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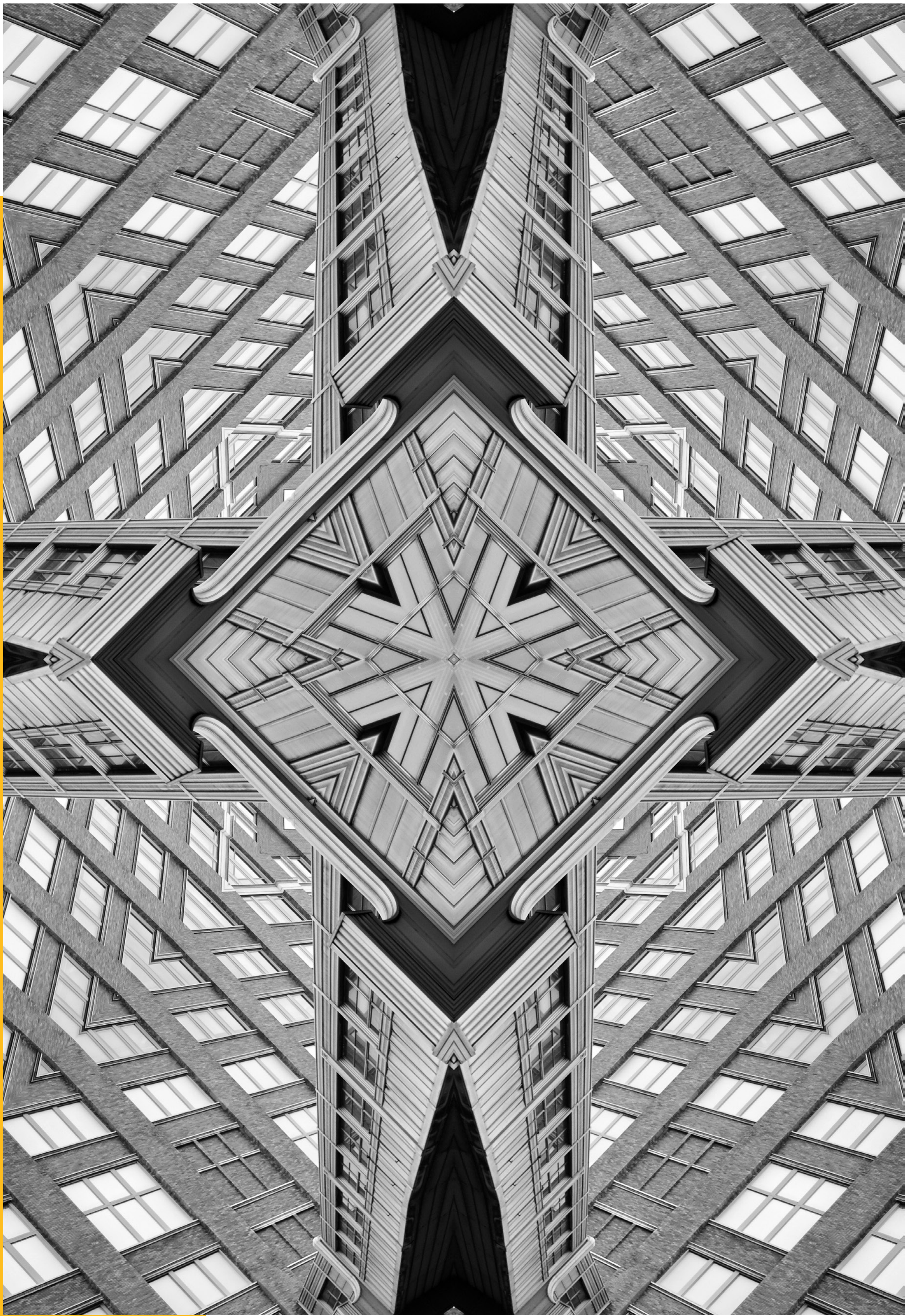

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The Case for Nurturing Military Scientists in the Indian Army

Vivek Gopal

Abstract

Many countries across the world are harnessing disruptive technology to maintain technological superiority over their adversaries. Research and development (R&D) organisations are key to this task. In the defence sector, focused R&D drives critical innovations and product development. India continues to lag in defence technology and remains dependent on imports. A crucial impediment is long product development cycles. Under the current government's self-reliance and indigenisation mission, India must consider establishing a dedicated R&D organisation at the services level of the Indian Army. A robust R&D ecosystem can accelerate technology development and reduce the gestation period of projects. This paper examines defence R&D organisations across countries and proposes a Synergised Army Technology Initiative for the Indian Army.

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Introduction

Many scholars have addressed the issue of defence research and development (R&D) in India, often through the lens of industry, R&D organisations, and military budget allocation. However, the heightened emphasis on indigenous content outlined in the Defence Acquisition Procedure (DAP, 2020) along with the frequent mention of "disruptive technology" in defence technology circles call for the issue to be revisited from another perspective. While there are several R&D organisations in the country, the innovation ecosystem needs reformulation and a new class of scientists—military scientists—who can carry out R&D from a military perspective, device out-of-the-box technology, and deliver prototypes for mass production by leveraging their technical expertise and experience gained within the organisation.

Before discussing the need for the establishment of a military R&D body, the following interlinked terms must be properly defined:[a]

1. Technology:

a. the practical application of knowledge, especially in a particular area

b. a capability given by the practical application of knowledge;

c. a manner of accomplishing a task especially using technical processes, methods, or knowledge new technologies for information storage

d. the specialised aspects of a particular field of endeavour.

2. R&D:

a. studies and tests that are done to design new or improved products

3. Innovation

a. new idea, method, or device

a As defined in the Merriam-Webster Dictionary, Merriam-Webster.com, 2020.

Introduction

4. Novelty

a. the introduction of something new

5. Indigenisation:

a. produced, growing, living, or occurring natively or naturally in a particular region or environment.

Thus, the technological development and progress of the nation are connected, with R&D leading to innovation, and vice versa.[1] Further, terms such as 'indigenisation', 'innovation', and 'R&D' have been used interchangeably in the literature.

Over the past few decades, the technology development cycle has undergone drastic changes.[2] However, the importance of in-house R&D within the military is yet to be properly addressed, due to the somewhat ill-founded premise that the army as an organisation is mandated "just to fight and win wars" as the "defence of the nation" and counter-narratives within research are often viewed parochially. In the 21st century, the armed forces can no longer play an ancillary role by being mere users of technology, and must transition to become developers of technology. Despite a well-established R&D infrastructure within India, projects suffer from prolonged gestation periods and failures, resulting in a blame game amongst the agencies involved. There is a need to not only learn and emulate the concepts and practices of countries that are developing cutting-edge technology, but also reconsider the requirement of a dedicated in-house R&D organisation negating the effect of intra- and inter-organisational impediments, which can arguably be attributed to inherent conservatism, the "frozen middle," or plain inertia.[b]

This paper studies the approaches undertaken by the US, Russia, China, and Israel, amongst others, before postulating what needs to be done in terms of setting up a dedicated Indian Army R&D Organisation.

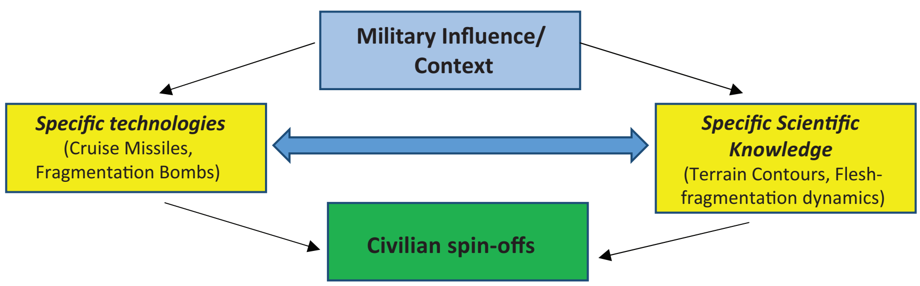
b While DRDO is a military-dedicated R&D body for all the three services, there is a need for in-house R&D organisations. This is based on the premise that the users of the technology should also be leveraged for product development as no one knows the requirements better than the end-user.

Civil and Military R&D: A Historical Perspective

Mowery, in his *Handbook of the Economics of Innovation*,[3] explains the historical relation between military and technology. Between the 16th century and the 19th century, the focus of R&D across the world shifted from demanding weapons, to establishing organised military R&D bodies. The World Wars further transformed the technological underpinnings, influencing innovations as well as military research.

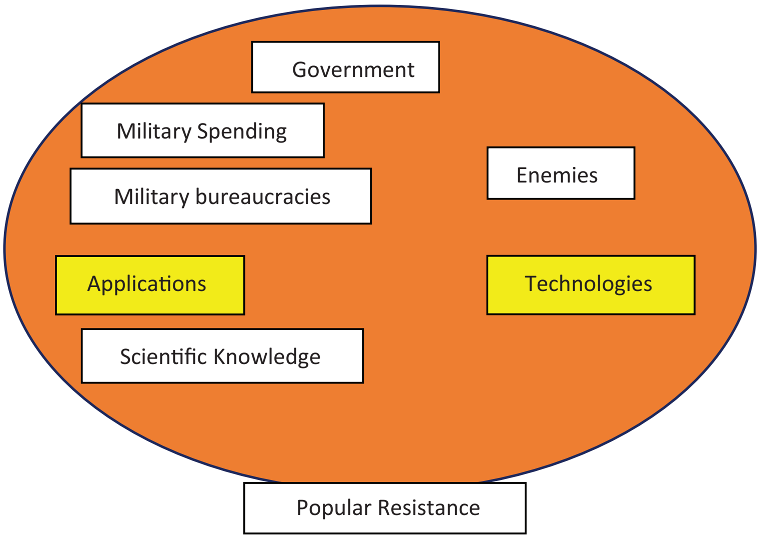
Figure 1 shows how the military used to influence technologies as well as the scientific knowledge required to support the developed technology. Such military knowledge and technology also produced civilian technologies, seen as subsidiary outputs (spin-offs)—less often from specific military technology than from dual-use technology.[4] Figure 2 shows modern military shaping, wherein a mix of various factors influence the decision (compared to the few in Figure 1). Moreover, the arrows from Figure 1 have disappeared and instead, a "soup of interactions" is responsible for the development of scientific knowledge and technology.

Figure 1:
The Military-Shaping Science and Technology



Source: "Militarised Technology," Chapter 2, in Technology for Nonviolent Struggle, *Brian Martin.*

Fig. 2:
The Military Shaping Specific Science and Technology



Source: "Militarised Technology," Chapter 2, in Technology for Nonviolent Struggle, *Brian Martin.*

Schmid, in his work "The Diffusion of Military Technology, Defence and Peace Economics,"[5] highlights the concept of technology diffusion as "the process by which an innovation is transmitted across members of a social system over time." Thus, military R&D influences civil technology development in many ways:

1. Military R&D expenditure may fund institutions or researchers engaged in activities that enhance civilian innovation, e.g. universities being funded by R&D funds.

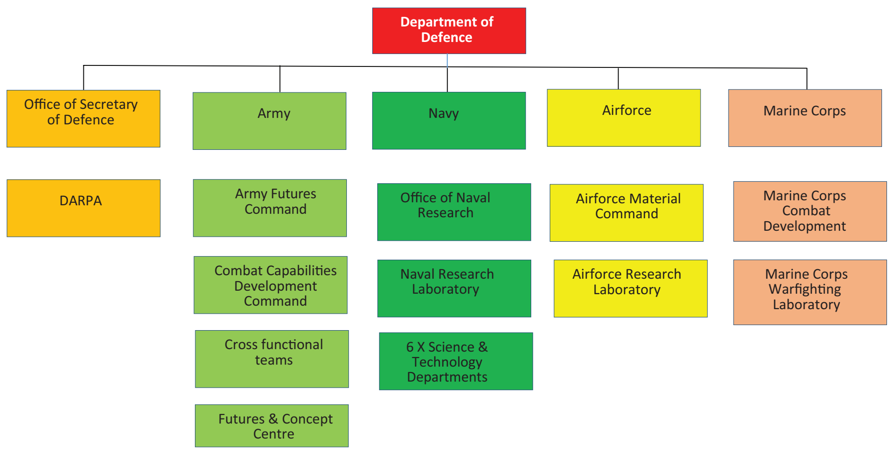
2. Defence spending on procurement activities can increase the demand for technology.

3. It can produce knowledge and new technologies that influence overall growth, as the existing technology base is utilised to develop new innovations.

United States

The US has always focused on developing cutting-edge technology and using it to its advantage during expeditionary operations all over the world. However, over the years, there has been a decline in the share of the US's global as well as military R&D, primarily due to the development of technologies by other countries. In response, the US has tried to re-energise the R&D ecosystem by taking steps such as the appointment of the Under Secretary of Defence (Research and Engineering), to make the organisation leaner and increase interactions with academia and industry. Figure 3 shows the defence laboratories associated with respective department verticals.

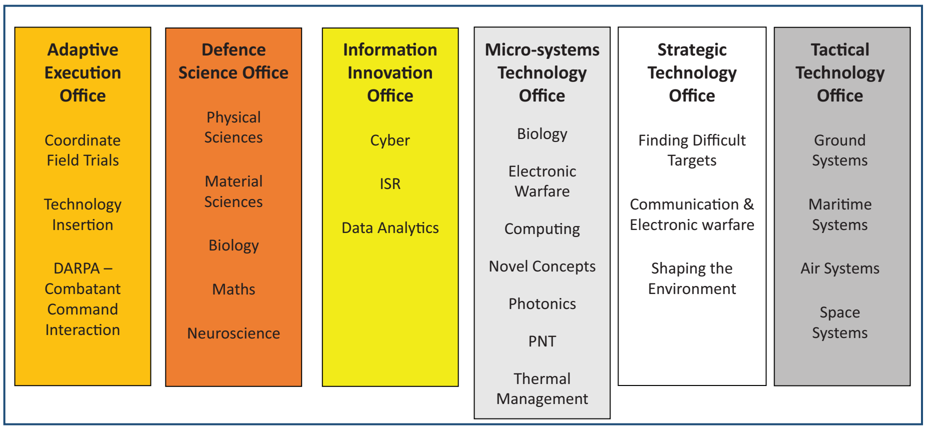
Figure 3:
US Labs Associated with Department Verticals



Source: https://futurewars.rspanwar.net/ideation-for-defence-rnd-in-india-the-us-approach-to-defence-innovation/.

DARPA: The Defence Advanced Research Projects Agency (DARPA) is considered the foremost body for military R&D, and many suggestions have been made by defence analysts in India to adopt the DARPA model. A non-hierarchical organisation, DARPA was established in 1958 in response to the erstwhile USSR Sputnik programme, to conduct oversees creative research and programmes that run for four to six years with high payoffs. It has six technology offices with 140-odd programme managers and a staff of around 250 personnel (See Figure 4). DARPA reviews the proposals it receives and allocates grants to the most innovative breakthrough technologies. Due to the disruption potential of these technologies, the programmes are often classified as "black."[c,6] DARPA's success lies in its ability to steer high-payoff research and convert new concepts into military programmes.

Figure 4: DARPA Organisation



Source: Google/ Open Source.

c Black ops: high-risk, high-reward programmes initiated by DARPA, which have immense disruptive potential to provide the user (US forces) with an unprecedented and high degree of technological asymmetry and is hence classified above top-secret.

The DARPA model is based on trust and autonomy, truncated tenures, and high-risk appetite with acceptance of failure. Strategically, its objective remains to anticipate and counter threats as well as simultaneously advance pathbreaking technologies.[7] Emphasis is laid on foundational research in Science and Technology (S&T), with the aim of "preventing surprise" and maintaining technological superiority and deterrence.

Table 1 provides a view of dedicated R&D labs in the US, with the military departments (See Figures 5a and 5b).

Table 1:
R&D Labs with Military Departments

Department	Associated Lab	Salient Features
US Army	**Army Futures Command** along with "Futures and Concept Centre," and "Combat Capabilities Development Command" and Cross functional teams	Assesses threat and future wars. Leading army scientists form a part of this organisation, which is the army's organic R&D branch. The Army Research Lab[8] is part of this organisation.

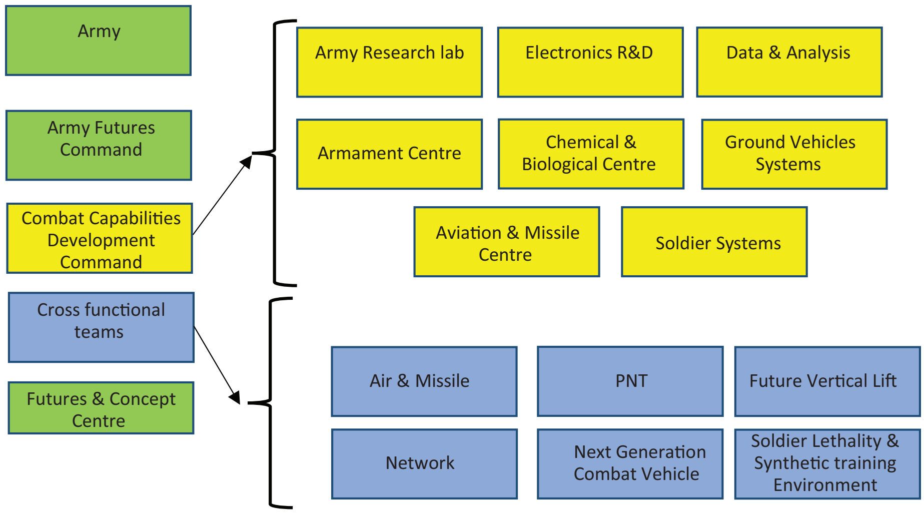
Department	Associated Lab	Salient Features
US Air Force	Air Force Research Laboratory (AFRL) under US Air Force Material Command. Wright Brothers Institute[d] and Cyberworx[e] are also noteworthy	Carries out R&D for the Air Force, with a workforce of nine directorates and nearly 10,000 personnel and various labs across the globe.
US Navy	Office of Naval Research/ Navy Research Lab and Wright Brothers Institute	Code 31 to Code 35 are the departments as listed on the website, with each department divided based on dedicated research areas
US Marine Corps	Marine Corps Combat Development Command	To develop future warfighting capabilities for the Marine Corps
Federally Funded Research and Development Centres (FFRDCs)	Owned by the federal government but operated by contractors, universities, other non-profit organisations.	More academically oriented compared to UARCs
University Affiliated Research Centres (UARCs)	Sponsored by a DoD military service, agency or component. These are located within a university or college and typically receive funding of several million dollars per year.	UARCs provide engineering, research, or development capabilities to the DoD
US Special Operations Command: SOFWERX	The US Special Operations Command (USSOCOM) has established a partnership intermediary agreement with the non-profit Doolittle Institute[9] to implement SOFWERX[10]	Assists in collaboration, innovation, rapid prototyping and exploration

Source: http://futurewars.rspanwar.net/ideation-for-defence-rnd-in-india-the-us-approach-to-defence-innovation/.[11]

Army Open Campus Initiative and Army Venture Capital Initiative:[12] The Army Research Laboratory describes its Open Campus Initiative as "an effort to create strong, enduring S&T partnerships" through the co-location of Army R&D personnel in S&T hubs. US Congress has been supportive of these efforts as well as of DOD-backed venture capital funds, citing the Central Intelligence Agency's non-profit In-Q-Tel[13] as a successful model.

d https://www.wbi-innovates.com/
e https://www.usafa.edu/af-cyberworx/

Figure 5a: Army Futures Command Vertical



Source: https://www.arl.army.mil/who-we-are/.

Army Research Laboratory

Overview

- ARL is the link between the scientific and military communities with the mission to discover, innovate and transition science and technology to ensure dominant strategic land power.
- The lab's research continuum stretches from current operations support to early, long-term, basic research that explores new technologies.
- ARL drives opportunities in power projection, information, lethality and protection, and Soldier performance for the Army of 2030 and beyond using a framework of eight science and technology campaigns - a systematic course of aggressive S&T activities envisioned to lead to enhanced land power capabilities in the deep future.
- Core competencies: materials sciences: information sciences: ballistics; aeromechanics; human performance; survivability, lethality, vulnerability analysis and assessment.
- Major Partners: RDECOM RDECs, PEOs, DARPA, Army Test and Evaluation Command.
- People:
  - o 1,975 civilians
    - • 1,379 scientists and engineers
      - • 552 doctorates, 479 master's degrees, 348 bachelor's degrees
  - o 37 military
  - o 914 contractors

Figure 5b:
US Air Force Research Lab with Directorates

Source: https://www.afrl.af.mil/.

There are numerous other innovation-related organisations in the US, e.g. the Defence Innovation Unit (DIU), the Defence Innovation Branch (DIB), and the Strategic Capabilities Office (SCO). Noteworthy amongst these is the DIU, with its provision to exercise the "Other Transactional Authority,"[f] allowing it to bypass the long tedious channels and procedures, and fast-track a given project.

Thus, the R&D landscape in the US point drives home the importance of having dedicated/organic or captive labs within the defence forces and long-term associations that foster relationships between the developer (innovator) and the user.

f Congress has expanded the DoD's authority to use other transactions (OTs). OT agreements do not have to comply with federal procurement regulations and are generally viewed as giving federal agencies additional flexibility, including the ability to develop agreements that are specifically tailored to the needs of the project and its participants.

Russia

The study of Russian R&D initiatives[14] is important since most imports are from Russia. The Russian philosophy is covered by two schools of thought: the Revolution in Military Affairs (RMA), i.e. doctrine shaping the way wars are fought; and the Military Technological Revolution (MTR), i.e. reliance on technological superiority as a winning factor. Defence-related R&D has been pinned as the decisive factor for national security and as an accelerator of other sectors of the economy.[15]

The Military-Industrial Commission (VPK) under the president coordinates the operations of the defence-industrial complex and implements the innovation strategy of the defence sector.[16] To realise its innovation goals, in 2012, Russia established the Fond Perspektivnykh Issledovanii, or Foundation of Prospective Research (FPI), which aims beyond bureaucratic wars for operations and procurement and has a different professional credo—high-risk, long-term fundamental R&D for breakthrough military and dual-use innovative technology. The FPI has been considered analogous to DARPA.

The defence sector plays a dominant role in the Russian R&D system and in its innovation. It employs 50 percent of all researchers, receives about 35–40 percent of total R&D funding, accounts for 70 percent of all high-technology products, and around 42 percent of its production goes for the civilian market.[17] While some scholars are sceptical about the pace of progress of Russian R&D and how long it has taken to recover after the 1990s,[g] many have appreciated Russia's display of its technological prowess in Syria.

g It was generally perceived by the world militaries that Russia, after 1990, will be slow in terms of R&D as well as defence-related projects. However, the technology demonstrated in Syria as well as in the Armenian conflict have proved otherwise, mainly in the field of Electronic Warfare.

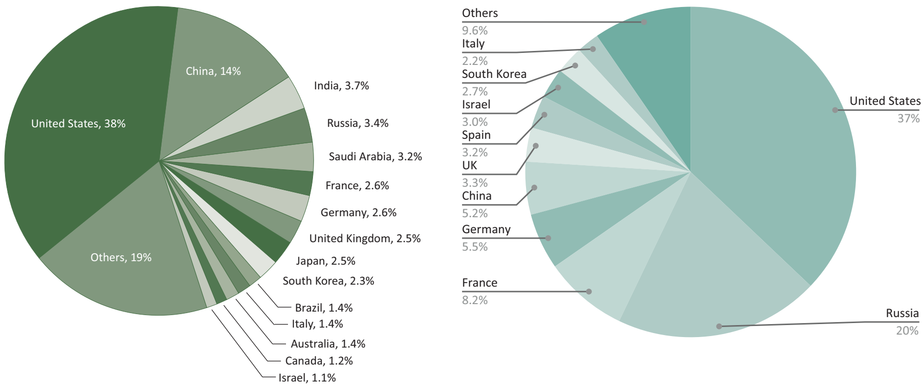
Israel

Israel's geopolitics has played a pivotal role in its impetus towards establishing strong military R&D. In over 70 years, Israel has become a key exporter of military technology and ranks amongst the top 10 countries for arms exports based on the quality of products and superior R&D and innovation.[18] The SIBAT[h] International Defence Cooperation 2018-19 defence directory[19] shows the products and areas of R&D in Israel's defence industry. Figure 6 shows the global share of arms exports, placed at three percent for Israel, a 77-percent increase since 2014. What drives Israel into being a world-class supplier are *strategic necessity* and its *culture of improvisation*. IDF Chief of Staff Lt. Gen. Aviv Kochavi is promoting a plan to establish an IDF division for innovation and development of technological systems for different branches of the army based on their future operational needs.[20]

"Israeli military-technological innovation and adaptation have benefited greatly from the country's uniquely non-hierarchical—even anti-hierarchical society. Israelis are remarkably casual, informal, assertive, and flexible in their dealings with each other."[10] This resulting overall informality and absence of hierarchy, together with a "common and collective sense of insecurity," helps spur innovation—especially in the military-technological realm—by breaking down barriers to interaction and creating an atmosphere that encourages and enables the free exchange of ideas.[21]

h http://www.sibat.mod.gov.il/Pages/home.aspx

Figure 6: Israeli Defence Forces: Statistical Figures



Source: SIPRI Database, 2020.

Overall, the defence industrial sector in Israel contains around 150 firms, divided into three categories for classification: a) large state-owned or government-controlled defence companies, including Israel Aerospace Industries, Israeli Military Industries (now privatised) and Rafael; medium-sized firms, all in the private sector, which rely on defence production for their viability but also have large-scale civilian production, particularly in the production of telecommunication equipment; the small and medium-sized enterprises that produce a narrow range of products mainly for the defence sector. The major organs of the Israel Defence industry are shown in Table 2.

To generate new ideas and innovative solutions, the Israeli community recruits the *crème-de-la-crème*, resulting in ground-breaking technologies. The Talpiot[22,23] secret programme (a result of the Yom Kippur War) at the Hebrew University is one of them—a handful of 50 students (until 1979, only 25 students were allowed) trained extensively in STEM subjects.

Table 2: Key Organs of the Israeli Defence Industry

Directorate of Defence R&D	Responsible for all functions related to defence R&D, including the creation of infrastructure for advanced scientific and technical know-how, sponsoring advanced R&D, and fostering relationships with academic R&D institutions, amongst others. It is jointly run by the MoD and the IDF.
Rafael (Armaments Development Authority)	Rafael is an MoD affiliate, and Israel's largest firm engaging in R&D for armaments and sophisticated combat platforms required by the IDF. Of Rafael's employees, one-third are university-trained, 50 percent are technicians and practical engineers, and the rest are administrative workers.
Israel Aircraft Industries (IAI)	Limited liability state-owned enterprise, with major innovations in the aerospace domain.
Israel Military Industries (IMI) Systems Ltd	Now called Elbit Land Systems, Israel's largest company. Pivotal innovations in C4I, surveillance and communication systems.

Source: http://futurewars.rspanwar.net/ideation-for-defence-rd-in-india-defence-innovation-approaches-of-russia-israel-and-france-part-i/.

"The secret to Talpiot's success lies in a stringent selection and testing process to identify boys and girls who are not only gifted scholastically but are also creative, idealistic, resolute and demonstrate leadership."[24] In a nutshell, Israel's policy is based on the following tenets:[25]

(a) **Generous investment in R&D** to encourage innovation and adaptation.

(b) **High-quality university system** that focuses on STEM technology development. The government has always prioritised R&D and the three main universities of Israel are within the top 100 in world ranking viz., Hebrew University, Technion (Israel Institute of Technology), and Weizmann Institute of Science.

(c) **Military spill-over** nurtures technocrats, who later go on to establish successful start-ups. The IDF and Ministry of Defence can be considered incubators of technology.

(d) **Commercialisation of the technology** developed in universities has been an important pillar in the Israel R&D landscape. Firms affiliated with universities have patented technology, e.g. the Ben Gurion University, BGN Technologies, Ramot, Tel Aviv University.

The Talpiot Program – Highlights

The soldiers of Talpiot begin their military service at Hebrew University but are housed separately. They are taught physics, mathematics, and computer science (as part of their undergraduate degree), and the courses are taught at an accelerated rate, nearly 40 percent faster.

These students are also trained in military strategy and complete an officer's training course. They spend their summers doing 12 weeks of basic training, the one given to the paratroopers. Talpiot soldiers take special courses in each force of the army—intelligence, navy, and air force—to learn about the weapons systems. They sit in cockpits of fighter jets and shoot off weaponry to gain a real understanding of operational and technological needs.

During the second year, they choose a project for three months. This is where a lot of early versions of innovative tech comes from. The professors who proposed the Talpiot programme insisted that innovation was possible only by young minds.

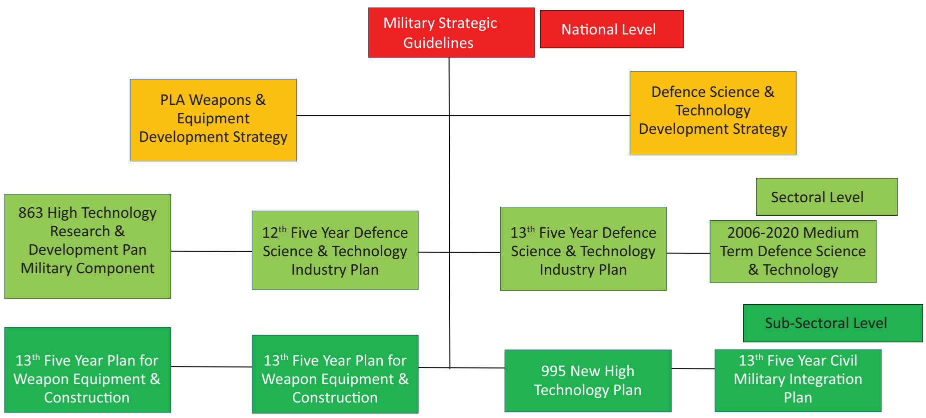
Source: https://curiouslog.com/talpiot-israel-super-school-military-tech-sustainable-innovation/.

(e) **Government support** is crucial in "encouraging and financially supporting pre-competitive (joint) research of companies and universities; encouraging and supporting technology transfer from academia to industry; encouraging (with financial tools) R&D cooperation with multinationals and FDI; financial support of very early-stage entrepreneurs and technologies through incubators and dedicated funds; supporting the evolving of new S&T based industries not through government targeting but through consensus building of academia, industry, finance community and foreign expertise; acting as a catalyst in building networks and industry ecosystems, initially for the ICT industry and now for life sciences and clean-tech."[26]

China

Two themes govern the Chinese thought process: *techno-nationalism* and *indigenous innovation;* they are driven by the CCP.[27] Figure 8 shows China's plans towards technological development in terms of dual-use technology.

Figure 8: Chinese Technology Development Strategy and Plans



Source: www.uscc.gov/research/planning-innovation-understanding-chinas-plans-technological-energy-industrial-and-defense.

Richard P. Suttmeier, Professor of Political Science, says, "China should develop its own strengths and explore 'asymmetric' measures in core technologies that would otherwise be unlikely for China to catch up by 2050. More efforts should be put into these critical, bottleneck fields."[28] The country's military strategy plan at the national level, called the MSG (Military Strategy Guidelines), gives a broad outline of the overall objectives to be reached. The MSG is supported by the WEDS (Weapons and Equipment Development Strategy) and WECP (Weapons and Equipment Construction Plan). WEDS provides the overall strategic rationale for the country's armament development, while WECP is responsible for the implementation of the strategic requirements and tasks set out in the WEDS. WECP is duration based and is at the organisational level, i.e. national or service arm. The MLDP (Medium- and Long-Term Defence Science and Technology Development Plan) is drawn up by the COSTIND (Commission for Science Technology, and Industry for National Defence) to bridge the gap between the S&T of developed nations. It focuses on guiding defence-related basic and applied R&D. Important issues highlighted in the MLDP are:[29]

(a) **Enhancing capacity for indigenous innovation and building up the defence innovation system,** to give the defence industry a more involved role in innovation.

(b) **Creating a favourable environment to promote innovation,** including incentives such as IPR protection and reformed management procedures.

(c) **Increasing the scale and channels of investment in defence science and technology,** by requiring defence enterprises and research institutes to invest at least three percent of their sales revenues in R&D and allowing them to tap the capital markets for fund-raising through public and private offerings, bonds, and bank loans.

(d) **Improving the ability to leverage foreign sources of technology and knowledge transfers,** by finding opportunities for international R&D cooperation, including encouraging research institutes to set up joint research centres and laboratories.

(e) **Meeting the PLA's requirements for advanced weapons and equipment, and promoting civil-military integration.**

(f) **Cultivating a capable scientific and engineering workforce,** through initiatives such as talent training plans, special priority on critical disciplines, and the establishment of defence science, technology, and innovation teams.

The '995' New High-Technology Plan[30]

This plan is aimed at developing asymmetric capabilities for China and deploying high-technology weapons on top priority. To quote from the study, "Do some things but not others, concentrate on developing arms most feared by the enemy." Thus, China plans to introduce and digest foreign technology, especially through engineering.

The '863' High-Technology Research and Development Plan[31]

This plan proposes the establishment of expert leading groups and specialised research centres to introduce cutting-edge technological products in leading economic sectors. Trying to bridge the civil-military gap, the intended goal for this plan was to have 39 percent projects for civilian use, 45 percent for dual-use, and 16 percent for national security.

In addition to the plans described above, Chinese authorities promulgated an *innovation-driven development strategy* (IDDS)[32] in May 2016, providing the roadmap for the development for the next 30 years spanned over three stages: becoming an innovative country by 2020; a top-level innovation leader by 2030; a global innovation power by 2050. To carry out this strategy, they have promulgated a four-step approach.[33] The various stages as enunciated are together called "IDAR."

- Introduce: The import of foreign technology through research, joint development, and joint ventures.
- Digest: Analyse and disseminate the findings with the help of several analytical organisations in place.
- Absorb: Assimilate the technology through various facilities and engage in reverse engineering and other types of manufacturing processes to produce advanced copies of foreign models.
- Re-innovate: To improve the models through reverse engineering, such as J-11B (Russian SU-27) & J-15 (SU-33).

With a growing focus on defence R&D, the Chinese have decided to overhaul the defence and civilian R&D infrastructure. The research institutes (RIs) are at the core of R&D capability development and are also known as *"shiye danwei,"* i.e. they are subject to state ownership restrictions and cannot be restructured into listed entities. Another initiative has been to club the various plans into five new comprehensive plans to cut down corruption, time delays & structural efficiency: National Natural Science Fund; National Major Science and Technology Plan; National Key R&D Project (NKRDP); Special Fund for Technology Innovation; and R&D Base & Professional Special Plan.

Additionally, academic research institutes include the Chinese Academy of Military Science (AMS), which was restructured in 2017, alongside the National Defence University and the National University of Defence Technology. Six research institutes under the PLA General Departments were merged into the AMS. Joint research projects are now being organised by the AMS to lead the way for technology growth. In its new avatar, the AMS is well-poised to emerge as a technology incubator for the PLA.[34]

Overall, the Chinese R&D approach, with a focus on STEM has the following salient features: vigorous pursuit of civil-military integration, an apex body to control and coordinate the activities; adoption of the DARPA model; acquisition of foreign technology; and a focus on disruptive military technologies and military research institutions.[35]

> "Two themes govern the Chinese thought process: techno-nationalism and indigenous innovation. They are driven by the Communist Party."

Defence R&D Transformation

The defence industry is required to not only produce state-of-the-art technology and products, but also ensure that they remain future-proof and are delivered on time and within an ever-constrained budget. Thus, it is imperative to invest in the right partners with the proper capabilities.[36] According to Stephen Peter Rosen, Professor of National Security and Military Affairs at Harvard University, "Military R&D is always done amid a lot of uncertainty & no planning can estimate the outcome or the investment in the project."[37] Geopolitical context, including regional dynamics and its understanding, will thus act as a stepping-stone towards R&D in the defence sector. Opportunities are available for various scholars to help contribute to this field, assisting in achieving RMA at a much faster pace.

Another key aspect to address is whether defence organisations should treat themselves as active knowledge creators or only as consumers of ready-to-use products. Should governments invest in R&D instead of just obtaining knowledge and technologies from a plethora of suppliers? In this regard, there are a few compelling arguments in favour of defence forces undertaking R&D:

(a) To assist policymakers in managing uncertainty and evading strategic risks.

(b) To address the unique needs of the armed forces.

(c) To help the armed forces be a "smart buyer" in the acquisition process.

(d) To promote *quid pro quo* knowledge sharing and circulation of ideas.

(e) Interagency use of technologies developed or made available as a by-product.

Adam Grissom's 2006 paper[38] on the various models that can be proposed for a dedicated R&D establishment listed them out as the Civil-Military Model, which considers greater cooperation between the industry and defence forces; the Inter- and Intra- Service Model, with cooperation between the services as well as between the various branches of the forces; and Cultural Model, which has more to do with how seniors in the organisation can affect a planned change or how external factors can reshape the culture of the organisation and inform change. Grissom finds that military innovation changes the way that armed forces act in the field; has significant scope and impact; and increases military effectiveness.

A 1996 study[39] by the National Research Council lists out the five pillars that are essential to any world-class R&D model (See Figure 9).

(a) **Customer Focus**: End-to-end involvement of the customer, and the customer's satisfaction with the product.

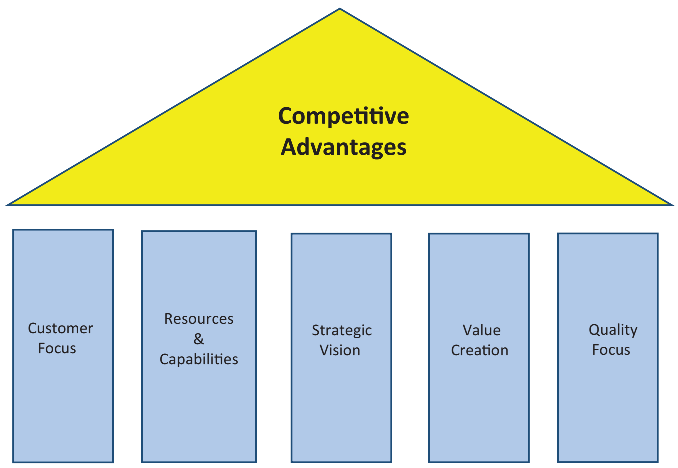
(b) **Resources and Capabilities**: Both in terms of finances and skill-sets, to ensure productivity.

(c) **Strategic Vision**: Mavericks and think tanks working in tandem to anticipate the requirements of future wars and prepare accordingly.

(d) **Value Creation:** By developing products that add value to the end user.

(e) **Quality Focus:** On research as well as product development.

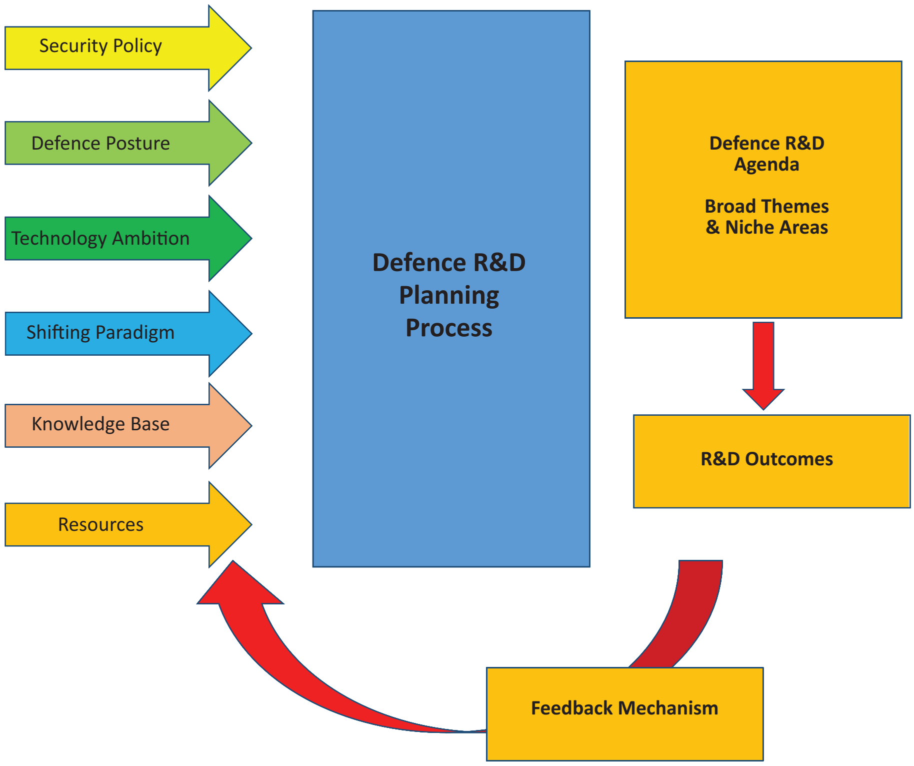
Figure 9:
Five Pillars of R&D Model



Source: https://doi.org/10.17226/5486.

While these five pillars are essential, they must be combined with a robust feedback mechanism to ensure course correction wherever needed in the R&D process. See Figure 10 for inputs that drive the R&D process, leading to niche technologies as outputs.

Figure 10:
Feedback Process as Part of R&D Process



Source: https://doi.org/10.17226/5486.

According to the 2020 paper "Defence R&D: Lessons from NATO Allies," the following are critical pre-requisites for the R&D model:[40]

(a) **Openness**: Despite the important security considerations and secretive assignments, defence R&D mechanisms are built upon open collaboration and knowledge sharing with industry and academia.

(b) **Communication Frameworks**: Effective and efficient communication network is critical to ensure that the R&D community can access the senior policymakers and provide inputs during decision-making.

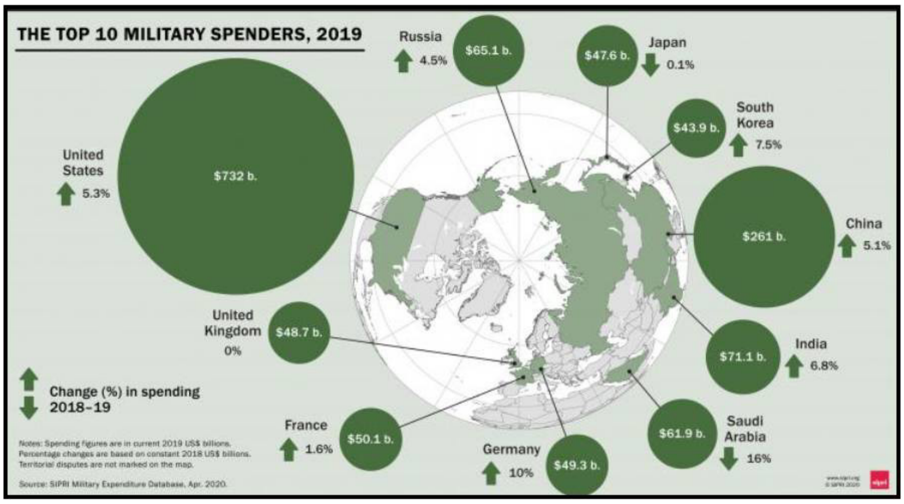
(c) **Knowledge Brokering**: A centralised knowledge hub or repository facilitates the translation of military language into STEM principles and vice versa. The locus of responsibility for defence R&D outcomes is vested here.

(d) **Mobility of People**: Scientists, engineers, analysts, and military and civilian defence personnel move between the civil and military domains by means of temporary secondments and career assignments. This is because "individual mobility is necessary to improve broadcasting and creating knowledge inside the network."[41] This facilitates the circulation of expertise through the recycling of ideas.

(e) **Competition and Partnerships**: The spin-offs accrued are useful for civil and commercial use. Partnerships also ensure tacit accountability of projects.

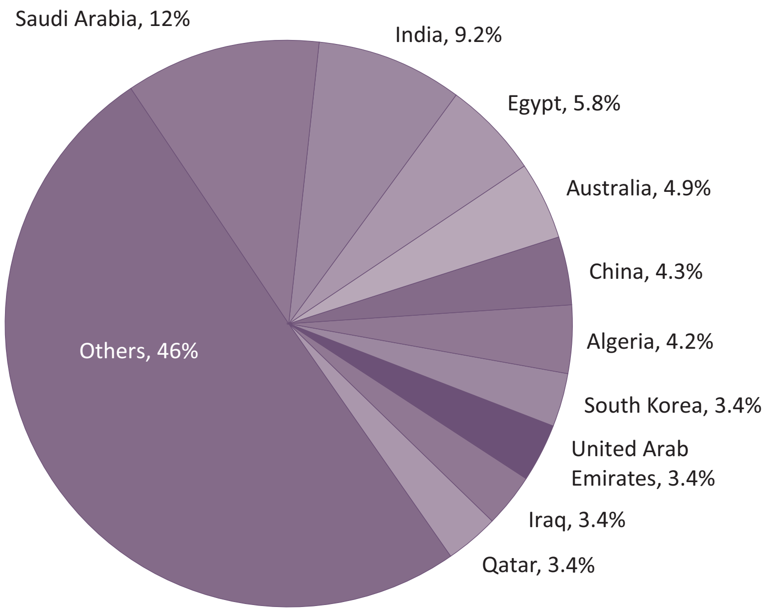
The following figures bring out the global state of military spending and imports (See Figures 11a and 11b). India is amongst the top five spenders, with expenditure pegged at US$7.1 billion. India's share of arms imports is at 9.2 percent of the global share.

Figure 11a: Top Military Spenders of the World



Source: https://www.sipri.org/research/armament-and-disarmament/arms-and-military-expenditure/military-expenditure.

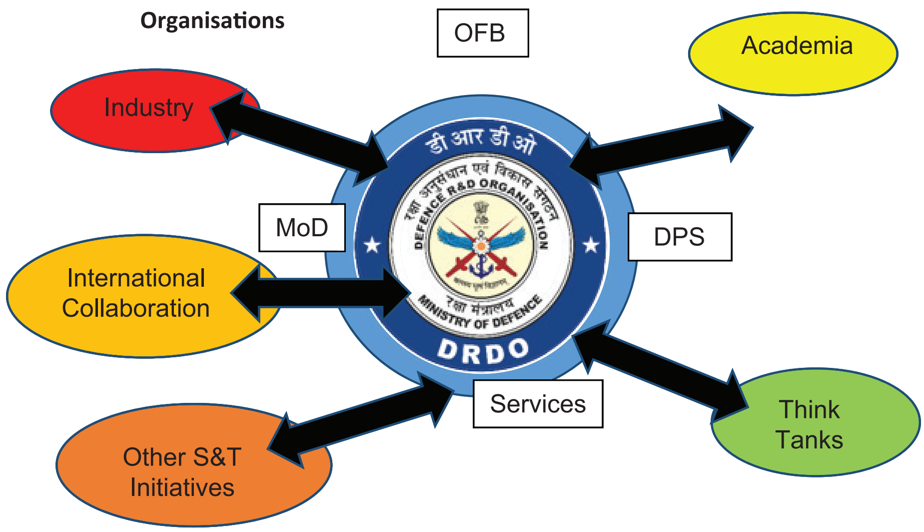
Figure 11 b: Global Share of Arms Imports



Source: https://www.sipri.org/research/armament-and-disarmament/arms-and-military-expenditure/international-arms-transfers.

Figures 11a and 11b show that despite the various R&D organisations associated (with DRDO being the mainstay for defence R&D, see Figure 12) with labs and academic institutes, India is yet to catch up with the countries discussed in this paper, e.g. the US, Russia, Israel, and China.

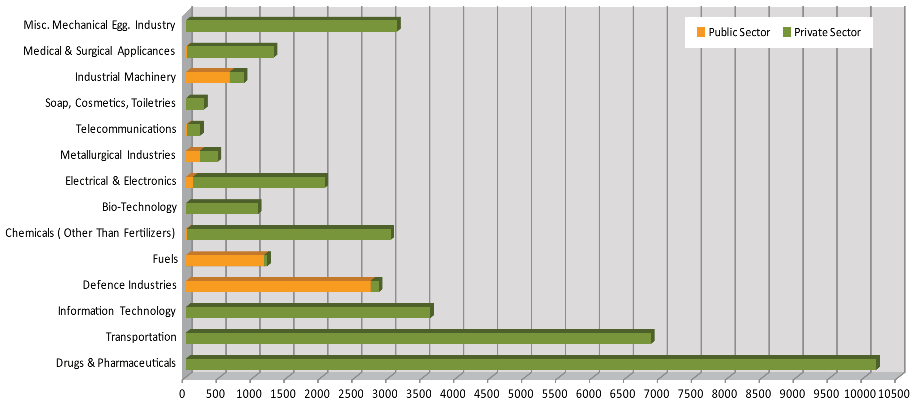
Figure 12: DRDO and Its Associated Labs and Associations with Other Organisations



Source: MoD Annual Report, 2018-19.

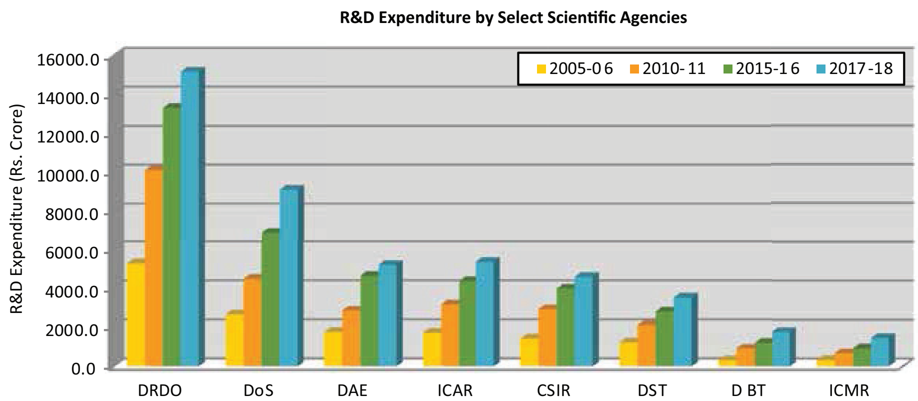
In India, civil R&D is more pronounced than military R&D (See Figure 13a and 13b), and the latter is funded almost wholly by the government. There are contradictory views as well as complementary relationships between the two R&D approaches. While some argue that military R&D should just be used to fill in the gaps, others claim that civil products are often a result of military R&D (by-product). Most countries aim at dual-use technology development instead of "pure development" for military purposes.[42]

Figure 13a: R&D Expenditure Under Various Heads



Source: NSTMIS, Department of Science & Technology, Government of India, https://dst.gov.in/.

Figure 13b: R&D Expenditure by Select Agencies



Source: NSTMIS, Department of Science & Technology, Government of India, https://dst.gov.in/.

The National Research Development Corporation (NRDC) lists its aim and vision as follows:[43]

Vision: "To be a leading Technology Transfer Organization in India"

Mission: "To promote, develop, nurture and commercialize innovative, reliable and competitive technologies from R&D institutes through value addition and partnership. To sensitize R&D institutions and industry about technologies that need to be developed and commercialized."

NRDC should produce a directory of technologies with a list of incubators to help the Indian Armed Forces establish coordination with agencies to develop and deliver in the way it is best suited to be employed and utilised. In recent years, R&D has gained traction in many countries, proving the military's interest in and inclination for it, driven by a) the need to maintain superiority over adversaries; and b) to adapt itself to the civilian pace of technology growth.[44]

Why Has the Indian Armed Forces Not Nurtured an In-House R&D Organisation?

The bullet-proof helmet[45] developed in-house in the Indian Army in 2020 captures the zeitgeist of the contemporary in-house R&D and innovation scene. In the present COVID-19 crisis, establishments are working towards developing oxygen generators to make up the shortfall as well as ventilators to augment the government aid. To quote Finkel, "In regard to innovation, in order to make new ideas a reality, military organizations must overcome this combination of 'passive' military conservatism, risk management concerns, and biases stemming from the inherent nature of organizations. Before getting to the missing piece in the puzzle, it is also important to note that the mirror effect of 'negative innovation' exists as well, based solely on the desires of some commanders to make changes for the purpose of seeming innovative or influential."[46]

All SHQs need think tanks and technology centres to serve as incubators for technology growth and project implementation. This is of paramount importance as we transition from an importing nation towards manufacturing one. The primary task of such centres should be to identify a) technology and products that the private and public sectors must develop to meet the needs of the services; and b) future wars and the applicable technology to meet country-specific needs.

The organisation must include subject matter experts (SMEs), since the process of transitioning towards specialities and super-specialities will require general knowledge and conventional credentials. MTech and PhD qualified personnel must be further audited, and aptitude assessment for research should be endorsed in confidential reports. Military R&D requires people with risk-taking capabilities and innovative thinking, not simply experts or a high-powered steering committee with a conservationist approach.

Furthermore, there is an urgent need to change the mindset that services exist only to fight. The R&D and innovation processes must not be left at the behest of DRDO or any such DPSU. The Indian Armed Forces must be involved stakeholders, not just a procurement agency or end user. Innovation must be seen as an integral part of warfighting. In-house resources must be utilised gainfully.

In his paper, Rosen states that if a military R&D organisation is to be established, the mission statement/core competencies should focus on the following aspects:

(a) Maximising soldier survivability and combat effectiveness.

(b) Incorporating the latest trends in all aspects to evolve a lethal & more potent soldier system.

(c) Out of the box thinking (*positive absurdity*[i]); ground-breaking technological ideas; and interactions with other organisations including academia, higher education institutes and research organisations.

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i A term coined by the author. Mavericks or out-of-the-box thinkers might propose ideas that sound outlandish but have the potential to flourish into great innovations.

(d) Promoting ground-breaking innovations and rapid prototyping.

(e) Incentivising investments in technology, with the IPR aspects in mind. Without a collaborative effort between the industry and the defence forces, innovation and R&D will suffer.[47]

(f) Accepting failures and developing a strong risk appetite. Currently, the procedures being followed are risk averse. As Ron Adner writes in his report for Harvard Business Review, "The unfortunate nature of probability is that the true probability of an event taking place is equal to the product (not the average) of the underlying probabilities."[48] In his article "Why Military Programs Go Wrong,"[49] Bill Sweetman summarises the reasons for the failure thus:

i. "The new systems were 'almost perfected in the laboratory',

ii. There were unforeseen complications and delays during the development of the operational systems,

iii. There were unforeseen support and training requirements that compromised the operational use of the new systems and introduced new vulnerabilities,

iv. The new systems failed to deliver the expected 'force multiplier' effect,

v. There were unforeseen consequences from the operational use of some new weaponry."

India's Defence R&D: Recommendations

One way to increase knowledge transfer and collaboration between academia and industry is to fund individual commercialisation efforts by smaller businesses, e.g. the Small Business Innovation Research (SBIR) programme in the US. Micro-, small- and medium-sized enterprises (MSMEs) are significant centres of innovation. The Indian Army can opt co-located clusters, say at Command level (could further be extended to Theatre level), with matching academic (research) centres in its establishments. The spelt-out tasks for an Army R&D model include transforming traditional policymaking models:

a. Identifying key principles and values.

b. Identifying and engaging key stakeholders and core areas for priority investment and support.

c. Engaging multilaterally with academia, industry, MSMEs.

d. Enhancing transparency and accountability, and reducing military bureaucracy.

e. Developing a regulatory framework with a single apex organisation.

f. In the absence of will or cooperation among various agencies (which undermines the effort to reach a consensus), formulating strict guidelines to ensure a well-synchronised array instead of organisational or personality-driven one-upmanship.

g. Facilitating the economics of the model.

h. Encouraging "jugaad technology,"[50] since these ideas may spur a new technological thought process.

Suggested Model for Indian Army R&D Organisation

Many experts and committees have recommended a model similar to DARPA in the Indian context. To understand why the model is successful, it is important to distil the aspects that work, namely, enormous freedom while executing projects and adequate funding. A 2014 study[51] compared the competencies of DARPA and its Indian equivalent (See Figure 14). The study found that while 80–85 percent of the projects undertaken by DARPA are unsuccessful and/or shut down, this is accepted by the US government.

Figure 14: Assessment of Organisations on Equivalence with DARPA

Activity Research	Indian Research Activity	US Inter se %	US Work Performer	***Indian Performer***
Basic Research	Extra mural research	3.0	University 60 % & DoD Research labs 25%	Academia & R&D institutions
Applied Research	Science &Technology	7.1	Industry 50% DoD R&D 30%	DRDO in collaboration with Centres of Excellence
Advanced Technology Development	Technology Demonstration	7.9		
Prototyping & Weapon Component Development	Mission mode	19.4	Private Firms	DRDO with Industry
System Development		17.4		
RDT&E	Infrastructure Facilities	6.6	-	-
Operational System Development	Product support	38.9	Private Firms	DRDO extends ToT to Production Agency

Source: "Assessing High-Risk, High-Benefit Research Organizations: The 'DARPA Effect'," SITC Policy Briefs, Vol. 2014.

A 2013 Harvard study[52] that looks at how DARPA approaches problems highlights Pasteur's Quadrant (See Figure 15), which is part of a concept put forth by Donald Stoke,[53] wherein the top left quadrant represents the classic notion of basic research and the bottom right quadrant refers to purely applied research. The actual use-inspired research is the top right quadrant (Pasteur), crucial for meaningful contributions. As seen in Figure 15, DARPA lies largely in the Pasteur Quadrant.

Figure 15: How DARPA Approaches Problems: The Pasteur Quadrant

Quest for Understanding ↓	Practical Use →	NO	YES
YES		*Pure Basic Research (Bohr)*	*Pasteur Quadrant*
NO		*Unnamed*	*Pure Applied Research (Edison)*

Source: hbr.org/2013/10/special-forces-innovation-how-darpa-attacks-problems.

In proposing a model for the Indian Army R&D Organisation, it is imperative to note that a one-size-fits-all approach cannot be followed, since R&D organisations must be driven by the nature of the military, which differs across regions. However, India can and should draw on the successful R&D organisations across the world and use them as a guide to define an India-specific model. Indeed, the Indian Navy, too, serves as a case study, having taken the lead in terms of in-house R&D with its recently established Naval Innovation and Indigenisation Organisation (NIIO)[54] and the existing Weapons and Electronic Systems Engineering Establishment (WESEE).

The NIIO is a three-tiered organisation. Naval Technology Acceleration Council (N-TAC, Vice Chief of Naval Staff at the apex) will bring together the twin aspects of innovation and indigenisation and provide apex-level directives. A working group under the N-TAC will implement the projects. A Technology Development Acceleration Cell (TDAC) has also been created for the induction of emerging disruptive technology in an accelerated time frame.

Four years ago, the Indian Army had set up the Army Design Bureau (ADB), aimed at being the "facilitator for research and development efforts and initiation of Procurements of Weapons and Equipment required by the Indian Army."[55] Of the Technology Research Centre (TRC) and the Simulator Development Division (SDD) as part of the ADB, the latter has played a noteworthy and pivotal role in developing simulators for various projects in the Indian Army. The simulators have been fielded and are being gainfully utilised. TRC's role is mostly limited to recognising the correct technology thrust areas and serving as an interface with the DPSUs and industry. Additionally, there is increased focus on start-ups as part of the "Defence Innovation and Start-up Challenges."

The Proposed Army Model

1. **Synergised Army Technology Initiative (SATI)**: The SATI will engage with academia, industry, venture capitalists, as well as handle the financing of projects (e.g. matching finance principle for synergy projects as followed in the present Innovation for Defence Excellence scheme).

2. **Army Scientific Advisory Committee (ASAC):** The ASAC will be headed by an officer called the **'Army Scientific Advisor (ASA)**, hand-picked by the Principal Scientific Advisor (PSA) to the government, based on technological expertise exhibited during their service profile. The officer must meet a detailed set

of qualitative requirements must be met and the scientific value added while in service must be evaluated, beyond "professional performance." The selected individual will liaise one-to-one with the PSA on project-related issues and will be able to form and dissolve project teams based on the life cycle of the product being designed and developed. The organisational structure of the ASAC under SATI is proposed as in Figure 16.

3. The ASA will be assisted by **Arms Representatives**, **Scientists** (Officer of DRDO/ PSU on Deputation), **IPR professionals**, **DGQA** (Techno Managers), **Trial Experts**, **Industry** (as associates), **Funding Agency**, and **Academia** (Higher Education Institutes).

4. The **Army Design Bureau, Directorate of Indigenisation, and Simulator Development Division** are proposed to be merged. The Strategic Planning Directorate as well as relevant training and doctrine branches will be brought under the umbrella of ASAC.

5. Exploit the **National Knowledge Network**, which is connected to GLORIAD,[j] (funded by the US National Science Foundation) and to the European Union grid GEANT.[k]

6. **Horizon Core Technology Group (HCTG**) (as suggested in the MoD Annual Report 2003-04) will help forecast requirements and will form part of ASAC.

7. **Special Research & Development Group (SRDG)** units will be formed at the rate of one per command and will be the lowest functional level of the SATI implementation strategy. Teams will be able to peel off and work independently, and will have freedom of movement for trials etc. The Group will be modular, with project-based teams and temporary affiliations, and will therefore be completely cross-functional.

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j GLORIAD (Global Ring Network for Advanced Application Development) is a high-speed computer network used to connect scientific organisations in Russia, China, US, the Netherlands, Korea and Canada. India, Singapore, Vietnam, and Egypt were added in 2009.

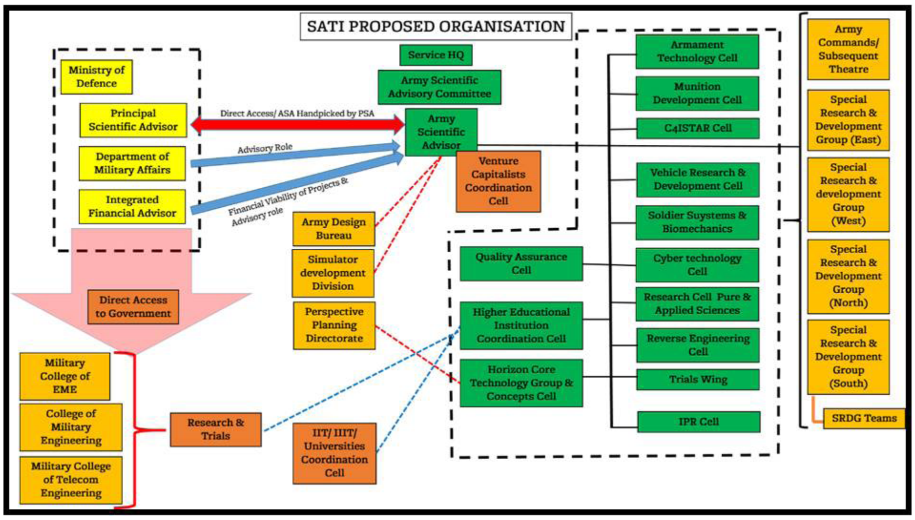
k GÉANT is the pan-European data network for the research and education community. It connects national research and education networks (NRENs) across Europe, enabling collaboration on projects ranging from biological science, to earth observation, to arts and culture.

8. Programmes such as the Israeli Unit 81 and Talpiot will be launched in India and involve young students who show promise in applied sciences and have a flair for research. Selected individuals will undergo stringent testing and training to fine-tune the skills required for design and development. HRD policy must be tweaked to suit the requirements of transfers, tenures, career progression, etc.

9. Military test beds and incubation centres will need to be established at command level. The existing training establishments will serve as test beds as well as research crucibles.

10. Project Management principles and approaches will strictly be followed, and the ASAC will have absolute power to start, invest or shut down a programme.

Figure 16:
Synergised Army Technology Initiative Proposed Organisation



Source: *Author's own*

Notes for the Proposed Organisation

1. The PSA and the Military Advisor may later, together, form part of the National Security Council.

2. The financial adviser will be useful in vetting projects as well as be an integral part of the venture capitalists cell. The Delegated Financial Powers under Schedule XI (R&D) head must be tweaked to cater to this structure, with financial ceilings at par with the budget needed for futuristic development.

3. The ASA has been kept one-to-one with the PSA for fast-tracking projects and avoiding red tape. The Secretary, Department of Military Affairs will play an important advisory role.

4. Thirteen cells are to be established to cater to various technology centres of use to the Army. A cellular structure has been proposed to keep the organisation lean and agile in terms of functioning. Cells are to have a mix of officers and scientists, and the strength should not exceed more than five to seven personnel per cell.

5. Trial Wing and IPR Cell will cater to the trials of prototypes developed, as well as delve into matters of IPR/ patents.

6. The Higher Education Institution Coordination Cell will have the mandate of coordinating research work in service training establishments as well as IITs (Indian Institutes of Technology)/ IIITs (International Institute of Information Technology (IIIT) and other leading universities. The budget allocation for research work will be based purely on merit. The service training establishments will carry out an audit of MTech and PhD students and ensure that practical work is carried out in these institutes. Research and collaborative prototyping should also be mandated to these service institutes. A common entrance exam may be thought of to select candidates, followed by interviews and a mini-project development to finally retain officers for research work.

7. The Army Design Bureau as well as Simulator Development Division to come under the ambit of ASA. The Strategic Planning (erstwhile Perspective Planning) Directorate, as well as relevant "Concept" branches of Army Training Command, can be amalgamated as a lean HCTG to formulate the roadmap for future ground-breaking technology.

8. At the Command level, it is proposed to have SRDGs (six to eight officers/scientists). These SRDGs will have only relevant offshoots from the "Cells" at SHQ level. To move around freely inside the Command/Theatre, they may further work as need-based "Teams." These teams will be formed from the SRDGs to prevent any bloating of the organisational structure.

9. The catering to the terms of engagement/career progression aspects for the scientists involved can be re-evaluated as needed.

> "India should draw lessons from successful R&D organisations across the world and use them as a guide to define an Indian Army-specific model."

Conclusion

Lt Col Vivek Gopal *is an Instructor at a premier training institute.*

The success of any R&D programme depends on the extent to which the priorities are aligned and embedded into both the national security imperatives and the consequent S&T plans. So far, intramural organisations, such as government labs, have been the mainstay for R&D in India. A dedicated military R&D organisation and its impact on innovation offer vast opportunities, since military establishments greatly influence technological change in most developing/developed economies. There is a pressing need for a new type of publicly funded R&D model—multidisciplinary, motivated by establishment needs, and subject to accountability from public funding agencies.

The process of change will be based on recurring iterations. Hierarchy-bound command and control structures will have to be shaken out from the organisational conservatism.[56] The "frozen middle"[I] in the organisation must be tackled so that ideas are allowed to germinate.[57]

India must foster the "defence research culture," and military and civilian interaction should be facilitated to encourage development in various areas. In some areas, civil and military scientists are already utilising the same set of results differently for varied products in the same laboratory. For the Indian Army, there is a greater talk about the transformative nature of technology and the disruption caused by it. While the acquisition component of the Indian Army is undergoing a reform under the Defence Acquisition Procedure, 2020, discussions on the R&D aspect are still underway. Planners must address the issue of R&D, particularly the "in-house" aspect of this critical activity, which has seen the start in terms of the ADB and the already existing SDD.

A knowledge-intensive in-house organisation must be developed to initially develop as a joint venture and later bloom into a full-grown establishment. India must first acquire technology before adopting and absorbing, i.e. "Fail Fast, Recover Faster." The Indian Army needs to be cognisant of the fact that rapid development of technology and accelerated exploitation within the ambit of self-reliance (*Atmanirbharta*) is the need of the hour. While the long-term goal will be to establish

I The description of middle management used by Maile Carnegie, group executive of digital banking at ANZ Group in Australia: "people in [the] organization who are no longer experts in a craft, and who have graduated from doing to managing and basically bossing other people around and shuffling PowerPoints." Also see, ihttps://www.strategy-business.com/article/Thawing-the-frozen-middle?gko=23a42

Conclusion

an organisation such as DARPA, with the present funding, leveraging various in-house resources in the most optimal way lay the foundation for the establishment of the fully army-managed (acquire, adapt and absorb) R&D organisation.

The general military praxis will have to undergo a metamorphosis and the locus of R&D will have to shift from government-funded DPSUs to in-house development within the military. The R&D organisation may evolve into a joint structure, with congruence coming into play once the aspects of "jointness" further evolve and are well established. The process of reform will always be arduous and challenging, particularly when organisational inertia is coupled with personality-driven objectives. India must consider adopting an Act similar to the Goldwater Nichols Act for handling R&D.[58]

Finalising the details and logistics of establishing in-house, dedicated military R&D bodies in India will require further research. What is clear, though, is that it is an imperative.

"The success of any R&D programme depends on the extent to which the priorities are aligned and embedded in both the national security imperatives and the consequent S&T plans."

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The ARL has been charged with focusing on foundational research; targeting and conducting research to drive change within, across, and between disciplines; creating knowledge products for warfighting concepts; development of operating systems; and interacting with universities via the ARL Open Campus and the Army Research Office (ARO). Recommendations with respect to the ARL are threefold:

(a) Recommendation 1: The Army Research Laboratory (ARL) should further encourage and facilitate all members of research projects, particularly junior members, to make the scientific contacts necessary to adequately assess their research in the context of the entire field.

(b) Recommendation 2: The Army Research Laboratory (ARL) should emphasise the identification of a set of fundamental research questions underlying the current research portfolio that can provide a long-term focus in areas of artificial intelligence and machine learning.

Endnotes

(c) Recommendation 3: The Army Research Laboratory (ARL) should develop a mechanism for collaboration between ARL and industry on software development. Specifically, ARL should use and develop software platforms in collaboration with open-source software libraries that will enable ARL to keep up to date and to rapidly develop software.

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