws light on India's defence procurement over the years and the distribution among Indian and foreign vendors. It can be seen that between 2014-2020, the average share of military procurement through foreign vendors was approximately 42%. A Standing Committee report found that almost 40-60% of the content being used to develop platforms by Hindustan Aeronautics Limited (India's premier Defence PSU for Aerospace and Defence) was being imported[14].

Table 3: Total procurement from foreign and Indian vendors (2016-17 to 2020-21) (Rs crore)[15]

Year	Total procurement	Foreign vendors	Indian vendors	% of Procurement through foreign vendors
2016-17	69,150	27,278	41,872	39%
2017-18	72,732	29,035	43,697	40%
2018-19	75,913	36,957	38,964	49%
2019-20	91,004	38,156	52,848	42%
2020-21	1,18,860	42,768	76,092	35%

Further, technology transfer is another issue that caused India to lag behind in acquiring and developing latest technologies. The unwillingness of foreign defence companies/ governments to transfer design and technology[16] to India through imports coupled with a lack of India's domestic defence R&D capabilities has led the country to a perennial state of playing catch up to the latest technologies through imports rather than developing any worthwhile domestic expertise around them. Transfer of Technology (ToT) entails the divulgence of technological 'know-hows' but not the 'know-whys' which limits the importers' level of scientific knowledge to merely assembling, testing, operating and maintaining the products[17]. On the other hand, a 'know-why' capacity is built through extensive research and iterative experimentation, something exporters are unwilling to share. Building the 'know-why' capability subsequently elevates the nation's R&D level for scientific discoveries of its own.

R&D monopoly: DRDO currently enjoys its stature as the country's premier defence R&D body. A highly regulated structure has always kept the industry away from playing a major role in defence sector R&D. This monopoly has time and again affected the armed forces as delays in delivery and sub-standard products have been rampant in the case of state owned enterprises. The government's efforts to push the private industry towards defence manufacturing has always met with opposition from DPSUs[18], which has negatively affected the growth and adoption of new technologies.

6. The way forward:

Now, more than ever, the need for restructuring the DRDO on a fundamental level is perhaps one way to go forward. Another easily identifiable route is opening up the defence sector to private industry for research and development. **The latest budget (2022-23) does seek to address these challenges by setting aside 68% of the capital acquisition budget for procurement from the domestic industry in addition to earmarking 25% of the R&D budget for the private industry including startups[19]**. Enhancement of the FDI limit in the Defence Sector up to 74% through the Automatic Route (from 49% since 2014) for companies seeking new defence industrial licence is another step in the right direction. Increasing the R&D budget of DRDO, the country's premier defence R&D organisation makes for a case in itself but given the high rates of failure and delays, the government should take into consideration the resources at their disposal and past track record.

It would perhaps make sense to look at some of the world's military superpowers to try and understand their defence R&D structure. Similar exercises have been done in the past when the Kelkar committee report[20] and the Rama Rao committee report had both looked at USA's Defence Advanced Research Projects Agency (DARPA) and suggested a similar model be followed in India as well. This paper intends to look at other global models to come up with suggestions that are possible to implement in the Indian scenario.

7. Global Defence R&D trends:

USA

USA's defence R&D expenditure dwarfs every other country's outlay. In 2019, USA spent Rs. 7,20,067 crore on defence research and development activities[21]. This figure is higher than some nations' entire defence budget. The US has consistently been spending approximately 13-15% of their defence budget on R&D[22].

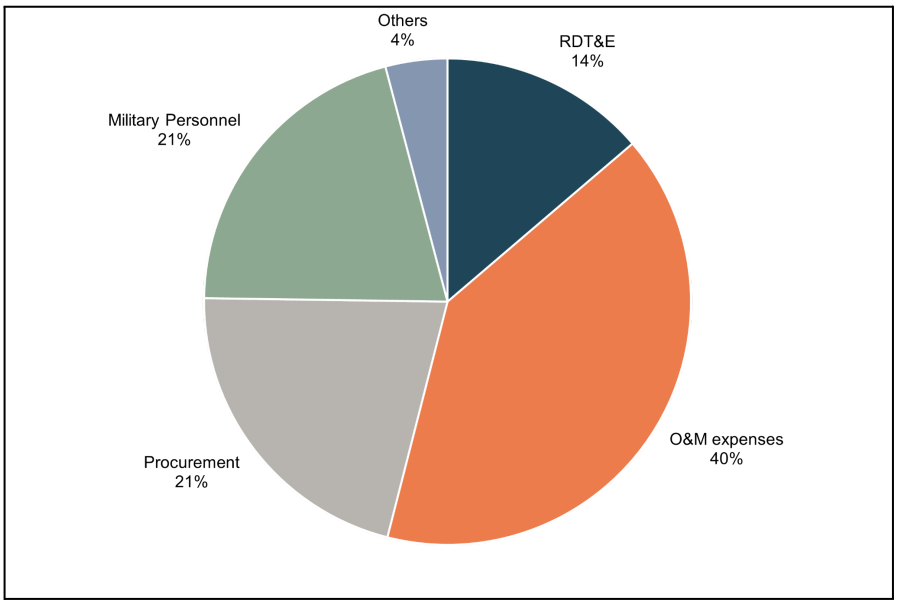

Figure 6: US Defence budget split 2019

The Department of Defence (DoD) is the country's largest governing body and supports the nation's military endeavours. The US DoD is divided into 5 departments as shown in Figure 7. Each department has its own R&D capacity albeit the Defence Advanced Research Projects Agency (DARPA) which reports directly to the Office of Secretary of Defence.

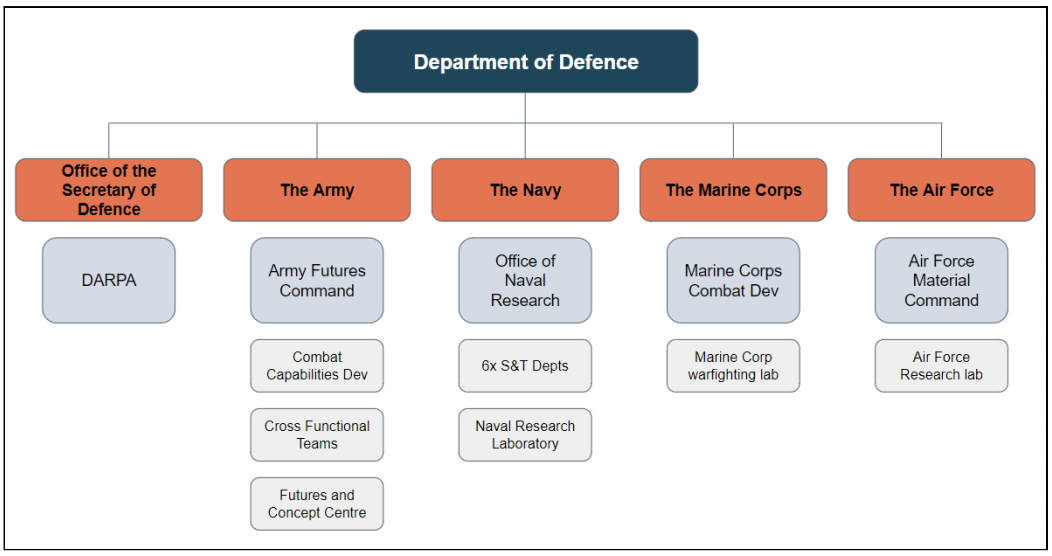

Figure 7: US DoD Structure[23]

DARPA functions to identify projects of a High risk, High reward nature[23]. The agency does not have any labs of its own but rather it works by funding projects identified by a team of program managers who have been given autonomy over resources and decisions. The project stakeholders can be the private sector industries, private or public research labs or even universities. The agency's working principles expect products to be highly innovative and capable of breaking technological barriers. Such high standards give rise to a number of failed projects but even rejections and failures are seen as pillars of groundbreaking R&D. It is important to note here that projects taken up by DARPA are time bound and typically last for 3-5 years[23]. What makes it even more interesting is that DARPA program managers can, at any time, close a project if they feel it is not ambitious enough and redirect funds elsewhere.

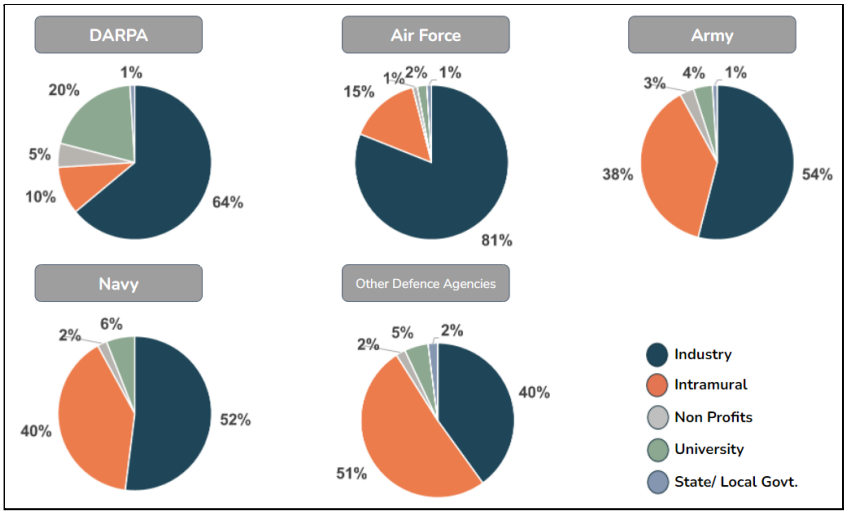

Figure 8: DoD Obligations by agency and performer FY 2019[24]

Figure 8 explains the share of stakeholders in R&D activities across US defence agencies. It can be seen that Industry is the biggest contributor to R&D expenditure in the US defence sector. Industry R&D funding has increased at an exponential rate in the US after 1960. From 1960 to 2019, the

federal government's share of total U.S. R&D fell from 65% to 21%, while industry's share more than doubled from 33% to 71%[25]. This was a result of industry's growth during the time (almost 15 times of its value in 1960). Opening of the defence R&D market not only increased competition among various stakeholders but also allowed the Government to take back seat and oversee rather than jostle with leaner and more efficient players more accustomed to the fast-paced environment.

China:

China's share of global R&D growth has seen a significant rise from 4.9% in 2000 to 23.9% in 2019[26], second only to the USA (refer Table 4). Although the Chinese model to acquire technological know-how has been slightly different and even criticised by some, there is no denying that the nation has achieved its status among global technological giants. China's success in this arena has been carefully crafted by their government over a number of years through policies that aid foreign direct investment, acquisition of technical and business expertise from US based companies, sending Chinese students to STEM universities across the world to study and get trained in future technologies and even building upon open source information in addition to demanding technology transfer from companies as a price against which to enter the country.

Table 4: Nations with largest share of global R&D expenditure (2019)[26]

Country	Percentage share of global R&D
USA	29.9%
China	23.9%
Japan	7.9%
Germany	6.7%
South Korea	4.7%
France	3.3%
UK	2.6%
Russia	2.0%

Much of Defence R&D has been traditionally dominated by the 11 State Owned Enterprises (SOE's) but in a recent shift, the Chinese government has realised the importance of Military-Civil Fusion (MCF)[27] and the apparent contribution to R&D by the private sector. This shift in strategy stems from the understanding that dual-use technologies have implications in both military and civilian sectors. The MCF's target is to anchor emerging and high technologies such as Artificial Intelligence, Robotics and Advanced Materials developed for civilian use, to boost military capabilities.

The success of the MCF model can be attributed to the Chinese policymakers who saw it as a strategic opportunity in the early 2000's. In 2010, not even 1% of China's civilian higher technology enterprises were involved in the defence sector but the Chinese leadership was impressed with USA's defence system which relied on partnerships between the government and private sector[28]. This led to the rise of MCF plans which were incorporated into the country's 2006 National Medium and Long-Term Plan for the Development of Science and Technology (2006-2020). Coupled with

attracting and developing scientists and engineers to further the nation's military prowess by using the Western economies' openness, the MCF approach led to transforming the Chinese defence sector into a technologically superior entity within a short span of time as compared to its geographical neighbours.

France:

France is one of the largest exporters of military equipment in the world with a share of around 11% in global exports of major arms between 2017-2021, next only to Russia (19%) and the US (39%)[13]. India is the largest client of military equipment for France with imports having increased tenfold between 2017-2021[12]. This increase can largely be attributed to the purchase of Rafale fighter aircraft and its delivery during this period.

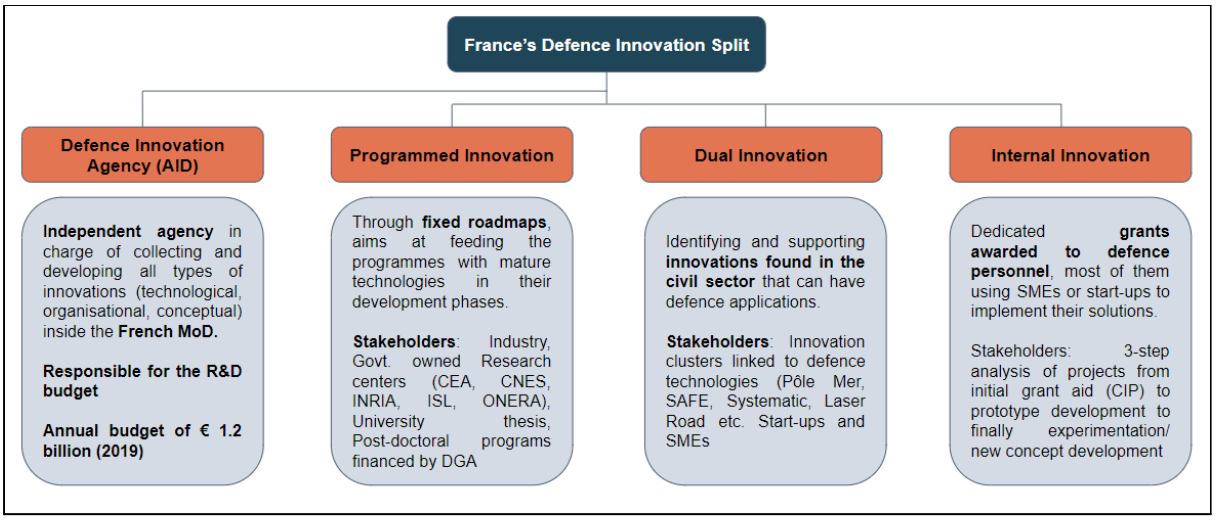

Figure 9: France defence industry innovation[29]

France's defence R&D structure split as shown in Figure 9 comprises verticals that focus on different areas and at varying levels of delivery times. Programmed Innovation focuses on R&D through defined roadmaps usually working on long term projects. Stakeholders can include the industry or government owned research facilities or even universities. The second vertical is Dual Innovation which looks at identifying dual-use technologies from the civilian space that can aid military development. Innovation clusters have been defined for the same such as the Aerospace Valley, a congregation of companies, universities and research centres in the field of aviation and space flight. Internal Innovation vertical seeks to award grants to defence personnel with ideas and innovative solutions who can work in conjunction with SME's or startups. Funds are granted for a prototype build which is then progressively assessed at 3 levels with the product maturing at every stage and finally sent into development and production for use in the armed forces. The Defence Innovation Agency (AID) is an autonomous body formulated to address all innovations inside the French Ministry of Defence. It is also responsible for the R&D budget allocations and aims at being a quick response team to assure quick turnaround. AID pilots all innovations with relevant stakeholders such as research centres, defence clusters, etc. The French defence R&D model addresses innovations

through different lenses realising that technological breakthroughs require different levels of intervention and expertise.

Russia:

Russia held the second largest share in global exports of major arms in the period between 2017-2021 at 19%, behind only the USA (39%)[13]. Though Russian arms exports have fallen in recent years (from 24% global share between 2012-16 to 19% between 2017-21), it still holds a significant share. India has been one of Russia's biggest clients of arms exports accounting for about 69% share of the country's exports in the period 2012-16 but the share took a dip to 46% in 2017-21 owing to India's shift to French imports and an overall reduction in dependence on foreign imports[13].

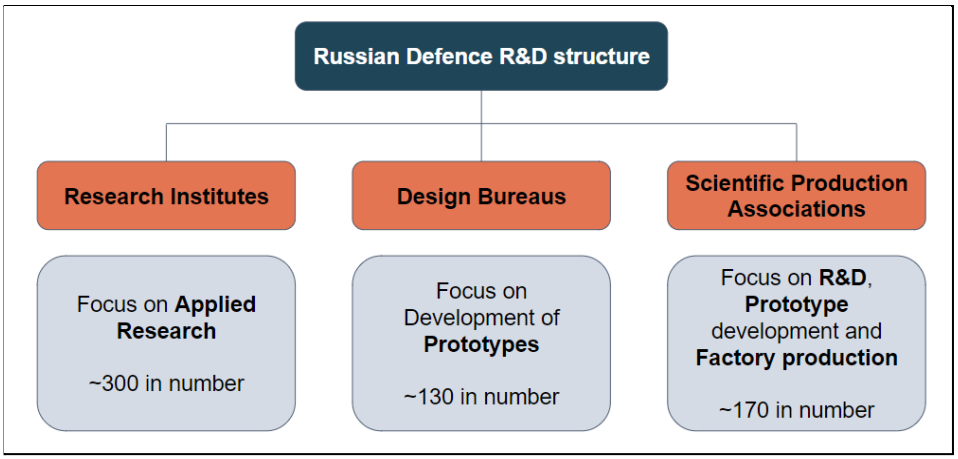

Figure 10: Russian Defence R&D structure[30]

The Russian Defence R&D sector is primarily controlled and funded by the government through state owned holdings such as Rostec which further controls most of the Russian defence corporations like United Aircraft Corporation, Kalashnikov, Uralvagonzavod, Russian Helicopters, High Precision Systems among others. Russian defence R&D is divided into 3 main components as illustrated in Figure 10. Research Institutes conduct applied research and are recipients of the majority of defence R&D budget. Design bureaus focus on designing and developing prototypes to be sent for factory production. Scientific Production Associations integrate the entire process from scientific R&D to prototyping to factory production under one roof. It is important to note here that, in 2012, the government established the Fond Perspektivnykh Issledovanii (FPI)[30], often translated as the Advanced Research Foundation, in order to expedite the development of breakthrough high risk R&D, modelled on USA's DARPA. While the Russian defence industry is among the top five in the world, it is well documented that concerns exist in terms of defence innovation. Studies have attributed extensive corruption, bureaucracy and an overbearing Soviet past to a lack of realisation of the full potential of Russian defence innovation[30].

Israel:

Israel being one of the highest spenders on R&D as a percentage of GDP[31] is testament to the fact that the country today stands as one of the most technologically advanced nations in the world. Israel's sustained focus on developing R&D capabilities has positioned it today as one of the major exporters of technically advanced systems with major expertise in defence R&D. The arms embargo in 1960's by France led Israel to invest heavily into defence R&D[32]. The government and Industries work in partnership to produce R&D for that is ultimately used by the Israeli Defence Forces.

Table 5: R&D expenditure as % of GDP (2020)[31]

Country	R&D expenditure as % of GDP
Israel	5.4%
South Korea	4.8%
USA	3.4%
China	2.4%
France	2.3%
UK	1.7%
Russia	1.1%
India	0.7%

Major stakeholders in the Israeli defence industry include Israel Aerospace Industries (IAI) (Government Owned), Rafael Advanced Defence Systems (RAFAEL) (Government owned), ELBIT systems (ELBIT) (public company) and Israel Military Industries (IMI) (Government owned). The ten largest defence enterprises account for approximately 75% of Israel's Defence base along with approximately 300 small scale industries working in tandem[33]. Israel also has active R&D participation by young individuals under the 'Talpiot'[34] program, wherein the brightest students are handpicked and trained in STEM subjects. Thereafter, they choose projects where there is high scope for innovation and new technology development. Further, a lot of innovative research projects are initiated by military personnel in partnership with MSMEs and startups. The idea of having multiple channels for nurturing research into active products is the focus in the Israeli defence sector.

8. Considerations for National Defence R&D:

The ever increasing pace of global scientific research and technological breakthroughs makes it imperative for any R&D organisation to invest heavily and continuously in these activities. Defence R&D is of paramount importance to any nation in order to mitigate risk and uncertainty when it comes to national security and defence strategy. Not only does it improve military capability but defence R&D also creates knowledge and innovation, an all-encompassing force capable of withstanding today's asymmetric threats. A nation's defence preparedness hinges a lot on the state of its military resources and thorough planning and a long term vision are required to enhance this level. One of the most important considerations a national government must take into account is whether they want to

be a knowledge creator in the field of defence R&D or a consumer of ready-to-use products[35]. While it is not necessary to choose either one over the other, there must be a vision in place to position national priorities after thorough deliberation.

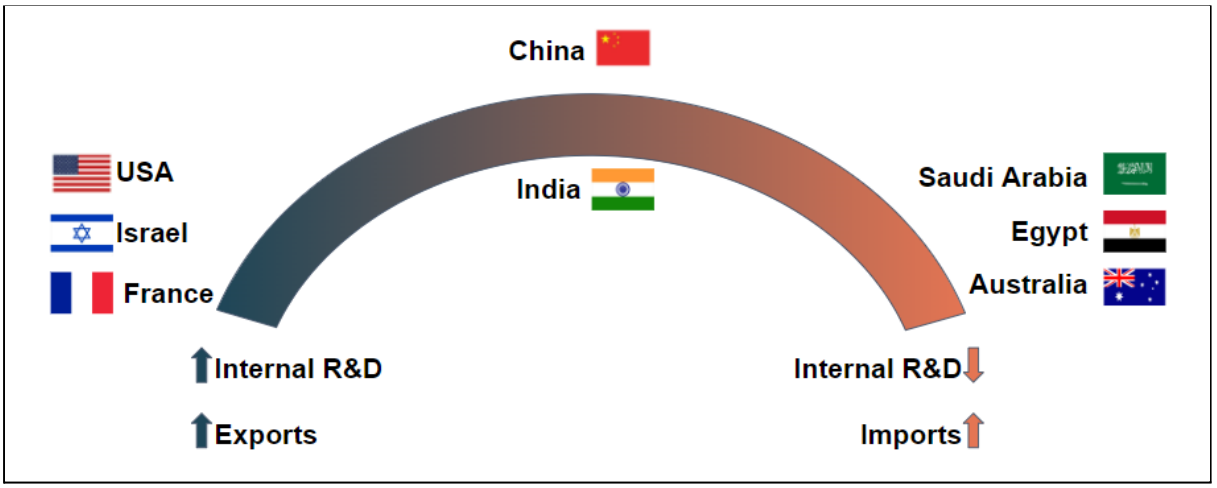

Figure 11: Defence priorities comparison

At this point it is necessary to take a look at where India sees itself between the two ends of the spectrum. From Figure 11, it can be understood that countries like the USA, Israel and France see themselves as knowledge creators, while nations like Australia, Egypt and Denmark can be considered as consumers of ready to use products. Global defence imports v/s exports provides a data driven take on this analysis[13]. Interestingly, China can be seen to be somewhere in the middle, seeking to create a knowledge base that has grown significantly in the past 20 years but at the same time importing critical technical expertise at a similar pace. In the current scenario, this may well prove to be the way forward - building long term capacity on one hand to create a ready R&D output for the future, while on the other, acquiring established technology for immediate use and study. This approach allows for a steady reduction in imports over a period of time while technological capabilities improve simultaneously.

India seems to be on a similar trajectory as China albeit not by design. India has found itself in such a position due to an inefficient defence R&D ecosystem. The country's defence imports have, in the past, been consistently high and though the Government's recent shift from foreign dependence to focus on local is appreciable, the problem that remains is the level of native support that the armed forces will receive. India's premier defence R&D agency, DRDO has been fighting long lost battles that some believe have cost the armed forces two technological cycles worth of advancements[36]. Delays in delivery and sub-optimal products are not the way to empower a nation's military. With the latest Union Budget (2022-23) opening up avenues for private industry and academia to participate in defence R&D, the Government seems to be clear on being open to external partnerships but a lack of structural clarity remains[37].

What the Indian defence R&D structure needs is a change at a fundamental level. It needs to take cue from some of the global practices while at the same time take into account the current resources available. Changes required at the structural level are discussed in the following section.

9. Recommendations:

The Indian defence R&D ecosystem is in dire need of an upgrade and one of the key drivers of the proposed shift are collaborative R&D activities. Much of the research conducted in the country today occurs in silos without fully realising the might of collaborative efforts. Given below is a framework of the proposed engagements envisioned for different stakeholders in the Indian defence R&D sector.

	Mission Centric Projects	Long Range Projects	Existing	Proposed
Industry			★ Industry role limited to licensed manufacturer ★ Very few incentives to participate in R&D	★ Industry to drive collaborations in mission centric projects ★ Long-term, open-ended research through an independent, DARPA analogous agency formed as a SPV under GoI's allotment of 25% of R&D budget to private industry and academia
Academia			★ Partnerships exist but notable R&D activities non existent	★ Academic CoE's to participate in long range projects involving fundamental and applied research ★ Government labs to be used by academicians to collaborate with industry for mission centric projects
Government			★ Government is the primary funder of defence R&D ★ DRDO the sole defence R&D performer	★ Government to act as a facilitator in bridging gaps and providing common ground to industry and academia for furthering defence R&D ★ Government to rework technology transfer policy to receive as much 'know-why' as possible on imports ★ Assessment of technology needed for developing R&D capability for the future
Services (Army, Navy, Air Force)			★ Current role of an end user/ consumer of products only	★ Services to have individual R&D units to focus primarily on mission centric outcomes ★ Active involvement in testing and feedback of research outputs
International partners			★ Import of foreign technology without adequate technology transfer	★ Basic research projects to be sought with international defence production giants ★ Arrangements for IPR ownership needed to provide benefit to Indian defence R&D ecosystem

Figure 12: Framework for stakeholder engagement. ***Note: Shaded area represents share of involvement***

1. Industry to establish a DARPA analogous agency: The Union Budget 2022-23 proposes an outlay of 25% of the Defence R&D budget to be earmarked for the private industry and academia for taking up design and development of military platforms through the Special Purpose Vehicle (SPV) model. This presents us with the opportunity to build an agency analogous to DARPA of the US that will focus on 'Long Range' projects. This program will focus on identifying long-range research projects with futuristic applications and will entail both basic and applied research. While it may not be necessary that all projects initiated under this format actually see the light of the day, it will be absolutely critical for the agency to pull the plug on unviable projects under its purview beyond predefined cost overruns to channelise funds for research elsewhere.

For such a DARPA kind agency to prosper, it will require active engagement between DRDO facilities (DRDO labs, Centres of Excellence, DPSUs) as well as private industry. What is perhaps most important is that this agency will need to be developed as a new-gen organisation directly under the control of the Ministry of Defence and function at a level equivalent to DRDO. The government's inclination towards localisation of Defence R&D will need the current system to move away from DRDO's sustained monopoly to a competitive and thriving ecosystem with substantive participation from industry and academia.

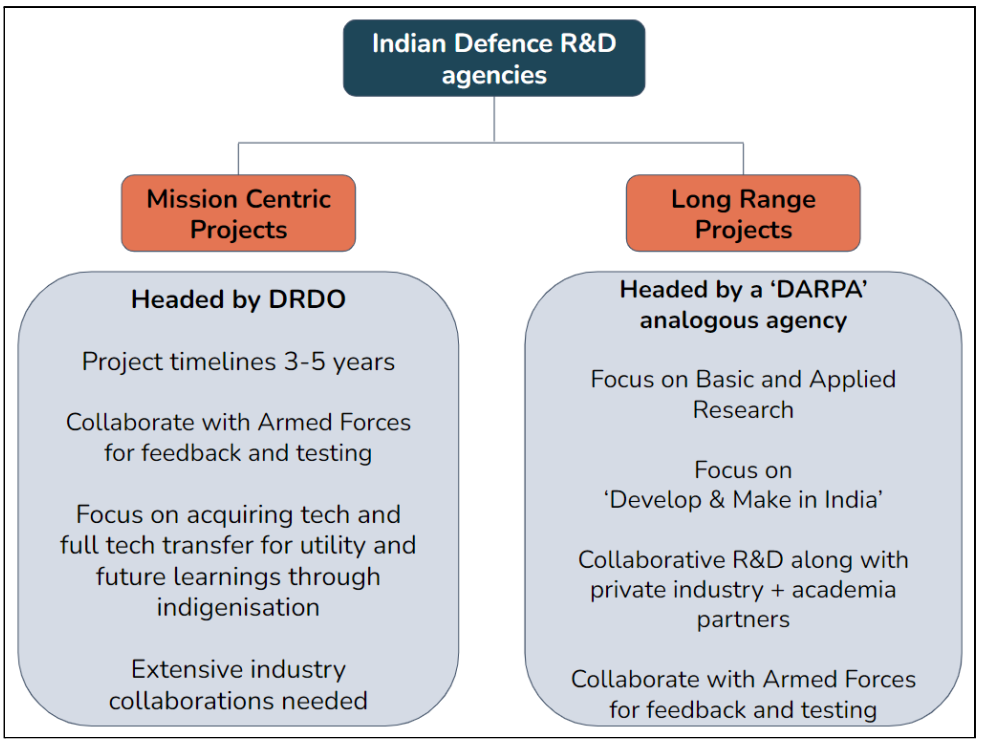

Figure 13: Indian Defence R&D Workflow

2. Categorisation of technology to assess domestic development readiness: While the Indian government has made amply clear its stance of reducing dependence on foreign imports to be of prime importance, it is imperative to formulate a system to assess domestic development readiness of technologies. The Indian government should classify technology as a prelude to the Defence Acquisition Procedure (DAP 2020)[38] categorisation. The 5 categories, namely Buy (Indian-IDDM), Buy (Indian), Buy and Make (Indian), Buy (Global - Manufacture in India) and Buy (Global) also need to have a system to judge the technologies on the basis of the following criteria.

Table 6: System to assess Domestic development readiness of technology

Technology	Nature	Requirement	Resources to develop	Cost to develop	Domestic development readiness
	Dual-use **or** Military specific	Immediate use **or** Future use	Available in India **or** not	Lower to develop **or** Import	Import **or** Make in India **or** Develop & Make in India

An assessment of any technology based on the above mentioned parameters should lead to a conclusion which presents a case for its domestic development readiness. For instance, a technology that is specifically required by the military with no civilian use and needed to be procured immediately regardless of the cost ranks low on domestic development readiness. Hence, it makes sense to import the required technology and subsequently study the same to build capability for the future. This translates the technology from 'Mission Centric' to 'Long Range' in terms of R&D. A strong transfer of technology policy is needed here to allow sharing of as much 'know-why' as possible. Secondly, if a

technology exists that has both civilian and military use that can be important in the future and even if Indian researchers/ industry have limited knowledge of the same, organisations should be encouraged to develop capacity even if it requires importing part of the product. Another combination exists wherein a dual-use technology that has scope for future development and also has resources available in India, the index is high and therefore should definitely be fully designed and developed locally. The matrices below show examples of technology assessments.

Technology	Nature	Requirement	Resources to develop	Cost to develop	Domestic development readiness
'X'	Military	Immediate	Not Available in India	High	Rank Low: Import

Technology	Nature	Requirement	Resources to develop	Cost to develop	Domestic development readiness
'Y'	Dual-use	Future	Limited in India	High	Rank Medium: Tech transfer + Develop local

Technology	Nature	Requirement	Resources to develop	Cost to develop	Domestic development readiness
'Z'	Dual-use	Future	Available in India	Low to Medium	Rank High: Design and Develop Local

The reasoning behind the assessment stems from the Indian government's sustained efforts to move away from the current dependence on importing defence technology. The long term goal of this exercise should be to improve domestic development readiness by increasing the number of resources available in India to conduct high calibre R&D activities. As long as the country continues to grapple with a paucity of local resources, the dependence on imports shall remain high. Efforts to change this requires engagement from the private sector, the academia and state owned defence enterprises in equal measure.

3. Extensive involvement of Armed forces: Another area of focus in the proposed structure is the involvement of the armed forces (Army, Navy and Air Force) in every vertical right from research to development and manufacturing. Currently, the armed forces serve only as users of products and as previously mentioned, there exists a huge disconnect between them and the technology development agencies. Not only this, the proposal also suggests individual R&D units to be set up by the armed forces akin to the US model. These R&D units shall serve their respective verticals of the armed forces and will aim to perform tactical research and prototyping of projects led by military personnel themselves. Research support needed will be provided by various Military Academies such as College

of Military Engineering, Military College of Telecommunication Engineering in addition to academic Centres of Excellence under DRDO. Development of prototypes can be conducted in partnership with Defence PSUs, SMEs or even startups. The Indian Navy has already shown the way through the inception of the Naval Innovation and Indigenisation Organisation (NIIO)[39], a body formulated to encourage self dependence in naval defence capabilities through interactions with industry and academia. Similar efforts are also needed within the Army and Air Force.

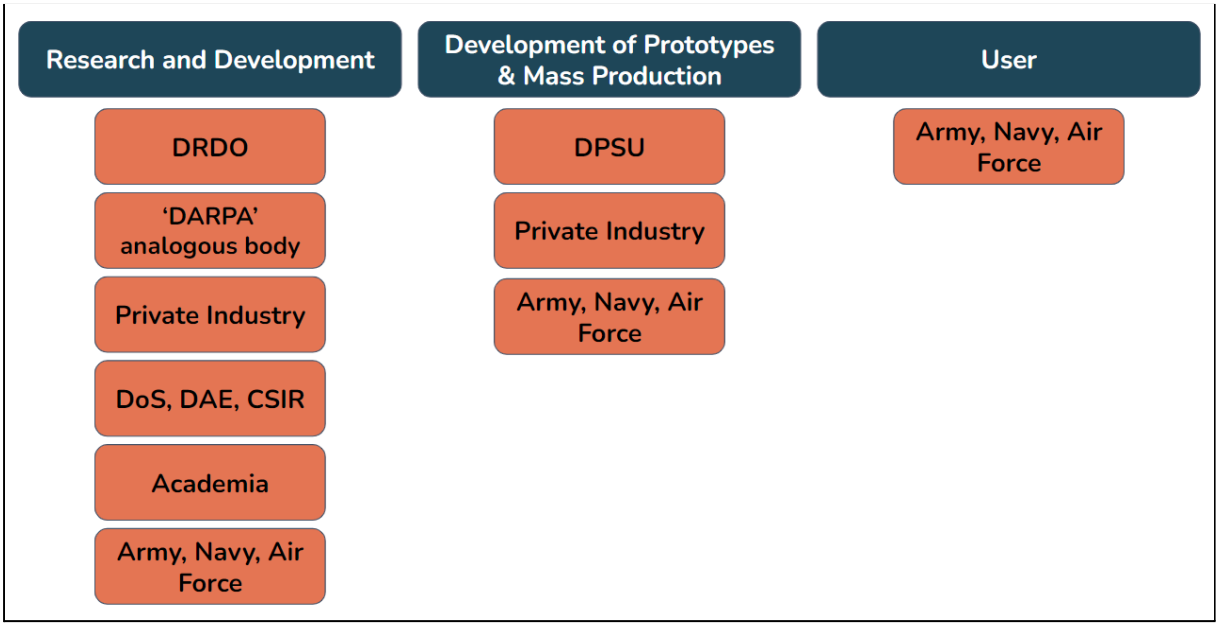

Figure 14: Proposed Defence R&D structure

4. Basic Research projects with global defence enterprises: While imports and technology transfer opportunities are beneficial in the short term, seeking to keep pace with the latest advancements across the world, it is equally necessary to build the nation's scientific capabilities in research and development. For the same, international collaborations can be sought for fundamental research while arrangements need to be sorted out to own the intellectual property rights of the research findings in India. Ownership of IPR needs to be resolved on priority to keep learnings, licences and profits stemming from any research within the country. The Indian government can seek to build such partnerships with companies like Lockheed Martin, Boeing, SAAB among others. Research programs can be opened up to students of Centres of Excellence (CoE) and researchers of DRDO labs. Focus on basic research and ownership of IPR can at least put India on the path towards self-reliance in defence R&D.

5. Private industry participation: Private industry participation statistics across the globe in terms of defence R&D have already been highlighted previously. Industry's lack of involvement in defence R&D has hampered the technological development of the entire ecosystem. It is high time the industry is given its chance to compete with the likes of DRDO and DPSUs. The proposed structure of setting up an agency like DARPA to drive long range projects can provide the industry a platform to explore joint ventures and other avenues for collaboration. Structures that explore joint R&D programs with DRDO or DPSUs could also be a possibility wherein the private sector establishments can bring in technical expertise to DRDO facilities or vice versa. Perhaps existing efforts such as the Defence Innovation

Organisation (DIO) can be expanded to include private sector enterprises in addition to HAL and BEL as well. This step will not only drive up the funding of projects but also scale up the speed of new technology absorption.

10. Conclusion:

The Indian defence sector has been playing a catch-up game with the latest technologies and their global suppliers for some time now and the trend will not show any desired change if the defence R&D sector is not reviewed and reformed for far-superior outcomes. The R&D budget is too insignificant in comparison to major global military spenders which explains India's shortfalls in building a noteworthy domestic defence industry. The difference in R&D expenditure between India and our neighbour China is vast enough to merit a serious discussion given the current geo-political climate. Even South Korea, a relatively new entrant in the global Science and Technology space, is ahead of India in terms of defence expenditure on R&D.

A wide industrial base from which research can take a quantum leap is the need of the hour along with an inclusion of the entire ecosystem to work collectively towards research that strengthens national security. While the government has already made its intentions clear on having a more local footprint on defence R&D, a few structural gaps may need to be addressed. One of the biggest takeaways from findings listed in this paper is that monopolisation of R&D with DRDO has stymied the growth in the Indian defence landscape whereas a more competitive environment is the way to move forward. Studying the global context has also shed light on the effect of active participation of private industry on defence R&D capabilities and provides us with some successful global models to replicate. There is also a need for a long term vision and an achievable roadmap that paves the way for increasing the country's defence R&D capabilities. The fruits of this labour will probably be visible in decades to come, but only if milestones are set, monitored periodically and outcomes realised consistently.

11. References

[1]https://prsindia.org/budgets/parliament/demand-for-grants-2021-22-analysis-defence
[2]https://prsindia.org/budgets/parliament/union-budget-2021-22-analysis#:~:text=Expenditure%3A%20The%20government%20proposes%20to,higher%20than%20the%20budget%20estimate
[3]https://www.indiabudget.gov.in/
[4]http://164.100.47.193/lsscommittee/Defence/17_Defence_22.pdf
[5]https://www.mod.gov.in/sites/default/files/MoDAR2018.pdf
[6]https://www.drdo.gov.in/sites/default/files/inline-files/Support-to-Indian-Industry_1.pdf
[7]https://www.drdo.gov.in/adv-tech-center
[8]https://tdf.drdo.gov.in/scheme
[9]https://idex.gov.in/about-dio
[10]https://www.indiatoday.in/magazine/special-report/story/20120423-drdo-failed-in-its-mission-due-to-delay-high-cost-758057-2012-0
[11]https://www.firstpost.com/india/drdo-decay-part-1-keeping-end-users-in-dark-poor-planning-flouting-of-sops-hurt-uav-projects-reveals-cag-test-audit-8092171.html
[12]https://www.thehindu.com/news/national/india-to-develop-jet-engines-for-aircrafts/article37762645.e
[13]https://www.sipri.org/sites/default/files/2022-03/fs_2203_at_2021.pdf
[14]http://164.100.47.193/lsscommittee/Defence/17_Defence_7.pdf
[15]http://164.100.47.193/lsscommittee/Defence/17_Defence_28.pdf
[16]https://ur.booksc.me/ireader/32972701
[17]https://idsa.in/system/files/jds/jds_11_3_2017_transfer-of-defence-technology.pdf
[18]https://www.gatewayhouse.in/wp-content/uploads/2020/08/Defense-Industrial-Agenda_Sameer-Patil_2020_Final.pdf
[19]https://economictimes.indiatimes.com/news/defence/25-rd-budget-reserved-for-private-industry-in-defence-manufacturing/articleshow/89284049.cms
[20]http://164.100.47.193/lsscommittee/Defence/14_Defence_33.pdf
[21]https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2020/FY20_Green_Book.pdf
[22]http://164.100.47.193/lsscommittee/Defence/17_Defence_22.pdf
[23]https://futurewars.rspanwar.net/ideation-for-defence-rnd-in-india-the-us-approach-to-defence-innovation/
[24]https://ncses.nsf.gov/pubs/nsf21329 Table 9
[25]https://sgp.fas.org/crs/natsec/R45403.pdf
[26]https://sgp.fas.org/crs/misc/R44283.pdf
[27]https://www.orfonline.org/research/chinas-military-civil-fusion-strategy/
[28]https://www.cfr.org/blog/civil-military-fusion-missing-link-between-chinas-technological-and-military-rise
[29]https://www.iris-france.org/wp-content/uploads/2020/09/63-Policy-Paper-Def-Innov-France-September-2020.pdf
[30]https://foi.se/report-summary?reportNo=FOI-R--5124--SE
[31]https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm
[32]https://www.cairn.info/revue-journal-of-innovation-economics-2013-2-page-37.htm
[33]https://www.files.ethz.ch/isn/16867/OP25.pdf

[34]https://curiouslog.com/talpiot-israel-super-school-military-tech-sustainable-innovation/
[35]https://kaitseministeerium.ee/sites/default/files/elfinder/article_files/icds_report-defence_r_d-lessons_from_nato_allies.pdf
[36]https://thewire.in/security/defence-spending-hal-drdo-military
[37]https://www.orfonline.org/research/bigger-not-necessarily-better/#_edn16
[38]https://www.mod.gov.in/sites/default/files/DAP2030new.pdf
[39]https://www.indiannavy.nic.in/content/hon%E2%80%99ble-raksha-mantri-shri-rajnath-singh-launches-naval-innovation-and-indigenisation

12. Appendix

Table 7: Breakdown of Defence Budget (in Rs. crore)[3]

Budget Item	Actual 2020-21	Budget 2021-22	Revised 2021-22	Budget 2022-23
Defence Pensions	128,066	115,850	116,878	119,696
Ministry of Defence (Civil)	17,521	15,257	17,587	20,100
Capital outlay on Defence	134,305	135,061	138,851	152,370
Defence Services (Revenue)	205,789	212,028	229,567	233,001
Total Budget	**485,681**	**478,196**	**502,884**	**525,166**

Table 8: Breakdown of Pay and Allowances (in Rs. crore)[3]

Pay and Allowances	Actual 2020-21	Budget 2021-22	Revised 2021-22	Budget 2022-23
Army	96,605	102,918	108,872	116,707
Navy	9,114	10,526	11,077	12,658
Air Force	17,514	17,964	18,919	20,038
R&D	3,613	4,004	3,934	4,270
Total Budget	**126,847**	**135,412**	**142,802**	**153,673**
Salary + Pensions	**254,913**	**251,262**	**259,680**	**273,369**
% of total budget	***52%***	***53%***	***52%***	***52%***