Strategic Perspectives on Growth Phases and Long-term Techno-economic Performance of India's DRDO

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The future of an organization is less determined by outside forces than by its history and the Defence Research and Development Organization (DRDO) is no exception. This article analyses the major achievements and shortfalls of the DRDO. It models the strategic dimensions of organization development. The value of production from defence industries arising from DRDO technology transfers is rapidly escalating, enabling the government's goal of self-reliance. The historical 'licence production' culture in the aeronautics, electronics and guided missile industries sustains imports of raw materials and small components worth billions of dollars annually. The article suggests architectural changes to aid the conversion of this vulnerability into an opportunity to create indigenous techno-industrial infrastructure and market worth nearly Rs 12,000 crore per annum through public-private partnerships. The way ahead is charted for techno-economic growth of self-reliant defence industry in partnership with the private sector by creating a Defence Techno-Industrial Consortium. Sustaining India's leadership in

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advanced systems and technologies is suggested through collaborative National Frontier Research projects.

In times of crisis, when doubts arise
Over a course of action, Raghava,
The king judges success or failure
Only by analysis: he has no other way.

– Vasistha: Rama[1]

Introduction

Elegance and skill in analysing matters of the past and the present moment is the key to efflorescence of any organization. Large, aging organizations fail to see that many clues to their future success is embedded within their own organizations and their evolving states of development. Larry E. Greiner, in his path-breaking research on cyclic, time-determined patterns in organization development,[2] discovered a consistent cyclic pattern of evolutionary and revolutionary change in the process of development of organizations, as they grew in size, budget, personnel, geographical locations, rates of growth of related industries and changing markets. Each evolutionary period creates its own cyclic revolution.

For instance, centralized practices and hierarchical style of management eventually lead to demands for decentralization and collaborative management styles. The nature of management's solution to each revolutionary period determines whether an organization will move forward into its next stage of evolutionary growth. Greiner observed that the future of an organization may be less determined by outside forces than by the organization's history. He suggested that 'the inability of management to understand its organization development problems *can result in becoming "frozen" in its present stage of evolution* or, ultimately, in failure, regardless of market opportunities.'[3]

This article establishes that Defence Research and Development Organization (DRDO), defence industries and the emerging integrated defence techno-industrial system are no exception when seen in the light of the Greiner and other models for organization development and evaluation. The model works well when pattern recognition skills are applied to existing, dynamic situations. Policymakers, scientists and analysts may also find insights to see the future of DRDO in the first half of the twenty-first century through analysis of the growth history of this organization in the second half of the twentieth century.

Genesis of Organization Development and Change Cycles in DRDO

In its long history of over 65 years, starting in 1948 as the Defence Science Organization (DSO) centred around a single laboratory (the Defence Science Laboratory [DSL], New Delhi), the DRDO has grown steadily to be the largest research and development (R&D) organization in India with over 52 laboratories spread across the country and providing substantial employment opportunities to the nation. This growth has never been a seamless, dynamically stable experience. The DRDO, too, had prolonged 'evolutionary' periods of growth where no major upheaval occurred; and several periods of substantial turmoil and discontinuities in organizational life. Today, its network of over 52 laboratories is deeply engaged in developing defence technologies covering various disciplines, like aeronautics, armaments, electronics, combat vehicles, engineering systems, instrumentation, missiles, advanced computing and simulation, special materials, naval systems, life sciences, training, information systems and agro-animal technologies for high altitudes.

The current annual budget of DRDO is about Rs 10,600 crore,[4] and stands at 5.1 per cent of India's defence expenditure (when it was less than 1 per cent of defence expenditure in early 1970s, increasing gradually at the rate of 1 per cent every decade thereafter). Such a broad-based, centralized R&D organization is unique in India, and indeed the whole world. Its vision currently is 'To make India prosperous by establishing world class science and technology base and provide our Defence Services a decisive edge by equipping them with internationally competitive systems and solutions'.[5]

The First 'Revolutionary' Stage (1958–61)

The DRDO was created in 1948, as the DSO, when D.S. Kothari was the first Scientific Adviser (SA) reporting to the Prime Minister, Jawaharlal Nehru, and Defence Minister, Krishna Menon. The DSL was a nucleus laboratory with the objective to conduct research in frontier areas of physics, chemistry and mathematics with a special focus on lasers and opto-electronics and rocket propellants. It even built a 4-stage High Altitude Sounding Rocket (HASR) with operational Second World War air-to-ground 3-inch diameter solid propellant rockets.

During the first 'revolutionary period' (1958–61), it transformed from being the 'Defence Science Organization' into the 'Defence

Research and Development Organization' functioning in the Department of Defence Production. Dr S. Bhagavantham was then the SA to the Raksha Mantri (RM) at the level of a Joint Secretary in the government. This transformation from the nucleus DSO to DR&D Organization took place by the amalgamation of the then already functioning Technical Development Establishment (TDEs) of the Indian Army and the Directorate of Technical Development & Production (DTDP) with the DSO. The Defence Science Laboratory (DSL) served as a precursor for as many as 15 present DRDO labs, including Defence Research & Development Laboratory (DRDL), Solid State Physics Laboratory (SSPL, Institute of Nuclear Medicine and Allied Sciences (INMAS), Field Research Laboratory (FRL), Institute of Systems Studies and Analysis (ISSA), Defence Scientific Information and Documentation Centre (DESIDOC), Defence Institute of Fire Research (DIFR), Systems Analysis Group (SAG), Institute of Technology Management (ITM), etc., and is still the original home of DRDO's prestigious LASTEC (Laser Science and Technology Centre). This revolutionary period saw the DRDO emerge as a consortium of laboratories, all reporting to the DRDO Headquarters in a variety of 'disciplines'—armaments, engineering, electronics, naval sciences and so on—each with its own career track for its scientists and service officers on secondment.

The Second 'Revolutionary' Stage (1971–74)

The second 'upheaval', this time a crisis of leadership, was in 1971 (that is, about a decade after its first 'revolutionary' change) when the organization broke away from the Department of Defence Production, and from projects umbilically tied to the three service headquarters, to emerge as a full-fledged, autonomous 'Department of Defence R&D', headed by Dr B.D. Nag Chaudhri as SA to the Defence Minister, who was designated as a full-fledged Secretary to the department. Large proportions of its budget were allotted in an unprecedented manner to strengthen buildup and infrastructure projects, far ahead of user-demanded projects. In this period, fresh strategic impetus and enhanced funding and manpower were made available to develop the systems and technologies of guided missiles in DRDL, gas turbine engines (at Gas Turbine Research Establishment [GTRE]) and high-performance tank engines (at Combat Vehicles Research and Development Establishment [CVRDE]), while work on unmanned aerial vehicles was expanded in Aeronautical Development Establishment (ADE). The DRDO Headquarters was restructured and a new Directorate of Rockets and Missiles was created to design and build strategic missile systems.

The Third 'Revolutionary' Stage (1981–84)

The third 'revolutionary period' or 'upheaval' was in organization management style and practices, breaking away from a directive, headquarters-oriented hierarchical style of management to a more delegative, collaborative management style. In the earlier 'growth stage' from 1975 to 1980, the technical directorates in DRDO Headquarters controlled the laboratories, which were working independently of each other. The R&D headquarters was responsible for technical coordination between the growing laboratories with the service headquarters and production agencies. To build new weapon systems by a laboratory like DRDL, for example, was becoming increasingly arduous in such a technically centralized management system.

The need for more decentralized project management systems for building complete weapon systems and platforms had become urgent after failure of two missile systems (Anti-Tank Guided Missile [ATGM] in the 1960s and Surface-to-Air Missile [SAM] in the 1970s) to go beyond the prototype flight test stage. This set the ground for the next major 'revolutionary' period that took place about another decade later from 1981, when Dr V.S. Arunachalam was SA to RM. In this period, architecturally new decentralized and integrated project management systems were conceived at the apex level of DRDO and created to design and build new weapon systems like Guided Missiles, new weapon platforms like Tanks and Combat Vehicles, Nuclear Submarines, and Supersonic Fighter Aircraft and the Airborne Warning and Control System (AWACS) programme. This was a strategic leap for DRDO into high-risk areas by the then SA to RM with a new team of carefully selected programme managers.

By the 1990s, these new programmes, in turn, spawned a variety of advanced technologies like phased array radars, infra-red homing devices, actuators and servo valves. The subsequent growth stage by collaboration between laboratories and industries took place seamlessly after Dr V.S. Arunachalam, when Dr A.P.J. Abdul Kalam, Programme Manager for the Integrated Guided Missile Programme (IGMDP), assumed charge as the SA to RM in 1992. Continuous consolidation and expansion of integrated programmes and laboratories took place till early 2001.

The Fourth 'Revolutionary' Stage (2001–still continuing)

The dawn of the twenty-first century saw the burden of tall hierarchies within the laboratories as well as the 20 year-old integrated programme management organizations creating a decline in and aversion to risk-taking design of new highly innovative *architectural systems to absorb advanced technological changes*. Meanwhile, top management emphasis on new technology and competence buildup project policies enabled tremendous growth of new technologies in laboratories, like new high-temperature, high-strength and lightweight hypersonic aerodynamics, supersonic combustion engines, advanced navigation systems, sensors and radars, advanced torpedoes and, above all, a variety of advanced environmental and ground test facilities across the board for futuristic systems and technologies required by the three services. These 'revolutionary' technologies now remain buried within the laboratories as in the 1970s. The impact of hierarchy had, once again, quenched the flame of risk taking, and ideologically uncompromising entrepreneurial project managers needed to break out of the past into architecturally advanced integrated systems and markets.

Essentially, it is seen that top management has only four options for advancing technological change. These imply either *refinement/upgradation in existing technology* and production processes of the twentieth century (which is mostly happening now) or making *disruptive changes* where existing technologies emerge from advances in scientific research in many institutions within and outside the nation. In this type of 'architectural' change, some of the existing management structures would be rendered obsolete, as happened in 1980s, *but with wholly different long-term perspectives*. It is the *challenge of perspective development for the defence techno-industrial system that now matters,* not internal restructuring alone, as has been attempted recently by DRDO.

Major weapon system development programmes take 15–25 years to unfold and deliver security and economic value to the nation. The 1980s era is over and gone. The strategic requirement for DRDO now is to develop new perspectives and sustain its dynamism and continue techno-economic creativity and growth on broader national scales by reaching out to create new systems and new markets by accessing technologies from other major government R&D agencies.

Symptomatic of this fourth revolutionary stage are the increasing voices appearing in public questioning the very existence of DRDO, which is further targeted by the media as being too large and ineffective. Many high-level committees have been set up to reorganize and restructure DRDO to breathe new life and dynamism to this institution. The DRDO has been restructured systematically almost every decade since its inception. *Each SA brought in unique reforms* that each time profoundly changed the character of the institution. The major reforms and restructuring that took place during the first three 'revolutionary' periods have been described earlier.

Now, in this 'fourth' revolutionary stage, the government set up the Kelkar Committee[6] in the overall context of defence preparedness in 2005. The committee was of the view that the reform measures proposed would lead to a progressive increase in the domestic share to 90 per cent over a period of five years. The Kelkar Committee recommended that a committee should be set up by the DRDO for working out a scheme on the basis of the Defense Advanced Research Projects Agency (DARPA) model that requires new technology perspectives. This recommendation is yet to be implemented by DRDO.

Thereafter, the government set up the Rama Rao Committee[7] on 8 February 2007, which submitted its report on 7 February 2008, making several major recommendations for reorganizing and restructuring the DRDO. As in May 2012, several recommendations have been implemented, such as nomination of nodal officers for interaction between the DRDO and services; introduction of Integrated Financial Advice (IFA) system for financial decentralization; and a dedicated Chief Controller Research and Development (Human Resource) has already been appointed at DRDO Headquarters. Several recommendations are at various stages of implementation, like creation of technology domain-based cluster of laboratories, increase of allocation for extramural research to 5 per cent of DRDO budget and internal restructuring of DRDO Headquarters.

The question arises why none of these measures have satisfied the public, analysts and many policymakers in India. It is clear, however, that few are aware of the true value of DRDO in macroeconomic terms. Inspite of visible advances by this organization, disparagement and condemnation of this institution has increased, yet another indicator of the continued existence of this fourth revolutionary period when national image and high performance are important factors for sustained growth.

The last few years of DRDO's history have seen an increasing spate of strident news articles and television documentaries using routine observations of the Comptroller and Auditor General (CAG) and related watchdog institutions like the Controller General of Defence Accounts (CGDA) to ridicule and pour scorn on highly reputed and advanced science and technology institutions in the government like the DRDO and its leadership. Unfortunately, some news articles in the media present exceptionally narrow and flawed perspectives.[8] Wild allegations have been made: for example, 'Crores of rupees are spent on research that mostly flops', is another theme here without any understanding of the operational and economic value of DRDO's services to the armed forces and the nation. *Unanswered media attacks demoralize new generations of scientists, paralyze organizational risk-taking capabilities at policy and technical levels (already burdened by the rigours of hierarchy), weaken the social fabric and irremediably harm the nation's sense of security and prosperity*. A somewhat dangerous trend is emerging here and this stage of organizational change needs careful understanding, especially at policymaking levels. A judgement of DRDO being a success or failure by policymakers can emerge only with a proper perspective of what the nation can expect from a public institution like DRDO in the management of technology in all its principal yet overlapping strategic functional dimensions, as illustrated in Figure 1.

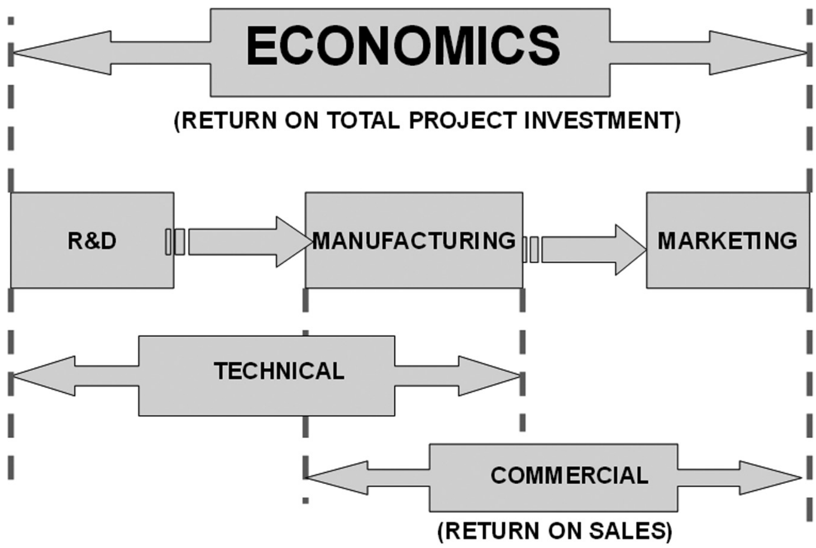

Figure 1 Strategic Dimensions of Technology Management in the DRDO

Source: Authors.

The three strategic dimensions of DRDO encompass, first, the *technical* processes in core R&D in its laboratories (where technologies are conceived and developed); followed by transfer of its technology to manufacturing agencies. Second, are the commercialization processes that include manufacturing within the production agencies from DRDO designs and specifications (which mean 'return on sales' to the production agency). This dimension includes user trials and technology absorption ('marketing') within the user units. Finally, based on this overlapping flow of technical and commercialization activities, the *economic* performance of DRDO as a whole is to be judged on the basis of return on total project investment. Only by a proper understanding and careful analysis of all these multidimensional activities can a large, complex organization be fairly judged by policymakers and critics.

Strategic Dimensions of Technology Management in the DRDO

R&D as Perceived by DRDO Scientists Purely as a Technical Process

Figure 2 shows the DRDO technical work flow in its core laboratories and its production agencies.

This flow diagram illustrates various stages of the technology development process within an R&D laboratory. Scientists observe

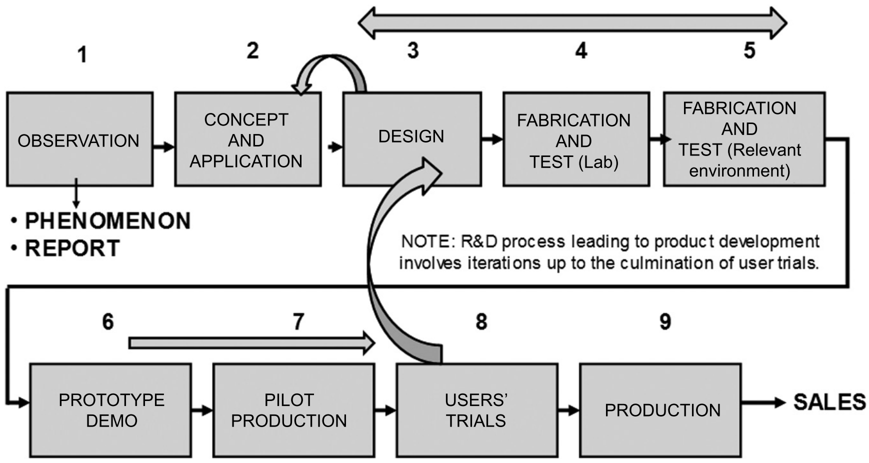

Figure 2 Technology Management as Viewed by DRDO Scientists and Production Engineers

Source: Authors.

external phenomena; then, based on such observation, they apply their knowledge, experience and insights in science and technology development to conceive new system and technology designs; and they examine the potential applications of their design of military nature. This work is followed up in different sections of the laboratory by in-house fabrication, performance testing in the relevant environment and performance analysis.

Prototypes are made in the laboratory, and many a time in selected industries, to meet design specifications. After passing exacting tests, they are produced in larger quantities by standardized, repetitive processes, by a production agency. Finally, after user trials, the system/technology is accepted and used for a sustained period by the army, navy and air force (or at times, all the three). This simplified linearized R&D process leading to technology development is what has been illustrated in Figure 2. Upheavals may take place at times when results during 'user's trials' call for revision of the design itself, as shown in the 'feedback' loops of Figure 2.

Most of the public criticism heaped on DRDO is focussed entirely on the outcome of what is seen as a simple process of technology/system development and on the basis of success or failure of the prototype of the final product to enter the next two stages. The DRDO has diversified projects, other than product development, numbering in thousands from its over 50 R&D laboratories in multiple disciplines of science and technology, which includes basic research to enhance knowledge, expertise and database; buildup projects to expand and modernize laboratories through growth of generic technology; experimental facilities to advance the state-of-art; and projects to develop advanced materials, components and devices needed for Users, all of which will be essential for future development projects. Therefore, fair and accurate judgement of whole organizations like DRDO need to be based on its techno-economic performance in the entire range of operational and strategic projects/ objectives over a long time span and not on myopic views expressed by self-styled experts who have had no exposure to the R&D processes and technology development.

A fundamental error made by analysts and the public critics of DRDO lies in the very approach to technical failure analysis with an implicit assumption that a reliable indicator of total organizational failure can be obtained through project portfolio analysis of pre-selected lists of 'failed' projects observed in routine audit processes. What is lacking

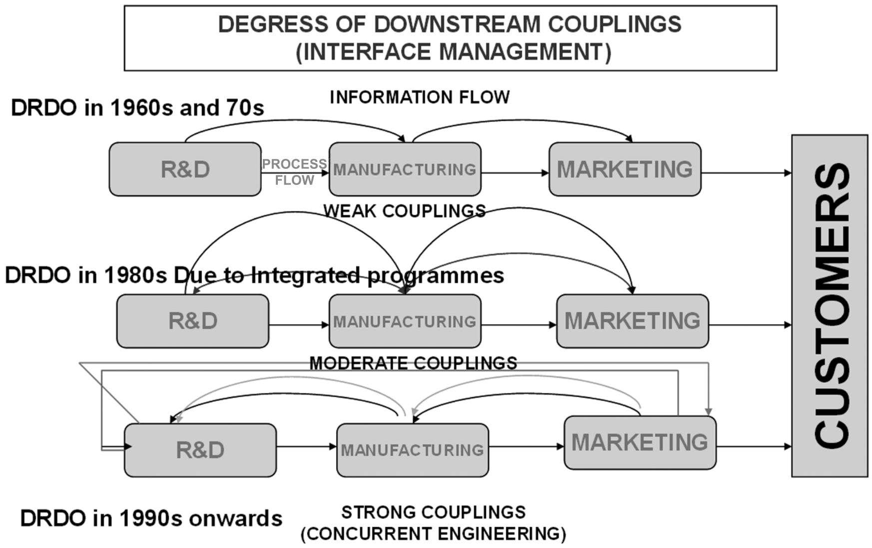

Figure 3 Manufacturer's View of R&D (technology management)

Source: Authors.

is an understanding and analysis of the whole range of strategic and operational functions in large organisations and a more precise definition of project success. However, as an R&D institution, the perspective of scientists is quite different from that of production engineers and their agencies. These recipients of technology transferred by DRDO see a more complex, non-linear picture (illustrated in Figure 3) in which the whole R&D process in DRDO is merely one start-up element!

R&D in DRDO as Perceived by Production Engineers as a Technical and Commercial Process

The production agency, that is, the manufacturer's perspective of R&D activities in DRDO laboratories, illustrated in Figure 3, describes the evolving nature of technology transfer and absorption linkages between the developer, producer and user agencies. This perspective is one which critics never see or perhaps do not even know about. Most of the so-called failures of DRDO projects in the early 1960s and 1970s arose from a lack of understanding of the requirement for very close 'couplings' or technology transfer mechanisms (based on warm, friendly and professionally respectful personal relationships) between the design scientists, production engineers and ultimate users.

The 1960s and the 1970s were thus decades of 'weak couplings' between DRDO laboratories and production agencies (ordnance factories and public sector undertakings [PSUs]). For example, in the guided missile field, the 1960s saw the technical success of an ATGM in the DRDO (the laboratory having done several hundred flight tests!) but then, there was no production agency ready to accept technology transfer even though there were large user orders arising from appearance of Chinese tanks in Ladakh. A similar fate awaited the next major missile development project on a medium-range SAM that never entered service even though it was technically a success in its flight trials.

In relation to R&D projects, the term project failure is a misnomer and cannot be a digital zero or one. The projects often declared as failed ones have yielded enormous knowledge and experience in terms of technologies, aspects related to R&D management as well as dynamics of processes leading to production and user satisfaction. This picture was dramatically reversed in the 1980s. Learning from these 'failed' projects, the DRDO strategically modelled integrated R&D programmes in a variety of systems and technologies based on the guided missile management experience. The 1980s thus saw emergence of inter-laboratory, inter-departmental R&D programme management organizations that were to be the 'strong couplings' needed between industry and DRDO laboratories that functioned independently in different departments of the Ministry of Defence (MoD).

Integrated Programme Management System (IPMS)

The evolution and maturation of such project linkages took over 20 years to realize from their inception in 1980s. The production agencies, that is, PSUs and ordnance factories, found it profitable (as seen by increasing returns on their net sales) and strengthening to work with DRDO in such integrated programmes. They slowly realized that the DRDO projects gave them technology 'know why' as well as 'know how'; and they modernized the manufacturing infrastructure and processes in a manner that foreign 'licence manufacture' projects, with reliance on 'know how' only, failed to do.

These integrated programme management organizations called for the users working at all levels, that is, from Secretary to Government level, through laboratory and factory levels, right down to the level of individual scientist/engineers, all working closely and respectfully together in close-knit teams with DRDO and production agencies.

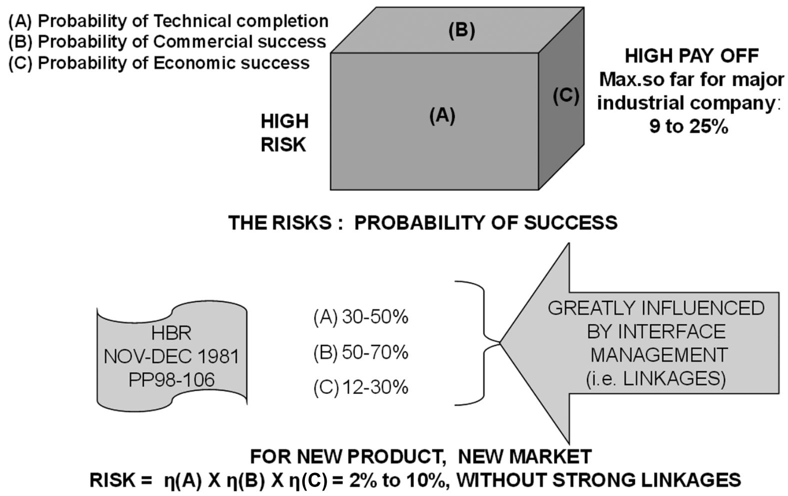

Figure 4 The Economist's View of the Technology Management Process

Source: Authors.

Continuous performance review at six monthly levels at Secretary level, three monthly level at laboratory/factory level and monthly/weekly at the engineer/scientist level ensured extremely durable, sustainable and 'strong' couplings between the DRDO, the production agencies and the Army, Navy and Air Force. These strong couplings and constantly upgraded IPMSs ensured continuity and sustainability of DRDO's R&D over extended periods of time from 15 to 20 years till the systems/technologies stabilized and were absorbed in user formations.

It is these strong couplings provided by the IPMS that then proceeded to yield astonishing technical and economic performance of DRDO. No longer can a single technical failure of a technology or system be seen in isolation of DRDO's technical and economic performance as a whole. The R&D is an uncertain process in all its dimensions—technical, commercial and economic—as illustrated in Figure 4. There is, therefore, need for a more accurate concept of probability of success of DRDO projects than merely a failure of a technical system during trials.

Defining Probability of Project Success

Defining project success depends not just on DRDO's own technical strengths, but on the role, perspectives and policies of its key partners, that is, production agencies and user services. A project passes to technical completion after completing its first stage of concept definition and R&D; then, through second stage of completion of production, commercialization and technology absorption by the users; and finally, the third stage of completion establishing its economic value addition. This process takes 20–25 years for a complex weapon system. Each of the three stages is to be analysed for its success or failure separately. Overall success probability is the product of three stage-wise success probabilities. Projects may fail at any stage, yet in a complex R&D and manufacturing system, they may find other commercial/user applications and emerge successful as a different project.

An early United States (US) study[9] (illustrated in Figure 4) found that for a complete R&D project life cycle in industrial R&D laboratories, the probability of technical completion is between 30–50 per cent *and possibly lower in military, space and other areas where major state-of-the-art innovations are sought*. The probability of manufacturing, commercialization (and user satisfaction), was between 50–70 per cent; and the probability of economic profitability was about 12–30 per cent, thus giving an overall probability of success for the organization as a whole an average of 1.8–10.5 per cent or much less in complex, multidisciplinary, inter-departmental collaborative R&D areas like where DRDO is engaged. Even the CGDA has brought out, as quoted in the media in the case of DRDO, that *the overall success of user projects has been 29 per cent*.[10] This actual project success exceeds the maximum of probability of success of 20 per cent reported by the US. Thus, implicit criticism of DRDO as a technically ineffective organization is misconceived at the very least. But besides the high probability of success factor, there are other criteria as well.

Economic Benefits to the Nation

A study report from National Council of Applied Economic Research (NCAER) in December 2008,[11] obtained from DRDO, brings out that annual value of production from India's public sector industries and ordnance factories from DRDO projects has increased from about Rs 13 crore in 1981–82 to over Rs 6,200 crore in 2006–07[12] (see Figure 5). The data were analysed to study the rate of growth of production value in defence industries from DRDO technology transfers over a complete 'mind-to-market' cycle. A major R&D 'mind-to-market' project cycle for development of a complex weapon system takes 15 years on average to deliver economic success, or payback, on commercialization.

For example, the 'payback period' from investment in DRDO from

Table 1 Growth Rate of Production Value from DRDO Technology Transfers to Defence Industries after 15 Year Payback Period from R&D Investment

Year of Investment in DRDO	*DRDO Budget (Rs Lakh) From Ref 8 (V_0)*	*Payback Period (Years)*	*Production Year after DRDO Project Payback Period*	*Production Value on DRDO Project Payback Period (Rs Lakh) (V_n)*	*Value Added Ratio (Production Value to DRDO Budget Value) $Z = (V_n/V_0)$*	*Annual Growth Rate of Production Value from 15th Year of DRDO Budget (%age)[13] r=100* {[Exp {(Ln (Z))/15}] –1}*
1992	77468	15	2007	622057	8.03	14.90
1991	68670	15	2006	695067	10.12	16.69
1990	69887	15	2005	473377	6.77	13.60
1989	59642	15	2004	297858	4.99	11.32
1988	57777	15	2003	251795	4.36	10.31
1987	56056	15	2002	235061	4.19	10.03
1986	43775	15	2001	197676	4.52	10.57

Source: Year-wise DRDO Budget (Revenue and Production Value Data).

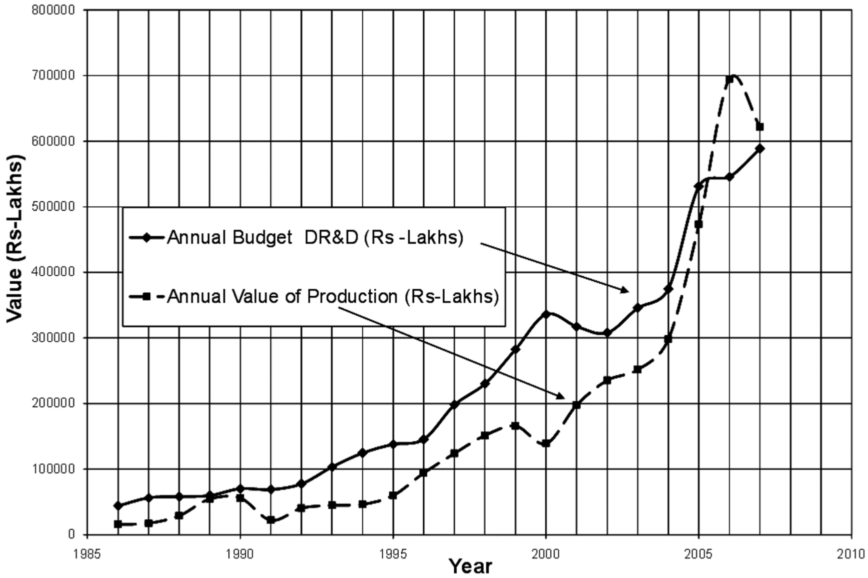

Figure 5 Annual DR&D Budget and Value of Production from DR&D Projects (Rs in lakhs)

Source: DRDO.

the R&D perspective for the year 1988 needs to be seen in the light of defence industrial production in 2003 and not estimated the same year! As seen from Table 1, from 1986 onwards to 1992, after a project payback period of 15 years, the integrated project management and review system (IPMRS) has delivered production value four to eight times the value of DRDO budget from 2001 to 2007. This amounts to a DRDO technological 'return on investment' at 10–17 per cent on its annual budget; the trend strongly increasing year to year as DRDO investments have spiralled upward after 1992.

This 10–17 per cent annual growth rate of production value in defence industries arising from DRDO technology transfers compares well with the annual growth rate of civil industry in India that was (on average) 3.6 per cent in the 1970s and rose to 9 per cent in 2004–08.

Self-reliance

The issue of 'self-reliance' in military mission–critical technologies is essentially determined by an accurate definition of this term. The 10 year self-reliance plan formulated in 1992, under the then SA to the RM, Dr A.P.J. Abdul Kalam defined 'self-reliance' in the form of an index, reflecting the percentage share of indigenous content in total procurement expenditure.

The definition of 'import dependency', as given in a very recent monograph from IDSA,[14] appears to the authors as a more accurate and dependable metric because, obviously, zero per cent imports mean 100 per cent self-reliance. Hence using this measure, and defining 'import dependency' as I_d, we define self-reliance as $(1–I_d)$. The IDSA Monograph No. 21 extensively referred to brings out the actual production value and import dependencies of the six defence public sector undertakings (DPSUs) and the complex of ordnance factories over a five-year period from 2006 to 2011. The results collated from the monograph are placed in Tables 2 and 3.

Trends in value of production from DRDO technology transfers data obtained from DRDO were presented in Figure 5 for a 27 year period, from 1980 to 2007. For comparing the values of this contribution to the defence production in recent years, as obtained from IDSA Monograph No. 21 referred to earlier, these figures are updated with DRDO data up to year 2012 and shown in Figure 6.

Table 2 Import Percentage of Total Production in DPSUs and Ordnance Factories (OFs)

Year	*HAL*	*BEL*	*BEML*	*Shipyards (MDL, GRSE, GSL)*	*BDL*	*Midhani*	*OFs*	*Average*
2006–07	67.04	36.41	31.21	29.86	22.32	30.00	5.27	31.73
2007–98	52.81	36.57	22.84	34.20	56.85	30.00	7.74	34.43
2008–09	62.35	45.23	23.46	40.14	66.15	30.00	14.85	40.31
2009–10	66.87	40.89	17.92	29.39	41.41	27.00	17.65	34.45
2010–11	69.65	33.96	17.20	23.89	28.89	30.00	30.52	33.44
Average Percentage Import Depen-dency	63.74	38.61	22.53	31.50	43.12	29.40	15.21	34.87

Source: L.K. Behera, 'Indian Defence Industry: Issues of Self-Reliance', n. 6.

Table 3 Total Value of Production in DPSUs and OFs (Rs crore)

Year	*2006–07*	*2007–08*	*2008–09*	*2009–10*	*2010–11*	*5 Year Average Production Value*	*5 Year Average Percentage Import Dependency*
HAL	9201.88	8791.52	11810.85	13489.59	16450.84	11948.94	63.74
BEL	4012.75	4111.37	5273.27	6247.88	5520.8	5033.214	38.61
BEML	2590.75	2826.95	3294.19	3739.92	3795.07	3249.376	22.53
Shipyards (MDL, GRSE, GSL)	2780.97	3212.37	3749.63	4593.45	4655.03	3798.29	31.50
BDL	385.84	505.84	523.06	631.61	910.98	591.466	43.12
Midhani	223.88	296.04	363.03	373.24	495.46	350.402	29.40
OFs	8282.72	9312.62	10610.04	11817.89	9038.78	9812.482	15.21
TOTAL	27478.79	29057.07	35624.43	40893.58	40866.96	34784.17	34.87
Total (All units)	173920.8						

Source: L.K. Behera, 'Indian Defence Industry: Issues of Self-Reliance', n. 6.

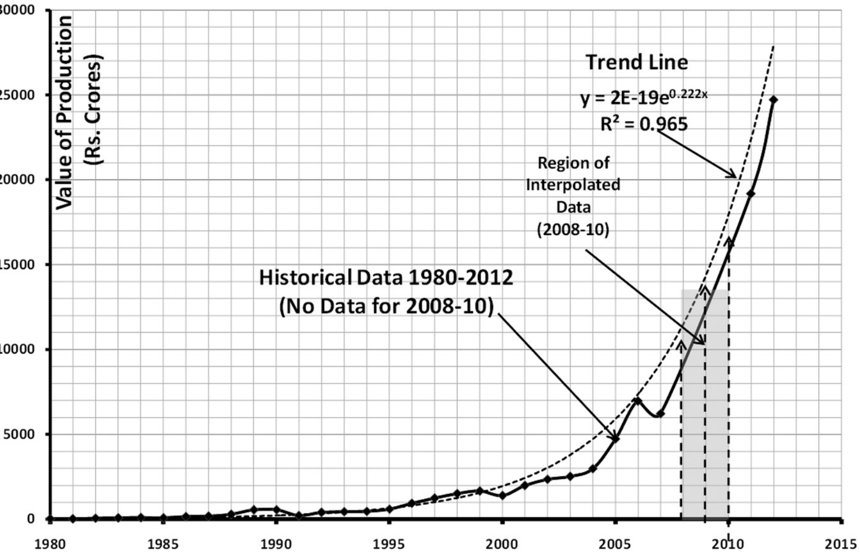

Figure 6 Historical Data and Trends in Value of Defence Production from DRDO Technology Transfers

Source: Historical data source (DRDO).

While the data for years 1980–2007 and 2011–12/2012–13 are historical, the data for three years, 2008–2010, were not available. These are obtained for this analysis by interpolation for three years of the 32 year annual data, 1980–2012, and are shown in Figure 6. Table 4 sets out the data comparing annual total value of defence industries (with and without aeronautics industry, namely, HAL) to value of production from DRDO technology transfers in the same period, 2006–10. The values of import dependency, also obtained from IDSA Monograph No. 21, are placed alongside for analysis.

From Table 4, the trend indicates *progressively increasing production value* of technology transfers from DRDO *with stabilizing import content between 32–40 per cent of total production value*. The dampening effect of Hindustan Aeronautics Limited's (HAL) high-value–high-import content production in aeronautics technologies on the contribution of DRDO to defence industry is evident. The percentage of production value from DRDO Technology Transfer to Total Defence Production (without HAL) in 2010–11 was 65.53 per cent and that came down drastically to 39.15 per cent when HAL is included. Further, the *average annual*

Table 4 A Comparison of Production Value from DRDO Technology Transfers with Total Defence Industry Production (With and Without HAL) with Import Dependency for Five Year Period

Year	*2006–07*	*2007–08*	*2008–09*	*2009–10*	*2010–11*
Total Production Value of Defence Industries (Rs crore)	27478.79	29057.07	35624.43	40893.58	40866.96
Total Production Value of Defence Industries without HAL (Rs crore)	18276.91	20265.55	23813.58	27403.99	24416.12
Production Value from DRDO Technology Transfer (Rs crore)	6951	6221	10500	13500	16000
%age of Production Value from DRDO Technology Transfer to Total Defence Production (without HAL)	38.03	30.70	44.09	49.26	65.53
%age of Production Value from DRDO Technology Transfer to Total Defence Production (including HAL)	25.30	21.41	29.47	33.01	39.15
5 Year Average %age Import Dependency (relative to total defence production)	31.73	34.43	40.31	34.45	33.44

Source: Data from Tables 1, 2 and 3, and Figure 6.

import content of defence industrial production over five years— that is, 2006–2010—is 33.44 per cent of Rs 34,784.17 crore, or *nearly Rs 12,000 crore per annum*. The bulk of this foreign exchange outflow goes to import of components and materials by the aeronautics, electronics and guided missile industries (HAL, Bharat Electronics Limited [BEL] and Bharat Dynamics Limited [BDL]).

Each of these seven defence industrial institutions contributes a share, high or low, to the total production value of defence industry. Each deals with one special aspect of defence technology as related to specific DRDO laboratories. Each production institution has its own import value, high or low. The average over five years are estimated and placed in the last two columns of Table 3. An analysis of these tables when placed in a matrix form yields new insights into the impact of DRDO on defence industrial production in the public sector (see Figure 7).

As per production output, the oldest (pre-independence) industries (ordnance factories and HAL) have high production value outputs; whereas the newer (post-independence) industries have relatively lower production output.

In terms of self-reliance, mechanical engineering-based industries (ordnance factories, Bharat Earth Movers Limited [BEML], shipyards, Mishra Dhatu Nigam Limited [MIDHANI]) have higher self-reliance, whereas electronics and aeronautics/aerospace industries have lower

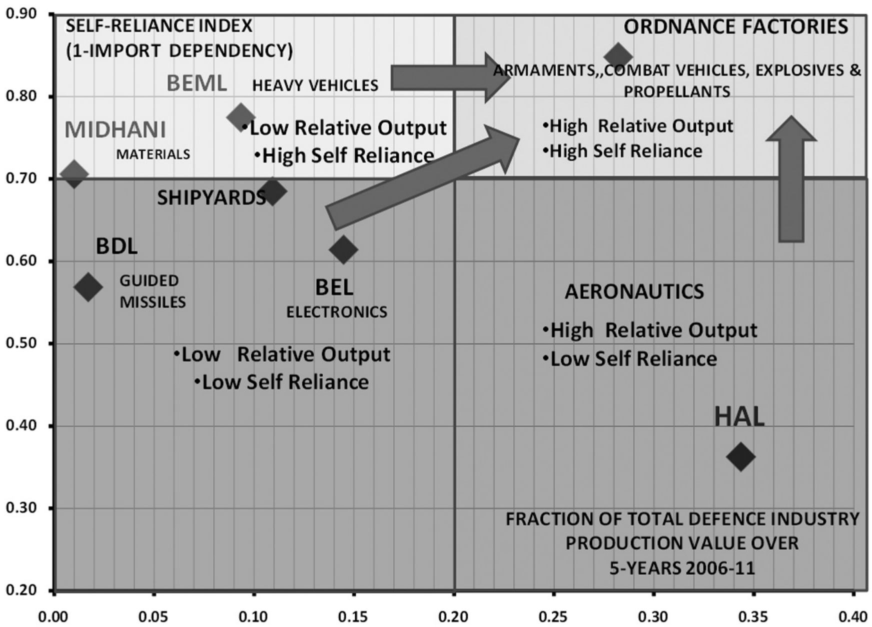

Figure 7 Techno-industrial Systems Perspective of Defence Industry

Source: Authors.

levels of self-reliance. For example, in aero-mechanical and electronic engineering-based technologies, import dependency here is highest: 64 per cent in HAL, 44 per cent in BDL and 39 per cent in BEL. The government has recently constituted the Chaturvedi Committee (2012) to study HAL and its recommendations are still classified. Recent collaborations between BEL and BDL with DRDO for the Akash missile system is a trend in the right strategic direction, as indicated in Figure 7.

A deeper analysis of the core issue of self-reliance in aeronautics industry has been carried out and presented by Behera.[15] The results are shown in Figure 8 from which it may be seen that aero-mechanical and electronic materials and components constitute nearly 90 per cent of the total import bill in one industry (HAL) alone. A similar situation would prevail in other aero-mechanical and electronics-based industries, BDL and BEL. This makes India both technically and economically vulnerable to external forces in aeronautics and electronics fields *unless the internal forces working at the level of materials and components break out of the era of 'licenced production'*. The vulnerability would cover the spectrum of materials and small components in sub-systems like hydraulics, pneumatics, electronics, computers, power supplies, sensors, temperature and pressure controllers and instruments.

This situation is unlikely to improve even with the introduction of the DRDO/Aeronautical Development Agency (ADA)-designed supersonic Light Combat Aircraft (LCA). The ADA is the nodal agency involved in the design and development of LCA along with HAL as a principal partner and in coordination with nearly 100 work centres spread across

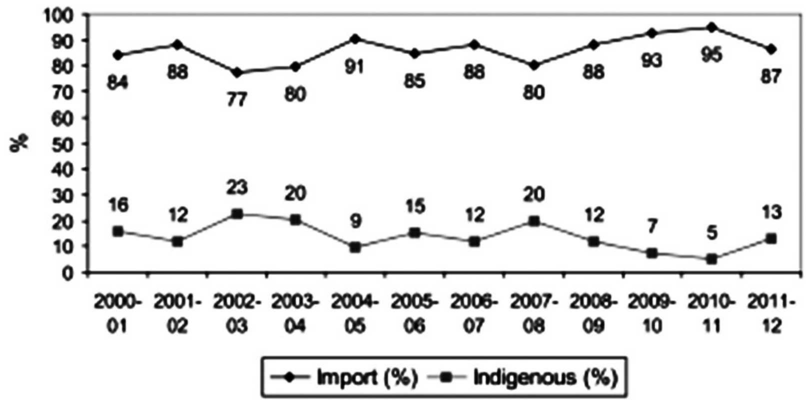

Figure 8 Actual Import Content of HAL Production[16]
(in terms of consumption of raw materials, components and spare parts)

the country. The ADA states[17] that 47 per cent of the LCA components are still imported, not to speak of related materials.

Need for a New 'Techno-industrial System' Paradigm for Self-reliance in the Defence Industry

No new vision or management system confined exclusively to defence industry or exclusively to DRDO will ever enable resolution of this historical licenced production era problem. A new integrated *techno-industrial system* vision is needed for a paradigm that brings together need for self-reliance in aeronautics/missile/electronics technologies with economics of production. Neither HAL/BDL/BEL with their in-house R&D nor DRDO laboratories/ADA having hundreds of work centres all over the country, appears to have resolved this hard-core historical problem related to the era of 'licenced production'. But then, there are models in the guided missile industry, where an entire ATGM system consisting of over 2,000 components and over a 100 varieties of materials was indigenized in a period of three years and was put on stream into quantity production.[18]

Integrated policies, systems and consultative procurement procedures are well in place and constantly upgraded in the MoD to ensure that indigenous R&D does not get marginalized because of these make–buy decisions. In the years 2007–08 to 2010–11, the total arms imports by India totaled about $10 billion (about Rs 50,000 crore),[19] whereas the total value of procurement in this period from production output of defence industries in India was Rs 1,73,921 crore (Table 2), presumed to be consumed by the armed forces in the main.

The ratio of arms and equipment procurement from indigenous production to total procurement by the armed forces was thus about 78 per cent, and the total direct imports by the services amounted to 22 per cent. To this direct import by the users, we have to add the import content of defence industrial production which is about 35–40 per cent. Taken together, the value of imports of weapons and equipment as a whole (direct buy and foreign exchange (FE) content of defence industrial production) is 57–62 per cent or, according to a recent news article, nearly 70 per cent.[20] The same news article also brings out that '…according to numerous reports to Parliament by the Comptroller and Auditor General, *a high proportion of these imported systems are frequently not serviceable, thus affecting the combat readiness of the armed forces*…' (emphasis added).

Techno-industrial System Vision

The defence industry imports are also not coming down in advanced technology areas and import content has stabilized between 30–40 per cent. Clearly, the stage is now set for an architectural change that involves developing a techno-industrial system vision for the geographically dispersed defence industrial complex as a whole. The aim is to reduce and finally eliminate the hard core of vulnerability of defending India: continued importing of large variety of high-technology components and materials by individual industries.

The indigenization processes of these fragmented, industry-wise imports of strategically vital raw materials and components needs to be reorganized by *a coherent centralized collaborative MoD/DRDO/defence industry/private sector approach*. This one single step would set the direction and pace of reform, and instill greater levels of self-confidence in the armed forces in the competence and dependability of India's defence techno-industrial system. It would also lead the way onwards for a techno-economically viable and full-fledged entry strategy for the private sector into advanced technologies and systems for dual use, national security as well as economic growth.

As mentioned earlier, Greiner had observed that *the future of an organization may be less determined by outside forces than by the organization's history*. The way ahead towards self-reliance in defence industry is now clear: it is the inner technological, manufacturing and commercial forces *within* DRDO and defence industries that need to be understood and the *MoD/DRDO/defence industry* needs to make an integrated effort (with the private sector) to help India break out of the historical era of licenced production.

Strategic Role, Major Technological Achievements and Significant Shortfalls of DRDO

From Tables 1–4, it is evident that the DRDO, with its technology spectrum encompassing the entire range of defence requirements, is now an emerging force behind self-reliant production in frontier areas of research. This self-reliance is now well established in the design of complex and advanced systems. Significant vulnerability still exists in the techno-industrial system as a whole at:

1. *Operational Levels* in indigenization of high-technology components and materials within defence industries (especially aeronautics, that is, HAL, and including LCA project); and

2. *at Perspective Planning Level* for designing and integrating revolutionary technologies into architecturally new systems and new markets that would sustain India in the frontiers of science and technology far into the future.

The DRDO laboratories have, however, brought in a quantum jump in the design and development of systems and many critical technologies of missiles and strategic systems, aeronautics, armaments, radars, combat vehicles and engineering, electronics and computer sciences, materials, micro electronics and devices, cyber systems, artificial intelligence, naval research and development and life sciences, thereby elevating India's capabilities on the technology fronts. Based on these technologies, India is today one of only four countries in the world to have a multi-level strategic deterrence capability; one of only five countries of the world to have its own Ballistic Missile Defence (BMD) programme and underwater missile launch capability; one of only seven countries to have developed its own Main Battle Tank (MBT) and an indigenous fourth generation combat aircraft; one of six countries of the world to have developed a nuclear-powered submarine; and one of select few countries of the world to have its own electronic warfare and multi-range radar programme.

Guided Missiles

After two decades of system and technology development of ATGMs and long-range SAMs, that were abandoned after successful prototype trials but failure to transfer technology to any production agency, the DRDO set up the IGMDP and nominated BDL as the nodal production agency for all missile systems developed by DRDL. Thereafter, from mid-1980s, DRDO made substantial progress particularly in this area. The flight test rate at the national range that was set up for this purpose has enhanced and nearly 40 missiles were flight tested in last two years.

Surface-to-Surface Missile (SSM) and ATGM

These include the ICBM class Agni 5, technology-driven Agni 4 and other long-range missiles with a strike range of 300–3,000 km, namely, Agni A1, A2, A3. These have been inducted into the services giving the needed strength to the nation. Prithvi, the medium-range surface-to-surface ballistic missile, and Dhanush, a ship-launched medium-range ballistic missile, have now been inducted. The Nag 'fire-and-forget' version of ATMG has had several failures resulting in schedule slippages in the process of maturation of advanced opto-electronic technologies. A version of Nag with new launcher is undergoing final user evaluation trials.

Surface-to-Air Missiles (SAMs)

While the Trishul, a short-range SAM, was abandoned due to technical problems related to its solid propellant, a large production order for the long-range Akash SAM has been placed with DPSUs. Akash, a SAM with multi-target engagement capability, has also been inducted into the Indian Armed Forces. Patriot system of the US with which the Akash system is compared took 22 years from its conception to induction, as compared to 28 years for Akash which started at a lower end of the technology spectrum. The indigenous content of Akash is about 90 per cent as per its value.

Anti-ballistic Missile (ABM) Systems

Concurrently, the endo- and exo-atmospheric air defence programme, an effective shield against the incoming theatre ballistic missiles, has demonstrated the interception capabilities at low and high altitudes making India the fourth nation in the world to have such a technology. The system is now available for deployment to protect India's highly populated cities and other military targets.

Air-to-Air Missiles (AAMs)

Astra, a beyond visual range AAM, enabling fighter pilots to lock-on and shoot down enemy aircraft from a distance of more than 80 km, is a sanctioned project and is being pursued in close and continuous coordination with the Indian Air Force, that is, it is being integrated with Sukhoi.

Unmanned Aerial Vehicles (UAV)

Many test flights of UAV Rustom 1 were completed, demonstrating a number of key technologies. Netra, a mini-UAV, is being used by the Indian paramilitary forces for aerial surveillance. Remotely operated Vehicle (ROV), Daksh, has been inducted into the armed forces. Naval missile system development is being accelerated.

Naval Torpedo/Missile Systems

An underwater missile, B-05, was test fired from a specially made platform to establish a technical capability of developing submarine-launched missiles. DRDO's contribution includes realization of Light Weight Torpedoes, Advanced Sonar Systems like Hull Mounted Advanced Sonar (HUMSA), USHUS and the state-of-the-art 'Payal' Sonar System for first indigenous nuclear submarine. Extensive technical trials at sea of the torpedo Varunastra have been completed and presently the user evaluation trials are going on. It is expected that these too will be completed shortly.

Aeronautics

Light Combat Aircraft Tejas is flying towards meeting its commitment to the final clearance. Airborne Early Warning and Control System, with number of mission-related indigenous systems on board, is undergoing final airborne evaluation trials. However, the failure of the Kaveri aircraft gas turbine engine at GTRE to get through the technology readiness-level barrier and establish reliability under various flight envelope conditions has been a source of concern and merits a case study in itself.

Armaments and Combat Vehicles

In the field of armaments and combat vehicles, DRDO has achieved considerable success with the development of the MBT—Arjun, multi-barrel rocket launching system—Pinaka, and engineering and bridging systems which spurred a number of variants and gave rise to key technologies. Two regiments for Arjun tanks have been inducted into the operational commands of Indian Army making India one of the few countries to have its own indigenous MBT. However, the DRDO has failed to make any impact in the domain of heavy artillery guns.

Electronics and Electro-optics

To meet the operational requirements of three services, in the area of electronics, a number of radars, like weapon locating radar, lightweight surveillance and target acquisition radar and low-level lightweight 3D radar, have been developed and trial evaluated. In electronic warfare, the completion of Samyukta, Sangraha and Divya Drishti has established India's self-reliance in this critical domain.

Self-reliance in ground-based and ship-based radars for both surveillance and fire control has been established along with multifunction array radar. With respect to Active Electronically Scanned Array (AESA) radar, work is in progress towards its realization within a few years. The development and demonstration of cathode and electron guns for multi-beam klystron are the stepping stones in harvesting micro-wave power for defence and space–energy applications.

In the electro-optics area, a number of systems have been developed by DRDO like image-intensifier holographic site, thermal site and gunner site, for which the armed forces have placed orders with ordnance factories, BEL and private industries.

Materials

The DRDO's development of titanium sponge and maraging steels, produced by the PSU MIDHANI, has significant benefits for the space programme. Indigenous naval steel for our aircraft carriers is another major DRDO achievement.

Soldier-related Technologies

A number of technologies directly related to enhancing the combat effectiveness and safety of soldiers have also been addressed by DRDO, such as bullet-proof jackets, breathing systems, farming in high-altitude areas, dengue, chikungunya, multi-insect repellent and food poison detection kits. In the field of nuclear, biological and chemical (NBC) technologies, a large number of DRDO systems, including reconnaissance vehicles and dosimeters, are in use. Solar-powered modular green shelters and bio-digesters for human waste management have been handed over to the army.

Spin-off Technologies

More than 12,000 units of bio-digesters have been integrated in Indian Railway coaches and established at Lakshadweep. The DRDO has developed many societally relevant products as spin-offs from missile technologies. Lightweight calipers developed by DRDO have greatly benefited over 30,000 polio-affected children. Two hundred units of critical care ventilators have been installed at various hospitals.

Advanced Test Facilities

The DRDO has established many state-of-art test facilities for development and production of key technologies, such as composite rocket motor, supersonic combustion Test Facilities to develop engines for hypersonic flight, servo valves on Government Owned Company Operated (GOCO) basis, Micro Electro Mechanical Systems (MEMS) fabrication facility, propellant casting facility, and many others. Also, strategic facilities for storage, integration, maintenance and calibration of missile systems have been established across the country.

Time and Cost Overruns

Generally, the development period of missile systems in advanced nations from conceptualization to assets creation is about 15 years, and India is no exception. If we look at the Agni programme, the development period, right from project sanction to technology development to development trials to creation of assets with the armed forces, including all the infrastructure and ground segments, is less than 15 years. The Patriot SAM system of the US, right from its conception to induction, took about 22 years. The nearest to Patriot in Indian scenario, Akash SAM system, has taken about 28 years from its initial conceptualization to deployment of first battery because none of the basic technologies were available at start.

In the case of supersonic fighter aircraft, the Eurofighter, for its sanction, took 15 years, Rafale, 19 years, and Gripen took about 15 years in advanced nations where the technology and infrastructure were already existing since the Second World War. Hence, the LCA taking 20 years for Initial Operational Clearance (IOC) cannot be considered as too much delayed (though there are differences whether this was a 'genuine IOC' or a 'motivational IOC'[21]).

With growing experience in managing large projects and rapidly maturing technology readiness levels in a variety of technologies, the situation now is different. Thus, Agni 5, termed as the 'game changer', had its maiden flight in just three years; Arjun Mark II, the vastly improved version of MBT Arjun (to meet the changes required by the army, based on their experience with Mark I), was developed in about two years time and is undergoing user trials. The same is true for other areas too, indicating India's entry to a new era of self-reliance and inclusive economic growth, marked by freedom from external, unethical controls and technology denials; all facilitated by DRDO with the active involvement of three services as the end user, academia and industry, including large number of small and medium enterprises and R&D institutions.

With regard to cost overruns in one project or the other, the overall techno-economic figures presented earlier speak for themselves. Investment in DRDO may now be seen as a worthwhile investment opportunity of public funds as well as having high value for national security.

Technology Management as an Agent of Architectural Change

No nation can sustain high economic growth *in the long term* without planning and implementing mechanisms that enable multi-level, cross-functional coordination of customers (the 'market'), R&D and manufacturing. Research and development is all about creating new technologies and/or refining existing technologies (the +X and –X axes in Figure 9). But as programmes expand for higher capacity utilization of DRDO technologies (fundamentally needed to sustain its long-term economic performance), then the customer/market dimension has to change also (the +Y and –Y axes in Figure 9); in the DRDO case, from a purely military technology to *dual use technologies for both military and civil markets*.

Thus, perspective development and strategic planning process need to consider future projects/programmes/missions in the framework of the concept of 'Technology Transcilience' (a term coined by the Harvard Business School when they viewed and analysed the technology growth process in the US industry). *Technology transcilience* envisages corporate DRDO strategic perspectives as falling into technology change processes of 'architectural change', where new products meet new and broader

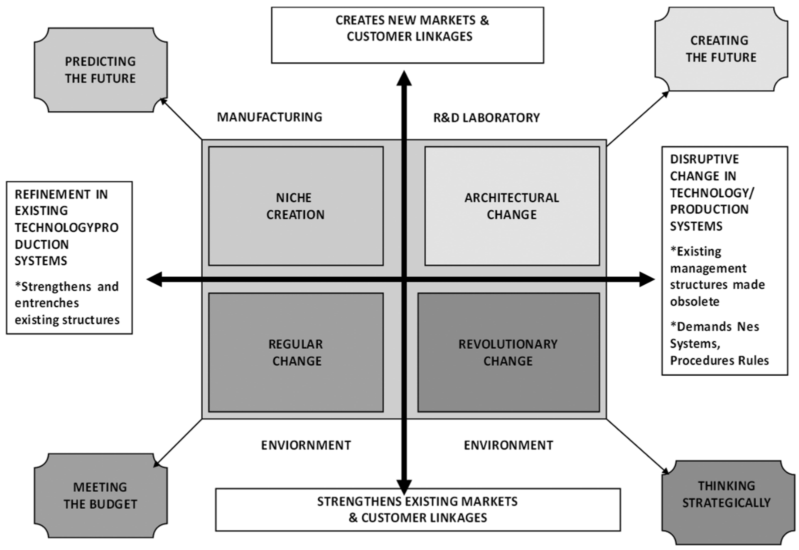

Figure 9 Technology Transcilience: The Paradigms of Technology Change

Source: R. Gopalaswami, Notes, Advance Management Programme, Harvard Business School, 1984.

markets; of 'revolutionary change', where new products fulfil needs of an existing market; 'niche creation', where existing products meet new markets; and 'regular change' taking place, mostly in production agencies where existing products are refined for existing markets.

Such a new perspective orientation in strategic planning and technology management is basic to an ultra-long-term Vision 2050 for DRDO in the national context, not merely in but beyond the MoD to a national context. Thus, DRDO will need to strengthen existing MoD markets and customers (Army/Navy/Air Force, the –Y axis in Figure 9) while reaching out to create new civil markets and customer linkages. A striking example is the bio-digester. Developed and produced for the Army, it has found extensive civilian use, and is now required to be produced in lakhs for the railways, Lakshadweep islands, tourist places and rural areas, with the potential to change lives of millions of people.

The strategic role of DRDO will then, within the decade, undergo yet another fundamental change as happened in the 1980s, when IPMSs were conceived and implemented. In the years to come, DRDO, as a diversification strategy for its huge R&D and manufacturing base, will have to enter into integrated mission management systems and the key would be to create new products and markets in collaboration with other major R&D agencies in India and abroad.

Significance of Recommendations of High-level Committees

It can be seen that the reforms and reorganization recommendations of the Rama Rao Committee, cover technology change management calling for 'regular' and 'niche' changes in technology and market. These changes can bring in better and more effective systems of R&D governance. Further, these reforms relate to the functioning of DRDO alone; hence, they do not address the actual nature of import dependencies arising from the historical 'licence production' ecosystems and culture prevailing in DPSUs, and *how they have a reverse coupling effect* (as illustrated in Figures 2 and 3) when DRDO attempts to transfer major systems into such legacy production enterprises. This calls for an overall techno-industrial systems perspective that is brought out in this article.

This time-lined study of cyclic changes in growing organizations indicates that DRDO may have 'frozen' in its long-term 'revolutionary' and 'architectural' systems, technology and application development processes. In this context, Greiner, in his concluding remarks, cautions that many organizations would actually like to remain 'frozen' in a 'crisis of red tape'. He says,

> …*A management that is aware of the problems ahead could well decide not to grow.* Top managers may, for instance, prefer to retain the informal practices of a small organization, knowing that this way of life is inherent in the organization's limited size, not in their congenial personalities. *If they choose to grow, they may do themselves out of a job and a way of life they enjoy…*[22]

'Architectural and revolutionary change' processes that would disrupt organization cultures and procedures are not easily created by self-sustaining hierarchies. The need for disruptive and revolutionary changes had been studied by the DRDO in 1998 as a potential for creating a new future for DRDO and the nation as a whole through 18 major national missions.[23] These recommendations called for intense coordination between various central government ministries/departments, but were not implemented. No nation has been able to sustain a high level of defence preparedness without closely coupling national security to economic and self-reliance growth goals. A diversification strategy for the Government of India into self-reliance in defence technologies as well as architecturally new missions in advanced sciences for enhancing creativity could result creating a new model of public–private partnership that has been examined threadbare and is yet to take-off. The way ahead lies in two specific domains described next.

The Way Ahead: Architectural and Revolutionary Changes Creating New Markets and Technologies

The major area where focus for self-reliance is needed is at the roots of the defence industry, to break out of imports of basic components, raw materials and parts in the aero-mechanical and electronics engineering areas. The target for this proposed architectural change is to reduce this 35–40 per cent import dependency to less than 10 per cent (Kelkar Committee's goal) within the next five years. The means proposed are as follows.

Creating an Architecturally New Defence Techno-Industrial Consortium (DTIC)

Sixty-six years after Independence, India is still dependent on imports of critical weapon platforms, systems, components and raw materials. There is clearly a need for an architecturally new form of integrated defence R&D and manufacturing concept, strategy and structure that would bring in *a third force*, the private sector in a big way into defence industry.

Phased Defence Techno-Industrial Strategy and Structure

The new strategy and related new structures to create a Defence Techno-Industrial Consortium (DTIC) will enhance self-reliance in defence technologies in DRDO and the private sector. This will also expand the manufacturing capacities of these technologies in DPSUs and the private sector industries into indigenous high technology products for the DPSUs and new platforms/systems for the armed forces. This architecturally new strategy would unfold in two phases:

DTIC Phase 1 (Production): Strategy and Structure

1. *Strategy:* To outsource all items currently imported by DPSUs to the emerging DTIC, with DRDO strengthening technological capabilities of private sector. The private industries would be setting up units and joining DTIC in collaboration (wherever necessary) with foreign companies which are supplying components and materials directly to the DPSUs and DRDO. The goal is to transform currently imported items into indigenous versions and serve an existing DPSU market *worth Rs 12,000 crore per annum* of components, raw materials and sub-systems in advanced technology areas like aeronautics, electronics and guided missiles; and reduce the import dependency of DPSUs to less than 10 per cent in the short term (five years).
2. *Structure:* The structure for Phase 1 of the strategy would be setting up of a Defence Techno-Industrial Board (DTIB). The Board would oversee the planning, commissioning and functioning of the Defence Techno-Industrial Consortium (DTIC). Assisted by DRDO, the DTIC would carry out defence industrial product development and production (in collaboration with DPSUs) of the critical high technology components, raw materials and sub-systems, now being imported, for example, by HAL, BEL and BDL.
3. *Scope of Collaborative Programmes within DTIC:* The scope of work of DTIC would cover the whole spectrum of raw materials, components and sub-systems required for Defence and Aerospace industry. DRDO would provide comprehensive, technology

development support to the private sector industries. The DPSUs would provide complete data and information to manufacture the entire range of production in the DTIC. *This combination of three forces—DPSUs, DRDO and private sector industries—would enable India break out of the historical era of licence production in defence public sector industries.*

4. The components, materials and subsystems supplied by the DTIC would have import content not exceeding 10 per cent to the quality and environmental standards as required, assisted by both DRDO and DPSUs. Issues of Intellectual Property (IP) would be addressed jointly with DRDO and DPSUs. Each industry would be evaluated for its Technology Readiness Levels (TRLs) by the DTIB and manufacturing partners would be selected from the consortium depending on TRLs.

DTIC Strategy and Structure Phase 2: Involvement in R&D

As Phase 1 strategy unfolds guided and controlled by the Defence Techno-Industrial Board (DTIB) the private sector industries would technologically and culturally understand the defence industry requirements, systems and procedures. While DTIB would set the pace of growth for self-reliant defence industry in Phase 1, Phase 2 would see the emergence of R&D capabilities in the private sector, thereby resulting in rapid growth in research in the defence and aerospace sectors.

The budgetary allocation of DRDO would need to be substantially enhanced to enable DRDO support and fund R&D in private industries. The private industries should also invest R&D and come out with technological advancements in the defence and aerospace sectors.

Futuristic R&D

Based on advances in its laboratories, DRDO is now well positioned to identify frontier technologies with high economic value that are essential for the country, and should carry out research in collaboration with other national research organizations/laboratories, academia, and industries. It is suggested that a Frontier Technology Wing/Organization be created to plan, organize and coordinate advanced research in an effective and dynamic manner. The wing/organization can be part of DRDO or can function as an independent organization. Special provisions, features and facilities with adequate freedom and power for this Frontier Technology Wing/Organization would be required from the government on the lines of DARPA, as recommended by the Kelkar Committee. The research would encompass novel advances in areas like advanced sensors, materials, nano-technologies, photonics, aero-cryogenic heat exchangers, advanced aerospace propulsion, among others. The Frontier Research wing should come out with cutting edge technology systems and solutions to sustain India's leadership on par with the concurrent research across the globe.

Conclusions

The exponential rise of production value from DRDO technology transfers, as seen in Figure 6, suggests that it is but a matter of a few years before the entire production value from India's defence industries emerges from DRDO technology transfers, barring the remnant technologies from the licence production era.

Of continuing concern is the sustained presence of the defence techno-industrial Achilles heel: imports of hundreds of varieties of raw materials (metals and non-metals) and thousands of small components in the aeronautics, electronics and guided missile industries, worth billions of dollars, a historical legacy of the 'licence production' era, with no determined, integrated, focused, time-bound efforts to find indigenous alternatives and solutions. China had mastered this small but most vital detail which assured its ascendency in the world. India can do this within the next five years by creating infrastructure and market exclusively for this purpose, as suggested, as a public–private partnership venture.

Of much greater significance than the monetary value alone is DRDO's contribution to nation building, generation of vast knowledge base leading to creation of ecosystem conducive to development of cutting-edge technologies and transformation of these technologies into manufactured products of high standards. The indigenous systems design/engineering capability and capacities generated in the process of DRDO's evolution in collaboration with manufacturing agencies and the armed forces has given the nation much-needed strategic strength and leverage in the global geopolitical arena. This has set the stage for the nation to embark on challenging new dual use systems and technologies of revolutionary as well as architectural nature that bring territorial and economic security of the nation for which measures have been suggested in detail.

The country is now on the threshold of another massive revolution that can rapidly generate the economic, military and strategic strength to achieve the status it deserves through frontier areas of R&D requiring collaboration between many ministries/departments, public and private sectors. One such set of frontier missions has been described. Thus, policies promoting indigenous development, including generous and flexible framework of government funding of R&D endeavours are the need of the hour. The media can play a crucial role and make its own contribution in such nation-building activities.

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5. History of DRDO, available at http://drdo.wordpress.com/2007/01/01/history-of-drdo/ 1 January 2007.
6. Behera, L.K., 'Indian Defence Industry: Issues of Self-Reliance', IDSA Monograph Series No. 21, July 2013.
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8. Yadav, Yatish and Nardeep Singh Dahiya, 'The Secret World of DRDO', *New Indian Express*, 2 September 2012.
9. Mansfield, E., 'How Economists See R&D', *Harvard Business Review*, November–December 1981, pp. 98–106.
10. See Yadav and Dahiya, 'The Secret World of DRDO', n. 8, the media report that brings out details of CAG observations to criticize the DRDO.

11. Singh, Kanhaiya, *Economic Analysis of DRDO*, NCAER Study Report, obtained from DRDO, December 2008.
12. Year-wise DRDO budget (revenue and capital and production value data in Figures 4 and 5; and Table 2 were obtained from Behera, 'Indian Defence Industry: Issues of Self-Reliance', n. 6, in graphical form and the figures extracted from the graphs were further validated in correspondence by DRDO).
13. Estimating the rate of growth: From the exponential relationship:

$$Y = a^x$$
$$\text{Ln } Y = X \ln a$$
$$\text{Hence, } x = \text{Ln } (Y/a)$$
$$\text{Let } V_0 = \text{Value of production at the base year}$$
$$V_n = \text{Value of production after "n" years from the base-year}$$
$$r = \text{Factional annual growth rate, and } R = 1 + r$$

Placing this relationship in exponential relationship,

$$X = n$$
$$a = R$$
$$\text{Then, } \text{Log } (V_n / V_0) = n \text{ Log } R$$
$$\text{Hence, } R = 1 + r = e^{[\text{Ln } (Vn / V0)]/n}$$
$$\text{And } r = \{e^{[\text{Ln } (Vn / V0)]/n}\}\text{-}1\}$$
$$r\ (\%\text{age}) = 100 \times [\{e^{[\text{Ln } (Vn / V0)]/n}\} - 1]$$

For n =15 years, we have

$$r = \{[\text{Exp } \{(\text{Ln } (V_n / V_0))/15\}]\ \text{-}1\}\}$$

as indicated in Table 2.
14. Behera, 'Indian Defence Industry: Issues of Self-Reliance', n. 6, pp. 51–56, Tables 2.3–2.13.
15. Ibid.
16. Ibid., Figure 4.1.
17. Indigenous line replacement units for LCA Tejas, available at http://www.aame.in/2012/08/imported-components-used-in-light.html.
18. R. Gopalaswami's contribution as Chairman and Managing Director (CMD), BDL, to total indigenization of the 'Konkurs' ATGM system in 1990–93 (in collaboration with DRDO/Defence Metallurgical Research Laboratory [DMRL] and a public sector engineering consultant, Metallurgical & Engineering Consultants Ltd [MECON]) when supply lines for licence production of materials and components from erstwhile Soviet Union collapsed. Materials and components were sourced from hundreds of small and medium industries throughout India as identified by MECON. Collaboration with Russian specialists was obtained for certification of these industries and initial operational clearance for these materials and

components. The entire programme was managed by young engineers of BDL.

19. Stockholm International Peace Research Institute (SIPRI), *Yearbook: Armaments, Disarmament and International Security*, available at http://www.indexmundi.com/facts/india/arms-imports (see below Table 3).
20. '…DEFENCE Minister A.K. Antony has said on numerous occasions that India still meets around 70 per cent of its military hardware and software requirements through imports…'. See Ravi Sharma, 'Failing to Deliver', *The Hindu*, 5 March 2013, available at http://www.hindu.com/thehindu/thscrip/print.pl?file=20130503300809600.htm&date=fl3008/&prd=fline.
21. Ibid.
22. Greiner, 'Evolution and Revolution as Organizations Grow', n. 2.
23. Report of the Expert Committee Constituted by the Department of Defence Research and Development, Ministry of Defence, *Integrated Strategies, Technologies and Missions for Comprehensive National Security*, August 1998.