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The Fault Lines

Laxman Kumar Behera

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Laxman Kumar Behera, Ph.D

Defence Innovation in India: The Fault Lines

Introduction

Self-reliance in defence needs has been an avowed objective of Indian policy makers since independence. This has led to the creation of a huge establishment, comprising of hundreds of entities, in the both public and private sectors, to innovate state-of-the art weapon systems for the country's armed forces. However, the capability of these units to innovate new weapon systems has been less than satisfactory. This has led to the import of vast quantities of arms, year after year,[1] with the country getting the dubious distinction of being the only major global economic power with an archaic defence Research and Development (R&D) and production base.

This paper makes an in-depth analysis of India's defence innovation mechanism, by examining two key players - the Defence Research and Development Organisation (DRDO) and the defence industry, their innovation record and the challenges they face. The paper however begins by defining innovation and its approach towards innovation. This is followed by an examination of India's overall innovation structure and analysing defence innovation within a larger context.

Innovation: Definition and Approach of the Paper

Although, India's first science and technology policy dates back to 1958, the term innovation did not find explicit mention until the

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1 According to the Stockholm International Peace Research Institute (SIPRI), India is the largest arms importer with a12 per cent global share during 2008-12. See Paul Holtom, et al, "Trends in International Arms Transfers, 2012", *SIPRI Fact Sheet*, March 2013, http://books.sipri.org/product_info?c_product_id=455#.

Science and Technology Policy was announced in 2003.[2] The definition of the term was provided five years later in the draft National Innovation Act, 2008 circulated by the Ministry of Science and Technology (MoST) for public scrutiny and comments. The 2008 Act defines innovation as a "process for incremental or significant technical advance or change, which provides enhancement of measureable economic value, and shall include (a) introducing new or improved goods or services (b); implementing new or improved operational process; and (c) implementing new or improved organisational/managerial processes." The Act also lays down four different ways for measuring innovation outcomes: "(1) increase in market share, (2) competitive advantage, (3) improvement in the quality of products and services and (4) reduction of costs."[3]

The approach taken by this paper for dealing with innovation, particularly in the defence sector, however differs from that of the MoST. The deviation is largely due to the sheer practical difficulties of obtaining credible data across sectors to measure innovation outcomes. To overcome this shortcoming, albeit partially, the paper uses the standard input-output model and critically examines India's progress in key innovation inputs (R&D expenditure, human resource, etc.) and outputs (scientific publications, patents, etc.). The usefulness of the model is that apart from being a proxy for the country's innovation potential (as opposed to innovation outcome) it also facilitates comparison with other important countries.

In the defence sector, innovation performance is also gauged by three other parametres, not necessarily in any particular order. The first one relates to India's self-sufficiency in meeting defence

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2 Sunil Mani, "Is India Becoming More Innovative Since 1991? Some Disquieting Features", *Economic and Political Weekly*, 44 (46), November 14, 2009, pp. 41-51.

3 Ministry of Science and Technology, Government of India "The National Innovation Act of 2008", http://www.dst.gov.in/draftinnovationlaw.pdf.

hardware requirements through indigenous efforts. The self-sufficiency, reflected in the form of a Self-Reliance Index (SRI), is used in the paper as a statistical proxy for India's defence innovation progress. The second one relates to technology development and the design and development capability of the major players in the defence innovation set up. The third one pertains to, what Tai Ming Cheung notes, the industry's "soft innovation capabilities" in terms of technology assimilation or absorption.[4]

State of Indian Innovation: The Larger Context

Defence innovation is part of the larger innovation system consisting of, but not limited to, nearly 4,288 R&D institutions employing over 4,40,000 people.[5] As in any other field, the various elements of this larger system are often inter-linked and have a direct bearing on each other. This interplay is due to the commonality of technologies, equipment and human skills that can contribute to each other in certain circumstances. The oft cited success story of such an interplay is India's advanced space and atomic programme and the successful missile and nuclear weapon development.[6] An analysis of India's larger innovation system would thus reveal its key features (depth, progress and global standing) and its implications for defence innovation.

A key feature of India's larger innovation system is the relative progress of India's science and technology base and its international recognition. This is evident on multiple parameters ranging from:

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4 Tai Ming Cheung, "The Chinese Defense Economy's Long March from Imitation to Innovation", *The Journal of Strategic Studies*, 34 (3), June 2011, pp. 325-354.

5 Ministry of Science and Technology, Government of India, *Directory of R&D Institutions 2010*, p. ix; Ministry of Science and Technology, Government of India, *Research and Development Statistics 2011-12*.

6 For an earlier account of the interplay of space, atomic energy and defence sectors, see Dinshaw Misty, "India's Emerging Space Program," *Pacific Affairs*, 71 (20), Summer, 1998, pp. 151-174.

the number of scientific papers published by Indian researchers; to the number of patents filed by Indians; the knowledge/technology intensity of Indian economy; and the growing participation of Indian scientists and R&D organisations in international mega science projects. From 2006 to 2010, the total Indian contribution to 16 major scientific journals grew at an annual average of 12 per cent, to 65,487 research papers. This is against the world average growth of four per cent.[7] India's global share has also almost doubled from the early 2000s and stands at 3.5 per cent in 2011.[8] The increase in the number of science publications has also improved India's global ranking to ninth place in 2010, from 13th place in 1996.[9] More importantly, the quality of Indian scientific publications, as measured in terms of citation impact, has also improved and now stands at 0.68 which is higher than that of countries such as Russia and China.[10]

The number of patents filed by Indians or Indian entities (either in India or abroad), between 2000 and 2011, went by 443 per cent to 15,860, of which 8,841 were filed in India, and the remaining 7,019 in other countries. In terms of the number of patent applications filed by 'residents', India is ranked tenth in the world in 2011 (the corresponding rank for 2001 was 21). India has also improved its ranking by five notches to 20th in terms of patents filed by Indians aboard during the same period.[11]

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7 Elsevier, *International Comparative Performance of India's Scientific Research*, Report prepared for the Department of Science and Technology, Ministry of Science and Technology, Government of India, November 2012, p. 6.

8 Press Information Bureau, Government of India, "India's Position among top Scientific Powers", March 11, 2013.

9 Press Information Bureau, Government of India, "Status of Research and Development", May 22, 2012.

10 Elsevier, *International Comparative Performance of India's Scientific Research*, note 7, p. 11.

11 See World Intellectual Property Organisation, http://www.wipo.int/portal/index.html.en.

The broadening of India's knowledge base and its invention capacity is also slowly percolating down to the broader economy which is made evident in the increase in knowledge-driven manufacturing, high-tech content in exports, and the emergence of a strong aerospace industry. Between 2005 and 2009, knowledge-intensive production as a percentage of the country's GDP rose from 8.6 per cent to 11.6 per cent. Between 1988 and 2008, the high-tech content in India's exports more than doubled from 7.3 per cent to 16.9 per cent.[12]

India is globally recognised for its advanced space establishment, especially for its capability in the design and manufacture of satellites and spacecrafts. The successful launch of India's first dedicated navigational satellite on July 01, 2013, bears further testimony to this effect.[13] The country is ranked sixth globally in terms of both space budget and technological capability. Compared to the defence sector, the space industry is much more self-reliant, with domestic industry providing around 70 per cent of the total technology content.[14] The space sector is now evolving into a strong aerospace industry, with many enterprises joining the larger sector. The growing capability of the aerospace industry is evident from the export of 'aircraft, spacecraft and parts thereof' in which there has been a significant growth from less than $80 million in 2005-06 to over $2,265 million in 2012-13.[15]

India is rapidly becoming an international hub for R&D activities, particularly for those related to Information Technology (IT), drugs

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12 Sunil Mani, "India" in *UNESCO Science Report 2010: The Current Status of Science around the World* (United Nations Educational, Scientific and Cultural Organisation: Paris, 2010), p. 365.

13 Press Information Bureau, Government of India, "India's First Dedicated Navigational Satellite IRNSS-1A", July 04, 2013.

14 Planning Commission, Government of India, http://planningcommission.nic.in.

15 Ministry of Commerce and Industry, Government of India, http://commerce.nic.in/eidb/default.asp.

and pharmaceuticals, space research and biotechnology among others.[16] By 2008, the number of foreign R&D centres operating in India had risen to 750, from less than 100 in 2003.[17] India's global recognition is perhaps best exemplified by its association with many mega international science projects, including the India-based Neutrino Observatory (INO), the Facility for Anti-proton Ion Research (FAIR) in Germany, and High Energy Physics (HEP) projects at CERN for which India has made contributions both in cash and kind. The latter include hardware, skilled manpower (about 80 scientists) and software for the construction of the Large Hadron Collider (LHC); the sub-systems of the Compact Muon Solenoid (CMS); and A Large Ion Collider Experiment (ALICE) detectors for the development of the LHC Computing Grid.[18]

The above encouraging trends notwithstanding, India's progress in science and technology remains far below global standard in many areas. Despite the increase in scientific publications, India's contribution to the top one per cent journals is only 2.5 per cent.[19] The citation impact of Indian scientific publications, although growing, continues to hover below the world average of 1.0.[20] Inventiveness in basic sciences, measured by the creation of intellectual property, is far lower than in countries like the US, China, Japan and South Korea. Table I shows the trend of India's patent

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16 Controller General of Patents, Designs, Trade Marks and Geographical Indication, Ministry of Commerce and Industry, Government of India, *Annual Report 2010-11*, p.3.

17 Sunil Mani, "India", note 12, p. 363.

18 Department of Atomic Energy, Government of India, *Mega Science and Global Alliances*, Report of the Planning Commission Working Group, p. 5; Press Information Bureau, Government of India, "Indian Scientists Involved in the Research for Higgs Boson", August 09, 2012.

19 Ministry of Science and Technology, Government of India, "Science, Technology and Innovation Policy 2013", p.5.

20 Elsevier, *International Comparative Performance of India's Scientific Research*, note 7, p. 4.

grants with respect to China – a country which in past two decades has made rapid progress in science and technology and moved from, what some observers have described as, "R&D obscurity to challenging the US (and likely succeeding) for global R&D leadership."[21] The trend is shown in three categories: 'resident', 'non-resident' and 'abroad'. In 1997, the number of patents granted to India was 49 per cent that of China. By 2011, this had been reduced to a mere four per cent. Moreover, while China's patents are being increasingly accounted for by the 'resident' category (which in fact has surpassed the 'non-resident' category since 2009); India's patents are still, overwhelmingly, 'non-resident' patents.

Table I. No of Patents Granted: China and India

	China				India			
Year	Resi-dent	Non-Resident	Abroad	Total	Resi-dent	Non-Resident	Abroad	Total
1997	1532	1962	160	3654	546	1161	80	1787
1999	3097	4540	213	7850	633	1527	157	2317
2001	5395	10901	327	16623	529	1020	288	1837
2003	11404	25750	580	37734	615	911	622	2148
2005	20705	32600	870	54175	1396	2924	888	5208
2007	31945	36003	1557	69505	3173	12088	1125	16386
2009	65391	62998	3111	131500	1725	4443	1466	7634
2011	112347	59766	5817	177930	776	4392	2108	7276

Note: A 'resident' patent grant refers to a patent granted in the country to its own resident; 'non-resident' to a patent granted in the country to a non-resident; and 'abroad' to a patent granted in a foreign country.

Source: Table prepared by author based on data taken from World Intellectual Property Organisation, http://www.wipo.int/portal/index.html.en.

21 Battelle and R&D Magazine, *2013 Global R&D Funding Forecast*, December 2012, p. 4

Apart from patents, India's innovation capacity, measured in terms of other parameters, is also limited. This is made evident by a number of composite parameters available in various studies as per which India's innovation ranking varies between 50 and 70, depending on the parameters applied. For instance, as per a joint report published by the Institut Européen d'Administration des Affaires (INSEAD) and the World Intellectual Property Organisation (WIPO), India ranks 64 (out of 141 countries) in the global innovation index. The report also points out that although India is ranked relatively higher in terms of market sophistication (46); knowledge and technology outputs (47); and creative output (34); it fares poorly in terms of institutional support (125); human capital and research (131); infrastructure (78); and business sophistication (75).[22]

The *Global Competitiveness Report 2012-13* published by the World Economic Forum (WEF) also highlights India's poor competitiveness and ranks the country 59 (out of 144 countries). Table II provides an overview of India's innovation ranking in terms of six key indicators and with respect to Brazil, Russia, India, China and South Africa (BRICS) and some major industrialised economies. It shows that India is placed below all selected advanced industrialised economies (US, UK and Japan) on every indicator, although it scores better than some BRICS countries on some. India is ahead of Brazil, China and Russia in the quality of research institutions. However, the research undertaken by such institutions does not necessarily percolate down for commercial use, because of weak linkages with the industry. This is partly exhibited by India's poor score on university-industry collaboration compared to most BRICS countries. Moreover, none of the Indian research institutions figure in the top-50 global science institutions. According to the

[22] Soumitra Dutta (ed), *The Global Innovation Index 2012: Stronger Innovation Linkages for Global Growth*, Report of the Institut Européen d'Administration des Affaires and World Intellectual Property Organisation (INSEAD), 2012.

SCIMAGO database, which is often cited by the Indian government in various official documents, the Council of Scientific and Industrial Research (CSIR), the largest and most diverse science and technology organisation under the Indian MoST, is currently placed 82nd globally and 14th in Asia. The CSIR's poor ranking has drawn the ire of parliamentarians who have urged the government to make all efforts to enable the organisation to figure in "at least first 10 global organisations in its field" within the next five years.[23]

India scores better than all the BRICS nations on the availability of scientists and engineers. But in terms of its population, it has one of the lowest densities of R&D personnel. With 137 researchers per million people, India is far behind many countries including: Japan (which with 5573 researchers per million people has the highest density of researchers among the major S&T powers in the world); the US (4663); South Korea (4627); the UK (4181); China (1071); and Brazil (657) among others.[24] The low density of researchers apart, India is also plagued by the poor quality of its workforce. A 2007 survey by the Federation of Indian Chambers of Commerce and Industry (FICCI), expressed its concerns regarding skill shortages in 20 industry sectors, including engineering/heavy equipment and machinery, IT, biotechnology and pharmaceuticals.[25] This in turn is indicative of the poor quality of the Indian educational institutions, and is a matter of grave concern, given

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[23] Standing Committee on Science and Technology, Environment and Forests, *Demand for Grants 2013-14*, 244th Report (Rajya Sabha Secretariat: New Delhi, 2013), pp. 8-9.

[24] Hugo Hollanders and Luc Soete, "The Growing Role of Knowledge in the Global Economy", in *UNESCO Science Report 2010: The Current Status of Science around the World* (United Nations Educational, Scientific and Cultural Organisation: Paris, 2010), p. 8.

[25] Federation of Indian Chambers of Commerce and Industry, "Survey on Emerging Skill Shortages in the Indian Industry", July 2007.

that India has one of the largest pool of universities and technical institutes in the world (33,023 colleges, 523 universities and 40-odd institutes of national importance (INI) as of 2010-11).[26]

Table II. Innovation Indicator: Ranking of Select Countries

Country	India	Brazil	Russia	China	S. Africa	US	UK	Japan
Capacity for innovation	42	34	56	23	41	7	12	1
Quality of scientific research institutions	39	46	70	44	34	6	3	11
Company spending on R&D	37	33	79	24	39	7	12	2
University-industry collaboration on R&D	51	44	85	35	30	3	2	16
Availability of scientists and engineers	16	113	90	46	122	5	12	2
PCT patents* granted per million population	63	48	44	38	37	12	18	5

*: PCT patent refers to patent granted under the Patent Cooperation Treaty (PCT)

Source: Klaus Schwab (ed), *The Global Competitiveness Report 2012–13* (World Economic Forum: Geneva, 2012).

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26 Ministry of Human Resource Development, Government of India, *Annual Report 2010-11*, pp. 80-94; and http://mhrd.gov.in/instiutions_imp.

One of the primary reasons for India's poor innovation index is due to the less than desired level of investment in R&D and its skewed funding pattern. India's total R&D spend (in Purchasing Power Parity, or PPP, terms) for 2013 is estimated at $45.2 billion, that is one-fifth that of China (the second biggest R&D spender since 2009[27]) and one-ninth that of the US, which leads the global R&D spend with a 30 per cent share. India's current R&D spend, although increasing in absolute terms, is not however commensurate with its rising economic profile and its own policy goal of increasing the expenditure level to two per cent of the GDP.

Table III. Top-10 R&D Spenders in the World, 2012 and 2013

	2012		2013*	
Country	GERD (PPP US$ Billion)	R&D as % of GDP	GERD (PPP US$ Billion)	R&D as % of GDP
US	418.6	2.68	423.7	2.66
China	197.3	1.60	220.2	1.65
Japan	159.9	3.48	161.8	3.48
Germany	90.9	2.87	91.1	2.85
South Korea	55.8	3.45	57.8	3.45
France	50.4	2.24	50.6	2.24
India	40.3	0.85	45.2	0.90
UK	42.0	1.84	42.4	1.84
Russia	37.0	1.48	38.5	1.48
Brazil	29.5	1.25	31.9	1.30

Note. *: Figures for 2013 are forecast; GERD: Gross Expenditure on R&D

Source: *Battelle and R&D Magazine,* 2013 Global R&D Funding Forecast, December 2012.

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27 "OECD Science, Technology and Industry Outlook 2012", http://www.oecd.org/sti/sti-outlook-2012-china.pdf

Since the economic liberalisation in early 1990s, the Indian economy is growing at a steady pace, although in recent years the growth rate has somewhat moderated. According to the International Monetary Fund (IMF), India is now the third largest economy in the world (in PPP terms), surpassing Japan in 2012.[28] Compared to its economic standing, India's global R&D ranking is seventh. The ranking goes further down when calculated in terms of R&D intensity (i.e., total R&D expenditure as a percentage of GDP). Among the top-10 global R&D spenders, India has the lowest share - 0.9 per cent of GDP- a marginal increase from 0.7 per cent in 1995-96 (see Table III for the top-10 global R&D spenders and their R&D intensity for 2012 and 2013). Compared to this, China has more than doubled its R&D intensity from 0.6 per cent in 1996.[29]

A striking feature of India's R&D spending is, that unlike many other advanced countries (such as US, Japan, South Korea and China) where 60-75 per cent of R&D spending is accounted for by the business sector, it is diametrically opposite in the case of India.[30] The government support for R&D in India is largely focussed on classical objective for public R&D funding such as defence, space, nuclear energy, health and agriculture. However, as mentioned earlier, and as stated in a recent document of the Ministry of Commerce, the government-led R&D has "had little effect in terms of enhancing the technology depths of Indian firms."[31] This is because of several factors ranging from poor collaboration between

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28 International Monetary Fund, *World Economic Outlook Database*, April 2013, http://www.imf.org/external/pubs/ft/weo/2013/01/weodata/index.aspx.

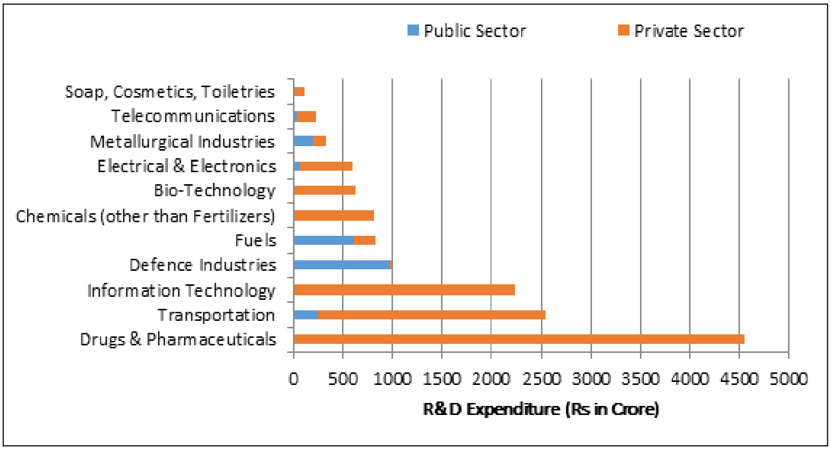
29 Ministry of Science and Technology of the People's Republic of China, *S&T Statistics Data Book 2001*.

30 For an international comparison of R&D spending see National Science Board, "Science and Engineering Indicators 2012", p. 4-47.

31 Department of Commerce, Government of India, *Report of the Working Group on Boosting India's Manufacturing Exports for12th Five Year Plan (2012-17)*, p. 171.

the R&D agency and industry, lack of accountability, bureaucratic red-tapism, and the poor human resource base. This also has significant implications for innovation in sectors like defence, where the industry's role is minimal. Presently, the industrial sector in India spends a mere 0.54 per cent of its annual turnover on R&D,[32] and accounts for a mere 0.23 per cent of country's R&D intensity.[33] Nearly half of the industry's R&D spend is concentrated on the two areas: drugs and pharmaceuticals, and transportation which have little relevance for defence innovation (Figure I). The industrial R&D spend on defence, which although ranks fourth, accounts for a mere 6.9 per cent, and is mostly undertaken by the government-owned enterprises, whose track record of innovation is poor, to say the least (see the section on defence industry).

Figure I. R&D Expenditure by Leading Indian Industry Groups, 2009-10



Source: Ministry of Science and Technology, Government of India.

[32] Planning Commission, Government of India, *Mid-term Appraisal of 11th plan*, p. 410.

[33] Press Information Bureau, Government of India, "Status of Scientific Research in the Country", March 04, 2013.

Defence Innovation: Major Actors and their Innovation Performance

DRDO

The DRDO is almost synonymous with India's defence research and development and is the main player in India's defence innovation system. Its primary responsibility is to design and develop state of the art weapons systems for the armed forces.[34] Besides DRDO, others, particularly the defence industry and few S&T organisations are also part of this system and contribute in a variety of ways.

The DRDO was formed in 1958 by amalgamating the Defence Science Organisation (DSO) with the Technical Development Establishments (TDE) of the army and Directorate of Technical Development and Production (DTDP). At the time of the merger, the DRDO was a small organisation with only 10 laboratories. Over the years DRDO has grown into a huge organisation, and presently consists of 52 research laboratories and establishments spread across the country. The organisation has a workforce of 27,337 including 7,702 scientists/engineers and 10,351 technical staff.

The DRDO labs and establishments, which cater to virtually all possible dimensions of defence technology, are grouped into nine clusters namely: Aeronautics; Armaments; Combat Vehicles and Engineering; Electronics and Computer Sciences; Materials; Missiles and Strategic Systems; Micro Electronics and Devices; Naval Research and Development; and Life Sciences.

[34] The charter of duties of DRDO is however larger than design and development of arms. As per the Allocation of Business Rules of Government of India, DRDO's charter of duties also includes rendering scientific advice to the defence minister and the armed forces on all aspects of science and technology impinging on national security.

Headquartered in New Delhi, the organisation is headed by a scientist, designated as Director General, DRDO (DG DRDO), who in this capacity is also the Scientific Advisor to the Raksha Mantri (Defence Minister) – SA to RM- and one of the five secretaries in the MoD. The head of the DRDO is supported by a number of senior scientists (nine as of 2012) from within the organisation who are designated as Chief Controllers of Research and Development (CC R&D).

Like the organisation itself, DRDO's role in defence R&D has also evolved over time. At the time of its formation, the organisation was mainly an inspection agency. It was only in the 1970s and 1980s that the organisation was put into design and developmental mode, with government sanctioning a number of high-profile projects including the Main Battle Tank (MBT) Arjun (sanctioned in May 1974), Integrated Guided Missile Development Programme (IGMDP) (July 1983), and Light Combat Aircraft (LCA) (August 1983).

Table IV. Value of DRDO-developed Systems inducted or under-Induction (As on August 2013)

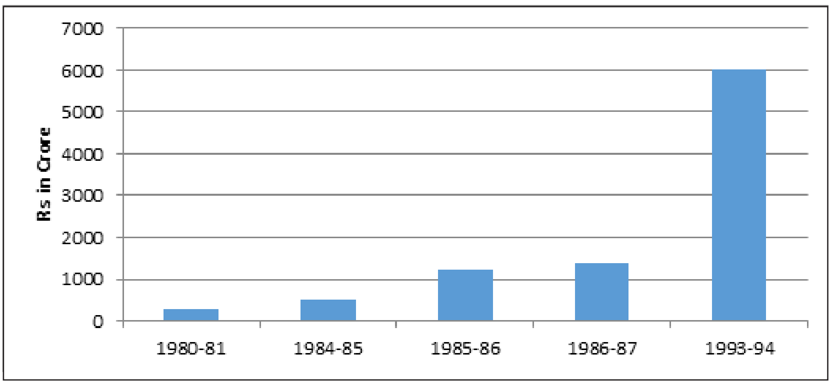
Systems	Inducted (Rs in Crores)	Under Induction (Rs in Crores)
Missiles	4667.79	60605.69
Electronics and Radar Systems	7606.19	21513.75
Advanced Materials and Composites	3504.96	138.84
Armament Systems	8304.33	4339.75
Aeronautical Systems	3049.37	23699.69
Combat Vehicles & Engineering Systems	12686.43	8236.89
Life Sciences Systems	246.91	286.29
Naval Systems	873.39	329.93
Total	40939.37	119150.82

Note: Strategic Systems are not included.

Source: Rajya Sabha, Parliament of India, http://loksabha.nic.in/.

With the maturing of many programmes, DRDO-designed and developed products are now being increasingly cleared for bulk production and induction into the Indian armed forces.[35] During the past three years, as many as 36 different major products designed by the DRDO have been inducted into the armed forces. These include a range of missile systems, radars, Electronic Warfare Systems (EWS), combat vehicles, Unmanned Aerial Vehicles (UAV), robotic systems, Submarine Escape Suits (SES), and ready to eat meals, among others.[36] By August 2013, the cumulative production value of all DRDO-developed items (inducted or in the induction process) has exceeded Rs1,60,000 crore[37] (Table IV)- a significant increase from the eighties and early nineties (Figure II).

Figure II. Value of Production of Items Designed and Developed by the DRDO



Source: Ministry of Defence, Government of India, *Annual Report* (relevant years).

[35] For an overview of DRDO developed products, see Suranjan Pal and William Selvamurthy, "Capability-Building in Defence Science and Technology: A Perspective from the DRDO", *Strategic Analysis*, 32 (2), March 2008, pp. 259-284.

[36] Press Information Bureau, Government of India, "Induction of Products Designed by DRDO in Armed Forces", May 08, 2013.

[37] Press Information Bureau, Government of India, "Final Operational Clearance for LCA Tejas Next Year: Antony", May 29, 2013.

As the premier defence R&D agency in India, the DRDO is often judged by not only what it designs and develops, but also by the indigenous content of those products– the latter being a sensitive topic among the Indian parliamentarians, policy makers and defence analysts. More often than not, the organisation is asked to furnish statistics to show the level of domestic content in its developed items. Given the local sensitivities about the indigenous content, and the pressure on the DRDO to ensure that, the extent of indigenisaton can also be used (in the Indian context) one of the indicators of DRDO's innovation performance.

Table V provides an overview of indigenous content in major DRDO-developed systems. Barring four products namely the Airborne Early Warning & Control (AEW&C) system, the BrahMos cruise missile, the Long Range Surface to Air Missile (LRSAM) and the MBT Arjun, in which the import content is more than 50 per cent; in others the domestic content can be deemed satisfactory (considering that India's self-reliance target is 70 per cent). This in turn is evidence, not only of the DRDO's credibility in developing technology and prototypes, but also of the organisation's role in partnering and, often hand-holding, Indian industry, other S&T institutes and academia for co-development of many technologies and subsystems and final production of the items. As per the official DRDO estimates, the organisation is now working with 800 large and small private/public sector industries, and more than 100 academic and S&T institution across the country[38] – a huge spin-off from India's defence innovation point of view, more so as India had a very small defence science and industrial base when the DRDO was formed way back in late 1950s.

[38] In early 1990s, the DRDO partnership was limited to 70 academic institutes, 50 national S&T centres and 150 public/private industries. See Ministry of Defence, Government of India, *Annual Report 1993-94*, p. 33.

Table V. Import content in the major systems developed/ being developed by the DRDO

System	Import Content (%)	System	Import Content (%)
Pilotless Target Aircraft (PTA), *Lakshya*	5-7	Supersonic Cruise BrahMos Missile	65
Remotely Piloted Vehicle (RPV), Nishant	10	Long Range Surface to Air Missile (LR-SAM)	60
Aircraft Arrester Barrier	5	Multi Barrel Rocket System, Pinaka	10
Light Combat Aircraft (LCA)	40	Main Battle Tank, Arjun	55
Airborne Early Warning & Control (AEW&C) System	67	Radars	5-10
Combat Free Fall (CFF) System	35	Electronic Warfare Systems	5-30
Parachutes	0	Sonars	5-30
Heavy Drop System	10	Pocket Dosimeter (PDM)	12
Agni Missile	15	Portable Dose Rate Meter	9
Prithvi Missile	15	Roentegnometer	6
Surface to Air Missile, Akash	10	Nuclear, Biological and Chemical (NBC) Recce Vehicle	5
Anti-tank Missile, Nag	30	NBC Water Purification System	5

Source: Standing Committee on Defence, Lok Sabha, Parliament of India

However what is more significant from the defence innovation point of view is that the expansion of the defence innovation base has, to large extent, gone hand in hand with the enhanced manufacturing capability of the Indian industry. As was stated by the outgoing DRDO chief, Dr VK Saraswat, the Indian industry, beginning with the I*ntegrated Guided Missile Development Programme* (IGMDP), has improved its capability from that of "built to print' to 'built to specification', 'built to design' and 'built to requirements' by being part of DRDO programmes. This has allowed many Indian enterprises to manufacture technologically advanced products that conform to international military standards, and become part of the global supply chain[39]- the latter aspect is also evident from the huge increase in India's export of aerospace products in recent years. The maturing of Indian industry has also had a positive impact on DRDO's own activities under the 'stores' budget head that caters to the organisation's revenue expenses (primarily of industrial nature) on projects, programmes, schemes and IT-related activities among others. As claimed by the DRDO, around 80 per cent of the organisation's stores budget is spent in local currency, indicating that Indian industry can provide significant support to DRDO's revenue oriented R&D activities.

DRDO's contribution to defence innovation is perhaps best described by several of its high profile projects' global comparison. As has been highlighted by the DRDO and its chief at various forums, India is:

> …one of the four countries in the world to have a multi-level strategic deterrence capability; one of the five countries of the world to have its own Ballistic Missile Defence (BMD) programme and underwater missile launch capability; one of the seven countries to have developed its own MBT and an indigenous 4th generation combat aircraft; one of the six countries of the world to have developed a nuclear powered submarine; one of the select few countries of the world to have its own EWS and multi-range radar programme.[40]

The above comparison is however to be acknowledged with a degree of caution, because not all of the above mentioned projects are matured enough or have passed the developmental phase into production and deployment. The BMD programme, nuclear submarine and combat aircraft are, for example, still years away

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39 See interview with Dr VK Saraswat, DG, DRDO, in *Defence ProAc Biz News*, May-June 2013.

from induction. Moreover, the projects that have passed through the developmental phase for production are not necessarily 100 per cent indigenous as many key components and technologies used in them are imported. For instance, the power pack, gun control and fire control systems of the MBT Arjun and the engine of the LCA are sourced from abroad, indicating the lack of indigenous capability in these critical areas. The technological shortcomings in the LCA are further highlighted by the recently published list of 121 systems (pertaining to avionics, electronics, hydraulic, landing gear and propulsion) that the Aeronautical Development Agency (ADA) - DRDO's nodal agency responsible for design and development of LCA - wants to indigenise with the participation of Indian vendors.[41] The import content of the products listed in Table V is a further indication of technological gap in many of DRDO's developmental projects.

The technological gaps in frontline military technologies, especially in comparison with advanced countries, is perhaps best illustrated by the list of 26 'critical technologies' listed for acquisition from abroad by the DRDO through the MoD's defence offset guidelines that stipulate a minimum 30 per cent re-investment (via technology transfer and other means) of the arms import cost in the domestic industry. The list includes nano technology-based sensors and displays, technology for hypersonic flights, low observable [stealth] technologies, focal plane arrays, gun barrel technologies, and fibre laser technology, among others (Table VI).[42]

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[40] See Interview with VK Saraswat chief of DRDO, in *Engineering Watch*, March 2013, p. 9.

[41] Aeronautical Development Agency, "Indigenous Development of Line Replaceable Units (LRU's) for LCA-Tejas", http://www.ada.gov.in/ADA-IND.pdf.

[42] For the complete list of technologies, see Defence Research and Development Organisation, http://drdo.gov.in/drdo/English/List_of_Critical.pdf.

Table VI. List of 26 Critical Defence Technologies

Sl No	Name of Technology	Sl No	Name of Technology
1	MEMs based sensors, actuators, RF devices, Focal Plane arrays.	14	Pulse Power network technologies
2	Nano Technology based sensors & displays.	15	THZ technologies
3	Miniature SAR & ISAR technologies	16	Surface Coated Double Base (SCDB) Propellant
4	Fiber Lasers Technology	17	FSAPDS Technologies
5	EM Rail Gun technology	18	HESH Ammunition technologies
6	Shared and Conformal Apertures	19	Muzzle Reference System
7	High efficiency flexible Solar Cells technology	20	Composite Sabot manufacturing technology
8	Super Cavitations technology	21	MET projectiles
9	Molecularly Imprinted Polymers	22	Titanium casting, forging, fabrication and machining
10	Technologies for Hypersonic flights (Propulsion, Aerodynamics and Structures)	23	Precision Guided munitions
11	Low Observable technologies	24	Shock Hardened Sensors
12	Technologies for generating High Power Lasers	25	Gun Barrel Technologies
13	High Strength, High Modulus, Carbon Fibers, Mesophase pitch-based fiber, Carbon Fiber Production Facility	26	Advanced Recoil System

Source: Defence Research and Development Organisation (DRDO).

DRDO's lack of original innovation is also partly revealed by its Intellectual Property Rights (IPR) portfolio. It should be noted that the DRDO is the biggest R&D spender among all the government-owned scientific agencies in India (in 2009-10, it accounted for 31.6 per cent of total R&D expenditure of major scientific organisations, distantly followed by the Department of Space (DOS) (15.5 per cent), Department of Atomic Energy (DAE) (14.4 per cent) and Council of Scientific and Industrial Research (CSIR) (10 per cent), among other agencies).[43] However, compared to its large funding, it has fewer IPRs to its credit. For instance, compared to the CSIR which maintains a portfolio of over 5,600 patents, including 2,350 abroad; DRDO's IPR portfolio consists of around 1,400 patents, copyright designs and trademarks.[44]

The DRDO's technological gaps have often prompted the organisation to grab as many R&D projects as possible. However, many a time, the organisation is constrained to complete the projects and achieve the technological deliverables within the allotted time frame and budgetary provision. This has often led to the mid-way cancellation of projects. For example, a 1989 review of all DRDO projects led to closure of as many as 618 projects (out of a total of 989 projects).[45] Although, resource crunch was the reason cited for the short-closure of the projects, it nonetheless underscored the organisation's inability to develop technologies for the projects it had initially pursued. It also reveals the absence of a strong oversight mechanism for scrutinising the feasibility of the programmes before they are taken up. A 2007 report of the parliamentary committee takes note of the various developmental projects (including the Airborne Surveillance Platform (ASP), cargo ammunition, 30mm fair weather towed air defence gun system)

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43 Ministry of Science and Technology, Government of India, *Research and Development Statistics at a Glance 2011-12*, p. 4.

44 *DRDO Newsletter*, 31(12), December 2011, p. 3.

45 Standing Committee on Defence, 10th Lok Sabha, *Defence Research and Development: Major Projects*, 5th Report (Lok Sabha Secretariat: New Delhi, 1995), p. 8.

being abandoned midway by the organisation.[46] A 2012 Report of the Comptroller and Auditor General of India (CAG) is also critical of DRDO for the dismal progress made in several projects.[47]

Almost all of DRDO's flagship projects including the MBT Arjun, LCA and Kaveri Engine have witnessed significant time and cost overruns, apart from poor user response. The cost overrun of MBT Arjun (the development of which was closed in 1995 as against the originally envisaged bulk production by 1984) was a whopping 1884 per cent.[48] Although, Arjun has now been inducted into the army, the numbers do not inspire confidence. As against an inventory of over 2,000 Vijayanta tanks which the Arjun was supposed to replace, only 248 tanks have so far been ordered, indicating the user's lack of confidence in the indigenous tank. A 2008 parliamentary committee report also mentions the army's dissatisfaction with the Arjun which reportedly "performed very poorly" in a winter trial.[49] Similar is the fate of the LCA. Sanctioned in early 1980s as replacement for MiG fighters, the project is yet to get the final operational clearance, which is now expected in 2014 - over three decades after the project was sanctioned.[50] Like the MBT Arjun, the LCA has also got few orders so far. As against 870-odd MiG-series of aircraft which the LCA was intended to replace, only 40 units have been ordered for production by the HAL.[51] The poor user satisfaction is also evident from IAF's decision

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46 Standing Committee on Defence, 14th Lok Sabha, *Defence Research and Development Organisation*, 14th Report (Lok Sabha Secretariat: New Delhi, 2007), pp. 39-40.

47 Comptroller and Auditor General of India, *Union Government (Defence Services): Army and Ordnance Factories*, Report No 16 of the Year 2012-13, pp. 54-67.

48 Public Accounts Committee, 13th Lok Sabha, *Design and Development of Main Battle Tank Arjun*, 5th Report (Lok Sabha Secretariat: New Delhi, 2000)

49 Standing Committee on Defence, 14th Lok Sabha, *Demands for Grants 2008-09*, 29th Report (Lok Sabha Secretariat: New Delhi, 2008), p. 75.

50 Press Information Bureau, Government of India, "Final Operational Clearance for LCA Tejas Next Year: Antony", May 29, 2013.

51 Press Information Bureau, Government of India, "Delay in Manufacturing of Tejas by DRDO", March 20, 2013.

to deploy the initial lot of LCAs in south India, far away from the active borders of China or Pakistan.[52]

Defence Industry

Being the producer of arms of various types, the Indian defence industry constitutes a natural part of India's defence innovation system. The main players in the system are the nine Defence Public Sector Undertakings (DPSUs) and 39 Ordnance Factories (OFs) under the administrative control of the Department of Defence Production (DDP) of the MoD and a small but growing number of private enterprises. With a turnover of over $10.5 billion (in 2010-11) and a workforce of nearly 1,80,000, these enterprises constitute one of the largest defence industrial bases in the world. Three enterprises, Hindustan Aeronautics Ltd (HAL), OFs and Bharat Electronics Ltd (BEL) also figure in the Stockholm International Peace Research Institute (SIPRI) top-100 global companies.[53]

HAL is India's biggest defence enterprise with a turnover of Rs 14,204 crore in 2011-12.[54] Established in 1954, the company has 19 production centres, 10 R&D centres and a workforce of 33,600, including around 2150 designers. HAL is primarily responsible for manufacture of both rotary and fixed-wing aircraft, their engines and accessories. So far, HAL has produced 15 types of aircraft based on in-house R&D and 14 others under licence.[55] Among the DPSUs, HAL also has the highest spend on R&D. In 2011-12, its total R&D expenditure amounted to Rs 967.5 crore, representing 6.8 per cent of its total turnover. The company is the prime

52 "First LCA squadron to be stationed in Sulur: DRDO", *Zee News*, September 21, 2011, http://zeenews.india.com/news/nation/first-lca-squadron-to-be-stationed-in-sulur-drdo_732796.html.

53 The Ranking of HAL, BEL and OFs are 33rd, 48th and 77th, respectively. See Stockholm International Peace Research Institute, "The SIPRI Top 100 arms-producing and military services companies in the world excluding China, 2011", http://www.sipri.org/research/armaments/production/Top100.

54 Hindustan Aeronautics Ltd, *Annual Report 2011-12*.

55 Ministry of Defence, Government of India, *Annual Report 2012-13*, p. 64.

production agency for the LCA. Its current major R&D projects include the Intermediate Jet Trainer (IJT), Light Combat Helicopter (LCH), Light Utility Helicopter (LUH), and HTT-40 basic turboprop trainer aircraft. The company is also the co-development partner with Russia for design and development of the Fifth Generation Fighter Aircraft (FGFA) and Multi-role Transport Aircraft (MTA).

BEL, the second biggest DPSU, is India's premier defence electronics company with a core competence in radars, sonars, communication, EWS, electro optics and tank electronics. With a manpower strength of 10,791, the company's turnover touched Rs 6,012 crore in 2012-13. The BEL is the most innovative defence enterprise among all DPSUs in India. It spends the largest percentage share of turnover on R&D (8.2 per cent in 2011-12)[56] and has a large pool of R&D personnel (2,162 of which 1,863 are engineers).[57] It also works closely with various national scientific organisations including over a dozen laboratories of the DRDO.[58] BEL's R&D focus has increased the company's turnover from domestically developed products. For instance in 2011-12, 81 per cent of its turnover came from products developed domestically, with in-house R&D contributing to 54 per cent of total sales.[59]

Bharat Earth Movers Limited (BEML) is the third largest DPSU in terms of the turnover (Rs 3504 crore in 2011-12). However, unlike other DPSUs, most of BEML's revenue comes from the non-defence sector which accounted for nearly 88 per cent of its turnover in 2011-12. The company specialises in earthmoving equipment. Bharat Dynamics Ltd (BDL) is India's main production agency for all types of missile systems. It manufactures a range of the tactical

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56 Bharat Electronics Ltd, *Annual Report 2011-12*, p. 1.

57 Bharat Electronics Ltd, "Research and Development", http://www.bel-india.com/r-d.

58 Standing Committee on Defence, 14th Lok Sabha, *Defence Public Sector Undertakings*, 9thReport (Lok Sabha Secretariat: New Delhi, 2006), p. 19-20.

59 Bharat Electronics Ltd, note 57, p. 1

and strategic missile systems developed by the DRDO, besides undertaking the licenced manufacturing of Russian and French-origin Anti-Tank Guided Missiles (ATGM). Mishra Dhatu Nigam Limited (MIDHANI) is the only DPSU that does not manufacture any finished product for the armed forces. It produces a wide range of super alloys, titanium alloys, and special purpose steels among others. The rest of the four DPSUs are dedicated defence shipyards. These are: Mazagon Dock Ltd (MDL), Garden Reach Shipbuilders and Engineers (GRSE), Goa Shipyard Ltd (GSL), and Hindustan Shipyard Ltd (HSL) – the latter was acquired in 2010 by the MoD from Ministry of Shipping for construction of strategic vessels for the Indian navy. Among the four shipyards, MDL is the leading warship builder, with the capability of constructing all types of frontline warships (excluding aircraft carriers, and nuclear submarines).

Compared to the DPSUs, the OFs operate at the lower end of the technology spectrum. The OFs however have longest experience, with the establishment of first factory dating back to 1801. In terms of manpower, OFs are also the largest defence production set up, with 98,914 employees on their payroll as of 2010-11. They produce a vast range of products – about 938 “principal items” that include combat vehicles, anti-tank guns, anti-aircraft guns, field guns, mortars, small arms, bombs, rockets, projectiles, transport vehicles, clothing and leather items, among others.

Compared to the state-owned enterprises, the Indian private sector is a relatively new entrant into India’s defence production sector. Until 2001, when the government liberalised the defence production, the role of the private sector was restricted to supplying parts, components and raw materials to their state-owned counterparts. Post-liberalisation, an increasing number of enterprises have shown a keen interest in this sector, and bagged a large number of industrial licences from the government, a necessary condition for manufacturing arms and ammunition. As of October 2011, the government had given 205 such permissions to over 100 private entities, with a proposed investment of Rs 11,889 crore and employment opportunities for 39,129 people. So far around 34 companies have commenced production, with some enterprises having succeeded in bagging orders from the MoD. In addition, an increasing number of private companies have taken advantage of the liberalisation policy which allows foreign direct investment up to 26 per cent. Twenty-six joint ventures (JVs) between foreign companies and the Indian private sector have already been formed.[60]

The vastness of the Indian defence production base, as explained above, is however in stark contrast to its poor innovation record. Measured in terms of key inputs (R&D spending) and outputs (patents, in-house design and development, technology assimilation and indigenisation), the defence industry is often found wanting. Going by the number of patents and copy rights, that are the most common yet powerful indicators of innovation, the DPSUs and OFs are way behind their global peers (Tables VII and VIII). More surprisingly, four of the nine DPSUs, do not have even a single patent or copyright to their credit. Compared to this, the US-based aerospace major, Boeing has 1,000 patents in a single programme, the 787 Dreamliner.[61]

Barring HAL and BEL, which have dedicated R&D centres and spend 6-8 per cent of their turnover on R&D, other defence enterprises have, what is termed by India's defence minister, a "miserly attitude"[62] towards R&D spending (Table IX). Even the R&D spending of HAL/BEL does not necessarily comparable with their global peers. For instance the French company, Thales, spends 20 per cent of its revenues on R&D,[63] compared to the eight per cent spent by the BEL, arguably the most innovative defence enterprise in India. The lack of in-house R&D in most of the enterprises makes them perpetually dependent on either DRDO or foreign companies for technology for production. In the case of the OFs, the largest and oldest MoD run organisation in India, the

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60 Ministry of Defence, Government of India, note 56, p. 60.

61 "Guarding the 'Gold'", *Boeing Frontiers*, May 2010, available at http://www.boeing.com/news/frontiers/archive/2010/may/i_eot.pdf.

62 Press Information Bureau, Government of India, "Antony asks Industry to give up Miserly Attitude Towards R&D", January 31, 2013

63 Thales, "Facts and Figures", http://www.thalesgroup.com/Group/About_us/Facts_and_Figures/.

in-house developed products contribute only 7.5 per cent to their turnover.

Table VII. No of Patents/Copy Rights held by DPSUs/OFs (As on March 2012)

DPSU / OFs	No.of Patents or Copyrights
Hindustan Aeronautics Ltd (HAL)	6
Mishra Dhatu Nigam Ltd	5
BEML	3
Bharat Dynamics Ltd	2
Bharat Electronics Ltd	6
Hindustan Shipyard Ltd	-
Goa Shipyard Ltd	-
Garden Reach Shipbuilders & Engineers Ltd	-
Mazagon Dock Ltd	-
Ordnance Factories	1
Total	23

Source: Lok Sabha, Parliament of India, http://loksabha.nic.in/

Table VIII. Patent Scorecard of Major Global Defence Companies

Name of Company (Country/Region)	Patents Granted	
	2010	5-Year Average
Boeing (US)	664	458
Lockheed Martin (US)	374	298
EADS (Europe)	328	169
Raytheon (US)	246	190
General Electric (US)	220	190
United Technologies (US)	220	132
Safran (France)	195	129
Honeywell (US)	143	99
Northrop Grumman (US)	130	163
Rockwell Collins (US)	123	72

Note: Patents include utility patents granted in the US

Source: Lindsey Gilroy and Tammy D'Amato, "The Patent Scorecard 2010: Aerospace and Defence", *Intellectual Property Today*, http://www.iptoday.com/issues/2010/11/the-patent-scorecard-2010-aerospace-&-defence.asp.

The lack of R&D in the defence industry has however created a unique problem in Indian context. As observed by a former chief of the DRDO, since most of the Indian production agencies "do not speak R&D language, it leads to difficulty in [absorption of technology and] transforming research designs into manufacturing."[64] The difficulty is often manifested in the form of undue delays in the production schedules of the concerned entities. The delay in the construction of Scorpene class submarines by the MDL is one example of how the lack of R&D can lead to 'teething problems' in the absorption of technology.[65] The undue delay in the production of the MBT Arjun is partly due to the OFs inability to absorb the technology given by the DRDO.

Table IX. R&D Expenditure by Indian Defence Industry, 2011-12

DPSUs/OFs	Value of sales (Rs in Crore)	R&D expenditure (Rs in Crore)	R&D expenditure as % of sales
HAL	14204.21	967.51	6.81
BEL	5703.63	468.21	8.21
BEML	3648.37	97.79	2.68
MDL	2262.87	--	--
GRSE	546.33	0.26	0.05
GSL	269.7	--	--
HSL	564.04	--	--
BDL	959.12	15.09	1.57
MIDHANI	509.01	3.98	0.78
OFs	12390.72	35.71	0.29

Source: Author's database

64 V.S. Arunachalam, "In Season of Blame: A Defence", *Deccan Chronicle*, May 09, 2013, http://www.deccanchronicle.com/130509/commentary-dc-comment/commentary/season-blame-defence

65 Press Information Bureau, Government of India, "Scorpene Submarine", March 14, 2011.

In terms of in-house design and development, the capability of the Indian industry is largely limited to HAL and BEL. However, the capability of these enterprises is way behind their globally peers. HAL, India's biggest defence enterprise, is a classic example of the innovation backwardness of Indian defence industry. Notwithstanding its ambitious mission and vision statements that speak of becoming a "significant global player in the aerospace industry" and achieving "self-reliance in design, development, manufacture and upgrade of aerospace equipment", HAL is at best a fringe player in the global aerospace sector. Its capability for design and development seems to have drastically diminished from fighter aircraft to trainers and helicopters. In the 1960s, HAL had shot into global prominence with the successful development of HF-24 Marut, which was rated a good fighter by experts at that time. Now, the company plays second fiddle to others: either the DRDO for indigenous fighter aircraft development or foreign companies for co-development and licence manufacturing of such planes. Even when HAL is a co-developmental partner, its role is limited. For instance, HAL's contribution is believed to be around 15-25 per cent in the case of Fifth Generation Fighter Aircraft (FGFA).[66]

However in spite of HAL being reduced to manufacturing helicopters and trainers, the company is still unable to translate its capability into a successful product within a reasonable timeframe, resulting in these systems being imported from abroad. A case in point is Indian Air Force's (IAF's) changing inventory of trainers. At one point of time, the IAF's entire trainer inventory consisted of HAL-designed planes such as HPT-32 (for basic training) and Kiran Mk-I and Mk-II (for stage-II and stage-III training). With the ageing of these trainers and HAL making no credible replacement

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[66] "AK Antony to take up Issues Related to FGFA Project with Russia", *The Economic Times*, October 17, 2013; and Ajai Shukla, "India to Develop 25% of Fifth Generation Fighter", *Business Standard*, January 6, 2010.

available in time, the IAF looks set to make up its entire inventory with imported trainers. The MoD has already signed contracts with UK-based BAE Systems for Advanced Jet Trainer (AJT) Hawk and Switzerland -based Pilatus for basic trainers. HAL's hopes of complementing the Pilatus with its HTT-40 seem to have run into a dead end. The IAF does not seem to be interested in HTT-40. Rather it wants more Pilatus planes for basic training.[67] Initial reports suggest that the MoD is not inclined towards HTT-40 because of its high cost, although HAL has recently made feverish attempts to stay on the race.[68] The Intermediate Jet Trainer (IJT), another plane being developed by the HAL as replacement for Kiran is headed nowhere. The project, sanctioned in 1999, is not expected to get initial operational clearance before the end of 2013 (as against the planned induction from 2005-06 onwards), causing frustration in the IAF, which has threatened to use the Pilatus instead of the IJT.[69]

HAL's poor design capability is equalled by its poor record of technology assimilation and indigenisation. The company is overwhelmingly dependent on foreign sources for production inputs (raw materials, parts and components). Between 2000-01 and 2011-12, its dependence on import inputs varied between 77 per cent and 95 per cent. Interestingly its high import dependence is both

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67 Ajai Shukla, "Indian Air Force at War with Hindustan Aeronautics; Wants to Import, not Build, a Trainer", *Business Standard*, July 29, 2013.

68 Ajai Shukla, "MoD Rejects HAL's Proposal to Build Basic Trainer", *Business Standard*, December 19, 2012.

69 Standing Committee on Defence, 14th Lok Sabha, *In-Depth Study and Critical Review of Hindustan Aeronautics Limited*, 17th Report (Lok Sabha Secretariat: New Delhi, 2007), pp. 39-41; Standing Committee on Defence, 13th Lok Sabha, *Demands for Grants 2003-04*, 19th Report (Lok Sabha Secretariat: New Delhi, 2003), p. 53; Ajai Shukla, "IAF Laments HAL Delays in Delivery of Intermediate Trainer", *Business Standard*, February 05, 2013; Biswarup Gooptu, "HAL to Work for Quicker Clearance of Defence Programmes", *The Economic Times*, February 7, 2013

for indigenously developed products and products manufactured under licence. For example, as stated in a a 2010-11 report of the Comptroller and Auditor General of India (CAG), the import content in HAL's indigenously developed Advanced Light Helicopter (ALH), *Dhruv* (the design and development of which started in 1984, with the production beginning from 2000-01) is 90 per cent as against the 50 per cent envisaged originally.[70] The high import dependency in licence manufacturing is best exemplified by the SU-30 MKI, of which the HAL is manufacturing 222 units in four phases since 2004-05. Although, HAL has embarked on the last phase of manufacturing the aircraft from the raw materials (supposed to be the highest form of indigenisation of the aircraft), the maximum indigenisation it has achieved so far is only 33 per cent.

State of India's Defence Innovation: Measuring through Self-Reliance Index

Unlike the composite indicators available for larger innovation systems, there is no specific indicator (at least in the Indian context) to measure defence innovation. However, some indirect quantitative indicators are available to measure the progress made in defence-specific R&D and production in India. One such indicator relates to self-reliance, a declared objective of the MoD. The self-reliance, measured by an index showing the percentage share of domestic content in total procurement expenditure, has often been used to measure India's progress in defence R&D and production. Way back in 1992, a Self-Reliance Committee under the then SA to the RM, Dr APJ Abdul Kalam (who later became the President of India) had worked out a plan as per which the index was to increase from then 30 per cent to 70 per cent by 2005. However this goal has not

[70] Comptroller and Auditor General of India, *Performance Audit of Activities of Public Sector Undertakings*, Report No. 10 of 2010-11 for the period ended March 2009, pp. 23-25.

been achieved till date. What is more bewildering is that the MoD, which is otherwise quite open about disclosing defence related data, does not include source-wise (domestic and foreign) procurement statistics in its annual defence budget. This not only inhibits any precise estimation of self-reliance but also leads to quite wide variations in the self-reliance index, as estimated by different people.

The author in a recent study has tried to estimate India's defence self-reliance index from 2006-07 to 2010-11, based on statistics derived from multiple sources that include the parliament, annual reports of the state-owned defence enterprises and the MoD's annual defence budget. The formula used to estimate the index is a modified version of the methodology used by the Kalam committee. The author's index takes into account the direct import (of military equipment), indirect imports (raw materials, parts and components imported by the defence industry for production purposes), and the indigenous content in India's total defence capital procurement. The self-reliance index is arrived at by taking the percentage share of the indigenous content (as opposed to total supplies from domestic enterprises) in the total procurement expenditure and is presented in Table X. As the estimate shows, the increase in the self-reliance index although higher than in 1990s, is not substantial, even two and a half decades after the self-reliance target was set.[71] It also shows that the volume of indirect imports is quite substantial and in the range of 60-153 per cent of direct imports during the study period! This in turn indicates the poor performance of the entire defence establishment, particularly in respect of R&D and the production agencies, which despite their size have been unsuccessful in achieving the self-reliance target.

71 For the detailed methodology, data-related problem and self-reliance index see Laxman Kumar Behera, *Indian Defence Industry: Issues of Self-Reliance*, IDSA Monograph Series, No 21, July 2013, http://www.idsa.in/system/files/monograph21.pdf

Table X. Self-Reliance Index for 2006/07-2010/11

1				2006-07	2007-08	2008-09	2009-10	2010-11
2	Domestic Capital Supplies of which	2(a)	Indigenous Content (Rs in Crore)	12892.74	11596.66	10931.30	14873.22	18059.57
		2(b)	Indirect Import (Rs in Crore)	8466.42	6144.91	8866.00	11047.26	13384.98
3	Direct Capital Import (Rs in Crore)			5541.28	10161.85	10203.12	13411.91	15443.01
4	Total Capital Procurement (Rs in Crore)			26900.44	27903.42	30000.42	39332.39	46887.56
5	**Indigenous (%) (Self-Reliance Index)**			**47.93**	**41.56**	**36.44**	**37.81**	**38.52**
6	Indirect Capital Import (%)			31.47	22.02	29.55	28.09	28.55
7	Direct Capital Import (%)			20.60	36.42	34.01	34.10	32.94

Source: Laxman Kumar Behera, *Indian Defence Industry: Issues of Self-Reliance,* Institute for Defence Studies and Analyses (IDSA) Monograph Series, No 21, July 2013, p. 52.

Defence innovation: The Fault Lines

Lack of Higher Organisational Structure for Defence Innovation

The biggest weakness of India's defence innovation system is the absence of an organisational mechanism that is responsible for: setting policy goals; bringing various stakeholders (users, R&D and production agencies) on board a common platform; reviewing projects in terms of their viability; monitoring the progress of indigenous projects and fixing accountability. The absence of such an organisation has often led to ad-hoc decision-making, duplication of efforts, waste of resources and, more importantly, less than the desired results. A glaring example of the lack of direction and monitoring by a higher authority can be seen in India's attempts to develop and/or manufacture three types of transport aircraft. The first one is the 15-20 ton class Multi-role Transport Aircraft (MTA)[72] for which HAL is joint development partner along with Russian entities. The second is the Rs 11,879 crore 'Avro Replacement Programme' in which the MoD wants to involve the private sector to manufacture 40 aircraft.[73] The third project is the Council of Scientific & Industrial Research (CSIR)-led design and development of a civilian 70-100 seater aircraft. In all these projects, the critical national capability in project management, design, development and production is fragmented, as these programmes are executed by different agencies. Moreover, project execution by different agencies is not necessarily in keeping with their proven capability. For instance, the MoD's attempt to involve private sector in the manufacture of 40 aircraft has more to do with the IAF's frustration with HAL rather than a genuine faith in the capability of the private companies - some of which have in fact voiced their concerns

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72 Press Information Bureau, Government of India, "HAL signs MTA Follow-on Contract with Russian Partners", October 12, 2012.

73 Lok Sabha, Parliament of India, "Purchase of Transport Aircraft", Unstarred Question No 530, answered on August 13, 2012.

regarding the viability of the programme because of the lack of economies of scale. The capabilities of the CSIR to lead the design and development of a civilian aircraft are also questionable. Its previous attempt to design and develop Hansa (a two-seater trainer aircraft), and a 9-14 seater light transport aircraft, Saras was beset with many problems. The CAG which undertook a through audit of the above projects had highlighted the gross project mismanagement, performance shortcomings, the high-dependence on imported technology and materials, and time and cost overruns. The shortcomings in the management of the two projects were so glaring that the CAG had gone to the extent of cautioning the CSIR against pursuing its then plan to develop a 70 seater aircraft.[74]

In the absence of an oversight structure, the crucial element of defence innovation, that is, R&D is undertaken in a piecemeal manner and is largely viewed as a mere by-product of the procurement process. The DRDO, whose core mandate is to design and develop state-of the art weapon systems and provide the necessary technical advice in all matters of weapon acquisition, has been marginalised in the procurement process to the extent of being just another stakeholder competing for its fair share of resources in the defence budget. The budget seeking attitude of the DRDO has in fact been institutionalised by the MoD's Defence Procurement Procedure (DPP), a document that lays down the rules and procedures to be followed in arms procurement, and the responsibility of various agencies in the procurement chain of command. As per the DPP provisions, arms procurement, which flows from the armed forces long- to short-term plan documents, is to be initiated by the respective services with the initial suggestion of source of procurement, which is invariably import-oriented. The DRDO's role is limited to contesting those import-oriented proposals if it believes they can be developed or produced indigenously.

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[74] Comptroller and Auditor General of India, *Report No. PA 2 of 2008 (Scientific Departments)*, pp. 1-31.

The role of the DRDO in the procurement process is further marginalised by the DPP's offset policy which aims to leverage India's huge arms imports for building a strong indigenous defence R&D and industrial base. The offset policy provides for transfer of technology (including the 26 critical technologies listed for acquisition by the DRDO) as one of the ways in which foreign companies can discharge their offset liabilities. It does not however give the DRDO any say in the selection of technologies that are to be mandatorily transferred via the offset route. Rather, the policy allows complete freedom to the foreign suppliers to choose the technology they want to share with the Indian industry!

The existing mechanism has clearly not fostered indigenous defence innovation, as the country still remains largely import dependent for its critical defence hardware requirements. Instead of addressing the core issue, the government has so far been content with making minor and cosmetic changes. For instance the government has added a new provision in the DPP 2013, wherein the armed forces are required to provide a justification in their procurement proposal as to why the proposed item cannot be acquired from the domestic sources.[75] As argued by many, this change is merely cosmetic as the same reason for justifying why a system needs to be imported could be cited to justify why the items cannot be sourced indigenously. Even if this change is considered to be a genuine reform measure, other aspects such as an R&D policy and creation of synergy among stakeholders still remain unaddressed.

It is noteworthy that unlike other sectors of importance for which there are a host of policy statements,[76] there is no policy statement specific to defence R&D, although the MoD's first ever Defence

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[75] Ministry of Defence, Government of India, *Defence Procurement Procedure 2013: Capital Procurement*, p. 9.

[76] At the national level, India has at least five major policy documents. These include the Science, Technology and Innovation Policy 2013, Electronics Policy, Cyber Security Policy, National Manufacturing Policy, and Defence Production Policy.

Production Policy (DPrP) –announced in January 2011 - makes a passive reference to "broaden the defence R&D base of the country."[77] The weakness of the DPrP is that the policy document is not supported by a concrete R&D or manufacturing plan to be executed by the concerned agencies – a key weakness highlighted recently by the Economic Advisory Council to the Prime Minister (PMEAC).[78] It is also noteworthy that the absence of concrete plan is a feature of the of MoD's Technology Perspective and Capability Roadmap (TPCR), which was announced in April 2013 with the intention of providing the industry an "overview of the direction in which the armed forces intend to head in terms of capability over the next 15 years."[79] The idea behind providing such an advance overview of the armed forces' long term capability requirement is to give the industry the lead time to develop the relevant technologies and put them into production.

Although, the TPCR offers details regarding the specific capabilities required by defence forces, the document falls short of quantifying those requirements to enable the industry to translate them into viable business opportunities. Perhaps, a bigger weakness of the document is that it shifts the entire risk of technology development and production to the industry without any commitment on the part of the MoD. This is best amplified by the 'disclaimer' of the TPCR which states that the participation of the Indian industry is "solely at its own discretion [and the] Government of India (GOI) is not responsible for any loss by the industry whilst complying with the stipulation in this document or with changed requirement

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77 Ministry of Defence, Government of India, "Defence Production Policy", January 01, 2011, http://mod.nic.in/writereaddata/DPP-POL.pdf.

78 Economic Advisory Council to the Prime Minister, "Economic Outlook 2013-14", September 2013, p. 28

79 Ministry of Defence, Government of India, "Technology Perspective and Capability Roadmap", April 2013, p. 3.

due to any reason." By laying down such condition, the declaimer however fails to recognise the fact that technology development or indigenous production is as much a responsibility of the government as of the domestic industry. Since the TPCR's disclaimer absolves the government of any responsibility to ensure that certain capabilities be developed in-house, it creates uncertainty within the industry and R&D agencies about future course of decision making.

The lack of synergy among the stakeholders for indigenous projects can also be seen in the context of the indigenous development of the 155 mm/45 calibre towed gun by the OFs. As acknowledged by the MoD, the development of the gun involves all the stakeholders (army, OFs, DRDO, quality assurance and maintenance), and this "has been done for the first time in the country."[80] It is however to be noted this synergistic approach for gun development was not the result of a planned exercise, although such an approach seems to yielding rich dividends.[81] It is the repeated failure of the army and the MoD to import a gun system (since India imposed a ban three years after the Bofors contract was signed in 1986) that forced the defence establishment to look for an

80 Ministry of Defence, Government of India, note 56, pp. 61-62.

81 The Minister of State for Defence is on the record, saying that the internal firing conducted by the ordnance factories "has met the planned objectives, [leading] to indent for 114 [units] of 155 mm × 45 calibre artillery guns." Reports also suggest that army may go for an initial order of 414 guns. More importantly, involvement of all stakeholders seems to have a benign effect on the developmental time and indigenisation. As noted by the chief of the OFs, as against 60 months usually taken for such developmental efforts, the gun was developed in 16 months. The developed gun has 65 per cent indigenous content and is planned for increase to 85 per cent in a short period of time. See Lok Sabha, Parliament of India, "Test of Guns", Unstarred Question No. 5330, Answered on April 29, 2013; Rajat Pandit, "Desi Bofors to Plug Gap in Army's Long-range Firepower", *The Times of India*, March 07, 2013; "Ordnance Factory Introduces Indigenous Version of 155mm Gun", *The Economic Times*, January 04, 2013.

indigenous option. Interestingly, the gun development by the OFs is based on the technologies acquired through the Bofors contract. During all these years, nobody thought about using the bought out gun technologies for indigenous production. While the army repeatedly scouted for an imported gun, the production and developmental agencies sat on the technologies. More importantly, the MoD, particularly the DDP, which is entrusted with the task of indigenisation, development and production of defence items, remained a mute spectator. Had the army been successful in its import attempts which goes back to as early as 1997 when then army chief approved an internal proposal to import a truck mounted gun from Celsius (the successor of Bofors), the indigenous efforts would not have perhaps taken off.

The Rama Rao Committee (RRC), constituted by the MoD to review the functioning of DRDO, in its report (*Redefining DRDO*, submitted in March 2008,[82]) identified organisational shortcomings as the key weakness in India's defence innovation system. To rectify this institutional gap, the committee had suggested the creation of a high-level Defence Technology Commission (DTC) under the chairmanship of the defence minister. To make the DTC an overarching body and key decision making institution for all aspects of defence innovation and self-reliance, the RRC also suggested that its other members should include all the senior most functionaries of the armed forces, ministries of defence and finance, departments of atomic energy and space, and the National Security Advisor (NSA).[83] The committee had also suggested that two eminent personalities from the fields of science and technology and industry also be co-opted as members. It was the RRC's view

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[82] Press Information Bureau, Government of India, "Recommendations of Rama Rao committee on DRDO", April 23, 2008.

[83] Interview with Amiya Ghosh, member, committee on Refining DRDO, August 01, 2013

that such a high powered body with cross ministerial/departmental membership and representatives from industry and wider science and technology field would create synergy among stakeholders, and provide the required direction and thrust to India's defence innovation efforts. As per the RRC recommendations, the DTC would be responsible for articulating the defence R&D policy, setting R&D targets and monitoring them. In addition, the DTC would also be responsible for enabling the DRDO to play a larger role in India's defence procurement, including technology transfer through offset route. However, five years have gone by and the DTC is yet to be created. The latest information (as of April 2013) is that a cabinet note has been prepared for its creation.[84]

Poor Human Resource Base

India's defence innovation is also constrained by a poor human resource base, in terms of the quality and quantity of the scientific cadre and optimisation of human resources. This is clearly apparent in the context of the DRDO, which is at the heart of India's defence innovation system. Despite its extensive charter of duties, and vast array of technological interest, the DRDO has only 7,700-odd scientists. In comparison, Indian Space Research Organisation (ISRO) which works in fewer technological fields has more scientists (around 8,000).[85]

The DRDO's limited scientific cadre notwithstanding, the organisation has the highest auxiliary and administrative personnel to scientist ratio (Table XI), indicating the lack of optimisation of human resources. If the organisation is to achieve the average of

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[84] Press Information Bureau, Government of India, "Defence Research and Development Organisation", April 22, 2013.

[85] Standing Committee on Defence, 15th Lok Sabha, *Demands for Grants 2012-13*, 15th Report (Lok Sabha Secretariat: New Delhi, 2012), p. 78

other major scientific agencies (which include the departments of space and atomic energy, among others), if not the private sector (that has the lowest proportion of auxiliary and administrative staff to R&D staff) it can save 8,774 support staff, including 4,828 personnel from its auxiliary service, Defence Research Technical Cadre (DRTC).[86]

Table XI. Number of Auxiliary and Administrative Staff per R&D Staff/Scientist (As on April 2010)

	Auxiliary	Administrative
DRDO	1.3	1.2
Major Scientific Agencies	0.7	0.7
Private Sector	0.6	0.2
Overall R&D Sector	0.6	0.6

Note: The manpower strength of DRDO is as of 2011

Source: Ministries of Defence and Science and Technology

The DRDO's limited manpower base is further constrained by a number of other factors : high attrition rate among scientists, the low educational profile of the scientific cadre, and poor training, all of which make the organisation less dynamic a place for the well qualified and motivated talent to work in.

The DRDO despite being the premier R&D agency in India has the problem of scientists leaving the organisation. For instance, during 2002-06, a total of 1007 scientists left the organisation- an attrition rate that the government itself has acknowledged to be higher than in the private sector.[87] The attrition rate has however

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86 A similar argument but for an earlier period is made by Ravinder Pal Singh, "An Assessment of Indian Science and Technology and Implications for Military Research and Development", *Economic and Political Weekly*, July 29, 2000, pp. 2762-2775.

87 Press Information Bureau, Government of India, "Exodus of Scientists from DRDO", April 26, 2007.

come down from high of 273 in 2007 to 65 in 2009. This decline can be attributed to the increase in the salaries of all government employees (including the DRDO scientists) post the implementation of the Sixth Central Pay Commission (CPC) recommendations. However, the benign effect of the CPC now seems to be waning as the number of resignations has again started to rise. For instance in 2011, 86 scientists left the organisation, compared to 63 in 2010.[88]

The poor educational profile of DRDO scientists has been a perennial problem for the organisation, impacting some of its high profile projects. For instance in an internal review report of 1987 pertaining to the PINAKA Multi Barrel Rocket Launcher (MBRL) project, the organisation had identified the "non-availability of adequately qualified manpower as one of the constraints in the smooth progress of the project."[89] The situation has however not changed over the years. In 1995, the CAG had made an observation regarding the persistence of the problem in a review report on six DRDO laboratories. In the case of the Armament Research and Development Establishment (ARDE), a key lab responsible for design and development of combat vehicles, the CAG noted that "about 48 per cent of the strength of officers was unqualified and represented level of education up to B.Sc, or Diploma in Engineering."[90]

The RRC which reviewed the functioning of the DRDO was particularly dismayed by the predominance of first degree holders in the DRDO's scientific cadre, with 60 per cent of the scientists being diploma holders, engineering and science graduates, or having

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[88] Press Information Bureau, Government of India, "Resignation of Scientists from DRDO", December 05, 2012.

[89] See Comptroller and Auditor General of India, *Union Government (Defence Services): Army and Ordnance Factories*, Report No 8 of 1995, p. 20.

[90] Ibid.

a masters degree in arts or science. It found that only 10 per cent of DRDO's total scientific manpower were PhDs (three per cent in engineering subjects and seven per cent in science subjects). The shortage of highly qualified scientists in research labs is so acute, that as many as 43 per cent of laboratories employ less than two per cent PhDs. This educational profile, the RRC noted, was not at all satisfactory for India's premier defence R&D organisation, that is mandated to design and develop frontier defence technologies.

More startlingly, the RRC also observed that the majority of the DRDO's scientific cadre is not 'research trained', a feature that is also common to other high-end R&D organisations such as the department of atomic energy and ISRO. Given the class room oriented teaching focus in most Indian educational institutes, these agencies often struggle to get 'research-ready material' for their R&D programmes. However while some other agencies have taken steps to address this critical issue, the DRDO is yet to get its act together. For instance, the ISRO, which faced a "severe shortage" of highly talented scientists and engineers for R&D in space science and technology, set up the Indian Institute of Space Science and Technology (IIST), which has been up and running since 2007.[91] With an intake of 150 students per year, the IIST offers graduate, post-graduate and doctoral programmes in areas of space science and technology. The students who successfully pass out from the IIST are required to work in ISRO for a minimum of five years. The DRDO on the other hand does not have an IIST-like institute. It relies on its Defence Institute of Advanced Technology (DIAT), for training in-house scientists, and that too for a limited 20-week period. Unlike the IIST, it does not tap fresh talent and educate and train them for future absorption in its laboratories.

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91 Press Information Bureau, Government of India, "Setting up of Indian Institute of Space Science & Technology (IIST)", April 26, 2007.

The RRC in its report to the government had made a number of suggestions to enhance the human resource profile of the DRDO. Among others, it had suggested that an eminent HR expert be hired to develop a roadmap for improving the DRDO's manpower base. The RRC had also recommended the decentralisation of DRDO's personnel recruitment system and allowing the concerned lab heads to spot talent and induct it in the shortest possible time. The RRC further suggested that the government study the models developed by the ISRO and atomic energy for the training of their respective personnel. Higher compensation, and performance linked incentives were also recommended by the RRC to incentivise high calibre scientists to work in the DRDO. However, like the DTC, the RRC's recommendations on human resource development do not seem to have been taken seriously. The MoD's latest annual report, which has a dedicated chapter on DRDO, is silent regarding the steps taken on these fronts.

Meagre Budget and Lack of Emphasis on Indigenous R&D

Although, India's stated policy is to achieve "substantive self-reliance in the design, development and production of equipment/ weapon systems/ platforms required for defence",[92] yet when it comes to resource commitment the focus appears to be elsewhere. Compared to the US and China which spend in excess of 10 per cent of their defence budget on R&D, India's current spending is less than six per cent.[93] Even this percentage share was allocated only after 1980s before which the allocation for R&D was negligible - about one per cent of the defence budget in 1960s, rising to about two per cent in the early eighties.[94] This meagre share of the defence budget, together with India's relatively small defence budget, means

92 Ministry of Defence, Government of India, "Defence Production Policy", January 2011

93 International Institute for Strategic Studies, *Military Balance 2013*, p. 262; Ministry of Defence, Government of India, *Defence Services Estimates 2013-14*.

94 Standing Committee on Defence, 10th Lok Sabha, *Defence Research and Development: Major Projects*, 5th Report (Lok Sabha Secretariat: New Delhi, 1995), p. 4.

that defence R&D budget in absolute terms is minuscule compared to that of other major countries. In absolute terms, the DRDO's 2013-14 budget of Rs 10,610.2 crore ($1.8 billion[95]) is a mere three per cent of the US DoD's $ 67.5 billion R&D budget (for 2014).[96]

This low defence allocation for DRDO has an unintended impact on the type of projects the organisation can take up. This is obvious from the current project portfolio of the DRDO (Table XII). Of a total of 546 projects valued at Rs 85,766 crore, a staggering 89 per cent, in value terms, is accounted for by 153 Mission Mode (MM) projects. These projects are applied research in nature, normally based on technologies that are proven and readily accessible/ available,[97]undertaken at the formal request of the armed forces, and accorded the highest priority. This however leaves a meagre amount (less than 10 per cent) for basic research or on experimental projects, that are categorised as Science and Technology (S&T) and Technology Demonstration (TD). Although, these projects are crucial for generating new technologies for future use and hence vital from India's defence innovation point of view, DRDO's limited budget does not allow much priority to them.

Table XII. DRDO's Project Portfolio (As on 2011)

	Projects		Project Value	
Project Category	No	%	Rs in Crore	%
Mission Mode (MM)	153	28	76564	89
Technology Demonstration (TD)	232	42	5934	7
Science and Technology (S&T)	124	23	1383	2
Infrastructure Development (IF)	37	7	1885	2

Source: Defence Research and Development Organisation (DRDO)

95 Conversion of Indian rupee into US$ is based on average exchange rate for the first five months of 2013-14.

96 US Department of Defence, "National Defence Budget Estimates for FY 2014", p. 8.

97 Nabanita R. Krishnan, "Critical Defence Technologies and National Security: The DRDO Perspective", *Journal of Defence Studies*, 3(3), July 2009, pp. 91-105.

Acknowledging the importance of higher investment on defence R&D, the Standing Committee on Defence in a report presented to the Parliament in 1995 had suggested that the allocation for DRDO should be progressively increased to 10 per cent of the defence budget by 2000. While making the suggestion, the Committee had taken note of the Self-Reliance Review Committee's plan (to achieve 70 per cent self-reliance by 2005) which was itself linked to a higher budgetary allocation for DRDO.[98] However, the DRDO's budget was never raised to the 10 per cent level during the recommended period, peaking at a much lower level of 6.74 per cent, and that too much later, in 2008-09. Since then, there has also been a gradual decline, further indicating the low priority accorded to defence R&D in the annual defence spending.

Table XIII shows DRDO's share in India's GDP and the country's total R&D expenditure which is much less than that of advanced countries. For example in 2012, the US DoD's R&D outlays amounted to 0.45 per cent of GDP and 16.82 per cent of total US R&D expenditure.[99]

The lack of focus on domestic defence R&D is also apparent in India's annual defence budgeting process, and particularly in the priority attached to resource allocation between the armed forces and the DRDO. If the allocation for the armed forces represents an investment on an immediate need, the allocation for R&D - which by its very nature is an investment for the future – is clearly less prioritised. This is evident from Table XIV, which shows that the percentage of under-funding of the DRDO during the eight year period to 2013-14 is consistently higher than of the armed

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[98] Standing Committee on Defence, 10th Lok Sabha, *Demand for Grants (1995-96)*, 4th Report (Lok Sabha Secretariat: New Delhi, 1995), p. 24; Standing Committee on Defence, 10th Lok Sabha, *Defence Research and Development: Major Projects*, 5th Report (Lok Sabha Secretariat: New Delhi, 1995), p. 6.

[99] US Department of Defence, "National Defence Budget Estimates for FY 2014", p. 10 and 262; and Battelle and R&D Magazine, *2013 Global R&D Funding Forecast*, December 2012.

forces as a whole. This could be due to several reasons, including the operational exigencies of the armed forces that sometimes necessitate import-driven defence preparedness to overcome the time lag and uncertainty associated with indigenous R&D projects. But what is inexplicable is the deliberate attempt of some vested interest groups to marginalise domestic R&D to gain from arms import. As K Subrahmanyam observes, Indian R&D has often to fight the 'import lobby' and in the process overestimates its deliverables, which in turn leads to delays, cost overruns and also failures.[100] So Indian defence innovation not only requires more R&D spending but it also must guard against the vested interest groups who profit at the cost of the India's own technological progress.

Table XIII. Share of DRDO in India's GDP and Total R&D Expenditure

Year	GDP (Rs in Crore)	Total R&D Expenditure (Rs in Crore)	DRDO's Expenditure (Rs in Crore)	DRDO's Expenditure as % of GDP	DRDO's Expenditure as % of total R&D Expenditure
1970-71	47638.0	139.64	17.55	0.04	12.57
1975-76	86707.0	356.71	52.13	0.06	14.61
1980-81	149642.0	760.52	83.70	0.06	11.01
1985-86	289524.0	2068.78	321.09	0.11	15.52
1990-91	586212.0	3974.17	689.57	0.12	17.35
1995-96	1226725.0	7483.88	1396.25	0.11	18.66
2000-01	2177413.0	16198.80	3342.34	0.15	20.63
2005-06	3693369.0	29932.58	5283.35	0.14	17.65
2006-07	4294706.0	34238.39	5362.82	0.12	15.66
2007-08	4987090.0	39437.77	6104.55	0.12	15.48
2008-09	5630063.0	47353.38	7699.05	0.14	16.26
2009-10	6477827.0	53041.30	8475.38	0.13	15.98
2010-11	7795313.0	62053.47	10148.92	0.13	16.36
2011-12	8974947.0	72620.44	9937.68	0.11	13.68

Source: Author's extrapolation based on data obtained from ministers of defence and science and technology and Reserve Bank of India (RBI)

[100] K. Subrahmanyam, *Shedding Shibboleths: India's Evolving Strategic Outlook* (Arthur Monteiro for Wordsmiths: New Delhi, 2005), pp. 29-41.

Table XIV. Comparison of Underfunding between Armed Forces and DRDO

Year	Projection (Rs in Billion)		Allocation (Rs in Billion)		Underfunding (Rs in Billion)		Underfunding (%)	
	Armed Forces	DRDO	Armed Forces	DRDO	Armed Forces	DRDO	Armed Forces	DRDO
2006-07	883.11	62.40	833.23	54.54	49.89	7.86	5.65	12.60
2007-08	962.70	69.31	898.68	58.87	64.02	10.44	6.65	15.06
2008-09	1098.41	85.23	988.62	64.86	109.79	20.37	10.00	23.89
2009-10	1418.79	95.16	1311.54	84.82	107.26	10.34	7.56	10.87
2010-11	1589.64	117.54	1359.50	98.09	230.14	19.45	14.48	16.55
2011-12	1997.05	148.43	1542.77	102.53	454.27	45.90	22.75	30.92
2012-13	2134.13	144.63	1821.00	106.36	313.14	38.27	14.67	26.46
2013-14	2623.54	164.83	1928.50	106.10	695.04	58.73	26.49	35.63

Note: Projection amount represents the resource requirement projected at the time of budget formulation exercise. The allocation represents funds made available in the budget announced in the parliament.

Source: Author's database

Industry's meagre role in R&D

As mentioned earlier, except for HAL and BEL, the rest of the Indian defence industry spends virtually zero on R&D. This can be largely attributed to the absence of, what can be termed, the 'R&D culture' in most of India's Central Public Sector Enterprises (CPSEs), in which category fall the nine DPSUs, the most dominant players in the Indian defence industry. It is noteworthy that until recently, R&D was not a mandatory function of the CPSEs, although some like HAL, BEL and Bharat Heavy Electrical Ltd (BHEL) among others ventured into the sector voluntarily. It was only in September 2011 that the Department of Public Enterprises (DPE) (the nodal department of the Ministry of Commerce and Industry responsible for 'coordination of matters of general policy of non-financial nature affecting all public sector industrial and commercial undertakings') issued a set of guidelines to enable the CPSEs to undertake R&D in a structured manner. Among other provisions, the DPE's R&D guidelines require all the profit-making CPSEs to formulate short- to long-term R&D plans (keeping in view their respective vision and mission statements) with the approval of their respective board of directors. More importantly, the guidelines enable the CPSEs to spend a certain minimum percentage of their Profit After Tax (PAT) on R&D (while the Navratna companies are required to spend a minimum one per cent of the PAT on R&D; the Mini-ratnas are required to spend 0.5 per cent). To force the CPSEs to undertake R&D in some form or other, the guidelines also include R&D in the criteria for a CPSE's performance evaluation.[101] The R&D can be undertaken either in the in-house facility and/or in collaboration with academia and research institutes.

Since the DPE's R&D guidelines are of recent origin, their impact on the defence PSUs who spend little or nothing on R&D, would be felt after some time. This is so, as setting up a dedicated infrastructure and the recruiting of qualified manpower for R&D job all require time. In the meantime, it is important that DPSUs formulate their R&D plans, for execution in times ahead. But the DPSUs do not seem to have acted upon it so far. The annual reports of the DPPUs, that are otherwise full of information, are silent on the progress made on this front.

The low priority given to R&D by industry is also due to the lack of incentives particularly in the case of the private sector which does not have the backing of the government to undertake expensive yet risky R&D projects. Until recently the procurement guidelines of the MoD did not have any provisions to allow the industry to undertake in-house product design and development. Since 2006, the MoD has although tried to address this issue by articulating a 'Make' procedure (under which the MoD is committed to fund up to 80 per cent of the developmental cost incurred by industry), it has largely remained ineffective due to the complexity of the procedures. The DPP-2013 has however made a commitment to

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[101] During finalisation of MoU targets, the CPSEs are also required to identify R&D projects (five for Maharatna & Navratna and three for Miniratna companies) which they want to execute in the assessment year.

simplify the procedures. The seriousness with which the 'Make' procedure is used in future would be key to promoting R&D within the private sector.

Lack of Reforms

An inhibiting factor in India's defence innovation endeavours is the absence of reform in the state-owned defence enterprises (DPSUs and OFs) and the DRDO. This has not only hampered the accountability and the efficiency expected from these organisations but also rendered them inward looking. The fundamental reforms suggested by a number of government-appointed expert groups have either been delayed, or implemented half-heartedly, thus preventing the full exploitation of their innovation potential.

In 2004, the MoD had set up a high-level committee under Vijay Kelkar (then adviser to the finance minister) to suggest measures to improve India's defence industrial base and increase self-reliance. One of the terms of reference for the Kelkar committee was related to the innovation potential of the DPSUs and the OFs, and the committee was specifically tasked to suggest measures to enable these entities to assume the role of designer and system integrator. The committee after year-long deliberations submitted its report in two parts, with the second part of the report - titled *Revitalising Defence Public Sector Undertaking and Ordnance Factories* - being completely devoted to the above mentioned terms of reference. The committee had observed that for the DPSUs and the OFs to become design house and undertake big system integration, they would need to change their way of functioning. For the OFs, that are departmentally-run organisations, the expert group recommended that "all ordnance factories should be corporatised into a single corporation under the leadership of a competitive management."[102] The committee also suggested that the corporation

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[102] Standing Committee on Defence, 14th Lok Sabha, *Indigenisation of Defence Production: Public-Private Partnership*, 33rd Report (Lok Sabha Secretariat: New Delhi, 2008), p. 20.

may be given Navratna status. The committee believed that a corporate status would provide the organisation with the necessary autonomy (in financial and decision making matters) which would enable them to focus on in-house design and development.

The Kelkar committee advocated for greater autonomy and accountability for the DPSUs that are already corporate entities, with some powers vested in their boards of directors. The Committee had recommended that HAL and BEL be accorded Navratna status, and BEML and MDL the Mini-ratna status by relaxing the eligibility conditions. Besides, the committee had also recommended that except for MIDHANI, other DPSUs should be allowed to acquire foreign technology by way of making outward investments. The expert group had suggested that the DPSUs should be "listed [in stock exchanges] for improved corporate governance and access to capital markets."[103]

The MoD's response to the Kelkar Committee report has been mixed. On the one hand, it has implemented some soft measures such as according Nav/Mini Ratna status to DPSUs but on the other hand it has completely shied away from implementing the main ones. Regarding the corporatisation of OFs, the MoD has said that "it has no intention to implement this recommendation." It has also delayed the public listing of DPSUs by saying that DPSUs have enough cash surplus and therefore do not need access to capital market. The MoD's above position does not however address the aspect of improved corporate governance and accountability, which the committee had visualised while making the suggestion for DPSUs' listing in the stock exchanges.

The RRC's 2008 report, the first of its kind since the DRDO's inception, had also suggested a number of reforms to enable the

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[103] Standing Committee on Defence, 14th Lok Sabha, *Indigenisation of Defence Production: Public-Private Partnership*, 33rd Report (Lok Sabha Secretariat: New Delhi, 2008), p. 84.

organisation to lead India's defence innovation. Apart from the DTC and HR-related measures as discussed earlier, the RRC also made two other crucial suggestions, relating to the management of DRDO laboratories and the role and structure of DRDO headquarters.[104] The RRC was of the considered view that the existing management of the 50-odd DRDO laboratories is 'excessively centralised' in New Delhi which is not 'conducive to accelerated R&D'. It therefore suggested the decentralisation of management by way of clubbing all the labs into five centres (each consisting of a number of laboratories with similar domain expertise), and devolving powers (related to material procurement, recruitment etc.) from the headquarters to them. The performance of the each centre, the RRC suggested, would be the responsibility of respective heads of the centres - to be designated director generals (DGs) - instead of the scientists sitting in New Delhi.

While making the above suggestion, the RRC had also redefined the role of the DRDO chief and the structure of DRDO headquarters. The RRC felt that as SA to RM, his responsibility to provide unbiased advice to the top political leadership is much higher and goes beyond the narrow organisational interests, that are inherent in his role as DG DRDO. The RRC therefore recommended that the DG DRDO be replaced by a chairman, DRDO, with a dedicated secretariat in the DRDO HQ. As chairman of DRDO he would also be the de facto convener of the DTC, the secretariat of which would be established under a dedicated CC R&D in the DRDO headquarters. As the convener of DTC, his responsibility would be to set the agenda for the DTC meeting and do the necessary follow-up. Consequently, he would be divested of his direct responsibility for DRDO's R&D performance which would then become the responsibility of the concerned DGs of the various centres.

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[104] For an overview of some of the RRC's recommendations see Amiya Kumar Ghosh, *Resource Allocation and Management in Defence: Need for a Framework* (Knowledge World: New Delhi, 2013), pp. 407-487.

To strengthen the SA's role, the RRC also recommended the restructuring of the DRDO headquarters and the creation of a System Analysis Group (SAG) which would undertake various studies and scenario building to apprise the SA regarding important technological developments, their implications for national security, and the state of domestic R&D. The SAG would be part of the larger Service Interaction Group (SIG) to be headed by a three star service officer in the restructured DRDO headquarters. The SIG, the RRC argued, would bridge the long-standing communication gap between the user (armed forces) and the developer which has been the hallmark of India's defence innovation system so far. Among other functions, the SIG would also be responsible for constituting joint teams for project monitoring and resolving any issues arising at the developmental stage. Like the SIG, the RRC also suggested that a group of scientists under a dedicated CC R&D should interface with the industry for DRDO-developed products. Among other functions, the group, named the CC R&D (Production Coordination), would be responsible for identifying production partners through a transparent process and with the active participation of the concerned centre, once the feasibility report of an project is finalised. It would also assist the MoD in its acquisition process, particularly with respect to offsets, technology absorption and trial evaluation.

As part of further restructuring, the RRC suggested for creation of a dedicated CC R&D would be responsible for two critical organisations: the Board of Research in Advanced Defence Sciences (BRADS), and Centre for Advanced Studies in Defence Sciences (CASDS). While the CASDS was visualised to address the training needs of the DRDO scientists, the BRADS was meant to exploit the 'outstanding' research capability (both human resource and research infrastructure) available outside the DRDO. Interestingly the RRC envisaged that the BRADS would function like the highly acclaimed Defence Advanced Research Projects Agency (DARPA) of the US, which has been at the forefront of 'radical innovation' in several cutting-edge technologies. To this end, the RRC suggested that the entity should be governed by a high level committee headed by the SA to RM. The RRC also suggested that BRADS would replace the DRDO's existing grants-in aid programme and its funding should be around 10 per cent of the DRDO budget.

As in the case of the DTC, these recommendations of the RRC have not been accepted by the government, although the government has notified some action points for implementation.

Conclusion

Despite some noticeable performance, India's defence innovation is by and large underdeveloped. This is amply evident from high import dependence for complete weapons systems, apart from large scale indirect imports (to support indigenous development and/or production), void in critical technologies (as mentioned in the list of 26 critical technologies listed for acquisition through offset route), and the poor patent scorecard of the DRDO and defence industry.

India's defence innovation in its present set up is constrained to deliver on its mandate because of a number of fundamental weaknesses. The first and foremost weakness of India's innovation is the lack of a higher organisational structure to provide direction and thrust to indigenous R&D. This combined with absence of a dedicated defence R&D policy and concomitant manufacturing plan has led to ad-hoc decision making and sub-optimal performance of the key players in the set up.

The sub-optimal performance of the defence innovation is also due poor human resource base and meagre resources devoted to R&D. The DRDO which is at the heart of the defence innovation is presently faced with major human resource challenges as seen from poor scientist to other staff ratio, high rate of attrition, low educational background of scientist, and poor level of training, which together indicate the organisation's lack of dynamism to work on the frontier defence technologies.

Despite India's ambitious aim to achieve substantive self-reliance in design, development and production of weapon systems, there is a lack of commitment to provide adequate resources for indigenous R&D. Presently India's defence R&D spending as accounted for by the DRDO is less than six per cent of the defence budget, compared to over 10 per cent devoted by the counties like China and US whose respective defence budgets are also substantially larger than India's. The poor investment on DRDO has also constrained its freedom to devote adequate resources for basic research as the organisation is overwhelming engaged in applied research based on existing technologies. With the defence industry or any other agencies not spending much on defence-related R&D, this has a long term consequence in terms of limiting India's capacity to innovate new technologies for future use.

India's defence innovation is also constrained due to lack of reforms of major players, particularly the DRDO, DPSUs and the OFs, which together form the core of India's defence innovation set up. The lack of reforms has virtually rendered these organisation inward-looking while at the same time inhibiting their efficiency and accountability.

India's defence innovation system is also constrained due to the weakness in India's larger innovation system, which is characterised by the poor investment on R&D, government-led R&D spending, low density of scientists/researchers, skill shortages in key sectors, industry's meagre role in R&D, and poor collaboration between research labs and industry. These factors have contributed to India's low inventiveness. This is evident from India' poor patent portfolio, especially with respect to China which has made a giant stride in science and technology over the past two decades. Addressing the weakness in the larger innovation system would go a long way in creating an enabling condition for defence innovation.

The Occasional Paper examines India's defence innovation performance, especially of the Defence Research and Development Organisation (DRDO) and the defence industry. The paper argues that the innovation performance of these two players is constrained by lack of a higher organisational structure which could provide direction and required thrust to the indigenous R&D. At the same time, the innovation performance is also constrained by poor investment on R&D, 'miserly attitude' of the defence industry towards R&D, poor human resource base, and the lack of reform of the entities responsible for innovation.

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