CHAPTER ONE

INTRODUCTION & METHODOLOGY
CHAPTER ONE

Introduction and Methodology

1.1 Introduction
1.2 Defence Research & Development Laboratory: Central Laboratory for IGMDP
1.3 Major Achievements In Missile Systems
1.4 Critical Technologies For India
1.5 Defence Supplies in India
1.6 Dual-Use Technology
1.7 1985: Defence Technology and Industry
1.8 1985-95: The Period Of Stand-Alone Sub-System Development
1.9 1995-2005: Graduation To Systems Engineering
1.10 Growth of Technology Capability in DRDO
1.11 The Guided Missile Development Programme
1.12 Brief Description of the PRITHVI System
1.13 The Effectiveness of PRITHVI
1.14 PRITHVI as a Cost-Effective Weapon
1.15 The Development and Production Experience of PRITHVI
1.16 Objectives of the Study
1.17 Scope of the Work
1.18 Methodology
1.19 Sources of Data and the Type of Research
1.20 Hypothesis
1.21 Chapter Scheme
1.1 Introduction

Integrated Guided Missile Defence Programme (IGMDP) has been a success story of introducing world-class missiles in the Armed Forces within a short span of time. It is a major success of a large Research and Development (R&D) programme of more than Rs. 3000 crores. Technology Management and Transfer during the programme have been a unique achievement with concurrent engineering inspite of American sanctions and MTCR (Missile Technology Control Regime). A research work is proposed to be taken up to study and analyse the system of Technology Management & Transfer in IGMDP, strengths and weaknesses of the system and outline the R&D Management and Transfer of Technology (ToT) principle and approach in Indian environment. The study is highly relevant to today’s environment in view of the following :-

(i) Technological innovations are often the consequences of articulated demands of the market and are sensitive to many factors, some technological, many economic and even social. The assessing and choosing of technologies is an important factor in linking it with the production of goods and services. Another major component is the way technology is transferred from laboratories and assimilated in industries. The latter embodies in it the diffusion of technology and the potential to teach the practitioner to be innovative. This process of acquiring skills, the so-called ‘learning by doing’ has turned out to be a vital factor in absorbing innovations for manufacture.
(ii) Many developed countries have become adept in transferring technology among their institutions. There are also examples where technology transfer has become a problem with poor diffusion and still poorer assimilation. One transfer does not blossom into many innovations, but ends as a solitary product or service, vulnerable to competition, and easily overtaken by newer innovations. Why is this so, even when the transfer between laboratories and industries is within the country?

(iii) India has the third largest scientific manpower and four excellent Government scientific organisations i.e. Council of Scientific and Industrial Research (CSIR), Defence Research and Development Organisation (DRDO), Department of Atomic Energy (DAE), Indian Space Research Organisation (ISRO) and many outstanding schools and universities in Science & Engineering. Indigenous high technology products in civil as well as Defence sectors are, however, limited. Seventy percent of the weapon systems held by Indian Armed Forces are of foreign origin. Under the leadership of Bharat Ratna Dr. APJ Abdul Kalam, development of major state-of-art guided missiles weapon systems i.e. AGNI, PRITHVI, AKASH, TRISHUL and NAG, were initiated in the 1980s under the Integrated Guided Missile Development Programme (IGMDP) out of which PRITHVI has been inducted into Indian Army Service. A critical study and research is undertaken on the management of IGMDP in order to document, analyse, and convert the process into a organisations structure. Emerging management principles are brought out comparing them with management principles advocated by various other schools of thought. The Management Principles in Technology Selection and Transfer as relevant to Indian environment in
High Technology areas have been formed for the benefit of the country’s management community.

1.2 Defence Research & Development Laboratory: Central Laboratory for IGMDP

Defence Research & Development Laboratory (DRDL) was established in 1961 at the campus of Defence Science Centre, Delhi as an expansion of Special Weapon Development Team (SWDT) formed in 1958. The laboratory was moved to Hyderabad in Feb 1962, to work on the design and development of missiles. During the initial phase, the laboratory successfully designed anti tank missile and indigenous rockets and proved in flight. The first computer IBM 1620 was installed in DRDL as early as in 1965. Necessary infrastructure and test facilities were established during 1972 to 1982, which included aerodynamics, structural and environmental test facilities, liquid and solid propulsion facilities, fabrication engineering facilities, control, guidance. FRP, rubber and computer facilities.

DRDL took a quantum jump in design and development of various types of missiles simultaneously leading to limited series production under Integrated Guided Missiles Development Programme (IGMDP) in 1982 onwards. PRITHVI - a surface to surface missile, TRISHUL - a quick reactions short range surface to air missile, Nag - a third generation anti tank missile and AKASH - a medium range surface to air missile, were taken up besides AGNI, which was initially a technology demonstrator.

Areas of work at DRDL are as follows: -

A. Systems
B. Aerodynamics
C. Computer, Communication & Range Systems
1.3 Major Achievements In Missile Systems

A. PRITHVI – Surface-To-Surface Tactical Ballistic Missile
   (i) Completion of Development of Army version and induction in service
   (ii) Development of 2 more types of warheads is nearing completion.
   (iii) Development of Air Force Version of PRITHVI.
   (iv) User Training and documentation, ESP for PRITHVI.

B. TRISHUL – Short Range Quick Reaction Surface-To-Air Air Defence Missile System
   (i) Proving of 3-beam guidance.
   (ii) Proving of Sea skimmer role.
   (iii) Development of TRISHUL combat vehicle (Dev and user version).
   (iv) Development of Launcher and Radar vehicle for Air Force version.
   (v) Development Trials of Naval version completed.
   (vi) Advanced stage in development trials of Army and Air force system.
C. AKASH – Medium Range Surface-To-Air Air Defence Missile System

(i) Realisation of Ramjet Propulsion Technology.
(ii) Realisation of phased Array Radar (Dev & user version) and other ground systems like BCC, BSR and 3D-CAR.
(iii) Completion of ToT to BDL for Assembly & Integration.
(iv) Successful flight against electronic target.

D. NAG - 3rd Generation Anti-Tank Guided Missile System

(i) Realisation of Nag Missile Carrier (NAMICA)
(ii) Realisation of Day Version Seeker.
(iii) All weather seeker under advanced stage of development.
(iv) Dev flight from Tube Launcher and NAMICA.

E. AGNI – Medium Range Ballistic Missile System

(i) Successfully established Re-entry Technology with Carbon-Carbon Heat shield.

1.4 Critical Technologies For India

A country takes a long time to develop technological strengths. What is important is that it concentrates on a few crucial or critical technologies, which can give it a decisive advantage in meeting the kind of economic instability, described above. It is interesting to note the list of critical technologies in the report of the USA’s National Critical Technologies Panel in March 1991. The criteria used for the selection are given in Table 1.1.
<table>
<thead>
<tr>
<th>Area/Subject</th>
<th>Criteria</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Needs</td>
<td>Industrial Competitiveness</td>
<td>Technologies that improve US competitiveness in world markets through new products, introduction and improvements in the cost, quality and performance of existing products.</td>
</tr>
<tr>
<td>National Defence</td>
<td></td>
<td>Technologies that have an important impact on US national defence through improvements in performance, needs cost, reliability or producibility of defence systems.</td>
</tr>
<tr>
<td>National Security</td>
<td></td>
<td>Technologies that reduce dependence on foreign sources, lower energy costs, or improve energy efficiency.</td>
</tr>
<tr>
<td>Importance / Critically</td>
<td>Quality of life</td>
<td>Ability to make strong contributions to health, human welfare and the environment, both domestically and worldwide.</td>
</tr>
<tr>
<td></td>
<td>Opportunity to lead markets</td>
<td>Ability to exert and sustain national leadership in a technology that is of paramount importance to the economy or national defence.</td>
</tr>
<tr>
<td></td>
<td>Performance / quality / productivity improvement</td>
<td>Ability to cause revolutionary or evolutionary improvements over current products or processes in turn leading to economic or national defence benefits.</td>
</tr>
<tr>
<td></td>
<td>Leverage</td>
<td>Potential that Government R&amp;D investment will stimulate private sector investment in commercialisation or likelihood that success in the technology will stimulate success in other technologies, products or markets.</td>
</tr>
<tr>
<td></td>
<td>Market size / diversity</td>
<td>Potentially serious damage may be caused if a technology is held exclusively by the other country and not the United States.</td>
</tr>
<tr>
<td></td>
<td>Vulnerability</td>
<td>Technology forms the founder for many other technologies or exhibits size / strong linkages to many segments of the economy.</td>
</tr>
<tr>
<td></td>
<td>Enabling / Pervasive</td>
<td>Ability to exert a major economic impact through the expansion of existing markets, creation of new industries, generation of capital or creation of employment opportunities.</td>
</tr>
</tbody>
</table>

It can be seen from the above that the criteria for selection of critical technologies mention national defence only as one element. Other criteria include their ability to enhance the quality of life for the American people, industrial competitiveness and energy security. Americans are acutely aware of their dependence for oil on the Gulf countries.

Critical technologies in the Indian context would certainly include space and atomic energy but there could be much more. Besides, even in the sectors of defence, space or atomic energy there are a number of items, which are not that critical in the sense that they would be available relatively easily from several sources. Many of the items would not involve numerous complex operations or be very costly; other items could be relatively easily stockpiled for future consumption. It is therefore, necessary to be selective in what we term as critical technologies.

1.5 Defence Supplies in India

Some facts and figures about the nature of the defence equipment and supplies in India need to be noted. The indigenous production is about 30% and there is a general feeling that this figure ought to be brought up to 70% in the long-term interest of our defence needs. In order to achieve this, we need to take several steps towards developing certain technological processes in our industries. However, most of these activities would not really qualify as critical technologies. The absence of certain processes in India so far has often been due to the same reasons as it is in the commercial sector: insufficient attention to absorb, adapt and upgrade imported know how and equipment. In the process, we have become stagnant technologically and industrially, and have missed out on indigenous improvements to imported systems. In most of these areas, it is possible for us to achieve self-reliance in
a relatively short period provided defence R&D, industries, the defence forces and other policy makers work together as a mission. This will not be a cakewalk, but with a concerted effort to build a few prototypes, modify them and subsequently go into production, we can meet our needs. We have experience in most of the industries of the sector. There is a tendency even in advanced countries to source out defence equipment and products from many assemblies and sub-assemblies drawn from the civilian sector making other similar products. Such an approach can also be adopted to speedily achieve the goal of self-reliance in at least 70 per cent of products and systems for the defence forces.

Even while this target is important, there are some critical areas in which India will not be given technologies easily by other countries, irrespective of whether or not India signs some of the existing unequal treaties. That is because they are critical technologies not only for defence, but also for several other purposes, as shown in table 1.1. Some examples would be sub micron level microelectronics or advanced transgenic biotechnology. The countries, which possess sub micron technologies, for example, can gain a top position globally. Advanced transgenic biotechnology can lead to global markets in agriculture, food products and medicines.

1.6 Dual-Use Technology

This discussion of strategic industries mainly concerns defence, space, atomic energy and also critical technology areas, which have the potential of multiple uses in the defence and civilian commercial sector in the future. Not those other areas do not have multiple uses. For example, canning or processing of food or preservation of food is equally applicable to the civilian sector, to the export sector or for supplies to the defence forces. But
since these are relatively well-stabilized technologies, which can be handled by inputs from several sources, including, often, imports in the first instance, we are not covering such dual-use items.

Newly emerging technologies such as robotics or artificial intelligence merit a closer look, these would have a crucial impact on future defence operations and also on many industrial sectors if they have are to be really competitive. As we look at the emerging manufacturing scenario, it will contain many elements of artificial intelligence and robotics in the medium-term future. If Indian products have to be competitive worldwide and if the aim is to earn substantially through value added products and services, India has to master these technologies. To import them fully from others will often not be cost-effective since the competing foreign companies would not like to part with their best technologies. Not even the better ones will be sold often enough. Thus, even if we do manage to purchase some technologies from them, they will be at a point of technological obsolescence where one has to struggle with very low profit margins, which is not good for any business.

Given the above broad considerations the technology areas critical for growth of strategic industries for India, are in the aviation and propulsion sector, high-end electronics, sensors, space communication and remote sensing, critical materials and processing, robotics and artificial intelligence. Before looking into some of these technologies, it is worth understanding something about the defence technologies and industries as they pertain to India.

1.7 1985: Defence Technology and Industry

In India, both the Defence Research & Development Organization and defence industries started experiencing certain restrictions on acquisition of
technology and products from the developed countries, particularly from 1985 onwards. At the same time, developed countries wanted to make India one of their main customers for arms and defence equipment. Obsolescent systems were offered for sale coupled with licensed production for a political price. Liberal credit and deferred payments were provided to propagate the business and make India perennially indebted.

The situation in India at that time can be described as follows. The industrial ambience had led to excellence in fabrication in limited areas. This means that after a design had been converted into fabrication drawings, Indian industry was in a position to convert it into a finished product. For low and medium level technology, these were established under licensed production. In defence production, the private sector played only a limited role. As far as the academic and R&D institutions were concerned, they were interested in working towards self-reliance and to break away from the licensed production syndrome. The DRDO itself was preoccupied with a large number of single discipline projects concentrating on self-reliance through import substitution and/or indigenisation. The end users often would like to see full systems.

1.8 1985-95: The Period Of Stand-Alone Sub-System Development

During the next ten years, that is, by 1995, certain industries graduated to design and development of sub-systems. This was due to the active partnership of the national science and technology agencies such as ISRO, DAE, DRDO and the industries. Many in the private sector who were hesitant to enter this field ten years earlier, started working with defence PSUs and other public sector companies to take up defence R&D tasks at the sub-system level. For example, private sector industries were in a position to develop phase shifters, displays tankage, communication systems, certain
types of electronic warfare systems, on-board computers, on-board transmitters, thermal batteries and even airframes. This marked a very important step for both the DRDO and Indian industry. Because of such interaction between R&D and industry, the enthusiasm and confidence of industrial establishments grew and enabled them to design sub-systems and to absorb the specified stringent processes of technology. Above all, it enhanced their willingness to take risks and go through the rigorous quality assurance and certification processes required for military systems.

1.9 1995-2005: Graduation To Systems Engineering

During the progress of large R&D projects, there were undoubtedly delays and cost overruns. But here it needs to be underlined that these projects needed support through the difficult phases of their development. In fact, R&D in India survived only because of the efforts of a few visionary scientists and leaders. But for them the nation would have been satisfied with making small items, surrendering to business interests that would use all means to convert India into a perpetual ‘buying nation’. Defence R&D is now taking the lead to reverse this trend through its self-reliance mission in defence systems. In DAE and ISRO too such an impulse for self-reliance is in the forefront.

The forecast is that by 2005, more industries would be in a position to take up stand-alone mode systems engineering and systems integration to the specified requirements of R&D organisations. Sub-systems like multi-mode radar, ‘KAVERI’ class aircraft engines, all composite carbon fibre composite wings, display systems, fly-by-wire systems for Light Combat Aircraft (LCA) and for futuristic aircraft, mission computers and air frames will be developed, engineered, produced and delivered for integration and checkout. Of course, this is the DRDO’s Vision. It is believed that the Indian industry
would respond given the national will on other fronts and that when the Indian industry becomes strong in systems engineering and systems integration as well as sub-systems development and fabrication, the Nation will have multiple options on choice of systems and industries to make them competitive and cost effective. In certain sub-systems or technologies India can even compete globally. There would also be a number of civilian commercial spin-off products and services, which can be marketed domestically and in foreign markets.

1.10 Growth of Technology Capability in DRDO

The DRDO was established in the 1960s. Its major task was to build science-based capability towards making improvements in the available imported systems and weaponry. In the '70s we saw development in ammunition and gun design, leading to production. In the '80s a tremendous thrust was given to major system programmes in design and development which lead to production of electronic warfare system, communication systems, missile systems, aircraft, main battle tanks and radars. These programmes gave a new impetus to multiple design and technology development centres resulting in the production of design capability for an integrated weapons system in the nineties. Now the vision for the DRDO is to promote the corporate strength of the organisation, and to make the nation independent of foreign technology in critical spheres. Technology innovation is expected to lead the DRDO and its industrial partners to global competitiveness in systems design and realisation. Let us look at the technological growth of a completed missile project, PRITHVI and an advanced developmental project, LCA under progress. The following observations are drawn from information made available during interaction with the DRDO scientists.
1.11 The Guided Missile Development Programme

In 1982, a detailed study was carried out for evolving advanced missile systems in order to counter the emerging threats to the security of India. Experts and members of the armed forces took part in this study and it resulted in the Integrated Guided Missile Development Programme comprising five projects. In July 1983, the government approved the programme, whereby a unique management structure was to be established, integrating the development, production, and the user services, with government machinery for expeditious implementation.

The Guided Missile Development Programme envisaged the design and development of our missile systems, PRITHVI, TRISHUL, AKASH and NAG, leading to their production. It also established the re-entry technology capability through AGNI (Fig 1.1 – 1.5 at the end of the chapter). The re-entry technology demonstration was completed by 1992, through flight tests of AGNI. PRITHVI was the first of the four operational missile systems to be inducted into the armed forces.

The technological goal of the programme is to ensure that the systems will be contemporary at the time of their induction into the armed forces. The systems have been designed to be multi-purpose, multi-user and multi-role in nature. The programme has adopted the philosophy of concurrent development and production to reduce the time-cycle from development to induction.

1.12 Brief Description of the PRITHVI System

PRITHVI is an all-weather, mobile and surface-to-surface guided missile, which can engage targets quickly and accurately over a range of 40-250 km. The weapon system is designed to engage targets beyond the range
of field guns and unguided rockets. The system is highly mobile with a minimum reaction time and has a capability of being deployed at short notice at desired locations. Its mobility also provides fire and scoot capability.

The PRITHVI missile is a single stage system and uses two liquid propulsion engines of three-ton thrust capability each. The guidance system of PRITHVI is based on a strap down inertial navigation system long with an on-board computer, which offers integrated solutions to navigation, control and guidance requirements.

Its flight control system allows the missile to follow the desired trajectory, by controlling the vehicle in three mutually perpendicular planes viz. pitch, yaw and control. The electrohydraulic actuation system is used to control the positioning error. The errors induced due to weather conditions such as wind, shear and gust can be corrected by the guidance and control systems of the missile. It is also possible to manoeuvre the missile in the final phase. The ground support system is equipped with special vehicles to carry out the mission, command and control, maintenance, logistic support and survey. The modular design and built in check-out and calibration facilities help in equipping the missile in the deployment area with the desired warhead and for carrying out a quick check of the missile's operational readiness.

1.13 The Effectiveness of PRITHVI

A manoeuvrable trajectory, its high mobility, low reaction time, its self-contained and self-supporting features and low footprint area make the PRITHVI missile system difficult to counter. Besides, the high accuracy of its system, its high warhead capabilities and absence of vulnerability to counter-measures, including Electronic Counter Measures (ECM), make the PRITHVI missile system potentially dangerous for the enemy. Possession
and deployment of a large number of PRITHVI missiles can act as a deterrent and prevent a missile attack from our adversaries.

In case of war, the powerful explosive and high accuracy of the PRITHVI missile has enormous potential to bring life to a standstill in cities and urban areas, to affect the morale of the enemy. Also, a sizeable portion of the enemy air force would be engaged in neutralizing the mobile missile launchers. The experience of Allied air forces in the recent Gulf war against mobile Sod sites supports this.

1.14 PRITHVI as a Cost-Effective Weapon

Usually, Vital Areas (VAs) and Vital Points (VPs) which are of high tactical and strategic importance have a high level of air defence protection. Much of this air cover is multi-layered, with some overlapping redundancy and is networked through computer communication links for ensuring effective command and control.

The deep penetration capability of the PRITHVI missile, up to 250 km range, will enhance the firepower of the air force against heavily defended targets in adverse weather conditions. In addition, the night attack capability of this missile will be useful for attacking targets like factories, petroleum dumps, marshalling yards and other static installations.

The accuracy of the system at 250 km will be further improved upon in Phase II, when terminal homing guidance or anti-radiation systems will be integrated into the PRITHVI system. A scheme for retrofit is being contemplated and designed. This capability will be an asset in attacking hard targets like armoured concentrations in their parking sites.
1.15 The Development and Production Experience of PRITHVI

India had certain strengths in design, materials and engineering when the project was initiated in 1983. However, the development of PRITHVI required aerospace quality materials like magnesium alloys for wings and certain special aluminium alloys for airframe and tankages, and navigational sensors of certain accuracy, all of which were not available within the country. The Missile Technology Control Regime, though not formally declared, was in effect in some form or the other. All these drove us to deliberately adopt an indigenous route right from the beginning. A number of critical technologies, materials and processes were developed by harnessing the available talents within the country and using innovative management methods. The development of the PRITHVI Inertial Navigation System is an example of this. Though we were able to get only the coarse class of sensors for the inertial navigation, our scientists came up with innovations to enhance their accuracy using software. The use of simulation in the design phase, and the hardware in loop simulation to fly the missile on ground, as well as the association of users at every stage, greatly helped in improving the effectiveness of the missile and reduced the number of user trials.

Throughout, the project was driven by goals of excellence in performance and of meeting schedules. Concurrency was built into every activity of the programme to reduce the time from development to induction. Aside from strengthening the country to face the threats from across the borders, PRITHVI has demonstrated that India can develop world-class high technology systems and devices by using its own indigenous strength, and thereby defeating the control regimes. An important benefit of the PRITHVI programme is the new breed of technologies and leaders, who can make our country stronger and self-reliant.
1.16 Objectives of the Study

The study is designed to analyse the organisation structure, methods, management guidelines, personnel management, motivation and methods for Technology Management and Transfer of Technology in Indian environment used by Bharat Ratna Dr. APJ Abdul Kalam in IGMDP. The specific objectives are: -

(i) To identify the major parameters resulting in successful technology selection, development of technology, production of a weapon system and efficient and quick assimilation of the technology leading to large scale production.

(ii) To establish the correlation between a effective team of research workers - interpersonal relationships and overall organisational effectiveness.

(iii) To establish the correlation between financial autonomy / decision-making processes to successful R&D organisation.

(iv) To evaluate the impact of charismatic leadership on good interpersonal relationship and effective team building.

(v) To study how team members react to accepting failure as part of the development process and its relationship with morale of the team.

1.17 Scope of the Work

(i) The IGMDP organisation structure and management functions are studied in detail bringing out the strengths and weaknesses. The methodology of choosing technologies for research adopted and assessment of risk factors are also analysed.

(ii) In the past, Acquisition of Technology route has been adopted in Military Weapons especially from erstwhile USSR. The experiences have not been very happy ones. Few cases of Acquisition of
Technology, its problems and lessons learnt are brought out. How much it helped in development of state of art technology and concurrent engineering has also been studied. An attempt is made to evolve a management structure for assimilation of indigenous developed technology.

(iii) It is well known that no developed country gives modern state of art technology for money or friendship. The Research & Development efforts on creating state of art technologies and putting it together to provide a viable and affordable weapon system in numbers is the success. Various successful and unsuccessful attempts have been studied, analysed and lessons drawn out. This has helped in outlining the management principles in selection of technologies. The productivity, rapid product introduction, reliability and high values factors are also studied to determine the management principles.

(iv) New organisational and finance control structures were adopted during the project phase of IGMDP and for the first time concurrent engineering concept was tried in DRDO. A study tries to determine its efficacy and how these structures could be adopted in R&D environment in other organisations. The aim is to consolidate the benefit of these structures broadly known as “Kalam Management Style” and structure them for R&D Management.

(v) In a short span of time, lot of innovations in IGMDP have been achieved with the consortium approach i.e. Industries, Universities and Laboratories working together. An effort is made to identify what were the motivating factors, generation of team spirit and methodology that no factors like personnel egos, recognitions, benefits etc. could come in the way of success? Kalam’s greatest asset was “making teams that deliver”. An in depth study is carried out research will be
carried out in man management, organisational behaviour and financial control under Dr. Kalam leadership.

(vi) Technology Transfer to public sector is difficult because public sector is rarely organised to participate in the technology transfer process. Successful Transfer of Technology of PRITHVI to Bharat Dynamics Limited (BDL) in the shortest possible time is the key success of the Technology Transfer Management Style adopted by Dr. Kalam. A research is undertaken to determine the factors that made it so easy and successful. The detailed study in the following areas has also been made: -

(a) Technology Transfer Process, cultures and its integration to ToT process.
(b) Communication and leadership aspects of success of ToT
(c) Equivocality and managerial skill.
(d) Motivation including charismatic leadership.
(e) Problems faced by IGMDP and Dr. Kalam’s unique solution.

1.18 **Methodology:** -

The study involves:

(i) Analysis of primary data relating to IGMDP.
(ii) Evaluation of various technology Management & Transfer Projects using Likert scale.

The methodology adopted for the study is briefly summarised below.

(i) The presentation on the general principles of ToT has been made on the basis of vast data and reference material available on ToT in general and ToT in India in particular.
(ii) The process of ToT in Indian Weapon System is studied and presented by going through the documentation of the scientific laboratories and
IGMDP in particular. The researcher personally attended several meetings, conferences, group activities of scientists in organisations under study. He made it a point to discuss with them various points relevant to ToT and the project in their hand. These included selection and development of technology, production of weapon system organisational effectiveness, teamwork, decision-making process, autonomy reaction to failure and morale. The researcher was specially permitted to be present for several meetings of scientists, research laboratory people, academicians and users. Observation method was used to gather the data relating to ToT process and problems. It was also helpful in cross checking the documented data with views and experiences of scientists and is covered in Chapter 6 to Chapter 8.

(iii) Data was gathered through a survey of scientists belonging to DRDO laboratories and Directorates. A questionnaire of issues relevant to ToT and projects of IGMDP were covered. The respondents were asked to indicate their options on the five point Likert scale. The data has been analysed quantitatively and conclusions are drawn. The methodology and analysis are presented in details in Chapter No. 8.

(iv) One main objectives of research was to study the leadership style of Dr. APJ Abdul Kalam. The published work of Dr. Kalam, his articles, speeches, and addresses to various gatherings has been studied by the researcher. The most important fact is that the researcher had the opportunity to attend some important meetings of Dr. Kalam relating to weapon-projects. The persons engaged in these projects right from a class IV servants to senior scientists and advisors were vocal on their observations and feelings regarding Dr. Kalam's way of work. All this has been presented in Chapter 9 to bring out the unique leadership of Dr. Kalam.
(v) The case study of PRITHVI is based on a detailed study of the documents and published material relating to the project and also discussions with scientists directly working on the project.

(vi) The observations, findings and conclusions are a part of each Chapter and are included in the paragraphs on the issues relating to ToT and the weapon-project. However the conclusions showing the relationship between ensuring smooth ToT through participation of all concerned with selection, production and use of technology and the leaders role in this process are given in the last Chapter.

1.19 Sources of Data and the Type of Research

Following sources have been used to collect the data: -

(i) **Primary sources** - Data is collected through a questionnaire given to scientists in research laboratories of DRDO and from Directorates. Observations method is also used to collect data relating to team spirit, reactions to failure, development of a sense of belongingness and Dr. Kalam's style of work. The circulars, minutes, notes circulated to scientists regarding the nature of work, responsibilities have also been an important source of primary data.

(ii) **Secondary data** - Extensive material was available on ToT in various developed and developing countries. Published data through books, articles, reports, directives, official notifications has also been used to present ToT process and issues related with it. The research is exploratory as well as analytical. The primary data collected from the survey analytically presents the ToT process and the environment suited for it. While on Dr. Kalam's leadership, the researcher had to explore through Dr. Kalam's writing, speeches, interactions with people and the way people in the project react to his style.
1.20 HYPOTHESIS OF THE STUDY

On the basis of the objectives of study and the conceptual framework of “Technology Management and Transfer of Technology in Indian Environment” and after reviewing the related studies the following hypotheses have been formulated:

1.20.1 Hypothesis One: The National Laboratories that had been developed had not become significant source of industrial technologies. India’s progress in this regard is slow. The leap frogging in development is the Mantra for India.

1.20.2 Hypothesis Two: Technology Transfer Impediment can be overcome by empowerment of Indigenous Technology and fight Finance and Technology Nexus. Approach globalization with low cost quality products.

1.20.3 Hypothesis Three: Economy of sale is an important feature of industry operations, particularly with capital-intensive manufacture. Finance risk reduction needs to be taken priority for technology growth.

1.20.4 Hypothesis Four: Major causes of DRDO major project having cost and time overrun are technology immaturity, lack of Producibility and user’s commitment to the product. This must be addressed at PRIORITY at Research level and also at policy commitment.

1.20.5 Hypothesis Five: IGMDP - success model consists of co-current engineering and networking of the teams.
1.20.6 **Hypothesis Six**: The success of ToT process depends on both a powerful champion and sponsor. A committed selfless leader with organization support and flexible style are vital for success.

1.20.7 **Hypothesis Seven**: Creation of positive environment for growth is the key to get a team of scientists to put heart and soul into a mission. IGMDP created the positive environment.

1.20.8 **Hypothesis Eight**: Clear communication like “Call a Spade a Spade” and clear aim is the key to success.

1.20.9 **Hypothesis Nine**: Challenges of “Mission impossible” could be met due to Dr. Kalam’s charismatic leadership in High Technology. TM & TOT model evolved during PRITHVI project of the IGMDP can serve an effective model for all other complex system of TM & ToT programme.

1.21 **Chapter Scheme**

A detailed study has been carried out to examine and analyse various methods of Technology Management and Transfer used by IGDM leader Dr. APJ Abdul Kalam and his team of Project Directors and Technology Director. The work has been divided into ten chapters as under:

**Chapter two** traces the history of the Technology Management and Technology Transfer in the world. It addresses the issues like technology gap between developed countries and developing countries, anatomy of technology transfer. It also outlines the restricted regime being used by developed countries as power projection and economic domination.
An overview of Technology Transfer & Technology Management is undertaken in chapter three. The theory of knowledge-based economy is the theme of this chapter. Present models of Technology Transfer & Management i.e. diffusion model, solver model and semi-active model has been discussed.

**Chapter four** discusses the Organisational climate and its importance to Technology Management & Transfer. Requisites for success, R&D Team, Team management, leadership, motivation, Technology and Economy are the few important parameters that influence the technology transfer have been reviewed.

**Chapter five** describes Technology Transfer in complex system. The Challenge of programme management is to find the practical middle ground between producing under developed systems and extended development.

"Technology Transfer – A DRDO perspective" – the study is based on the teams appointed by SA to RM to recommend the measures to improve the ToT process in DRDO and is discussed in **chapter six**. Lessons learned and salient point of each project has been outlined. Recommendations also have been made in the chapter to improve the system.

**Chapter seven** covers the most important of IGMDP methods i.e. concurrent engineering. It covers assessment and development of technologies, 3D development, networking of teams, review processes, production interface, real time technology transfer, test and evaluation, development to fabrication agencies, producibility of design, user participation and mass scale production.
Chapter eight gives the brief of the survey on Transfer of Technology covering different aspects related to its successful implementation. The survey is based on questionnaire of twenty questions on ToT to 128 scientists from twelve laboratories and directorates. The responses are analysed using the Summative or Likert scale for measurement of attitude and a summative evaluation was conducted. The results have been analysed in detail and is presented in the chapter.

Chapter nine analyses Dr Kalam’s leadership and his views on various factors of Technology Management and Transfer. It also outlines the leadership traits of Dr. Kalam such as humility, team building, personal responsibility and integrity, decisiveness, initiative and selflessness.

Chapter ten outlines the total Technology Management and Transfer structure in terms of organisation charts and methods. These methodologies can be followed by any organisation dealing with the complex system for ToT and TM.

Conclusions drawn in chapter eleven are the summary of the work in form of results and structure and highlights the lessons learned in point form.