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A Dismal Show Amid Pockets of Excellence: The State of Defense Innovation in India

Deba R. MOHANTY
Indicia Research and Advisory

Executive Summary

The story of the Indian defense technology sector, led by the Defense Research and Development Organization (DRDO), has so far been a concoction of hyper dreams, intricate individual and institutional problems, relative isolation, and virtual non-accountability. It is not surprising that despite possessing a few 'pockets of excellence,' the sector has delivered little on the ground over the decades, thereby perpetuating arms import dependency. The historiography of Indian defense technologies suggests that innovations—product, process, and organizational—have shown degenerative tendencies despite reasonable state support. Unless deficiencies and difficulties in the core areas of structural-organizational rigidities (organizational), demand-supply dynamic (product), and scientific institutional-industrial collaboration (process) are addressed under a larger, self-reliant defense science and technology and industrial (DSTI) landscape, the dismal story of Indian defense innovation is likely to persist for the long term.

Introduction

From a rich civilization to a modern independent state, the story of Indian science and technology in general and defense technologies in particular has been consistently inconsistent. This is evident from a growing, yet insufficiently developed, literature on the subject.[1] The documentation of the evolution and development of contemporary Indian defense science and technology by social scientists should be considered Herculean in the absence of reliable information in the public domain.[2] Even records of key areas of defense scientific achievements are often not available

1 The literature on Indian science and technology has nevertheless been growing in recent years. For an excellent historical account on the subject, see Robert S Anderson, *Nucleus and Nation: Scientists, International Networks, and Power in India* (University of Chicago Press, 2010). Also see Dhruv Raina, *Images and Contexts: The Historiography of Science and Modernity in India* (Delhi: Oxford University Press, 2003).

2 Most scholars complain of inadequate evidence available in the public domain for research on Indian science and technology. See Anderson, Nucleus and Nation; Santimay Chatterjee, M. K. Dasgupta, Amitabha Ghosh, eds., *Studies in the History of Sciences* (Calcutta: Asiatic Society, 1997); and S. Irfan Habib and Dhruv Raina, eds., *A Social History of Science: Themes in Indian History* (Delhi: Oxford University Press, 2003).

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because of national security restrictions attached to such programs. Such is the degree of isolation in the existing structural-institutional arrangements related to Indian defense technologies within the larger national governance structure that it has not only faced fierce resistance to reforms in institutional mechanisms but has also failed to meet growing demand for contemporary and next-generation technologies by the Indian defense and security establishment, thus perpetuating arms import dependency syndrome.

Major recommendations made by various committees on the defense sector have been selectively implemented or even kept on hold by the Indian government due to pressures from affected organizations. For example, the creation of a Chief of Defense staff has been resisted by the Indian Air Force, while nomination of Raksha Udyog Ratna (Champion of Industry) from the Indian private sector to be promoted as system integrators has been resisted by both state-owned defense companies as well as a few private companies. Major recommendations on reforms to DRDO made by the P. Rama Rao Committee have been fiercely resisted by many within DRDO.[3]

The disconnect between aspirations and reality is evident in almost every aspect of the Indian DSTI base, which consists of DRDO ,with 50 scientific laboratories, eight large defense public sector units, and 40 ordnance factories, complemented by academic and research institutions and private industries as required. This is worrisome for a country that otherwise harbors ambitions to display strategic autonomy in contemporary and future global affairs.

India's rising national power profile in international relations has attracted much attention in recent times. Recognition by major states notwithstanding, efforts by scholars and public policy institutions to calculate national power of countries like China and India have been underway for the past decade or so. The seriousness of this effort is indicative of the importance attached to emerging powers like India in the future distribution of power. Such calculations invariably predict India's rise as a major power but also caution that its rise is contingent on improvements that it must take in certain critical areas of governance and growth. This is evident in a series of comprehensive assessments on Indian national power by a prominent Indian think tank as well.[4] It is important to note that while all major components of national power have shown varying degrees of improvement in the past few years, Indian S&T and innovation capabilities stand nowhere near the top 10 powers in the world.[5] As noted by Daniel Drezner, the importance of economic growth to state power and of technological innovation to economic growth are undisputed, while military prowess is critically dependent on a strong indigenous DSTI base.[6]

It is in this context that a serious attempt must be made to understand the state of defense innovation in India. The universe of the Indian science and technology (S&T) sector is largely led by five institutions: the Department of Science and Technology (DST), Council of Scientific and Industrial Research (CSIR), Indian Space Research Organization (ISRO), Atomic Energy Commission (AEC), and the DRDO. Although ISRO and AEC have made substantial contributions to military applications in space and nuclear sciences, it is DRDO that has led the Indian defense S&T sector. It would not be wrong to assume that the story of Indian defense innovation is almost synonymous with DRDO. Actors like state-owned defense industries and private sector have played a marginal role, while contributions from universities and research institutions have been somewhat deficient.

This paper asks and attempts possible answers to three key questions. First, has the demand-supply dynamic in the Indian defense sector been adequately met by DRDO and defense production agencies in order to nurture product

3 This information is based on interactions over the last ten years by the author with serving and retired members of the armed forces, industry captains, and senior scientists from DRDO.

4 The New Delhi-based think tank Foundation for National Security Research has led the effort to calculate national power of major countries. Its National Power Index compares and contrasts national powers of 27 countries along six variables. Its latest index puts India eighth in global power ranking. For a detailed account, see "National Power Index 2012," in Satish Kumar, ed., I*ndia's National Security Annual Review 2012* (New Delhi: Routledge, 2013), 407–42.

5 India is ranked 17th in technological capability. Kumar, *India's National Security Annual Review 2012*, 413.

6 Daniel Drezner, "State Structure, Technological Leadership, and the Maintenance of Hegemony," *Review of International Studies* 27, No. 1 (2001): 3.

innovation? Second, has the DRDO been able to harness collaborative efforts in fostering both product and process innovations? And third, have structural-institutional dynamics within the DRDO and their links with higher defense organizational arrangements been responsive to much-needed organizational innovation? On the surface, answers to these questions would appear to be negative, but a deeper probe indicates that not everything is as bad as it looks.

The paper is divided into four sections. The first lays out the current and future defense technology needs of the Indian armed forces. It then goes on to examine the demand-supply dynamics and finds the gaps. The second section deals with strategies adopted by DRDO for improvements in its process innovation performance. The third section explains the complex internal and intra-institutional dynamics of DRDO and how these have helped perpetuate institutional rigidities and thus resistance to organizational innovation. The last section summarizes and lays out a set of policy prescriptions for the future.

Current and Future Needs: Yesterday's Technologies at Tomorrow's Price?

To say that India is a weapon merchants' paradise is to state the obvious. Although there is disagreement over figures primarily due to difficulties in verifying data, almost 70 percent of India's defense acquisition budget is devoted to imports.[7] Despite claims that the situation is improving, arms import dependency has been a major headache for Indian defense planners. Consider this: India's defense acquisition budget (hereafter capital expenditure) has grown from US$2.1 billion in FY 2002–03 to US$15.4 billion in FY 2013–14.[8] Almost 80 percent of budgetary allocations are spent on "committed liabilities and fresh acquisitions." Most of these acquisitions are from abroad and despite offsets, obligations, and license production arrangements, it is generally accepted that the import component of total acquisitions is almost 70 percent.

Another aspect that needs to be highlighted is that, contrary to popular belief, India is actually devoting substantial resources to national security, which includes both national defense (armed forces) and internal security (police and paramilitary forces). This approximates to 2.4 percent of India's GDP and accounts for nearly a quarter of central government expenditure.[9] This is not all. With a long-standing 'unspent syndrome' no longer a concern as both the Ministry of Defense (MoD) and the Ministry of Home Affairs (MHA) are quite able to spend the resources that they receive, and given the fact that both ministries have undertaken long-term equipment modernization plans, more resources will be allocated in the foreseeable future.[10] In sum, the Indian defense and security market is likely to wit-

7 Recommendations of a review committee constituted by the Ministry of Defense in 1992 led to the formulation of a "10-Year Plan for Self-Reliance in Defense Systems," which envisaged a major coordinated thrust for self-reliance in defense systems. The plan defined a self-reliance index—the ratio of the indigenous content of defense procurement to the total expenditure on defense procurement in a given financial year. The 10-year plan envisaged raising the self-reliance index value from a 1992–93 estimate of 0.3 to 0.7 by 2005. This implies that the import content of defense procurement would be brought down to 30 percent or less in that next decade. However, the index is at present hovering at 30–35 percent, suggesting that import content in arms procurement is still around 70 percent. Defense Research and Development Organisation, "14th Report of the Parliamentary Standing Committee on Defense," Lok Sabha Secretariat, New Delhi, March 2007, 3.

8 Indian defense expenditure stands at US$37.4 billion in FY 2013–14. The ratio between "revenue" (salary, pensions, and other revenue allocations) and "capital" (capital purchases including equipment, services, and infrastructure, etc.) expenditures has been roughly 55/45 respectively for the past ten years. For data on defense expenditure, see Defense Services Estimates, an annual publication from the MoD, for the relevant years. On budgetary allocations for national defense, internal security, and related departments for the relevant years, see the "Union Budget" available on the Ministry of Finance website at www.indiabudget.nic.in.

9 Approximate value of resources devoted to national security purposes was calculated by the author. Data available in www.indiabudget.nic.in for relevant years. Apart from MoD and MHA, other ministries and departments that contribute to national security efforts include the Ministry of Information and Technology, Ministry of Science and Technology, Department of Space, and Department of Atomic Energy (the latter two are under the administrative control of the Prime Minister's Office).

10 The MoD was pilloried earlier for not being able to spend its allocated resources and used to regularly return money to the central exchequer. This is no longer the case. For the past ten years, MoD has not only been able to spend the resources fully (with a couple of exceptions), but also has spent more under capital expenditures than allocated in recent times. Both MoD and MHA have ambitious equipment modernization drives. The MoD embarked on a comprehensive military modernization drive in 2012 that is to end in 2027, while MHA has

ness a considerable surge in procurement activities. This, in turn, leads to the question of whether the Indian DSTI is able to meet the growing demands of the defense and security forces.

Despite having 52 scientific laboratories under its belt and strong partnerships with about 40 academic institutions, 15 national S&T agencies, 50 public sector units that include 8 large defense public sector undertakings (DPSUs), 40 ordnance factories (OFs) and 250 plus private-sector industries, both DRDO and production agencies have largely failed to meet even the basic demands of the security forces. It appears that DRDO and the defense production agencies receive the most blame for this present state of affairs.

Interestingly, two contrasting narratives of DRDO's performance are evident in the public domain. One set of literature, authored mostly by former DRDO scientists, cites difficulties like the "triple trap" syndrome, scarce financial resources, isolation, technology sanctions, government apathy, dissatisfied end-users, frequent changes in quality requirements, and inefficient process innovations by production agencies, while lauding a few pockets of excellence.[11] The other set of arguments, while recognizing such problems, also blames DRDO and production agencies for overall inabilities in design and development deliverables. For example, the Parliamentary Standing Committee on Defense has severely criticized DRDO for its inability to meet the requirements of the armed forces, citing several instances of products refused by the armed forces (emergency flotation system for Mi-8, relocatable balloon barrage, among many others) and at least six major design and development projects that have faced severe cost overruns and delays, including the LCA Mark II, Nishant, Lakshya, Pinaka, Sambahak, Samyukta and the Integrated Guided Missile Development Program (IGMDP). Specifications changed by the armed forces that led to cost overruns include 30mm fair weather towed air defense guns, among others; abandoned projects include airborne surveillance platforms, cargo ammunition, a GPS-based system for replacing fire detection radar, and so on.[12]

DRDO has been working in frontier technologies and has claimed considerable advancements in the fields of aeronautics, armaments, missile systems, combat vehicles, advanced computing and networking, communication, secrecy systems, electronics, electronic warfare systems, radar systems, military engineering, life sciences, advanced materials, composites, underwater sensors, weapons, and warship technology. Moreover, efforts are also being made to meet emerging challenges in these fields.[13] Its product innovation ecosystem revolves around three layers

undertaken a similar long-term police modernization drive. The modernization drive is primarily equipment driven, but some efforts are being made on training, infrastructure, and related aspects.

11 Distinguished scientist V. Siddhartha coined the term "triple trap," arguing that "what is developed abroad will not suit our requirements, what is suitable for us will be denied to us, and what is not denied will be unaffordable." V. Siddhartha, "Technology in Future Needs of Our Armed Forces," in Satish Kumar, ed., *India's National Security Annual Review 2001* (New Delhi: Vikas Publishing House, 2002), 332. For DRDO critiques, see Siddhartha, "Technology in Future Needs," 227–49; Srinivas Bhogle, "Technology Review 2005," in Satish Kumar, ed., *India's National Security Annual Review 2006* (New Delhi: Knowledge World, 2006), 235–52; Srinivas Bhogle, "Technology Review: An Appraisal of DRDO," in Satish Kumar, ed., *India's National Security Annual Review 2007* (New Delhi: Knowledge World, 2007), 288–307; Dipankar Banerjee, "The Promise of Nanotechnology," in Satish Kumar, ed., *India's National Security Annual Review 2008* (New Delhi: Knowledge World, 2008), 463–80. A senior scientist from DRDO has cited a few examples of pockets of excellence in projects led by DRDO, like integrated network-centric tank (MBT–Mark II), next-generation mobility equipment, advanced versions of hand grenades and explosives and kits, avionics upgrades for LCA, indigenous version of AWACS, missile interceptors, composites, sensors, signal processing, and life sciences support systems for high-altitude deployment. For details, see P. S. Goel, "Technology Challenges in National Security," in Satish Kumar, ed., I*ndia's National Security Annual Review 2009* (New Delhi: Routledge, 2009), 403–20.

12 For details, see "14th Report of the Parliamentary Standing Committee on Defense." Most of the production agencies have also been criticized for not being able to deliver products on time. As recently as August 2013, the Chief of IAF Air Chief Marshal N. A. K. Browne criticized Hindustan Aeronautics Limited for not being able to deliver products like basic trainers, LCA, light utility helicopters, and light combat helicopters. "IAF-HAL Dogfight Over Trainers," *New Indian Express*, August 4, 2013, http://newindianexpress.com/thesundaystandard/IAF-HAL-dog-fight-over-trainers/2013/08/04/article1716645.ece?pageNumber=2. For criticism on the role of defense production agencies, see Defense Ordnance Factories in "7th Report of the Parliamentary Standing Committee on Defense," Lok Sabha Secretariat, December 2005, http://164.100.47.134/lsscommittee/Defence/14_Defence_7.pdf; Defense Public Sector Undertakings, "9th Report of the Parliamentary Committee on Defense," Lok Sabha Secretariat, March 2006, http://164.100.47.134/lsscommittee/Defence/14_Defence_9.pdf.

13 "14th Report of the Parliamentary Standing Committee on Defense,"1.

of application: 1) conceptual frameworks approval at the research board level; 2) laboratory-level experimentation; and 3) testing, evaluation and product maturation, which involves designated production agencies.

DRDO has constituted four research boards to nurture and harness talent in academic institutions, universities, R&D centers, and industry, the Aeronautics Research and Development Board, Armament Research Board, Naval Research Board, and Life Sciences Research Board. It provides necessary facilities for promoting basic research and to catalyze cross-fertilization of ideas with R&D agencies in other sectors to expand and enrich the knowledge base in their respective areas. The boards provide grants-in-aid for collaborative, defense-related, futuristic research having application in the new innovative systems.[14]

Many DRDO scientists claim that while the organization has made significant progress in the development of a few frontline technologies like aeronautics, warship building, electronic warfare, and infantry systems, most of the product innovations have actually happened in the sub-systems, components, and dual-use areas. These achievements oftentimes do not get the recognition or publicity that they deserve.[15] When DRDO's design and development efforts lag behind time schedules, the country has no choice but to fall back on importing from abroad.

Strategies for Process Innovation: Hampered by Isolation?

Process innovation in the Indian context revolves around DRDO and its relationships with academia, research institutions, state-owned defense production agencies, and private industry. As stated elsewhere, DRDO has been able to develop a wider network at the national level than at the international level, primarily because of sanctions imposed since the 1970s on DRDO and other Indian scientific institutions with linkages to military applications, such as space and atomic energy. Even at the national level, DRDO's efforts in forging partnerships need to be understood in the context of its relative isolation from both defense and non-defense areas in relation to Indian private-sector companies as well as foreign scientific establishments.

DRDO's laboratories have built excellent networks among themselves, especially in specific cluster areas like aeronautics, armaments, combat vehicles and engineering, life sciences, materials, naval technology, and missiles. The most active areas in these clusters are aeronautics, naval technology, missiles, and armaments. Technical directorates in these areas act to facilitate the work of laboratories and establishments, obtaining approvals of new projects from the government, facilitating the monitoring and review of ongoing projects, and also coordinating with other laboratories and directorates.[16] DRDO continues to have limited interactions with its counterparts in the DPSUs and OFs, but provides technical assistance to these production agencies.[17]

DRDO's interactions with academic and research institutions are similarly limited, although this seems to be improving. Its recent academic outreach includes five centers for excellence in explosives and propellants, polymer physics, nanotechnology, opto-electronics, and microwave. DRDO has signed memoranda of understanding with more than 50 universities and research centers, while more than 200 extramural research projects have been sanctioned to academics and researchers.[18] It has worked, partnered, and signed sub-contracts with more that 250 private companies on various assignments and projects.[19] Interactions or collaborations with foreign research institutions and private companies have been limited, except for a few partnerships with countries like Israel and Russia.

14 Details on DRDO's mandate, vision, areas of activities, and design and development achievements are available on the official website at www.drdo.gov.in.

15 Author interviews with a number of senior serving and retired DRDO scientists. However, contrasting views are often expressed by senior military officers, who question DRDO's innovation capacities.

16 "14th Report of the Parliamentary Standing Committee on Defense," 5.

17 "14th Report of the Parliamentary Standing Committee on Defense," 22.

18 www.drdo.gov.in.

19 A list of DRDO–industry partnerships is available at http://drdo.gov.in/drdo/English/IITM/Industry_compendium.pdf.

Despite tall claims, DRDO's overall performance in process innovation has suffered primarily because of its inability to be flexible in its outlook and interactions, especially with academia, research institutions, and private industry within India. Its relationship with academia is somewhat initiator-beneficiary, whereby academia is more at the mercy of DRDO for grant of projects than the other way round. Its relationship with industry is similarly one-sided, with companies dependent on DRDO's generosity. It has not attempted to improve the R&D branches of the DPSUs and OFs; rather its role has been polite indifference.[20] Of late, DRDO has developed ties with a few institutions from other countries, prominently Israel. DRDO laboratories faced sanctions from the international community, especially the United States and other Western countries, until recently.

Internal and Institutional Dynamics: Vertically Rigid, Virtually Unaccountable

At the institutional-organizational level, most of the elements of the Indian national defense sector have witnessed varying degrees of change in the last ten years, especially after the Indian government started implementing some of the more than 200 recommendations made by the Group of Ministers on national security management in 2001.[21] Most of these changes and the creation of new institutions took place within the MoD, with a few related to production activities within the Ministry of Commerce. The most prominent of these organizations include the Chief of Integrated Defense Staff, Joint Command, Strategic Forces Command, Defense Acquisition Council, Defense Production Board, Defense Procurement Board, and the Defense R&D Board.[22] However, DRDO itself has not witnessed any major changes in its structure, except for a few committees and councils. DRDO has a vertical structure, headed by the director general of research and development, who is also the secretary of defense R&D and scientific advisor to the defense minister. The head of DRDO is assisted by eight chief controllers. DRDO is a two-tier organization, with technical and corporate headquarters based in New Delhi, and laboratories and scientific establishments located around the country.

DRDO's vertical structural dynamic is clearly evident in its project approval and sanctioning arrangements. Once a proposal is initiated by a laboratory or group of laboratories, it is peer reviewed within the organization and consequently approved by DRDO headquarters. The proposal is seen by the integrated finance branch and approved by the DRDO director, who then sends it to the defense minister for approval by the Cabinet Committee on Security, the highest decision-making body on national strategic and security matters. Many affiliated institutions like the Aeronautical Development Agency, Society for Integrated Technology Applications and Research, Defense Institute of Advanced Technology, and Gallium Arsenide Enabling Technology Centre enjoy strong protection from DRDO.

Although DRDO claims to have injected reforms like creating a new office of Chief Controller R&D (Service Interaction) to improve its interactions with the armed forces or, for that matter, interacting more at the highest-level production and procurement related institutions like the Defense Acquisition Council, Defense Production Board, and the Defense Procurement Board, its vertical rigidity is clearly evident. It smartly opposes any new organizational innovations like including outside experts in DRDO or separating and splitting up research specializations by arguing that inter-disciplinary research and allied activities have been successfully carried out within DRDO in the past. The fierce resistance to recommendations made by the P. Rama Rao Committee mentioned earlier typifies DRDO's vertical rigidity and strong aversion to change.

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20 The Parliamentary Standing Committee on Defense has criticized DRDO for its inward-looking mentality. For details, see "14th Report of the Parliamentary Standing Committee on Defense," 19–32, 70–83.

21 GoM report on national security management, National Security Council Secretariat, New Delhi, February 2001.

22 Direct DRDO representation or participation is factored into most of these organizations, except for exclusive ones like the Strategic Forces Command, which may not require its membership. Apart from higher military organizations, the MoD has also announced a series of changes in the production and procurement sectors. Participation and FDI in the defense sector by foreign manufacturers was allowed in 2002. Recommendations of major committees like Kelkar, Prabir Sengupta have been considered, and the defense procurement procedure has been revised nine times in the last eleven years. Policies like defense offsets, changes related to transfer of technology, and many such measures have been undertaken to revitalize the Indian defense production sector.

The Future: Revitalization or Muddling Through?

Despite its best efforts and even some excellence in sub-system and component areas, India's defense innovation has so far been disappointing. Many of DRDO's strategic and advanced technology programs, including technologies that have matured, have endured lengthy delays that have led to technological obsolescence. As India's armed forces have embarked on a very ambitious military modernization drive, DRDO's ability to provide much-needed technological back-up for products and services is being severely tested. Signs of growing gaps between needs and expectations on the one hand and design, development, and proven systems on the other are obvious, which seems to have put added pressure on DRDO to put its house in order.

A comparison between what technologies the Indian armed forces want in the next fifteen years and what DRDO wants to develop through indigenous or collaborative routes gives an indication of where the country stands in defense innovation. In April 2013, the Indian MoD released its "Technology Perspective and Capability Roadmap" (TPCR), prepared by the Integrated Defense Staff Headquarters. The document gives an exhaustive list of technologies that the Indian armed forces wants in the future.[23] Interestingly, DRDO has also released a list of critical defense technology areas and test facilities for acquisition through offsets.[24] A close look at both documents would reveal that while cutting-edge research efforts need to be undertaken by DRDO in areas like nanotechnology-based sensors, miniature synthetic aperture radar and inverse synthetic aperture radar technologies, fiber lasers, technologies for hypersonic flights (propulsion, aerodynamics, and structures), high-power lasers, low observable technologies, composite sabot manufacturing technology, research in other areas like electro-magnetic railgun technology, shared and conformal apertures, flexible solar cell technology, carbon fiber, pulse power network technologies, muzzle reference systems, and precision guided munitions, could be carried out by private industry. In many high-technology areas like microelectronics, data fusion, cloud computing, flexible manufacturing, radars, sensors, system integration, robotics, computational fluid dynamics, combat UAVs, micro satellites, hyper-velocity projectiles, and plasma technologies, India is well behind its advanced counterparts in the West, Russia, and China.[25]

The question of whether India can catch up with the global leaders in defense innovation requires a comprehensive assessment of the strengths and weaknesses of the Indian S&T ecosystem in general and the defense technology arena in particular.[26] Reasonable strengths for defense innovation can emanate from a diversified and multi-disciplinary basic and applied research environment, from which DRDO could benefit. This exists in a rudimentary form and requires intelligent and pragmatic exploitation. Improvements in performance of scientific institutions can similarly be undertaken by the state.[27] Strengths also lie in India's large and youthful human resource base and the reasonable ability of the state to devote financial resources to sustain both basic and cutting-edge scientific efforts.

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23 The document is available in the MoD website: www.mod.nic.in. Before the TCPR, both the army and navy had released their versions of future technology requirements. See "15-Year Indigenization Plan," Directorate of Indigenization, Integrated Headquarters of the Ministry of Defense (Navy), October 15, 2008, www.ciidefence.com; and "Technology Requirements of the Army," www.ciidefence.com. Some reflections on future technology requirements can also be found in V. Siddhartha, "The Triple Trap, Dual Use, and Single Reform: Towards Self-Reliance in High Technology," in Satish Kumar, ed., *India's National Security Annual Review 2011* (New Delhi: Routledge, 2012), 441–49; and Amitav Mallik, "Self-Reliance in Defense Technologies," in Satish Kumar, ed., *India's National Security Annual Review 2003* (New Delhi: India Research Press, 2004), 166–83.

24 The list is available at www.drdo.gov.in.

25 Amitav Mallik, "Science and Technology for a Stronger India," in Satish Kumar, ed., *India's National Security Annual Review 2012* (New Delhi: Routledge, 2013), 379–84.

26 The Department of Science and Technology, Government of India, has recently released a comprehensive assessment of India's S&T, including defense technologies. Compendium on Science, Technology, and Innovation, http://www.dst.gov.in/Science%20Technology%20&%20Innovation%20Book.pdf. Also see Amitav Mallik, I*ndian Science and Technology: A Status Review* (New Delhi: Pragun, 2006).

27 "Bibliometric Study of India's Scientific Publication Outputs During 2001–2010: Evidence for Changing Trends," Department of Science and Technology, Government of India, July 2012, www.dst.gov.in.

However, India's weaknesses, most of which are self-created, outnumber its strengths, leading the entire defense technology innovation sector to excel in only a few pockets. For example, while the IT, biotechnology, and space sectors are maturing well, their application to the defense sector has yet to fully develop. Self-created weaknesses also include political apathy, the narrow outlook of scientific elites, and intense bureaucratic politics are prime reasons for its poor performance. However, an in-depth assessment would indicate that the state-controlled defense technology sector has been insulated from the larger governance structure instead of opening up to multi-disciplinary and wider interactions with both Indian and foreign scientific institutions.

The story of DRDO's evolution and development is a clear case of how a great institution can, over a period of time, become vertically rigid and virtually unaccountable such that it can do harm to itself and the state. Innovation efforts in this critical sector are bound to suffer as a result. Unless corrective measures in the form of a defense technology vision document as a guiding force, a pragmatic politico-bureaucratic direction, flexibility in structural arrangements with horizontal, inter-disciplinary interactions and diffusion, periodic reviews, and accountability within the institution and at the higher governance levels are undertaken with seriousness, the story of India's defense innovation is likely to be one of continuing to muddle through well into the future.