DEFENCE RESEARCH & DEVELOPMENT ORGANISATION (1958-1982)
RAMADAS P SHENOY
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1958–1982
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Ramadas P Shenoy

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FOREWORD

The history of an organisation is a coherent synthesis of thoughts, of persons and their activities over a long period in that organisation and the resulting growth of the organisation and of achievement of goals and milestones over a period of time. The project on History of DRDO was a long-cherished dream. The work was initiated by Dr APJ Abdul Kalam in 1994 and the project was assigned to Shri NS Venkatesan, Shri A Nagaratnam and Dr RP Shenoy because of their long association with DRDO.

As the growth of the organisation has multiple dimensions — its infrastructure, achievements, manpower etc., the authors have been able to weave a story of DRDO’s history in a lucid and highly readable book considering its multi-dimensionality. It is no mean task and finally it was left to Dr RP Shenoy to meet this challenge.

The defence research in India started from pre-independence era under British rule with supply of simple military stores to armed forces. Dr Shenoy has traced the growth of the DRDO from this period and described the major events and path taken by the organisation till 1982.

The book provides in-depth picture of the growth of DRDO in four chapters and an epilogue with specific reference to major contributions of five Scientific Advisers – Dr DS Kothari, Dr S Bhagavantam, Dr BD Nag Chaudhuri, Prof MGK Menon, Dr Raja Ramanna and further momentum imparted to the organisation by Dr Arunachalam, Dr APJ Kalam, to make DRDO one of the finest models of R&D organisation, not only in the country, but in the world as a whole.

The organisation has many laboratories catering to various disciplines of defence interest and author has traced the origin, development and achievements of some major laboratories of this era in the fourth Chapter. I hope, scientists and other readers will find this history of DRDO for the period, 1958–1982, quite interesting and useful.

27 August 2004
Delhi – 110 054

Dr VK Aatre
PREFACE

The monograph is about the Defence Research and Development Organisation (DRDO) of the Ministry of Defence, Government of India. It has been long in the coming. It was in 1994 that Dr APJ Abdul Kalam who was the Scientific Adviser to Raksha Mantri mooted the idea of writing the History of DRDO to three of us, Mr NS Venkatesan, Dr Ramadas P Shenoy and Dr A Nagaratnam. All of us had retired from DRDO after long service in the Organisation. Mr Venkatesan and Dr Nagaratnam had been with the Organisation from the Defence Science Organisation days while I had joined the DRDO soon after it was formed. We had worked with six Scientific Advisers beginning from Dr DS Kothari and ending with Dr VS Arunachalam. We had seen and experienced the changes that took place, the progress that was made, the problems that were faced and the achievements that were reached. Each of us agreed to write about the activities in specific science and technology areas in which we had either worked or had more than a passing knowledge.

To write about such a vast organisation, assistance was provided by the DESIDOC. Dr SS Murthy who was Director of DESIDOC at that time took upon the responsibility of collecting historic data from archives and from their own records. In addition, he organized several face-to-face meetings with top bureaucrats, eminent scientists and high ranking military officers who had retired but who had either served the Organisation earlier or who had close interaction with DRDO when they were in service. The DRDO Laboratories and the respective Directors, the Directors at DRDO Head Quarters and their personnel in most cases cooperated by providing detailed account of activities and helped in filling up the information gaps. Many senior personnel within the organization were also of help in providing their own perspectives on some of the major events that took place in this period. Thanks are due to all these eminent and senior personalities who took time to provide information and insight.

As things turned out, both Mr NS Venkatesan and Dr A Nagaratnam sent me their manuscripts but I found it difficult to draw a cogent picture of the progress across technologies or disciplines during the tenure of each Scientific Adviser. I started all over again, visiting major laboratories,
requesting heads of these laboratories to furnish dates and further details and slowly collected information and assembled data. I began the process of correlation with available records and specific narrations of events by the personalities to whom we had talked earlier. It was a long and arduous road relating the flow of events during the stewardship of each Scientific Adviser in the first twenty five years of the DRDO.

The book describes the events up to 1982 in four chapters: The first deals with the scenario that existed before independence under British rule and circumstances which introduced rudimentary military science for replacing stores locally. The post independence scenario deals with reports of OH Wansborough Jones and PMS Blackett on likely requirements of Indian Defence and identification of probable areas of research. The appointment of Dr DS Kothari who was Professor of Physics at the University of Delhi, as the Scientific Adviser and the setting up of the Defence Science Organisation are then brought out. The areas of research activities included operations research, physiology, applied psychology, electronics, food and nutrition, applied chemistry. The Chapter ends up with the contributions made by the organization to defence in its advisory role.

The second Chapter gives a picture of the process of transforming the Defence Science Organisation to Defence Research and Development Organisation for undertaking research and development in hardware, software and processes to meet the needs of the Services. The Chapter goes into detail the stewardship of Dr S Bhagavantam who, as Scientific Adviser over a period of about eight years built a cohesive organization while at the same time expanding the scope of its activities to cover all essential science and technology areas of application to the Services. The guidance and direction provided by him and the difficulties faced in operating within the government framework are also brought out. The Chapter ends up with the efforts and contribution of DRDO to meet the short term needs of the Services.

The third Chapter provides an insight to changes that took place in the next twelve years with three eminent physicists of the country assuming charge as Scientific Advisers for a period of about four years each. The contributions of Dr B D Nagchaudhuri, Professor MGK Menon and Dr Raja Ramanna to the growth and to the betterment of DRDO are presented in this Chapter.

The fourth Chapter highlights the growth of the major laboratories in the Organisation during the twenty five years of the existence of the DRDO. The charter, initial state and status of the major laboratories, the
difficulties faced during the learning period, the building up of the infrastructure, the challenges to be overcome in stepping up of the tasks from short term response to new system development and the achievements up to 1982 are presented in a consolidated manner. A short Epilogue has been added to bring out the contributions made by the DRDO in the areas of missile, aircraft, tank and electronics systems to the nation since 1982 under the helmanship of Dr VS Arunachalam, Dr APJ Abdul Kalam and Dr V K Aatre.

Before I conclude, it would be remiss in my part if I do not acknowledge the contributions of personalities who provided encouragement, assistance and made my task easier. First and foremost is Dr APJ Abdul Kalam who had the vision that the efforts of the early pioneers of DRDO needs to be recorded for posterity and then requested three of us to undertake the onerous task. I owe a debt of gratitude to Mr N S Venkatesan who alas is no more, and to Dr A Nagaratnam for the manuscripts they had provided and started me on this journey. Dr VK Aatre who had assumed charge as Scientific Adviser in 1999, took active interest in this project and but for his urging and constant encouragement, I would not have completed the first twenty-five years of the history of progress of the Organisation. I would like to thank him for it. I also record my appreciation of Shri VP Sandlas, former CC R&D (S) who as a Chairman of DRDO Monographs Committee, monitored this activity. Dr SS Murthy who was Director, DESIDOC in 1994 provided valuable assistance to get the project going and thanks are due to him from all the three of us. Dr Mohinder Singh, Director, DESIDOC is another person I would like to extend my thanks, because he would frequently telephone me from Delhi and visit me in Bangalore, and quite often, acceded to my request for more information about specific events of the past. In the final stretch of my effort to complete the writing and assemble it in a book form, I received considerable help from LRDE, Bangalore. I would like to thank Mr KU Limaye, Director, LRDE for the helping hand he and his people extended.

Bangalore                                     Ramadas P Shenoy
16th June 2004
THE BEGINNINGS – DEFENCE SCIENCE
CHAPTER 1

THE BEGINNINGS – DEFENCE SCIENCE

1.1 INTRODUCTION

Historically, nations had fought their wars with weapons developed before the outbreak of the conflict and produced these in large numbers with the onset of hostilities. Because of a lack of organised approach, the time normally taken to realise a weapon from concept through stages of research, development, testing, production in large numbers, training of the soldiers to use the weapon, and formulation of the tactics by the commanders, was far too long. No radical innovation, leading to the development and production of weapon systems, was therefore attempted during earlier wars and scientists and technologists were never taken into the military other than as combatants. The first break from this tradition came about in the World War I by the introduction of poison gas by the Germans and the tank by the Britishers. These were developed after the hostilities had commenced and were aimed at breaking the stalemate of the trench warfare. However, it was during the World War II that the break from the earlier tradition was final by the formation of essentially a civilian organisation which innovated for the military during the war period and provided the Allied Forces led by the USA, new weapon systems such as, the microwave radar, proximity fuse, and atomic bomb, to name a few, which tilted the balance against the Axis Forces led by the Nazis. In the immediate aftermath of the war, geopolitical considerations led to the Cold War which polarized the developed world into two main blocks holding distinct ideologies, with the USA being the leader of the Western Block and the USSR the leader of the other. The advice of Dr Vannevar Bush, that, “It is essential that the civilian scientists continue in peacetime some portion of these contributions to national security which

they have made so effectively during war”, was accepted and the close association of the scientists with the military continued in the USA\(^2\). In the decades after the cessation of the war, the US Department of Defense became instrumental in the development of electronics, aerospace engineering and other technologies, and sciences related to military operations. Integrated circuits, real-time applications of computers, software, supersonic aircraft and space technology, came into being and were progressed at a rapid pace that normally would not have been possible in the commercial competitive environment of that time.

1.2 S & T ACTIVITIES RELATED TO DEFENCE BEFORE INDEPENDENCE

1.2.1 Conditions Before World War II

The major military and economic power on the side of the Allies in the beginning of the World War II was Britain, which had an empire including India, to defend against the Germans and the Japanese. Even though in the period between the two wars, the admirals and the generals in Whitehall had shown little interest in science and technology, the threat of a major war, under which the country had lived for some years, had turned the thoughts of many of its talented scientists – even as early as 1934 – to problems of national defence before the hostilities had begun. The success of a scientific solution to the menace of the German magnetic mines to the Allied shipping was instrumental in bringing science and scientists of Britain fully into the war from its very early days. As the war waged, the British scientists from the universities were asked to participate in the problems concerning military requirements.

On the other hand, the policy followed by the British in India towards scientific and technical education, scientific and industrial research and development was in keeping with their role as colonial rulers. Even though India had a long and rich history of distinct indigenous techno-scientific traditions, the colonial policy did not encourage generation of technical knowledge or ensure its integration into the knowledge base existing in the country. Colonial, commercial and Government imperatives set the parameters for the transfer and absorption of new technologies by the local population. For example, the colonial

\(^2\) Head, Office of Scientific Research Development, USA, during World War II, which was largely a civilian science organisation.

Government had set up, by the turn of the last century, a dozen scientific institutions such as the Geological Survey of India but the work done by these organisations were specifically aimed to serve the commercial interests of the British. During World War I, when the lack of industrial development in the country and the uncertainty of imports affected the supply of manufactured goods, the colonial Government responded by setting up an Indian Industrial Commission (IIC). The IIC in its report suggested that manufacturing activities would have to be preceded by adequate scientific and technical services which were deficient in the country. In spite of limitations imposed by the colonial rule, local efforts and achievements in education had resulted in the country having a scientific and technical workforce by the time World War I had been declared in Europe. In the beginning of the 1930’s, even after repeated demands by the provincial Governments, scientists such as the Nobel Laureate Sir CV Raman, Dr JC Bose and some prominent British scientific workers, the colonial Government in India resisted pressure to set up a central body for scientific and industrial research similar to the Department of Scientific and Industrial Research (DSIR) set up in Britain after World War I. Later, even after the Governor General of India was advised by the British Government to set up an organisation similar to the DSIR in UK, it was not accepted on financial grounds. Instead, the Bureau of Scientific and Industrial Research (BSIR) was set up under Mr A Ramaswamy Mudaliar, Commerce Member of the Governor General’s Executive Council with Dr Shanti Swarup Bhatnagar as the scientist-in-charge. The scope of BSIR was limited to war-related research in collaboration with academic laboratories. For example, the Indian Institute of Science in Bangalore, was involved in training a considerable number of technicians in testing and calibration of electrical and radio instruments, in the repair of mechanical appliances for the Royal Air Force, and in the production of chemicals and gases for the fighting services. Even with meagre budget of Rs 500,000, BSIR by 1941 was able to work out a number of processes at the laboratory level for utilization by industry and thus established the case for greater funding by the Government. Mainly through the efforts of Mr Mudaliar and Dr Bhatnagar, in 1942 the Council of Scientific and Industrial Research (CSIR) was formed as an autonomous body with a research grant of one million rupees. However, throughout the war period, the application of the colonial policy in the domain of scientific research and cooperation excluded Indian scientists and scientific and industrial organisation from receiving valuable scientific inputs in such fields as nuclear energy, guided missiles, chemical and metallurgy of processes, new materials, and so on, while their
counterpart in Canada, Australia and New Zealand were given access to the data. Given this policy of exclusion from major war related information and efforts in scientific and industrial areas and a small budget, CSIR could play only a marginal role of substitution of products which were in short supply 4-6.

The colonial policy was enforced even more rigorously as far as defence planning for India was concerned. It was made an integral part of Britain’s own policy and strategy for the defence of the British Empire and was formulated in UK. To prevent a possible repetition of the 1857 Sepoy Mutiny, the British Government had made sure till World War I that the officers of the Indian Army were exclusively British. The Indian armed forces were predominantly the ground forces, namely the Army with the Royal Navy providing the backup on sea. As a sop to the increasing criticism by the nationalist elements, the British Government after the World War I created an Indian Navy and an Indian Air Force but these were only token forces. Even after political reforms were introduced in India in the form of legislative assemblies for the governance of the provinces with elected representatives, the subject of defence was kept out of the purview of Indian legislators. The position just before the outbreak of the World War II was, that the responsibility for civil Government and defence of the country vested with the Governor-General, subject to direction and control by the British Cabinet in London through the Secretary of State for India. The Commander-in-Chief was appointed by the Royal Warrant. He was the Supreme Commander of the Defence Forces in India and was the administrative and executive head. He was directly responsible to the Crown for the structure and strength of the Armed Forces, the recruitment and training of military personnel, the acquisition, usage and maintenance of military hardware, war preparation, and the conduct of war. In the order of precedence, he was next to the Governor General. The Armed Forces in India were thus an extension of the British War Office. The Commander-in-Chief was assisted in his executive responsibilities by four Principal Staff officers, namely the Chief of General Staff, the Adjutant General, the Quarter

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4 S Visvanathan, Organising for Science In The Making of an Industrial Research Laboratory. Chapter 4, Oxford University Press, Delhi, 1985.


Master General, and the Master General of Ordnance (MGO). Under the MGO, ordnance factories had been established in India for the manufacture of arms, ammunition and connected stores, clothing, harness and saddlery. These factories functioned as subsidiaries to the Royal ordnance factories in UK, as a result of which the production was limited to small arms and ammunition only. The first cell for inspection of the products of the Ammunition Factory at Khadkee was set up in 1869 and its scope was enhanced later to include modifications. It was also vested with the powers of the authority holding sealed particulars relating to production of the ammunition. With increase in activities, the cell became the Inspectorate of Armaments. For the purchase and development of general stores, the Inspectorate of Stores Services was formed and attached in 1929 to the Harness and Saddlery factory in Kanpur. A small cell was set up in Rawalpindi (now in Pakistan) in 1939 to include the inspection of telecommunication equipment and the scientific instruments for the army in India. It was called the Inspectorate of Scientific Stores.

1.2.2 Developments during World War II

With the outbreak of the World War II, large-scale recruitment campaign was launched to expand the strength the Indian Army. The size of the Indian Armed Forces expanded more than ten times and reached two million by 1943. Correspondingly, the ratio of the Indian officers rose from 10 per cent in 1938 to 35 per cent in 1944. The Defence Department of the Indian Government, which was a relatively small department before the war, had greatly expanded necessitating the formation of a War Department under the Commander-in-Chief for all important issues concerning the army and the war. A second department came into existence to look after relatively unimportant subjects such as military lands, printing, army list, prisoners of war, and so on. When war started, difficulties were experienced by the military in UK to sustain the increased equipment requirements of the eastern theatre of war. The Government of India was forced to put together facilities and resources for investigation and limited technical development of equipment for the armed forces. The existing inspectorates under the Directorate of Armaments were expanded and


utilized for conducting limited experiments in munitions and small arms so that reference to UK could be minimised. For clothing and general stores, the Controllerate-General of Inspection was established with the dual functions of inspection, and research and development. For vehicles, the Chief Inspectorate of Mechanization under the Director of Mechanization, carried out not only inspection but also technical trials. The small electronics cell was moved to Kolkata, where it became the main centre for supply of war stores for the fighting services.

The War Department was subsequently put under the South East Asia Command (SEAC) in 1943 and the Commander-in-Chief in India was entrusted primarily with the tasks of taking effective steps to prepare India as the base of operations for SEAC and for training of the troops. In addition to the War Department, a new supply department was created and an Indian member of the Governor-General’s Executive Council was made responsible for the mobilization of the country’s production potential for the war. Correspondingly, the role of the inspectorate was expanded to take up activities of indigenising the production of accessories and attachments to the main equipment, and to a limited extent, the modification of some of the equipment to stand the conditions of heat, humidity and dust10.

As the war was drawing to a close, the Government in Britain turned its attention to the postwar planning and reconstruction of the home country, the dominions and the rest of its empire in the colonial framework. It was in this context that the British Government requested the Royal Society through a communication from the Secretary of State for India to depute Professor AV Hill, who held a research fellowship of the Royal Society, to “see as much as possible of India’s scientific, technical and research work” and advise the Government on the organisation of scientific and industrial research as a part of the reconstruction plan for India in the postwar scenario and in coordination with similar activities in Britain. Professor Hill visited India between November 1943 and April 1944, and submitted his report entitled Scientific Research in India11. He identified a variety of problems confronting scientific research in India. Even though Indians had made notable contributions in physics, mathematics, and chemistry, he found that at the university level, areas such as geological sciences and biological sciences were weak in terms of teaching and research, biophysics was practically unknown except at the


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Bose Institute in Calcutta (now Kolkata), and biochemistry though strong in some universities, was not associated with physiology and biology but with chemistry. He also observed that scientific research was being conducted under a variety of disparate institutions which had prevented a balanced approach and a common policy for research. In spite of the enormous amount of clinical material available, practically no research was being carried out in clinical sciences by medical colleges. He went on further to state that none of the colleges and the departments of engineering and technology could be counted as centres of excellence. Further, he remarked that industries dealing with scientific and surgical instruments had not been established in the country. He also noted the widespread lack of interest in research on the part of the industry in India except for a few benefactors, in particular the House of Tatas who had made substantial contributions to science, medicine, and technology and who had set up a major industrial laboratory in Jamshedpur for metallurgy.

Professor Hill strongly advocated that research should bring about national development and suggested that an amount equivalent to one per cent of the national income should be spent on scientific research. He recommended a central organisation for scientific research under the Member of Viceroy’s Executive Council, responsible for planning and development. The central organisation for scientific research would comprise six separate boards, one each for medical research, agricultural research, engineering research, industrial research, war research and survey, and natural resources. Each of these boards would be functioning under the direction of a distinguished scientist in the concerned area, who not only was the principal officer of his board but he was also a member of the other five boards. The function of the Directors of the separate boards was to organise and initiate research in their respective areas on a nationwide basis and they also had a number of advisory committees that would assist them in various aspects of their work and in the allocation of grants for research activities. A joint estimates committee under the Member Planning would coordinate these estimates. Once the estimates were approved, the boards had autonomy in conducting their business. The Member Planning would be advised by a scientific consultative committee having six directors of the boards and six other eminent scientists, one from each of the areas as members. The follow up of scientific research into development was left to a development consultative committee consisting of representatives of industry and the professions. While this arrangement provided a communication channel between industry and science, the
utility of the scientific research or the sponsoring of scientific research activities arising out of the needs of the industry were largely left to the initiative of the users.

Professor Hill’s report also contained his observations with respect to the organisation of research activities undertaken for the armed forces in India. Commenting on the war research activities carried out in India, he stated that the scientific/technical organisation under the MGO was being mainly devoted to inspection, and was fully extended owing to the enormous increase of war production in India. He went on further to state:

“it was not designed for the contingency of India being the base for major military, naval, and air operations. The plan for improvements in the arrangement for research in connection with the Services should be done not only for purposes of present war, but in view of the future necessity of an Indian Government taking responsibility for the military, naval and air defence of India for the design and manufacture of her own war material and for devising the technical methods of her defence. The scientific knowledge and experience required for modern war cannot be improvised quickly, nor can it be purchased from others. A proper scientific organisation must be built up within the War Department itself.”

He highlighted the sense of intellectual isolation of scientists in India in his statement, “India and Indian scientists were not clear about what is being done, or has been done in war research in UK, USA, and the Dominions. There is a corresponding lack of knowledge in UK of the scientific resources of India, in men, equipment, and facilities, and of the scientific aspects of war requirements for operations for which India is or will be the base.” He attributed that this ignorance was due to lack of personal contacts between the scientists of the two countries and to the absence of an organisation in UK that could provide Indian scientists the particulars of war research undertaken in UK. Professor Hill concurred with proposal of the MGO for the creation of a new post of Scientific Adviser to the Commander-in-Chief to coordinate all scientific activities under GHQ in India, including extramural work. The Scientific Adviser (SA) would also assist the Operations Research Organisation under the SEAC (South East Asia Command). He would have a board (War Research Board) consisting of scientists, engineers, both officials and non-officials, belonging to various disciplines along with representatives from the Services. The work of scrutiny, selection, and monitoring of projects would be carried out by adequate number of committees under the chairmanship of different members of the Board. The whole organisation of the SA to C-in-C would be similar but on a smaller scale, to that of the Advisory Council
The Beginnings – Defence Science

(for Scientific Research and Technical Development) in the Ministry of Supply in UK. To ensure greater coordination between the civil and military requirements of scientific research, the War Research Board was made a part of the proposed Central Research Organisation. In particular, he pointed out that the specific human problems of health fitness and adaptation, both physical and mental, in fighting personnel in relation to their activities such as flying, diving, jungle warfare, and prolonged work in environment such as in armoured vehicles, airborne and sea/submarine-based environments, would be of considerable value in civil life and industry. In his opinion, in the event India is given the autonomy to organise its own defence within the framework of the British Empire, with War Minister of cabinet rank, then the SA would be a member of the War Council on the same level as the Service members of the War Council. He averred that such a step would ensure that India in future would not make the mistake of underrating the importance of scientific research and technical development in modern war.

In making his recommendations, Professor Hill drew upon the British experience of the organisation of research. While he might not have been unaware of the important differences between the two countries, he was silent about the validity of the British model to the Indian situation. The Hill Report and the Report of the Industrial Research Planning Committee of the CSIR (headed by Mr Shanmukham Chetty) contributed to the pattern of organising scientific research in India in the civilian sector. It appears that Professor Hill’s recommendations with respect to the organisation of scientific research in defence were not taken up by the Government of India as there was no perceptible change in the working of the Inspectorates in the Services after 1944 till the country gained independence. This view gains support from Mr SS Khera, who wrote about Indian defence in that period: “Scientists [prior to independence] had not much to do with the structure and work of the Indian military apparatus. The scientific services, such as they were limited to test the quality of stores and materials of different kinds, to ensure adherence to specifications. During World War II, there were perhaps small bits and pieces of somewhat elementary efforts, occupied with the substitution of locally available materials for those in short supply or things like that. Of true scientific research associated with the military apparatus as such, there was little or none”.12

1.2.3 Aftermath of the World War II

1.2.3.1 Postwar R&D in UK

In the immediate aftermath of the World War II, the organisation of R&D effort in the UK underwent a change. The Scientific Advisory Committee to the War Cabinet with eminent scientists as members, who had played a prominent advisory role in the matters relating to radars, jet engines, atomic energy, and major weapon development programmes, was replaced in January 1947 by the Advisory Council on Scientific Policy with the function of advising the Lord President in the exercise of his responsibility in the formulation and execution of Government civil scientific policy. The counterpart in the Defence Ministry was the Defence Research Policy Committee to the Minister for Defence, its role also being advisory. Even though these committees gave an impression to the outside world of strong central coordination, in reality, the decision-making remained widely dispersed among several departments, with each individual ministry continuing to build up their own competence in S&T. In the Defence Ministry also, decision-making was fragmented among the Ministry of Supply, the Admiralty, and the Air Ministry. The newly created Ministry of Defence was restricted to a minimal coordinating role.

The expenditure on R&D which was about nine million pound sterling in 1938, had burgeoned to more than seventy-five million pound sterling in 1947-48, of which the share of defence spending was about sixty million. Most of the Government spending in aviation and defence was in the industry. By the end of the 1950’s, there was considerable debate in UK about the high cost of research, especially in the fields of space, high energy physics, and radio astronomy and about the wisdom of non-directed approach of successive Governments to the various research councils administering the civil R&D and their relation to the rest of the fairly elaborate Government R&D system. The country was spending nearly half of its R&D resources in defence-related activities in spite of the fact that UK was no longer a world power. Worsening economic conditions, a growing debate about the role S&T should play in the modernisation of the economy compelled the Government, which came into being after the elections to create the office of the Ministry of Science in 1959, more to reduce political pressure than to fulfil an administrative need.\(^{13}\)

1.2.3.2 **The Indian Scenario**

The question of setting up a scientific research organisation for defence did not surface till after the end of World War II. In 1946, when it became evident to the Britishers that controlling India as part of the British Empire in the postwar period was going to be increasingly difficult, and that India and Indians would play a greater role in determining their own destiny, it was decided to invite Dr OH Wansborough Jones, who was the Scientific Adviser to the Army Council in UK, to advise the Defence Department on the organisation of scientific research in India for defence. Dr Wansborough Jones had an intimate knowledge of the utilisation of science and scientists within the defence forces in UK in the course of his thirty years of association. During the war years, he was involved in operational research in UK. He visited India and submitted his report on a proposed organisation for the Defence Services to the Commander-in-Chief in November 1946. He was given to understand that the Government of India intended to make the country, as nearly as possible, a self-supporting defence entity as may be at the earliest possible date, which means reducing its dependence on import of defence equipment from abroad as early as possible. To reach this goal, India would have to initiate scientific effort to explore scientific advances in their application to defence, and simultaneously take steps for development and production of the relevant scientific findings into actual stores or weapons for utilisation by the Services. The latter part would be dependent on the industrial infrastructure. Thus, Dr Jones observed, “for realising the aim, first, at a higher (that is, at the national level), it will be necessary to determine scientific strategy for the defence of India, that is, to determine the best allocation of total scientific effort available in the country”. Then he emphasised the necessity for a strong industrial base by stating, “treating the defence problem as a whole, the maintenance of the Armed Forces must be based on civil economy and it would be futile to develop well trained and adequately equipped Armed Forces without sufficient civil and industrial forces to maintain them.” He also pointed out that unlike UK, India has a single integrated Defence Department which administered to the needs of three Services, and therefore, there need be only one Scientific Adviser for the Defence Department and the three Services14.

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In the period immediately after the World War II, the Services were also undergoing changes in their organisations for aligning with the needs of the postwar peacetime requirements. For example, the ordnance factories where the various inspectorates were situated, were separated and placed under the Ministry of Defence. A review was carried out with respect to the research and technical development activities under the Army, and as a first step, the inspectorates which continued under the Services were placed under the Directorate of Technical Development. The Directorate of Technical Development was made responsible for technical services to the General Staff regarding arms, equipment, clothing and general stores, to certify the quality of every kind of store in the Army (except food) and to maintain particulars of production for all stores manufactured in India. In addition, the Directorate of Technical Development advised and assisted the ordnance factories and the industries in establishing the manufacture of the army requirements in India. In the two-year period (1945-1947), the inspectorates underwent some more changes to emerge in early 1947, as Technical Development Establishments. Under the Directorate of Technical Development three principal Controllerates, namely Armaments, Weapons and Ammunition, Vehicles and General Stores, were set up and made responsible for the work of the Technical Development Establishments (TDEs). The TDEs were spread out all over the country with main centres at Kanpur, Jabalpur, Khadkee, Ahmednagar, and Dehradun, in the different disciplines of armaments, vehicles, instruments and electronics, general stores and so on. The functions allotted were design, development, and modification of equipment for the Services and setting up of indigenous production and inspection establishment. One such TDE, (Instruments and Electronics), which was set up at Dehradun in April 1947 later became two DRDO laboratories, LRDE in Bangalore and IRDE in Dehradun.

In the meantime, political developments within the country were taking place much faster than anticipated, as a result of which an Interim Government was sworn in on 28 October 1946 with Pandit Jawahar Lal Nehru as Member for External Affairs and Commonwealth Relations Department, and with Mr Goverdhan Shankerlal Bhalja as Secretary, Defence Department. The Commander-in-Chief for the first time ceased to be a part of the Governor General’s Executive Council and became adviser to the Defence Member. Early in 1947, as a first step towards the creation of a defence research organisation, the search for a suitable scientist of stature and of
highest calibre and preferably with research experience connected with defence had begun. When it was realised that handful of the distinguished Indian scientists were not available for consideration, the search was extended beyond our shores to UK and two eminent scientists in UK were then approached for appointment as Scientific Adviser to the Defence Department for a short period until a suitable Indian scientist was identified for this post. Due to their academic and other commitments, their services could not be obtained and the creation of the scientific research organisation for defence had to be kept in abeyance. In the mean time, political events were changing rapidly and had led to the British Government announcing the division of the country and transfer of power to the two newly forming national entities, namely India and Pakistan. The search for filling up the post of Scientific Adviser appears to have been deferred till the two nations come into existence in August 194716.

1.3 POST-INDEPENDENCE SCENARIO

1.3.1 Independent India and the Change

Independent India had the good fortune to have Pandit Jawahar Lal Nehru as its first prime minister, a person who considered science and technology as the most important factors for lifting the nation out of the mire of grinding poverty to its true potential. Earlier in 1938, as Chairman of the National Planning Committee set up by the Indian National Congress, he had declared, “industrialisation (as) essential to the elimination of poverty and unemployment, as well as to national defence and economic regeneration in general” for India17. He was well aware of the contributions of modern science and technology to the higher standards of living of the advanced countries of Europe and the USA. He therefore took every opportunity to meet scientists and knowing about the progress in science and advances in technology. Thus, in January 1947, as President of the Indian Science Congress, he met a distinguished foreign invitee, Professor PMS Blackett, of Manchester University, who was deeply involved in UK in defence R&D during the World War II and later a Nobel Laureate in Physics, who had been invited to address the Science Congress. Pandit Nehru knew Professor Blackett’s experience in war and military affairs and got from him a first hand account of the role and contributions made by scientists in UK during the war to the defence effort.

16 Reference 8, p. 280-281.
During lunch at Pandit Nehru’s home, Panditji queried Professor Blackett regarding his views about the time it might take to Indianise the command structure of the military and about the indigenisation of military weapon production and supply. Nearly a month later, in February 1947, as part of the interim Government, Panditji had expressed his views on defence policy and national development as follows, “Defence cannot be considered in a vacuum. It bears an intimate relation to international affairs, foreign policy, industrial development, scientific research, and the resources of the country. The expert soldier knows much more about the technique of defence and the building up of defence forces than a layman does. But the expert soldier necessarily looks at the problem from his own narrow viewpoint and he is apt to ignore many other considerations. Our difficulties are increased by the fact that great changes are taking place in the science of war and it is quite possible and indeed probable that new methods of warfare might change the whole conception of war, modern defence as well as modern industry require scientific research, both on a broad basis and in highly specialised ways. Even more than before, war is controlled by latest scientific inventions and devices. If India has not got highly qualified scientists and up-to-date scientific institutions in large numbers, it must remain a weak country incapable of playing a primary part in a war.”

1.3.2 Report of Professor PMS Blackett

It was not surprising that Pandit Nehru, as Prime Minister of India, extended an invitation to Professor PMS Blackett through the Defence Minister to visit India and advise the Government on the research and development needs to make the country as early as possible a self-supporting defence entity. Professor Blackett’s credentials as defence expert were impeccable and India had no scientists with professional military experience. His association with military research in UK began in 1936 and he was acknowledged during the World War II as a naval expert and also was credited with Blackett Bomb Sight which was standard fitment on Allied bomber aircraft. He sat on key committees of UK that bridged the public and secret use of nuclear fission and he was in touch with those who were

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looking at future weapon systems. To Professor Blackett, India was not totally unknown as his family had an association with India earlier. His father’s brother was a missionary in India, his mother’s father had been in the Indian Army, and his mother’s uncle had been a tea planter in the country. Professor Blackett had not visited India before 1947 but in the quarter century period from 1947, he visited India at least a dozen times. After 1948, he usually stayed with the Prime Minister; visited the defence installations and held discussions with high ranking Service officers including the heads of the Services, high ranking civilian officers connected with the defence ministry, and also with the scientists.

Professor Blackett’s Report to the Defence Minister was submitted in September 1948\(^{21}\). In the letter forwarding the report to the defence minister, Professor Blackett mentioned that he felt it necessary to widen the scope of his analysis beyond that of organising of defence science to the needs of the Indian Armed Forces. He stated, “weapons and instruments of war can themselves hardly be wisely chosen without some guidance not only as to the general defence plans but also as to the programme for the industrial development of the country”. Therefore, he had ventured to take upon... [himself] the task of attempting to discuss in some detail the relationship between (a) defence science, (b) military strategy, and (c) foreign political and domestic industrial policies of India. He pointed out that the lack of experience in formulating defence policies makes this job difficult for the newly independent nation and the difficulty was further compounded by the great size of the country and the relatively low industrial production. He brought out that his report can be considered as a study of how India can best cut her defence cloth according to her scientific, financial, and industrial skill. He then went on to confirm his agreement with nearly all the recommendations made by Dr Wansborough Jones and expressed his happiness that the Government had already implemented some of these. He was delighted by the choice of Dr Daulat Singh Kothari as the Scientific Adviser to the Defence Ministry and stated that he was in complete agreement with the views of Dr Kothari with regard to personnel and organisation given in his proposal and already submitted to the Government.

\(^{21}\) Professor PMS Blackett, FRS of the Manchester University. A Report to the Hon’ble Defence Minister on Scientific Problem of Defence in Relation to the Needs of the Indian Armed Forces. New Delhi, September 1948. (Professor Blackett’s words are put between quotation marks).

\(^{22}\) Reference 19, pp. 260-262.
Professor Blackett, like Dr Wansborough Jones before him, made the observation that the goal of self-supporting defence entity requires a strategy at the national level for best allocation of scientific effort and for building up of the civil and industrial forces. This observation might have been prompted by their being most probably aware, at the outbreak of the war, of the inadequacy of the British industry, which was mostly antiquated and inefficient with machine tools in short supply. Britain also had, at that point of time, a grievous shortage of specialist designers with engineering background which made it difficult for the country to repair and maintain trucks, tanks, engines, and aircraft. The inadequacy of the British factories also forced the Government of Britain to place orders for mechanisms of even moderate complexity, on factories in the USA.

To decide on the approach to reach the objective stipulated by the Government, Professor Blackett first took up the estimation of the financial resources that might be available. The starting point was the 1948 figures for the national income, the central budget, and the amount allocated for the Armed Services out of the budget. He observed that the industrial productivity was low – it was estimated as 2 per cent of the corresponding figure for Britain -and since the percentage of financial resources allocated for the Armed Services in the central budget was already high (being 40 per cent), he opined that it is very unlikely, the present allocations for Armed Forces could be raised without affecting the rate of growth of industrialisation and the expansion of the national economy.

The upper ceiling for the availability of resources as well as the foreign exchange for the Defence Services, weapons and equipment having been estimated, Professor Blackett turned his attention to the type of armaments a modern army would have to possess. He categorised these mainly into two types, the first type namely, weapons which are newer and more sophisticated, such as the jet fighters and bombers, airborne radars, high altitude anti-aircraft guns with radar and predictors, heavy tanks, large and fast aircraft carriers, and so on; and the second type such as the light anti-aircraft guns, 25-pounder field guns, light tanks, motor transport, naval escort aircraft, aircraft for training, transport, and general military purposes, etc., which were technologically simpler. He opined that the latter could be productionised in India in a short period of time and this step “would give an extremely valuable stimulus to the.... (the national) economy and present a very considerable step forward in industrialization.” He further stated, “at present India

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would have to buy from abroad very sophisticated weapon systems and consider only the simpler ones for manufacture in the country in the immediate future. Therefore, a decision would have to be taken about the percentage of the resources and foreign exchange that would be spent on importing sophisticated weapons from abroad and for purchase of machine tools for production in India of the second type of weapons.”

He turned his attention next on the choice of weapons. Since very high performance weapons have to be imported, and that too for a considerable period in the future, he considered the option of replacing some of these by more number of lower performance weapons. Professor Blackett’s operations research experience led him to state, “a large part of military equipment and weapons are noncompetitive in the sense that the precise military performance is not decisively important and that a small inferiority in performance can be usually compensated for by increase in numbers”. Examples of such noncompetitive weapons and equipment according to him, are rifles, machine guns, field guns, Ack Ack (anti-aircraft) guns, naval escort vessels, submarines, motor transport light tanks, aircraft for coastal defence and antisubmarine operations, night bomber except against very heavy opposition.” He mentioned that even though there was no clearcut distinction between competitive and noncompetitive weapons, the reason for categorising these into two classes was because the engineering complexity of noncompetitive weapons being lower, these could be manufactured in India in a shorter period of time.

His plan of action for attainment of self-sufficiency in defence armament envisaged,
(a) Early indigenous manufacture of the simpler weapons,
(b) Working out a strategy and evolving military tactics in detail, to reduce for the immediate future, the need for complicated weapons which the country could not manufacture, and
(c) Preparation of long-term plans for the manufacture of high performance and complicated weapons as soon as the technological level and the degree of industrialisation would make this possible.

Professor Blackett stated that at the time of writing the report, India was dependent on UK and the USA for most of the weapons and heavy equipment used by its Armed Forces. If the country were to attempt to free itself of its dependence on import of weapons by the use of less up-to-date equipment and weapons, this would be against India’s security interests. On the other hand, a long and continued dependence on imported weapons might not be acceptable militarily and politically. Firstly, difficulties could
be experienced in getting the latest weapons from abroad without accepting military and political obligations, which might give rise to the risk of the country being drawn into conflicts against its will and not directly concerning it. Secondly, even if no strings were attached at the time of import of these weapons from another country political pressure could be exercised on the country by withholding deliveries of these weapons or spares. The difficulty would be all the more great, as these equipment have relatively long operational life, between ten and twenty-five years, in which case the country’s foreign policy would have to be aligned with that of another country for such a long period. This might be unacceptable in view of the fluid situation prevailing at that time, where the policies of the major powers kept changing rapidly. Professor Blackett pointed out that in spite of these constraints, there would be no escape from the fact, “the duration of dependence on a foreign power inherent in the continued use of imported major weapons is likely to be longer than is tolerable”. He was of the opinion that these arguments made it necessary for the country to plan its defence strategy with these factors in mind, and at the same time, aim at a rapid achievement of technological independence in the field of defence.

The apportionment of the financial resources among the three Services could only be decided based upon a strategic plan which should have the objectives of defending the country against enemy attack and of maintaining the internal unity. After considering different conflict scenarios, Professor Blackett was of the opinion that the most relevant one was a relatively small war against an evenly matched neighbour. In such a case the chief threats to India, against which defence would have to be planned are likely to be:

(a) Attack by land forces across a land frontier
(b) Combined land and sea attack along the coast
(c) Small-scale landing operations on the Indian coast to seize a port or other important objectives, and
(d) Attack on coastal shipping by aircraft, submarines or surface vessels.

Professor Blackett then analysed in detail the roles, the tasks, and composition of the Army, the Navy and the Air Force and drew conclusions about the type of equipment and systems that would be required to counter the threats outlined earlier. He analysed these requirements of the three Services from the point of view of technology and manufacturability in India and stated, “the problem of attaining technical self-sufficiency is likely to be achieved much earlier by the Indian Army than by the Navy or the Air Force. Already a considerable number of the major weapons are made in India by the ordnance factories and plans are
under way to add to these. Probably, the major deficiency at present is in motor transport, tanks and high-velocity guns but stocks of the latter are adequate for some time. As regards general army equipment (apart from weapons and vehicles) India is already producing a considerable fraction of what she needs and has the technical organisation to produce more. The radio industry appears to be rather backward and needs to be expanded so as to produce the main communication sets required by the Services.”

On the basis of the foregoing analysis, Professor Blackett picked out the following roles for the proposed Defence Science Organisation. It was mainly advisory and similar to the role played by the Director of Scientific Research and his scientists during the war in the British Admiralty. To be effective in such a role, he suggested that the scientists selected for the proposed Defence Science Organisation should be of the highest scientific calibre and they should be encouraged to retain their academic links while serving the Organisation. According to him, “These men will form groups studying various subjects, such as, radar, gun design, bomb, and gun sights, etc., both from official service manuals and from published literature. They should spend some time on loan to the relevant..... [Technology Development Establishments attached to the Directorate of Technical Development] where they should do actual bench work, and should be attached to relevant service units or training establishments to learn the actual use of weapons in service. Apart from the study of weapons and military technology, a considerable part of the effort of the scientific staff should be directed to the study of the broader aspects of military science”.

He specifically excluded at that point of time, research and development of conventional weapons which were not intended for manufacture in the country as well as new weapons and equipment that demanded a very high level of technology and which would not be suitable for use by the Indian Armed Forces, such as the guided missiles, high performance aircraft, supersonic aircraft, chemical, bacteriological and atomic warfare, millimetre wave radar, large ships, and so on. He was of the opinion that, “considerable advantage would result if a few carefully selected Service Officers were attached for a year or two to the scientific staff”. He wanted the scientists of the Defence Science Organisation to apply their analytical skills to the study of any military operation in progress in Kashmir. “Unless this study is carefully organised and carried out by trained team of operational research workers, many valuable lessons will be lost”.

With respect to aeronautics, Professor Blackett commented that “even though India has not the resources to make it worthwhile to embark on a large programme of aerodynamics research, she has adequate
resources to make possible successful Indian design of simple types of aircraft, provided the available resources are properly used and the collaboration between the design staff and aerodynamics department is close”. He suggested that “probably an aeronautical research and development establishment will be needed if India is to develop an air industry”.

However, in other technology areas related to defence weapons, he urged the Government to strengthen and expand the existing technical/defence development establishments so that the special problems of applying modern techniques to the manufacture, modification of military vehicles and weapons may be adequately dealt with. However, he did not suggest the merging of the TDEs with the Defence Science Organisation but instead wanted the Scientific Adviser to be consulted in respect of their research programmes and in the appointment of the scientific staff. He left open the merger of these two organisations by stating, “In a few years’ time, when the Scientific Adviser has staff adequately trained in the different branches of defence science, the position could be reviewed”.

Professor Blackett’s opinions, as expressed in this report, also influenced the thinking of the first Scientific Adviser. Professor Blackett later indicated that his effort from the beginning was, “to prevent India from unnecessary and costly introduction of weapons and strategies, which would not have practical value, and to focus attention on the military risks which India did face”. He elaborated it further to state that he was preparing India for war with a country the size and force of Pakistan and not with Russia or a Western Power24.

1.4 THE FIRST SCIENTIFIC ADVISER

1.4.1 The Search is On

Even as Professor Blackett was visiting India, the machinery of the Government was once again set in motion for the selection of a scientist to fill the post of the Scientific Adviser to the Defence Ministry. The selection of the scientist for the post went through careful scrutiny and consideration, before Professor Daulat Singh Kothari, Dean of the Faculty of Science of Delhi University, was requested in May 1948 to be the first Scientific Adviser. In July 1948, at the age of 42, he assumed charge of his office. Like most Indians of that period, he had very little knowledge of defence and

24 Reference 18, p. 263-265
Dr Daulat Singh Kothari  
(The First Scientific Adviser: 12 July 1948–18 March 1961)
therefore several factors might have weighed in his mind before he would have taken his decision. The compartmentalisation that existed between academicians and the technical personnel engaged in defence work, the perception that scientific work in defence is only of applied nature, the sharp distinction that was sought to be made in academic circles between pure and applied research with disadvantage to the latter (“a distinction nearly as sharp as the distinction between a gentleman and a liar at large”) and the interruption that would be caused in his research and teaching activities, were some of the negative factors against acceptance, while his interaction with Professor Blackett, whose opinion was being sought by the Government, would have been the single most positive factor. By his own account, when he accepted to become the Scientific Adviser and take up the work of creating and building a science organisation in defence, he had said to himself that he would take it up only for three years.

1.4.2 Dr Kothari as Scientist

Dr DS Kothari was a theoretical physicist who had come under the influence of Dr Megnadh Saha at the Allahabad University during his studies in physics for his baccalaureate and masters degrees. After he had completed his studies at Allahabad, Professor Megnadh Saha encouraged the young physicist to pursue advanced studies at the University of Cambridge, in UK, which was the mecca for nuclear scientists all over the world. At the university, he came to know Lord Rutherford, Peter Kapitza, RH Fowler, and Subramanyam Chandrasekhar who later migrated to University of Chicago and attained fame for his contributions to astrophysics. He maintained an unbroken lifelong friendship and research interactions with Professor Chandrasekhar. Dr Kothari worked in the area of quantum statistical mechanics and its applications to degenerate stars and planets. In particular, during his stay at the University of Cambridge, his research interests were focused on the effects of pressure ionisation in cold compact objects and he was able to show that bodies having masses greater than that of Jupiter would be unstable against collapse. He returned to India in 1933 and soon after joined the University of Delhi at Professor Saha’s insistence, as Reader in the Department. He continued his research work.

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25 Defence Science Journal, 1952, Page 171. Professor KS Krishnan, a member of the Defence Science Policy Board made this observation during the second Defence Science Conference about the distinction between pure research and applied research.

26 Defence Science Journal, 1952, p. 149. At the end of the Plenary Session of the second Defence Science Conference in Delhi, Dr Kothari made the statement that he had decided to stay only for three years as Scientific Adviser when he accepted the post.
at the Delhi University and under his guidance, soon the University of Delhi came to be recognised as the leading centre in the country in the field of quantum mechanics and quantum field theory, nationally and internationally. University of Delhi was the only university for several years to teach the methods of quantum mechanics and quantum mechanical theory at the master’s degree level. In 1942, he was made Professor along with Dr VKRV Rao, who had founded the Delhi School of Economics and played a major role in the overall growth of the University and in enhancing its reputation as a centre of learning. By the time the country attained independence, Professor Kothari had established his reputation as a person of intellect and a fine human being. Simplicity and humility coupled with a rare sense of duty and service were his main characteristics. He had an extraordinary memory for names and in spite of his busy teaching and research schedule, he was approachable by one and all, high or low, in the University.\textsuperscript{27,28}

1.4.3 The Framework

Along with the creation of the post of Scientific Adviser, the Government of India had constituted an Advisory Board with the objective of formulating a science policy in relation to defence. Within four days of his assuming charge of his office, the first meeting of the Board with the Defence Secretary as the Chairman, and comprising Dr HJ Bhabha, Dr SS Bhatnagar, and Dr KS Krishnan as members, was held, to make known to the newly appointed Scientific Adviser, the views of the members of the Advisory Board about the objectives and formation of an organisation for bringing science to bear on defence matters. Before its second meeting was held on 18 August 1948, the membership of the committee was enlarged to include the three Service Chiefs and the Financial Adviser (Defence) and was renamed as the Defence Science Policy Board. The main areas of concern for the Board were, wider aspects of defence science and policy, integration of military and scientific thought and planning defence research and development as a whole, taking into account the industrial resources of the country. In addition to the Defence Science Policy Board, a Defence Science Advisory Committee was constituted with the Scientific Adviser as the Chairman and with fourteen members comprising Director General Armed Forces Medical Services,
Defence Research & Development Organisation (1958-82)

Master General of Ordnance, Engineer-in-Chief, Director of Technical Development, Director of Weapons and Equipment, Army Headquarters; Director of Technical Services, Air Headquarters; Director of Naval Engineering, Naval Headquarters; Scientific Adviser, Navy; Director General of Ordnance Factories, representatives from CSIR and Ministry of Commerce and Industry; and Deputy Chief Scientific Officers—Army, Navy and Air Force. The broad functions of the Committee were to consider the technical and scientific aspects of Service requirements, to keep in close contact with research and development in the Services technical establishments, to initiate research and development in the Service laboratories, and to keep in touch with the scientific and industrial work in the national laboratories, universities, and other scientific and technical institutions in the country. Specialised panels and subcommittees under the Committee were also formed for subjects such as electronics, ballistics, and explosives.

1.4.4 The Defence Science Organisation

The role, activities, and the structure of the defence science organisation proposed to be set up in the Ministry of Defence was finalised by Dr DS Kothari and was adopted at a meeting of the Defence Science Policy Board held on 10 September 1948, which was at about the same time as the report of Professor Blackett was submitted to the Defence Minister. In preparing this report, he had to bear in mind the deliberations of the Defence Science Policy Board. The Board had stressed that after taking into account the low level of progress of scientific research in the country and the very limited availability of experienced research workers, the role of the Organisation in the general set up of Defence Services be an advisory one in the initial stages. He was also influenced by Professor Blackett with whom he held discussions and had exchange of views about the proposed organisation. This is very clear from the very first sentence of his note in which he first placed on record his deep appreciation for the help and advice he had received from Professor Blackett and described the visit of the latter to India as of inestimable value. A brief account of Professor DS Kothari’s note to the Defence Science Policy Board is provided in the following paragraphs.

Dr Kothari found the Technical Development Establishments functioning under the Army, inadequate for "systematic study of the new..."
very extensive and highly developed defence science and to deal with the basic defence research and investigations concerned with scientific rather than the purely technical or engineering aspect of defence science”. He pointed out that the most important function of the Defence Science Organisation (DSO) proposed by him would be that of rendering “effective help in the integration of scientific and military thought.” Dr Kothari considered that DSO constituted an essential and integral part of defence, because in the absence of a properly functioning DSO, defence services in the country cannot “for long maintain its efficiency, make use of its weapons and equipment, modify and improve them to suit local conditions or keep in contact with the progress in weapons and techniques of warfare generally.” He also pointed out that in a technologically backward country like ours, the demand for sophisticated weapons such as the atomic bomb, guided missiles, bacteriological warfare, is likely to be “more than ordinarily loud and insistent..... because of the lack of scientific background and understanding necessary for appreciation of the gigantic effort required for development and use of sophisticated appliances.” He countered the oft expressed sentiment that technological backwardness of the country should not bar the Armed Forces from acquiring sophisticated weapons by the argument that, “it would appear strange and rather impractical in the present times for a country to base its defences on imported key–men and weapons”. He was firm in his opinion that “the standard and efficiency of weapons and equipment of the Armed Forces must, in ultimate analysis be directly related to the technologies and industrial potential of the country.” Therefore, he stated that the pattern of Defence Science Organisations of UK and USA “would not for the time being, suit our requirements.” He stressed that, “a beginning on sound lines would be made and then the organisation be allowed to grow rather than discuss at this stage what the organisation should ultimately be”. Thus, he announced that “for a few years to come the primary aim of the Defence Science Organisation would be to learn their trade. The role of the organisation, will be purely advisory. The question of assigning, if at all, any executive responsibility to the Defence Science Organisation can only be considered after a few years when the defence scientists have been adequately trained in their work.” He proposed a compact organisation to work on topics of defence interest ranging from aircraft performance and instrumentation, applied psychology, ballistics, biological control, chemistry, defence science education, electrical communication including radar, explosives, heavy and light arms, naval research, operational research, optical instruments, physics including meteorology, prime movers, shipbuilding, and transportation. His expectations were that the personnel after a year or two of work at the TDEs would have the basic
knowledge of defence science with reference to Indian conditions and with special emphasis on performance rather than on constructional or on technical details of weapons and appliances of warfare. Thereafter, he envisaged the main function of the DSO would be one of rendering advice to the Ministry of Defence on matters of scientific interest to the Services. He also indicated that immediate thrust areas for the DSO would be on biological control of pests, harnessing of solar energy, thermodynamics of interchange of heat between human body and environment, electromagnetic wave propagation in hilly and dusty terrains, and working in collaboration with universities and with the CSIR so that the findings provide stimulus to the organisation and also lend some prestige.

Four years later at Kirkee in a speech on Science and Defence, Dr Kothari expounded his line of reasoning by stating, “How is a scientific establishment to be organised so that the men there will devote themselves completely, entirely and fruitfully to the pursuit of scientific research? This is a problem, difficult as well as delicate. It is beset with difficulties even in scientifically advanced countries. Firstly, the establishment should be manned by able and devoted men. Secondly, the conditions should be such as will allow them to grow in their full scientific stature and not dampen and dry up their enthusiasm and abilities. Thirdly, the problems to be worked at the establishment should be selected with the utmost care. This is extremely important. Do not have too many problems, but concentrate on a small number of problems selected judicially. In selecting problems, take account of the usefulness of the problems, the resources available for investigation and the speed with which these can be solved”\(^{30}\). Careful selection of talented and qualified personnel, concentration of effort, balancing usefulness of the problems with the aspirations of the scientists, appeared to have been uppermost in his thinking.

Dr Kothari’s note proposed a small and compact organisation with a flatter hierarchy of three layers. Forty senior scientists and 100 junior scientists was the proposed strength, for which sanction was obtained from the Government of India in June 1949. The appointments of 25 scientific assistants was added later after the organisation decided to set up laboratory facilities. The Government letter clearly specified the role for the Defence Science Organisation by stating that it should undertake a systematic study, investigation and research into the various branches of defence science for purposes of tendering advice and assistance to the Services with regard to their technical and scientific problems.

1.5 THE FIRST STEP

Dr Kothari along with Dr SS Bhatnagar, who founded the CSIR organisation, and Dr HJ Bhabha, the father of nuclear science in India, were the triumvirate who influenced the structure and the organisation of science and technology, research and development in independent India. All the three believed very strongly in the linear model of innovation also known as the science push model, which was universally endorsed by the scientific community world over, after the war. The linear model of innovation, assumed that scientists made discoveries, technologists after a time lag took them up and applied them, and still later, designers/engineers turned them into new products and processes. The success of the Manhattan Project and the microwave radar during the World War II had led to the vision of Big Science in the postwar period in which it was opined that by providing scientists and technologists with well-equipped laboratories and giving them freedom to carry out research, discoveries, inventions and new products and processes will follow for the benefit of the society31. Both Dr Bhatnagar and Dr Bhabha were committed to their visions and planned big, right from the beginning, one for industrialisation of India through science research, and the other for using nuclear energy for peaceful purposes for the benefit of the citizens. Hence, Dr Bhatnagar built the CSIR and Dr Bhabha, the Atomic Energy Organisation accordingly, by recruitment of the best scientific talent and building of well-equipped laboratories, which were called modern temples by Pandit Jawaharlal Nehru.

Dr Kothari, on the other hand, did not respond in the same way when he became the Scientific Adviser to the Ministry of Defence in 1948 and undertook the responsibility of organising scientific research effort in defence. There was no grand inauguration function or foundation laying ceremony with speeches from the Prime Minister or the President of India extolling the benefits that will accrue to the nation, followed by the Scientific Adviser giving his vision of the tasks to be undertaken, to mark the occasion. Since the means of communications were primitive at that time, there was little publicity and limited public awareness about the new science and technology organisation that had been created. In spite of this, and mainly due to the reputation of the Scientific Adviser among his peers that the response from qualified and talented scientists and engineers to join the organisation was heartening. Dr Kothari hand-picked the scientists who would constitute the Defence Science Organisation. These were from

...the various universities in India and were proficient in aeronautics, electronics, chemistry, mathematics, nutrition, physics, psychology so that research work in ballistics, electronics, chemistry related to explosives, paints and corrosion, food preservation and nutrition, psychological fitness profile for selection of Service personnel, battlefield stress and physical fatigue, could be initiated. Though the interviews were conducted by the Federal Service Commission (later the Union Public Service Commission) those selected had to pass the exacting standards set by Dr Kothari in aptitude, interest and competence in the desired scientific areas. The organisation was initially housed in the temporary hutments near the North and South Blocks of the Central Secretariat which had been built during the war to accommodate the swelling numbers of Government employees, most of whom had been demobilised after the war. Work was begun in the very first year in areas of ballistics, communications, explosives, food, operations research, and training methods. The names of the scientists and the scientific assistants who formed the Defence Science Organisation nearly three years later, is placed at Appendix I.

1.6 Dr Kothari as Scientific Adviser – Some Vignettes

Dr Kothari aimed to build what is now known as a boundaryless, learning organisation, stripped of hierarchical trappings and with two way communication between him and his scientists. Almost all the scientists who had been associated with Dr Kothari in the early days of the organisation and who were available to the author for discussions, have provided more than one example of interaction with Dr Kothari which bring out these aspects. The constraints of space do not allow the author to spell out all of them.

Mr CP De, who had a long tenure as the Director of Naval, Chemical and Metallurgical Laboratory (now renamed as Naval Material Research Laboratory), Mumbai, and who joined as a junior scientist and was placed in Mumbai for research in problems related to the Indian Navy, recalled with great affection the time Dr Kothari spent in his single room bachelor’s quarters at the YMCA in Mumbai. Whenever the Scientific Adviser came to Mumbai from Delhi, he would go to De’s room, take rest in his lodgings, have tea with him like any family member, would take the young scientist with him to meet eminent personalities, such as Dr Bhabha. In this way, the young scientist came to know some of the top intellects of the country and this stood him in good stead not only in his scientific pursuits but also in building the NCML and interacting with senior officers of the Indian Navy. Mr De also recalled the manner in which Dr Kothari...
The Beginnings – Defence Science

made the young scientists get into the habit of reading contemporary scientific journals and derive the benefits. It was the Scientific Adviser’s practice to send a note to a young scientist like him stating “please speak” and enclosed with it there would be an extract of an article from a scientific journal, or a report or experimental data pertaining either to his specialisation or to the problem the young scientist was working on. Mr De would read not only in depth as well as in breadth because he could expect a call from the Scientific Adviser for an in-depth discussion, and wide ranging probing at the end of which if he had prepared well, he would come out with a feeling of having gained by the discussion and with an urge to do even better next time.

Mr SL Bansal, who retired as a Distinguished Scientist of the DRDO, attributed that whatever he had achieved in the organisation was due to the initial training and advice he got from Dr Kothari. He reminisced that he could go and meet Dr Kothari at the Delhi University whenever he had some doubts or queries to be put to the Scientific Adviser. The Scientific Adviser would then find time and walk with him on the University grounds and with patience, clear his doubts as he would have done for a younger member of his own family. He told about one occasion when he queried the Scientific Adviser about his attending interview boards for the selection of young scientists for the Organisation. Dr Kothari, in his characteristic way explained that just as pillars are crucial structures for an edifice, he considered the calibre of the scientists recruited for the Defence Science Organisation to be a crucial factor for its efficacy and growth. Dr Kothari’s reply made young Bansal realise how great a responsibility each one of them carried in ensuring the future of the organisation. Consequently in all his endeavours, he tried to live up to the expectations of Dr Kothari. On another occasion, Dr Kothari asked him to be his representative in a meeting called by a senior Army officer in his area of work. The young scientist felt honoured that he has been asked to attend such an important meeting and prepared himself well. When he went to attend the meeting, the Army Brigadier who was chairing the meeting on learning that he represented the Scientific Adviser got up from the chair, welcomed him and gave him a very respectful hearing. That Dr Kothari commanded respect from the Services for his intellectual ability was brought home to him and it also firmed his resolve to master the subject.

Dr H Nath, a food and nutrition expert, who retired as Director of Life Sciences, and who at 30 was the youngest Senior Scientist recruited by Dr Kothari, recalled with a sense of nostalgia, two incidents in his early
interaction with the Scientific Adviser. In the first one, when he joined the Organisation, Dr Kothari put him at ease first in his characteristic way and then informed him that he being the youngest of the Senior Scientists, he would form the core group and also that he would have to take additional responsibilities such as the editorship of the Defence Science Journal and also represent him in the Materials Group formed for advising the Technical Development Establishment at Kanpur. Dr Nath felt elated as well as honoured that he was singled out for shouldering additional responsibility and he resolved to work harder so that the Scientific Adviser would not feel let down by him. On another occasion, he queried the Scientific Adviser why he preferred to designate his colleagues in the Defence Science Organisation as Scientists instead of the normal designation, Scientific Officers. Dr Kothari took time to explain to his junior colleague in his own way the reasons behind it. Dr Kothari said that as understood in the country, the job of an Officer in Government service is restricted to the normal office working hours, whereas he wanted to convey to all of his colleagues that he expected them to think about their work all the time as any true scientist would do. Hence, he stated that he preferred the designation Scientist to Scientific Officer.

Dr SS Ramaswamy, a physiologist who joined the Defence Science Organisation in 1950 and who later on retired as a member of the Atomic Energy Regulatory Board, had no hesitation in stating that the scientific temper and culture that Dr Kothari tried to instill in him and in other scientists in the organisation was a great asset that helped him throughout his professional life and he is grateful to Dr Kothari for this. He recounted how Professor Kothari, in spite of being a pure theoretical physicist, mastered in a very short time the essentials of the multi-discipline aspects of defence science and was able to guide and direct the scientists on which aspects that they should undertake work in their areas of specialisation. On joining the organisation young Ramaswamy queried Dr Kothari about the work he could undertake in the absence of laboratory facilities. Dr Kothari in his gentle ways pointed out to him that as a scientist, his greatest asset was his thinking capacity and that lack of facilities should not hold him back from taking up work. He suggested to Ramaswamy that in view of his training in physiology and as soldiers do a lot of walking and running, he should take up studies on the relationship of such parameters as the speed of walking, length of stride, energy consumption, and so on, in the mechanics of walking. On another occasion, after the Physiology group had moved to Jodhpur, and Dr Kothari was about to visit their unit, he was asked by his senior to make arrangements
for the overnight stay of the Scientific Adviser in the laboratory premises. Even though he was advised that he leave a few books/magazines of light reading for the Scientific Adviser to glance through before retiring to bed, Dr Ramaswamy left at his bedside table, a batch of newly received reports from the Food and Nutrition Laboratory of the US Army in the hope that it might interest the Scientific Adviser. To the surprise of the young scientist when he met Dr Kothari in the morning, the latter commended him for his thoughtfulness in leaving the reports at his bedside and stated that the subject matter of the reports would form the topic of his address that morning. Dr Ramsawamy recalled with a sense of awe, the way that Dr Kothari grasped the essentials in a totally different area in such a short time and presented it cogently and succinctly to the audience without losing their attention.

1.7 THE FIRST FOUR YEARS

In this manner, Dr Kothari focused his energy and effort to build the scientific temper in his scientists. He initiated the holding of weekly seminars in the Defence Science Laboratory where individual scientists were to report on some particular topic of defence interest. In spite of the many demands on his time, he generally managed to attend these seminars and participated in the discussions. In addition, he deputed selected civilian scientists on temporary attachment to military establishments to enable the defence scientists to acquire first-hand knowledge of field conditions.

He stressed that unlike in the academic world, in defence, research is a means to an end and that the most important thing in defence research and development was the selection of problems on which the available effort could be effectively concentrated and speedily attended to. Therefore, he considered that the research and development effort should be mainly directed to the twin objectives of enabling the Armed Forces to make the best operational use of existing weapons and equipment and of continually seeking new weapons, including the undertaking of major changes in existing weapons to gain a lead over potential aggressors. The first objective, according to him, could be met by operational research and that no other field of research or development had so far provided a larger yield than this scientific activity in relation to the effort expended on it. Scientists could achieve success in this area in closer association with Service personnel as an intimate knowledge and experience in their operational use was essential. Dr Kothari also considered that assistance to the Services to assess the operational effectiveness of different weapons would be extended so that within the available financial resources, the most effective
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weapons would be purchased. Apart from operations research, he desired that the Defence Science Organisation to assist the Services in other ways which he spelt out as

(a) modification of existing weapons to suit them to local conditions, such as tropicalisation, and operation of radar in the presence of super refraction
(b) keep abreast of the developments in advance weapons work in foreign countries
(c) suggest improvements in inspection techniques and procedures
(d) design and development work related to indigenous production of existing conventional weapons that were being imported
(e) research and also design and development of new weapons of the World War II class, and
(f) research with a view to develop radically new weapons.

The second objective, namely seeking of new weapons or carrying out major improvements to existing weapons embodied in (e) and (f) above, in his opinion, would be successful only against a background of high level scientific knowledge and industrial productivity. He opined that these tasks are not likely to be undertaken in the country for the next few years. Therefore, activities related to technology and weapon systems development were not taken up.

In early 1950’s the scientists of the Defence Science Organisation moved out of the “temporary hutments near the Central Secretariat and shifted to the second floor of the National Physical Laboratory of the CSIR to form the Defence Science Laboratory (DSL). This enabled the scientists of the DSL to get the benefits of interaction with the NPL scientists and also access to the laboratory facilities of the NPL. Further, they also could use the excellent library facilities available at NPL. The DSL was fortunate to have the services of Shri Dhanpat Rai who performed proactively in providing the scientists the latest information on the projects they were working on and also in their areas of specialisation. He spared no efforts to build a tradition of timely and efficient information collection and service and laid the foundation for the present DESIDOC. After the move to NPL premises it was decided to set up a small workshop for which Rs 15 lakhs were sanctioned to equip it over a period of three years.

Professor Kothari identified operations research, ballistics, explosives, armaments, rockets and missiles, food and nutrition, life sciences including medicine, environmental physiology and psychology,
as the areas for the defence scientists to work upon. Of these, operations research was given more importance for reasons cited earlier. He believed in starting the activities in a modest manner and in a small way and build them up and therefore, instead of departments, he set up cells in each of these disciplines. In the period 1949-1952, over 200 weekly seminars had been held covering topics related to defence science so that the scientists belonging to different disciplines could interact and also consolidate their knowledge on the topics.

In addition, two symposia, one on internal ballistics and the second on external ballistics were organised for interaction and exchange of views between the defence scientists and the Service technical personnel. These were found very fruitful as they clarified most of the issues – operational aspects for scientists and scientific aspects for Service Officers – and led to better understanding and appreciation of each other’s views. At the instance of the Defence Science Organisation, many universities, such as Delhi, Calcutta, and Saugor either introduced ballistics in their postgraduate courses which would benefit defence in terms of availability of more trained persons either for active duty or for Defence Science Laboratory for research activities. An Institute of Armament Studies was planned and established with the main object of studying and carrying out research on the performance of weapons and equipment, for serving as a centre for Service Officers to be trained in the principles and design of different types of armaments to take up Technical Staff Officers appointments, and for maintaining contacts with civilian research institutions. In 1952, laboratories were established in Mumbai and Kochi for taking up research in problems related to the Indian Navy. These formed the nucleus for the present Naval Materials Research Laboratory in Mumbai and the Naval Physical and Oceanographic Laboratory in Kochi.

To enlarge the scientific effort on defence beyond the confines of his fledgling organisation, and to create and promote awareness and interest of the academicians and other civilian science research and development organisations in defence science subjects, the second Defence Science Conference was organized in April 1952. The delegates and invitees were academicians from a number of universities, scientists from civilian research organisations such as the CSIR laboratories, scientists and service officers from the TDEs, experts from the armed forces, who for full six days covering over fourteen technical sessions, interacted, exchanged data, views and formed opinions as well as associations. The sessions covered internal
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ballistics, external ballistics, operations research, materials, rockets, electronics including radars, psychology and personnel research. However, the focus was on operations research, ballistics, psychology and personnel research.

The Defence Science Conference also marked the end of the full time involvement of Dr Kothari as Scientific Adviser to the Ministry of Defence. Dr Kothari, who had earlier given himself three years to hold the office of the Scientific Adviser was persuaded to continue for one more year. On completion of his tenure as full-time Scientific Adviser on a University Professor’s emoluments, he returned to research and teaching at Delhi University. His going back to the university was not because he did not consider the work in defence important, or because he had any difficulty in the Defence Ministry, but because he considered that the post of the Scientific Adviser was a post where other scientists should come in and see for themselves how important the work is and how interesting it is. The Government of India while respecting his wishes requested him to continue as Scientific Adviser to the Defence Ministry, which he performed on a token salary of Rupee one per month. He continued to provide guidance and direction to the scientists of the Organisation and advice to the Government on scientific matters pertaining to defence on a part-time basis for nearly ten years.

The major gains made by the Defence Science Organisation in the first four years of its existence was making the Services conscious of the role scientist, a could play in the solution of defence problems. Mr HM Patel who was the Secretary Defence and Chairman of the Defence Science Advisory Board in March 1953, stated that the organisation “cannot as yet claim to have done much more than made scientists and Services alike conscious of the fact that our scientists have a definite and direct role to play in the solution of purely defence problems. To my mind it is nevertheless a big achievement and it is all the more satisfactory in that it is the result on the one hand of proving to the Services by actually resolving some of their minor but for that reason annoying difficulties, that they can be of very real help to them and on the other hand of convincing the universities and other research scientists who have been hitherto totally unfamiliar with military matters that the problems of defence were in essence no different from other scientific problems and were indeed no less challenging. It is a matter of satisfaction that our organisation has already been able to make some contribution, however slight, to the pool of scientific knowledge on defence problems of common interest. I am confident that as our organisation
expands, slowly but surely, it will be able to play more adequate part in this cooperative endeavour”\(^2\). No rapid growth as was being experienced by the other S&T organisations in this period was visualised for the Defence Science Organisation.

1.8 PERFORMANCE BALANCE SHEET

The Defence Ministry after 1952 came under the direct charge of the Prime Minister who appointed a minister of state for looking after the day to day matters of the ministry. It is in this period that Dr D S Kothari as Scientific Adviser to the Defence Ministry came in closer touch with the Prime Minister and there is no doubt that Pandit Nehru’s regard for Dr Kothari’s abilities as a scientist and for his qualities as a human being also grew. Dr Kothari continued to remain part time Scientific Adviser to the Defence Ministry most presumably at the behest of the Prime Minister.

There was appreciation by the Services that, “Dr Kothari had a deep and penetrating knowledge of defence matters and there was no conference on military strategy or tactics in which he did not participate usefully. Whenever Dr Kothari was called into a meeting in the Ministry of Defence, he would speak out plainly and was listened to respectfully and his views were accepted...”. In 1952, he was able to convince the Army the usefulness of analysis in weapons evaluation and this resulted in the Directorate of Weapons and Equipment in the General Staff Branch of the Army, forming an ‘Operational Research Unit’ which was manned by scientists and soldiers together\(^2\),\(^3\).

Over a period of about eight years, the defence scientists in areas of operations research, ballistics, weapons evaluation, physiological and psychological readiness, and food and nutrition honed their skills and were able to assist the Services. A brief account of some of the work carried out would be in order.

1.8.1 Operations Research

The studies and investigations were, introduction of scientific techniques for evaluation of new weapon systems, analysis of the impact of


new weapons on tactics and strategy, and operational research studies to improve fire power.

1.8.2 Explosives

The focus was on the terminal ballistics and relating the chemical composition to the power of the explosive. The first set of studies covered the analysis of penetration of hollow charges against armour plates by the theory of pressure ionisation in condensed matter. This led to a better understanding of the phenomenon of armour penetration and made the indigenous design of antitank ammunition with modern powerful explosives, such as RDX and HMX, possible. An apparatus for measuring blast pressures was developed and investigations were carried out about the processes involved in the manufacture of RDX. Another area of investigation were on fragmentation of bombs and shells on explosion. Here, analytical studies led to the important conclusion that the same statistical theory is valid for both random fragmentation in star formation and for mass distribution of shrapnel from an exploding shell. Relationship between chemical composition and velocity of detonation of explosive compounds was studied for assessing their power and brisance. Investigation of the mechanics of explosive behaviour was carried out for specific chemical compounds and their sensitivity towards heat and impact were quantitatively established.

1.8.3 Military Physiology

The studies centred on the physiological problems of the Indian soldier in the tropical heat–dry heat conditions as in Rajasthan and wet-heat conditions as in Assam. Initial studies were carried out in controlled environment of the laboratory with respect to salt and water requirements with a view to check salt deficiency and drawing a regime of water intake. Another study focused on caloric requirements of the soldier by relating energy expenditure to actual consumption of food during collective training periods. Another set of studies referred to the load carried out by infantry soldiers in relation to different climatic and terrain conditions. The focus here was to establish a relationship between stride length, frequency of stepping and speed in normal walk and the impact of muscular fatigue so that the effect of load on the speed of marching and optimum load distribution could be determined.
1.8.4 **Applied Psychology**

The evolving of a reliable assessment method for selection to the Services was one of the investigations carried out by the Psychological Research Wing. The revised rating scale consisting of fifteen qualities based on four factors was developed and was adopted by the Services for use. Another area of study was about the human factor in man-machine systems, such as the fighter aircraft for efficient operation, flying safety and instrument design.

1.8.5 **Electronics**

The studies that were conducted were aimed to understand the effect of super refraction leading to anomalous propagation on the performance of radars. The anomalous propagation occurred in tropical countries in the summer and monsoon months and their study was essential to site future systems in these areas as well as to determine the coverage gaps that might occur, the time of occurrence and duration of the phenomena. The studies on obstacle diffraction and gain were aimed at the propagation aspects of radio waves in mountainous region which is the characteristic of the terrain on our northern borders, especially for location of transmitters, repeaters and receivers.

1.8.6 **Food & Nutrition**

One area of study dealt with the factors to be considered for formulating Service rations in tropical climates. In particular, the nutritive value of oil dehydrogenised serum cholesterol and phospholipid levels of service personnel was investigated prior to developing pre-cooked dehydrated foods for the soldiers. A new ten-man pack ration was developed and the techniques for production of quick cooking and easily digestible foods were evolved.

1.8.7 **Applied Chemistry**

The naval laboratory at Bombay undertook important studies on Fouling so that the formulation of specifications for antifouling paints could be generated for taking up indigenous manufacture.

1.8.8 **Biological Effects of Radiation**

These studies were initiated in 1956 for alleviation of human suffering and study of physical disorders like thyroid deficiency through *nuclear medicine* such as radio iodine.
1.8.9 Effect of Nuclear Explosions

This pioneering study was undertaken at the instance of the Prime Minister. In the foreword to the book, “Nuclear Explosions and their Effects” authored by the Scientific Adviser to the Ministry of Defence, and published in 1956, the Prime Minister stated, “About a year ago, I suggested to the Defence Science Organisation that an objective study might be made with the material available of the consequences of the use of nuclear, thermonuclear and other weapons of mass destruction.” The book antedated by over two years, the publication, “The Effect of Nuclear Weapons” by the United States Atomic Energy Commission. At the time of writing of the book, due to the Cold War, a large amount of data on fallout and radiation health hazards were classified by the super powers. In spite of the fact that Dr Kothari had access to only the published literature, the book authored by him was considered as an authoritative volume concerning all aspects of nuclear weapons. The book won worldwide acclaim for its thoroughness and completeness, went through two English editions, and was translated into German, Russian and Japanese languages. Among other things, the book provided a detailed analysis of the hazards of Strontium-90 fallout and pointed out that it was nearly four times more hazardous for vegetarians.

1.9 OTHER ASPECTS

1.9.1 Encadreing the Scientists

In 1953, the Government of India established the Defence Science Service (DSS) which covered the civilian scientists and engineers employed in the Defence Science Organisation, in the TDEs and their counterparts in the Navy and the Air Force, in the training institutions within the Defence Ministry. By this move, the scientists were encadred and derived the benefits of defined salary grades, periodic salary increments, annual leave, permanency of job, provident fund, pension and so on. The DSS was mostly Class I gazetted service by which the Government conveyed that it welcomed and desired to have talented and qualified scientists and engineers in the Organisation. There was also a provision for taking qualified Service Officers on deputation against Class I gazetted posts of scientists in the DSS. However, the DSS also had one level of Class II gazetted rank called the Junior Scientific Officer (JSO) but it did not affect persons with higher qualifications and experience as there was provision for direct level entry at all levels of the Class I gazetted posts of the DSS. In carrying out the fitment of persons to posts the Junior Scientists of the Defence Science Organisation found to their dismay that they were fitted into JSO grade which was Class II gazetted cadre.
1.9.2 View From Outside

The personality of Dr DS Kothari was such that in spite of his closeness to the Prime Minister he did not promote his own interests. Thus, though Dr Kothari was held in respect for his intellectual accomplishments and for his human qualities by the Service Chiefs and the top bureaucrats of the Ministry as well, the post of the Scientific Adviser to the Defence Ministry remained subordinate to the Defence Secretary and the Scientific Adviser was not made a regular member of the Defence Minister’s Committee where all important matters concerning the Services were dealt with. Firstly, the absence of a regular spokesman for science and technology at the highest level of the Ministry slowed down the penetration of science and technology and scientific methods into the higher echelons of the Services. This is borne out by Khera’s statement that, “...the scientific inoculation of the armed forces was not going to be easy, and in fact proved exceedingly difficult. The difficulty were not on account of deliberate opposition but largely through inertia and ignorance which is the universal characteristic of establishments everywhere. And ignorance is truly the quality of resistance.”34 Secondly, as the heads of the two other S&T organisations, Dr SS Bhatnagar was already Secretary to the Government of India and (Dr Bhabha had fought successfully for autonomy and freedom from bureaucratic control (he would become Secretary to the Government of India, Department of Atomic Energy in 1954)), it appeared to the outside world, that “in terms of organisational linkages, the defence research and development effort in India is given a lower place in the organisational hierarchy”35.

1.10 SUMMING UP

Major General BD Kapur, who later became the First Chief Controller of the Defence R&D Organisation and who worked closely with Dr DS Kothari perhaps summarises the general view held at that time about the performance of the Defence Science Organisation. “The basic science laboratory Dr DS Kothari had raised provided the nucleus for the formation of the Defence Research and Development Organisation. It was here that the outstanding scientists in defence in various disciplines including operational research, weapons evaluation techniques, came into form, who held their own in the world of science by offering papers at the

34 Reference 8, p. 270.
Commonwealth Defence Science Conference, where they were very much appreciated, some of them were also published in the leading journals of the world. The nuclei of physiologists, of applied psychologists and nuclear medicine specialists, all his trainees, were the foundation of the present major units. In addition to physiology, psychology and nuclear medicine, there were other areas of technology, such as electronics, ballistics, and explosives in which scientists of the Defence Science Laboratory had gained a measure of proficiency, experience and confidence in applying scientific knowledge and procedures in different applications to defence. The advisory role to which the Organisation had positioned itself: however, limited it to reactive response and the expertise to that of analysis. Thus, while the scientists had the knowledge of the technology, techniques, and analytical tools, they were lacking in the knowledge of and working experience in design of weapon systems which is essential to effectively transform technology into a force multiplier.

As the first decade of the Defence Science Organisation was drawing to a close, the intensity of Cold War would be felt at our national borders due to our neighbour Pakistan joining the US-backed military pact against the Eastern Block and acquiring new arms from the USA. The next decade would usher in new challenges to the organisation as a result of restructuring, expansion, and changes in workload.

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Reference 32, p. 28-29.
### Members of the Defence Science Organisation (April 1953)

<table>
<thead>
<tr>
<th>Senior Scientists</th>
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<td>1. Dr K Subba Rao</td>
<td>1. Dr NVV Parthasarathi</td>
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<td>2. Dr HK Acharya</td>
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<td>3. Dr RS Verma</td>
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<td>12. Dr VR Thiruvanakachar</td>
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<td>13. Dr BK Bannerjee</td>
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<td>14. Dr WTV Adiseshiah</td>
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<td>16. Dr SS Srivastava</td>
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<td>18. Sqn/Ldr MK Mookerjee</td>
<td>18. Mr Ranga Iyengar</td>
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### Defence Research & Development Organisation (1958-82)

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<td>19. Lt Cdr MS Malhotra</td>
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<td>20. Mr VS Hegde</td>
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TRANSFORMATION – DEFENCE RESEARCH
AND DEVELOPMENT
(1958–1969)
Pandit Jawaharlal Nehru and Shri Krishna Menon at Metcalfe complex
CHAPTER 2

2.1 INTRODUCTION
The arming of Pakistan from 1954 with the latest weapons as a result of its signing a military pact with the United States of America and the increased incursions by the Chinese on our north-eastern borders forced the Government of India to reconsider its policies with respect to defence. Right from the time the independent government of the country took charge, Jawaharlal Nehru and other leaders, who had fought for independence gave highest priority for putting country’s resources to improve the woefully low standard of living of the people. In their perception, the defence requirements were an unavoidable evil to be lived with and as far as possible, they kept government investment and spending for defence at the minimum necessary levels. The strength of the armed forces was more or less kept at the same level as at the time of independence and the re-equipping of the army which was by far the largest of the three armed services had been progressively deferred. The Ministry of Defence did not have a full time minister of cabinet rank as it was under the direct charge of the Prime Minister who could not devote full-time for it. In a similar manner, it did not have a full time Scientific Adviser as the incumbent Dr DS Kothari had gone back to his teaching and research at the Delhi University and was available on part time basis. In the words of the Chief of General Staff, Indian Army had equipment which were 14 to 18 years old and most of it obsolescent, if not obsolete, in the country of their origin. In such a situation, Pandit Nehru in 1957 reached out to one of his close associates, Shri VK Krishna Menon to become the Minister of Defence.

1Defence Science Journal, 1958, 8(3), 65.
2.2 SHRI VK KRISHNA MENON

According to his biographer, Shri VK Krishna Menon had the required credentials for the job as he had precise ideas about military matters. He had made a thorough study of defence, submitted several papers on it to various authorities and become recognized, particularly by the Left in Britain, as something of a military genius. Shri Krishna Menon who spent most of his life time in the United Kingdom during India’s struggle for freedom, burst on the Indian political scene after India had attained independence as the first High Commissioner for India in Britain and later as a cabinet rank Minister without portfolio in Nehru’s council of ministers. He greatly respected Nehru and accepted his leadership and would befriend those who had the ear of Nehru. He was a many sided personality with the positive qualities of a strong and sharp intellect, an enquiring mind, a hard working nature, a kind, generous, convivial and jovial disposition towards his friends; it was more than balanced by his coldness, general mistrust of people, domineering attitude, obsessive nature, and unfriendliness. This resulted in his becoming over a period of time, a person surrounded by controversies whether it was at the United Nations or with the top rung officers of the Armed Forces or with his own party colleagues. However, it does not detract from the vital contributions he made to defence production and to defence research and development by kick-starting the process towards the objective of self-supporting defence entity for arms and weapons – a goal that was enunciated by the government in the early years after independence.

2.3 DSO TO DRDO

2.3.1 Events Leading to the Formation of DRDO

When he took over the reins of the defence ministry Shri Krishna Menon was very much conscious of the need to provide better equipment for the Armed Forces from indigenous production. If the Prime Minister had the vision and the faith that science and technology would serve the cause of Indian defence, it was the conviction and enthusiasm of Shri Krishna Menon which brought about a sea change in defence, production and a complete transformation of the Defence Science Organization. He was a firm believer that Indian scientists, technologists and engineers are second to none and could achieve any target set in front of them provided they are given opportunities. Therefore, besides

strengthening defence production activities, he initiated the move to merge the laboratories engaged in import substitution and in minor changes/development activities mostly under the Army, with the Defence Science Organisation to form the Defence Research and Development Organisation with the Scientific Adviser as the head. The level at which the advice of the Scientific Adviser was earlier sought by the Ministry was raised and the post of the head of the organization was converted into Scientific Adviser to the Defence Minister instead of being Scientific Adviser to the Ministry of Defence. The Directorate of Technical Development and Production (Air) which was concerned with research and development activities related to aircraft as well as the Fire Adviser were also brought into the Defence Research & Development Organisation (DRDO). It appears that even though Shri Krishna Menon had given orders to the Defence Secretary to go ahead with the formation of DRDO in October 1957, this was not given effect to, as “the Chiefs of Staff called for no evidence and, having a preconceived notion on the subject [formation of the DRDO] opposed it and sent a dissenting note to the [Defence] Ministry”.

On his return from the United Nations by the end of December 1957, the Defence Minister held a meeting with the top civilian and military officers of the Ministry and the DRDO came into being on 1st January 1958 with Dr D S Kothari as the Scientific Adviser to the Defence Minister. The principal functions of the DRDO were defined as:

- Undertaking development and design relating to equipment, including armaments, ammunition, electronics, aircraft, vehicles and engineering stores based on operational requirements defined by the Services
- Carrying out applied research to solve the problems of the Services
- Rendering scientific advice to the Services Headquarters
- Evaluating and carrying out technical trials of new weapons and equipment or those designed and developed in the country
- Rendering technical assistance to civil trade for the development of new equipment, and
- Standardization of defence equipment and stores.


Defence Research & Development Organisation (1958-82)

The Scientific Adviser was assisted by the Chief Controller of R&D (CCR&D), a senior Service Officer and by a Chief Scientist (CS). The CCR&D was mainly responsible for coordinating R&D programmes with the Services and for efficient functioning of research and development activities of the groups of the erstwhile TDEs which had been merged with the DRDO, general administration of the scientific and technical establishments, and standardization of equipment and stores. The Chief Scientist had the responsibility for coordinating the research carried out in the research and experimental establishments, formulation of training policy and research programmes, to liaise with the universities national laboratories & research institutions, taking care of the scientific interests of the Ministry and Service Headquarters, and also for contacts with the Commonwealth countries in matters of defence research interest. The CCR&D and the CS were required to act conjointly in carrying out their functions and also on matters impinging on defence science.

The Scientific Adviser along with the CCR&D and the Chief Scientist formed the Management Group which had the responsibility for policy and control of the DRDO. The Chief Controller R&D was assisted in carrying out his functions by Controllers of Armament Development, Electronics Development, and Vehicles & Engineering Stores Development. Their main functions were, to ensure efficient functioning of the laboratories under their control, to decide in consultation with the laboratories the projects to be undertaken, their inter se priorities and the resources requirement, to facilitate the dialogue between the Services and the laboratories for definition of new weapon systems to ensure that the in-house equipment development meets the Services' requirements, and to assist the laboratories in the placing of development contracts. The Chief Scientist was assisted in his functions by an Officer-in-Charge, Coordination Division. The first incumbent of the post of CCR&D was Major General BD Kapur and that of the CS was Dr V Ranganathan who was designated as Deputy Chief Scientist (DCS). In addition to these two senior officials, the Director of Technical Development and Production (Air) reported to the Scientific Adviser and was made responsible for coordinating with the respective Controllerates in matters regarding development of stores for the Air Force, and for coordinating with the Chief Scientist regarding research activities for the Air Force.

The importance attached by Shri Krishna Menon to science and technology for leading India to self sufficiency in defence could also be appreciated by his constituting the Defence Minister's Research and
Development Committee which would consider all policy matters affecting the DRDO. The Defence Minister presided over the Committee and had besides the Scientific Adviser, as members, the Chiefs of Staff of the three Services, the Financial Adviser and the senior Secretariat Officers. The composition of the Committee was such that the Defence Minister ensured that all aspects of major policy decisions would be looked into and discussed before decisions were arrived at, and once decisions have been taken, implementation would not require any further concurrence from either the bureaucrats within the Ministry or from the Services. There was another committee called the Research and Development Advisory Committee with the Scientific Adviser as the Chairman and with distinguished civilian scientists, senior Service Officers and defence scientists as members to assist the Scientific Adviser in the formulation of science and technology policies to meet the needs of the three Services. These two new committees replaced the earlier Defence Research Policy Board and the Defence Science Advisory Committee respectively.

To cover all civilian scientists engaged in research, design, development and inspection in Ministry of Defence, the Defence Science Service was revised and expanded with the creation of an adequate number of posts at the level of heads of laboratories and lower levels for attracting scientists of high calibre to lead research and development efforts. Further, as a fallout of the Science Policy Resolution, the Government of India also sanctioned for the DRDO funds for building residential accommodation for scientific and technical personnel. This paved the way for the first of the laboratory and residential complexes of the DRDO at Pashan, Pune for the ARDE and ERDL and for the Institute of Armament Studies, near Khadakvasla.

It was also realized that lack of adequate scientific and technical personnel could slow down considerably the process of building the organization. Hence, in addition to the recruitment through the Union Public Service Commission, induction through the Defence Research Fellowship Scheme was also pursued. Accordingly every year a maximum of 50 young scientists and engineers in different scientific and engineering disciplines would be selected after a screening process and offered senior and junior research fellowships and would be trained for a period of two years after which those who were successful would be absorbed in the Defence Science Service as Junior Scientific Officer and Senior Scientific Officer Grade II respectively in the different disciplines of interest to the
Prof S Bhagavantam
(01 July 1961–13 October 1969)
DRDO. The remuneration provided during the training period of two years and the likelihood of absorption after training into DSS was an attractive prospect for engineers and scientists.

In 1958, with the merging of the TDEs with the DSO, ten laboratories came into being under the DRDO and by end 1961, the number had swollen to 21 laboratories. However, in July 1961, the services of Dr Kothari who had continued as Scientific Adviser to the Defence Minister were requested for taking over as Chairman of the University Grants Commission. Even though the fledgling DRDO needed Dr Kothari to direct and shape its destiny for some more time to come, the Defence Minister agreed to release him from his post. In his letter to Dr Kothari, he stated that "No one knows better than you how much I know I value your services and your near indispensability for Defence Science. However, there can be no defence without proper education... I am glad that you have acceded to my request to continue as Chairman of the Research and Development Advisory Committee. I feel sure that I can leave it to your judgement to meet both our needs and availability of your time and energy to give what best you can to defence science without defaulting on your duties to the University Grants Commission."  

2.4 Prof S Bhagavantam Becomes Scientific Adviser

The choice of successor to Dr Kothari fell on Professor Suri Bhagavantam who had earlier worked in London at the High Commission of India with Shri VK Krishna Menon. He was at that time, the Director of the most prestigious academic institution in the country namely, the Indian Institute of Science, Bangalore and he was at first reluctant to accept the invitation of the Minister, but under pressure from the Minister he later agreed to be the Scientific Adviser on a part-time basis in the first instance. Within a year, Professor Bhagavantam realized that he could not do justice to either of the two jobs and opted for being the full time Scientific Adviser to the Defence Minister.

Prof. Bhagavantam hailed from a family of Vedic and Sanskrit scholars of Andhra Pradesh. From the very beginning, he displayed his brilliance in his studies by standing first in high school examination and subsequently in the BSc. Degree in Physics of the University of Madras. On the basis of his academic record and a prizewinning essay written by him

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5 Letter dated 24th February 1961 from Shri VK Krishna Menon, Minister of Defence, to Dr DS Kothari.
on Physics, he was accepted by Professor CV Raman to join him at his laboratory at the Indian Association for the Cultivation of Science at Calcutta. At that time, he was not even nineteen years old but he worked hard and his research work was of such high calibre that Prof. Raman was impressed by his experimental as well as theoretical skills. He obtained his MSc. Degree under the direction of Professor Raman and when Andhra University was on the search for a faculty member in Physics to organize the department, Professor Raman had no hesitation in recommending his prized student for the post. Within a span of five years at the age of twenty eight, Bhagavantam rose to become one of the youngest professors anywhere in India and a little later he was called upon to shoulder the responsibility as Principal of the University Colleges of Science, Technology, Law, Arts, Commerce, etc. In spite of all the administrative duties where he showed his skills in the management of these institutions in rapidly changing political climate, he continued to carry out scientific research. The combination of proven administrative ability and a reputation in research attracted the attention of India’s political leaders who were on the look out for a Scientific Liaison Officer in London at the Office of the Indian High Commissioner. He accepted the post and carried out the job with rare distinction. During the short period of stay, he earned the respect of Shri VK Krishna Menon who was the High Commissioner, with whom he formed an abiding friendship. On his return to India, Dr. Bhagavantam became Professor and Head of the Department of Physics at Osmania University where he built up a school of physics which became known for its research nationally as well as internationally. His reputation as an able academic and administrator propelled him into the Vice Chancellorship of the University which he fulfilled with distinction. In 1957, the position as Director of the most prestigious academic institution, the Indian Institute of Science was offered to him. According to Dr BV Subbarayappa, the official historian of the Indian Institute of Science, Bangalore, “Bhagavantam’s period was particularly noted for obtaining a new status for the Institute. Bhagavantam succeeded in securing the status of a ‘Deemed University’ for the Institute. In addition, he also ensured that political and other pressures which have usually been the bane of Indian Universities, did not encroach upon the autonomy of the Institute. In any case, the ‘Deemed University’ status for the Institute added a new dimension; for, it allayed the apprehension... that the Institute was not gaining due recognition for its intensive training programmes and conferments”6. When Shri Krishna

Menon became the Defence Minister and began the reorganization of defence research, he turned to Professor Bhagavantam to become the Scientific Adviser after Dr Kothari relinquished the office.

Professor C Mahadevan one of the earlier associates of Professor CV Raman at the Indian Association for the Cultivation of Science at Calcutta, and who was working next door to Professor Bhagavantam stated in 1953 that, “one of the most remarkable scholars to come to Professor CV Raman for research was Professor Bhagavantam. He was in his teens... ...at that time, a number of people used to come to work and not having much initiative, and Professor Raman not having much time, either stagnated or left after some time. He [Professor Bhagavantam] was within a very short time one of the closest associates of Professor Raman in his work, and if I may say so, was one of the very few who could rise to levels to hold discussions with him. His work was characterised by highest standard and something out of the ordinary. He is remarkably clear headed and unassailable, whether in scientific work or in controversial conversation. Prof. Bhagavantam was not a mere first class first, he was exceptionally brilliant with intellectual gifts of the rarest type and a vision.” Dr M Krishnamurthy who was one of his closest associates from the Osmania University days and who later retired as CCR&D of the Defence R&D Organisation, states that, “Bhagavantam was a talented teacher, cast in the mould of Gurus of ancient India. He was a scholar in Telugu and Sanskrit ... He was a man of wit and humour and ready repartee. The way he used to defuse tense situations in various meetings by a ready and apt joke was worthy of emulation. He was warm hearted but sometimes had a severe exterior which frightened people away. Once they came close, they could not but feel attracted by his many qualities of head and heart. He was one of the very few persons who kept very friendly and close contacts with Professor Raman throughout his life ..” Dr V Ranganathan who worked as Deputy Chief Scientist with Dr Bhagavantam states that Professor Bhagavantam was a brilliant man who could have received top honours in physics if only he had devoted his time fully to science and scientific research.

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8 Dr M. Krishnamurthi, Prof. S Bhagavantam: A Biographical Note and Appreciation. Defence Science Journal, Prof. Suri Bhagavantam Commemoration Issue. 1990, 42(i), v-vii.
Dr VS Arunachalam who was the Scientific Adviser in the nineteen eighties stated that Professor Bhagavantam “took over the stewardship [of the DRDO] during the turbulent times of the sixties when there were concerns about the strength of our defence forces. The Defence Research and Development Organisation he was leading then, was a fledgling one with modest facilities and infrastructure. He soon realised that to provide, tactical advantage it was necessary to be technologically up-to-date and went about setting up laboratories. It is this foresight that is paying us rich dividends today.”. To those of us who were at the middle level in the DRDO, Dr Bhagavantam appeared as a man of few words, of serious mien, a person to whom one gave respect and listened to with attention when he spoke.

2.5 THE EARLY YEARS OF DRDO

In 1958, when the DRDO was formed, it appeared as though it had been forced on the Services by a Defence Minister by his sheer strength of conviction of the necessity for scientists and technologists to be involved with defence weapons, and by his influence with the Prime Minister. The Defence Minister with the concurrence of Dr DS Kothari entrusted the Chief Controller R&D with actual task of separating the personnel in the Technical Development Establishments under the Army who were predominantly involved in “development” activities, and finding the equipment and space for them to function. The Defence R&D Organisation had an able CCR&D in Major General BD Kapur who lightened the administrative burden of the Scientific Adviser in carrying out promptly, the wishes of the Defence Minister without ruffling too many feathers in the bureaucratic and Service circles. He was joined by Dr V Ranganathan who as Deputy Chief Scientist formed with him a cohesive team which had its task cut out for separating the personnel carrying out research and development tasks in the TDEs, in finding them laboratory space and getting them to function. In spite of the backing of the Minister, the going was hard and General Kapur has provided some glimpse of the difficulties he faced in the early days. He has stated that, “it became a real headache for me to segregate the ‘developing component’ of the Controller General of Defence Production [CGDP] Organisation and bring these components into the new fold of the ‘Defence Research and Development Organisation’, and find space for them in little nooks and corners of the
Ordnance factories with the indulgence of the Director General of Ordnance Factories (DGOF). The opposition came from not only within the Ministry but also from the Army. With lack of support of the Chief of Army Staff, I [Kapur] could get little sympathy from his Principal Staff Officers. Our effort for the Navy and the Air Force was so small that they were not bothered...”.

The separation of the personnel of the TDE into those who are suitable for R&D activities and those who would carry on inspection activities was not an easy task. It not only involved examining in detail their qualifications and work experience but also in overcoming the reluctance of the Army to release them. In addition, these personnel had to be provided with covered space and additional test equipment and laboratory facilities suitable for R&D activities. It took nearly ten years to set up these laboratories as detachments or as autonomous units under the DRDO umbrella. The major institutions/laboratories that constituted the Defence R&D Organisation at the time of its formation were:

- Armament Research and Development Establishment, Pune
- Defence Metallurgical Research Laboratory, Ishapore (presently located at Hyderabad)
- Defence Research Laboratory [Stores] (now called Defence Materials and Stores Research and Development Establishment), Kanpur
- Defence Science Laboratory, (named as Defence Science Centre and now called Laser Science & Technology Centre), Delhi
- Electronics Research and Development Establishment (now called Electronics and Radar Development Establishment), Bangalore
- Explosives Research and Development Laboratory (now called High Energy Materials Research Laboratory), Pune
- Defence Institute of Fire Research (now called as Centre for Fire, Environment and Explosive Safety), Delhi
- Indian Naval Physical Laboratory (now called Naval Physical and Oceanographic Laboratory), Kochi
- Institute of Armament Studies (now called Institute of Armament Technology), Pune
- Instruments Research and Development Establishment, Dehradun

Reference 3, p. 31-33.
The Psychological Research Wing which was part of the Defence Science Organisation automatically became a part of the DRDO. Out of these ten, two laboratories, namely the Armament Research & Development Establishment (ARDE), and the Explosives Research & Development Laboratory (ERDL) were directed to armaments. ARDE and ERDL were formed out of the TDE (Armaments) and TDE (Weapons) with a group of scientists who were carrying out import substitution and limited development of armament stores at the Ammunition factory, Khadkee, in the vicinity of Pune. These two institutions would from now on be concerned with tasks of design and development of small arms, guns and rockets for ARDE and of research and development of explosives for ERDL. The scope of activities of the Defence Science Laboratory was enlarged to include new activities namely, Weapons Evaluation and Guided Weapons Study. In addition, a Scientific Information Bureau was also set up mainly to collect and disseminate information on scientific and technical areas of relevance to the projects undertaken by the scientists. The Electronics Research and Development Establishment (LRDE) and the Instruments Research and Development Establishment (IRDE) were part of the TDE (Instruments and Electronics) which was at Dehradun. LRDE was nucleated from the scientists and technologists concerned with inspection and indigenisation of signals equipment related to the army and who had been shifted from Dehradun to Bangalore to be closer to the proposed defence factory Bharat Electronics Ltd. (BEL) which was being set up for manufacture of communications equipment in Bangalore. The personnel involved in indigenisation and limited development were separated from those carrying out inspection to form LRDE which then moved into hutments that had been used as barracks by the British troops during World War II. The charter of LRDE was to design and develop mobile and portable electrical generators, signal communication and radar equipment for the three Services. The IRDE remained at Dehradun to be nearer to the Ordnance factory at Dehradun for purposes of design and development of optical instruments such as telescopes and gunsights used by the Armed Forces. The Defence Metallurgical Research Laboratory (DMRL) was carved out of the TDE (Metals) which was earlier called the Inspectorate of Metals and Steel situated at Ishapore. The DMRL remained as a composite unit along with the inspectorate at Ishapore. The main purpose of DMRL was to carry out research and development with respect to metallic and ceramic materials of interest to defence. The Indian Naval Physical Laboratory (INPL) was taken over from the Indian Navy which had established it in 1952 for purposes of solving day-to-day problems.
and also for undertaking investigations in underwater acoustics, magnetism and physical oceanography. The Defence Research Laboratory (Stores) was created out of the TDEs at Kanpur which had earlier been part of the Inspectorate of General Stores. The main purpose of the TDE(L) had been inspection, routine testing and quality control of various nonmetallic materials in the general stores category used by the Army. That part of the TDE(L) which was responsible for indigenisation and substitution of nonmetallic materials was separated out and merged into the DRDO to be called the Defence Research laboratory (Stores). Thus, out of these ten main institutions/laboratories, three were part of the Defence Science Organisation, one was under the Navy, and the rest were under the Army.

The formation of the DRDO changed the main role of the scientists and technologists from that of being mere advisers to one of design and development of weapon, sensors, sighting, communication systems, and so on.

After more than a year, that is in August 1959, activities related to production were added to the earlier charter of responsibilities of the DRDO. These were,

- Modifications to existing equipment relating to design of improvement which is not of a minor nature
- Investigations and experiment at all stages of development with a view to determining the causes of failures, if any, and suggesting remedial measures for production
- Preparation of specifications of new weapons and equipment based on qualitative requirements given by the Services. Preparation of such drawings as may be asked for by production authorities in cases of establishment of indigenous manufacture under license.
- Technical guidance to civil trade for the manufacture of prototypes of equipment designs of which not to date have been sealed for Services use.

These activities linked the development conducted either by DRDO or by any other agency with the concurrence or under the guidance of DRDO to the production agency in such a way as to facilitate the manufacture of the product that has been designed and developed.
Thus, right from the beginning, the emphasis was on applied research, design and development leading to production and thus aim for self-sufficiency in arms, weapons, and materials for Defence.

2.5.1 Expansion of the DRDO

Shri Krishna Menon foresaw very clearly that attaining self-sufficiency in defence requires continuous and dedicated research and development effort in many scientific and technology areas which may not always be forthcoming from other departments and ministries unless there is a corresponding civilian requirement. Therefore, he decided to expand the scope of the DRDO to cover almost all important areas of interest to the three Services in a phased manner and used all means at his command to overcome opposition to his plans for expanding the scope of activities of the DRDO. For example, the need to set up a separate metallurgical laboratory in DRDO was first questioned as CSIR had already established National Metallurgical Laboratory (NML) in Jamshedpur. Major General Kapur the CCR&D included Director NML as a member of the Committee to examine the need for setting up DMRL and convinced the latter of creating the new laboratory since the orientation of the defence laboratory would be towards research and development of materials crucial to defence. Similarly, at the time of setting up for Defence Food Research Laboratory in Mysore, as the CFTRI under the CSIR was already in existence, it was suggested that a separate laboratory in food sciences need not be set up for defence. The Defence Minister countered the argument by stating that the food and nutritional requirements of the Services cannot be determined in isolation to the total environment in which the military personnel operate in peace and war times. He cited the examples of sailors in submarines and soldiers in high altitude and cold regions to highlight the need for continual and integrated approach which cannot be devoted by organisations outside of defence. The reason for situating DFRL in Mysore was that it could draw upon the infrastructure and expertise of CFTRI whenever necessary so that duplication would be minimized.

By the end of 1961, the DRDO had twenty-one major institutions/laboratories of which the eleven new ones were

- Aeronautical Development Establishment, Bangalore
- Defence Food Research Laboratory, Mysore
- Defence Laboratory, Jodhpur
The two laboratories namely, the Aeronautical Development Establishment (ADE) and the Gas Turbine Research Establishment (GTRE) were set up to meet the needs of the Indian Air Force. ADE was newly created with the nucleus of a few scientists/technologists drawn from DTD&P (Air) and was entrusted with the task to support ongoing acquisition of equipment for the Indian Air Force; to undertake research and development for improvement of safety, performance and reliability of aircraft; to give type approval of aeronautical stores offered by the industry; and to provide assistance in evolving aeronautical standards and specifications, their application and implementation. GTRE was nucleated from the Gas Turbine Research Centre set up at Kanpur with funding from CSIR with the aim of designing and manufacture of small turbojet engines. It was shifted to Bangalore to be closer to HAL and after being absorbed into DRDO as GTRE, it was oriented towards design and development of aero engines for military applications and for establishment of test and research facilities in this area. Defence Food Research Laboratory (DFRL) was a new laboratory created around the core of scientists of DSL who had worked in the areas of food and nutrition with nearly ten years of experience in carrying out research and development in nonoperational and operational feeding of the Armed Forces, i.e., supply, and storage including preservation to prevent chemical and biological degradation under all kinds of environments prevailing in the country. The Defence Laboratory, Jodhpur was a new institution that was set up as a consequence, of both the Minister and the Scientific Adviser being certain that since the arid regions of Rajasthan, a border state, would play major part in any future conflict with our neighbour, a focus on the likely problems that the Indian Army would face in operating in this region need to be addressed. The Laboratory
Defence Research & Development Organisation (1958-82)

was housed in the Ratanada Palace which was not in use. The Defence Research & Development Laboratory at Hyderabad was formed around the core group at DSL, which was constituted as a study team on guided weapons in 1958-1959. The purpose for which the laboratory was set up was to design and develop missiles for the Armed Forces. The Field Research Laboratory at Leh was taken over by DRDO from the Indian Agricultural Research Institute which in turn had set it up under Professor Boshi Sen, a well known botanist, at the instance of the Prime Minister. The main purpose of this laboratory was to study agriculture and animal husbandry in high altitudes so as to make available to the military personnel serving in inhospitable regions, fresh, varied, tasty and nutritious food. The Institute of Nuclear Medicine and Allied Sciences (INMAS) was the brain child of Dr DS Kothari, the Scientific Adviser who had formed in the Defence Science Laboratory, a Radiation Cell in 1956 to focus on developing techniques of radiation medicine for better healthcare for the Service personnel and also for civilians. The Defence Minister as well as the Prime Minister welcomed the establishment of INMAS with great enthusiasm and this was perhaps the first institution of its kind in the world exclusively devoted to promotion and development of techniques of nuclear medicine for medical research, diagnostics and therapy. The Institute of Systems Studies and Analysis (ISSA) at Delhi was created to focus on reliability and performance evaluation to assist the Services in the selection of weapon systems, plus wargaming and simulation of weapons and equipment. The study team set up earlier in 1958-1959, for Weapons Evaluation formed the core for the new laboratory. The Naval Chemical and Metallurgical Laboratory (NCML) was transferred from the Navy to DRDO. It was already functional with the Navy for rendering scientific assistance to the naval dockyard and the fleet in their day-to-day maintenance problems and to keep the fleet operative. In addition to routine testing of samples, the NCML was also taking up investigations on problems of corrosion, barnacles materials used in by the Navy marine environment specific to the Navy. The Solid State Physics Laboratory (SSPL) was a new laboratory created for the purposes of carrying out research and development in solid state matters of interest and use in electronic devices and circuits. The emergence of transistors had fired the imagination of physicists in the study of different types of compounds designated as semiconductors which could possibly be useful in electronic circuits as oscillators, rectifiers, switches and amplifying devices. The nucleus of scientists for this laboratory came out of the DSL where a small band of scientists were carrying out studies on semiconductor materials of
interest to electronics. The Terminal Ballistics Research Laboratory (TBRL) was newly set up for the specific purposes of providing facilities for basic and applied research in detonics, high energy materials, blast/damage effects, immunity/lethality of ammunition, and defeat of armour. In addition, it was required to assist in the design, development and performance evaluation of armament stores. The core group of scientists for this laboratory came from the Weapons Evaluation study team that had been formed earlier in 1958-1959 at DSL.

The expansion was not only in terms of the fields of research and development but also in terms of a network of R&D institutions throughout the country. The subjects covered ranged from aircraft, aero engines, chemistry, electronics, food and nutrition, materials, metallurgy, nuclear medicine, operations research, physics, psychology, textiles and so on. The laboratories spread the message of the importance of science and technology to defence. The concern at that time was not to situate the laboratories at places which were within near reach of the potential aggressor. In each of these cases, in accordance with the condition imposed by Dr DS Kothari, the Scientific Adviser, the institutions were housed in existing buildings which were either armed forces barracks/temporary hutments earlier used by the Services or palaces of the princes which were not in use after the merger of the princely states with the Union of India. The DR&D Organisation adhered to the earlier practice set by the Defence Science Organisation in not investing in civil works at the time of setting up the laboratory or the training institute.

2.5.2 Further Expansion of DRDO

Dr Bhagavantam who took over as Scientific Adviser, in July 1961, understood Shri Krishna Menon well and was equally convinced as the Minister was, that for indigenisation of weapons and equipment in defence leading to self reliance, it is necessary to build a strong R&D base and to link it as closely as possible with production without losing the autonomy needed for R&D. Therefore, with the full backing of the Minister, in 1962 alone six more new laboratories were added to the growing list, thus bringing the total number to twenty seven. The six new institutions were,

- Defence Electronics Research Laboratory, Hyderabad
- Defence Institute of Physiology and Allied Sciences, Chennai (later on shifted to Delhi),
Defence Research & Development Organisation (1958-82)

- Defence Institute of Work Study, (now renamed as Institute of Technology Management) Mussoorie
- Directorate of Psychological Research, Delhi (renamed as Defence Institute of Psychological Research)
- Field Research Station (later converted to Laboratory), Tezpur
- Research & Development Establishment (Engineers), Pune.

The Defence Electronics Research Laboratory (DLRL) was a new laboratory that was created in recognition of the extended scope of application and rapid technological advances that were taking place in electronics. The charter of DLRL was to take up all research work and technique-oriented activity in electronics while the work of LRDE at Bangalore was changed to broadly cover equipment-oriented design and development in electronics. This was in accordance with prevalent global thinking about the model of innovation namely, the linear innovation model. In the course of a few years, DLRL’s work focused on cryptography, and electronic warfare, while the thrust at LRDE was for terrestrial communications, speech secrecy and radar systems. The Defence Institute of Physiology and Allied Sciences (DIPAS) was formed around the core group set up in DSL in 1952 to carry out applied research in physiology for the Armed Forces. On the recommendations of the Parliamentary Consultative Committee, a separate full fledged R&D laboratory, DIPAS was set up by end 1962 at Chennai and was immediately involved in high altitude effects as there was little or no information available on that subject. Defence Institute of Works Study was set up at Mussoorie to take up work study methods with application to defence activities. Over a period of years, the aim of the Institute has changed and currently it imparts training in technology management for the DRDO scientists. The Directorate of Psychological Research (DPR) was nucleated from the Psychological Research Wing established in Delhi under the Defence Science Organisation. Its main emphasis was in developing excellence in areas of selection, recruitment, placement and trade classification for defence services and also for undertaking research on morale, motivation, attitude, job enrichment, leadership effectiveness and human engineering factors. The Field Research Station (later named Defence Research Laboratory) at Tezpur was established for purposes of carrying out indoor and outdoor exposure trials on military stores under hot and humid climatic conditions prevailing in the north eastern part of the country. The Research & Development Establishment (Engineers) with the acronym
(R&DE Engrs) at Pune was spun out from TDE (Vehicles) in 1962 from Ahmednagar. Personnel carrying out import substitution and limited development of light weight engineering structures were separated from inspection personnel to form the new laboratory under the DRDO. The laboratory was given the mandate of designing and fabricating assault bridges, mine layers, portable masts and ladders, engineering tools primarily used by the Corps of Engineers in the Army.

Shortly, thereafter Shri Krishna Menon was ousted as Defence Minister by his party men and the creation of new laboratories slowed down with his exit. In the course of the next six years only eight more laboratories came into existence. These were,

- Defence Research & Development Establishment, Gwalior
- Systems Analysis Group, Delhi
- Himalayan Radio Propagation Unit: (later renamed as Defence Electronics Applications Laboratory) Dehradun
- Vehicles Research & Development Establishment, Ahmednagar
- Combat Vehicles Research & Development Establishment, Avadi, Chennai
- Aerial Delivery Research & Development Establishment, Agra
- Naval Science and Technological Laboratory, Vishakapatnam
- Snow and Avalanche Study Establishment, Manali.

The Defence Research & Development Establishment (DRDE), Gwalior owes its origin to the Jiwaji Industrial Laboratory set up by the Maharaja Jiwaji Scindia of Gwalior in 1947 to carry out R&D related to forest products and mineral resources of the erstwhile Gwalior state. After the state merged with the Union of India, the Laboratory languished for funds and in 1963 after the Chinese invasion of our borders, it was acquired by DRDO from the state of Madhya Pradesh as a detachment of the Defence Research Laboratory (Materials), Kanpur. It became an independent laboratory in 1972 and was given the charter to carry out R&D in toxicological and environmental problems related to defence including protection against chemical and biological weapons. The Himalayan Radio Propagation Unit was established in 1965 at Dehradun to collect, study and investigate radio propagation in our border areas and
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In mountainous regions for the purpose of enabling communication links to be set up by the Armed Forces. In 1970’s it was renamed as Defence Electronics Applications Laboratory (DEAL). The Vehicles Research and Development Establishment (VRDE) was spun out in 1965 from TDE (Vehicles) in Ahmednagar. Personnel carrying out import substitution and limited development of vehicles used by the Army were separated from inspection personnel to form the new laboratory under the DRDO. The VRDE was given the charter to design, develop, test and tender advice on motorised vehicles used by the defence forces. In 1966, with the commencement of indigenous production of tanks at Heavy Vehicles Factory, Avadi, Chennai, DRDO set up a detachment at Avadi from VRDE for rendering support in technology transfer from Vickers. A year later the need for handling R&D activity in the area of fighting vehicles was felt as a result of which the detachment was given the status of independent laboratory called VRDE, Avadi. In the nineteen seventies it was renamed as Combat Vehicles Research & Development Establishment (CVRDE). With the concurrence of Indian Navy, the gap with respect to R&D in underwater weapon systems such as mines, torpedoes and so on, was sought to be covered by setting up the Naval Science and Technological Laboratory (NSTL), Vishakapatnam for underwater test ranges, design and development of marine navigation aids and for studies in noise and vibration. During the Chinese hostilities against our borders the need to combat the hazards of snow and avalanches in order to maintain roads and lines of communication especially in winter was felt by the Indian Army and accordingly the Snow and Avalanche Study Establishment (SASE) was set up in Manali with the aim of assisting the defence forces in these aspects. Thus, by the time Dr S Bhagavantam relinquished his office by the end of 1969, the DRDO had expanded into thirty three R&D laboratories and two training institutions covering practically all major science and technology areas related to defence activities.

2.5.3 Reach of DRDO

The Defence R&D Organisation was spread far and wide in this land of ours; from Tezpur in the east to Mumbai in the west, from Leh in the north to Kochi in the south. The scientific and technological fields of activities covered almost every aspect of defence activities. Of the thirty five establishments, twelve of them namely, ADE, ARDE, CVRDE, DLRL, DRDL, HRPU, NPOL, IRDE, LRDE, NSTL, RD&E (Engrs) and VRDE would be engaged primarily in the development of hardware/software culminating in equipment and systems for the Services such as
armaments, avionics, communication systems, electronic warfare, fighting vehicles, light weight engineering structures like bridges & portable masts, missiles, night fighting equipment, radars, sonars, torpedoes and so on. Out of the remaining institutions, DMRL, DMSRDE, and HEMRL would focus their attention on materials of specific application in defence such as armour, high temperature resin systems, high energy materials for gun ammunition, rockets, missiles and so on. Three laboratories, namely ADRDE, DFRL and NMRL were established to work on products and processes such as parachutes and other aerial delivery systems; packaged foods for the land-based and the submarine-based naval personnel; and anticorrosive materials and processes such as cathodic protection, anti corrosive and antifouling paints for the marine environment. GTRE and SSPL would build up expertise in the areas of critical and special components and subsystems such as gas turbine engines for combat aircraft, electronic materials and devices, infra red detectors, microwave ferrites, and so on. Thirteen laboratories namely, DIFR, DIPAS, DL(J), DIPR, DRDE, DSL, FRS(L), FRS(T), INMAS, ISSA, SAG, SASE, TBRL would undertake investigations, research, instrumentation, and mathematical modelling for specific problems which are unique and outside the purview of commercial interests such as arid region needs, high altitude requirements, cold region as well as humid & hot region effects on flora, fauna and humans, defensive protection against chemical and biological warfare, radiation effects and protection, wargaming, electronic media secrecy, deciphering, snow and avalanche studies, basic and applied research in detonics, immunity studies against ground shoot and blast effects, studies on motivation, leadership effectiveness, stress effects, and so on. DIWS and IAT are training institutions with the former concentrating on work study and technology management techniques while the latter focused on imparting science and technology inputs on a systematic and programmed basis for the Service personnel. Two laboratories namely, ADE and GTRE had the Indian Air Force as their main customers while the Navy's specific problems were looked after by INPOL, NMRL and NSTL. CVRDE, R&DE (Engrs), SASE and VRDE would have the Indian Army as their customers. The rest of the laboratories were driven by the tri-service needs, the major customer being the Indian Army which is the largest and predominant among the three Services. The gamut of activities ranged from investigations and studies, applied research, development and engineering of hardware to limited production. While the investigations and studies conducted would be partly pro-active and partly reactive to a user problem, the applied
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research activities addressed problems or issues specific to our climate, food habits, physical or psychological make-up, strategy and tactics and other similar factors. The design, development and limited production activities were predominantly based on User Services requirements. The rate of change in the technology disciplines handled by the DRDO ranged from very high such as in electronics encompassing communications, computers, electronic warfare and radars, to a low rate in other technologies such as textiles, leather and so on.

2.6 START-UP HICCUPS

2.6.1 R&D & Government Set Up

The DRDO was the only S&T organization to which every rule of the government was applicable. Many of the rules had been framed for governing India by the British and the process of changing the rules to suit an independent sovereign nation with democratically elected government were by no means complete by the time DRDO came into existence in 1958. These rules did not suit research and development activities because R&D by its nature is a change agent whereas in the government, laid down procedures are essential and departures from laid down procedures were discouraged. So each of the changes brought about by DRDO without any earlier precedence was a long and time consuming process that required patience and skill for navigating the files through the departments within the Defence Ministry and some times through other ministries.

Earlier, before Dr Bhagavantam had accepted the post of Scientific Adviser and later had moved to Delhi in September 1962, he had sounded the Defence Minister about vesting the post of Scientific Adviser with the financial and administrative powers of a Secretary to the Government of India but Shri Krishna Menon during his several visits to Bangalore, had used all his persuasive powers to make him accept the post without insisting on these powers and also assured him of full support. The lack of administrative power and not being a Secretary to the Government of India did not really affect him as long as Shri Krishna Menon was the Defence Minister. Dr V Ranganathan, former Deputy Chief Scientist recalled that there was complete rapport between the Minister and the Scientific Adviser and there were several occasions, when Shri Krishna Menon had walked into the Scientific Adviser’s office for his opinion. Further, whenever he sensed delays on matters concerning the DRDO, the Minister would call for the relevant files and papers and record his
decisions before sending the papers down the bureaucratic channel. These acts did not go well with the bureaucrats of the Ministry. As ill luck would have it, within a few months of Dr Bhagavantam’s move to Delhi, Shri VK Krishna Menon was forced out of office by his party men and Shri YB Chavan who was former Chief Minister of Maharashtra took over the stewardship of the Defence Ministry. Professor Bhagavantam had to start all over again with the new Defence Minister. The relationship did not have the same warmth that he enjoyed with Shri Krishna Menon.

In the new set up the Scientific Adviser could not follow up with the same pace for improved infrastructure for DRDO in terms of increased resources in men, plant and equipment to consolidate the benefits of expansion. His administrative experience as Vice-Chancellor or as Director of the Indian Institute of Science had not prepared him for the bureaucratic mind-set which required even minor aspects concerning the Scientific Adviser or the DRDO to be sent to the department for prior clearance and approval. A glimpse of what he would have faced at that time was evident in a lecture delivered by him in 1970. He stated, “the administrator talks of hierarchy, beaten channels as being essential prerequisites for an orderly progress in any endeavour. Freedom to pursue problems that is assigned to him, unhampered and in his own way, is to a scientist his life blood. It is like the freedom of an individual when the latter asserts his inalienable right to go to hell along his chosen path. In a government even if an individual decides to go to hell, he cannot do so along his chosen path. He should go through the proper channel. A path already laid out and proven by others, is the safest to follow in routine matters but will lead to no new results in innovative science, and should be avoided. Lack of understanding and lack of a dialogue between these two groups of people often results in productive projects being dropped, wrong projects being supported and the targets in many cases being ill conceived or inadequately estimated”11.

He earned the respect of the politicians who were in charge of the Defence Ministry during his tenure as Scientific Adviser and found them responsive to the idea of forming an autonomous body for DRDO similar to the Atomic Energy Commission and the CSIR. In this context, Shri AM Thomas who was the Minister for Defence Production stated at the 8th Annual R&D Conference in 1965 that, “The only major research organisation in the country which still functions under the normal Government procedure is the Defence R&D Organisation. I feel that with the resources at our disposal, if we want to achieve the objectives set in the

shortest possible time, a measure of autonomy should be vested with the Defence R&D. Such an autonomous body should, however, operate in close collaboration with the three Services, the production and the inspection organisation so that the requirements of the users are always kept uppermost in mind while formulating the programmes of research and development work. It will be my endeavour to work towards this end and it is this point that I want to stress".12

Even though the move to form an autonomous body ultimately did not take place, the fact that at the political level the question of autonomy to DRDO was being considered, might have somewhat eased the problems posed by bureaucracy in providing the DRDO with resources and reducing the delays. Over the long term a working relationship appeared to have been established with the bureaucrats. Dr S Bhagavantam would be the Scientific Adviser for about four more years until the last quarter of 1969.

2.6.2 Dissensions Within

After the initial transition period, the clash of cultures between the diverse elements that now constituted the DRDO, began to surface up mostly in the laboratories primarily dealing with application of technology and engineering. The laboratories involved in science and research were spared of the tensions because they had personnel with similar views, qualifications and experience. The first group was mostly populated by the Army Officers and some civilian scientists who had come into the DRDO through the TDE route and the second group by almost all of the civilian scientists, some uniformed officers of the erstwhile Defence Science Organisation, and the newly appointed qualified scientists and engineers. By virtue of their work, experience and professional backgrounds, the two groups had differences of opinion regarding the role of DRDO vis-a-vis the Services. The erstwhile TDE personnel mostly concentrated in the newly formed R&D Establishments and Headquarters Directorates of the DRDO strongly believed that DRDO should look into the immediate needs of the Services and build up their confidence by taking on equipment or weapon system development only after the Services spelt out their requirement in the form of Qualitative Requirement/Operational Requirement (QR/OR). According to them, the Services are the best judges of what they need and the scientist who has no combat experience cannot presume to know the needs of the Services better than the Services themselves. On the other hand, the other group consisting

12 Proceedings of the 8th Annual R&D conference held at Bangalore, 29 April to 1 May 1965, p. 9-12.
mostly of personnel whose earlier experience was mostly in the Defence Science Organisation, had equally strong convictions that any R&D activity initiated after the Services had brought out their QR/OR was bound to fail because by the time the equipment was developed by DRDO and was produced by the public sector/departmental undertaking, the companies abroad would have produced a version more advanced than ours. Therefore, according to them the only way out of this situation was for the scientist to initiate R&D work ahead of the Services and based on his perception of how the new scientific and technical advance would benefit the Services. The first group had their feet firmly rooted in the present and on the Services being able to guide the DRDO on development, based on what they need, whereas the second group had their eyes focused on the future and the scientist being the best judge of what the future will unfold. The antipathy between the two groups was heightened by the fact the civilian scientists considered that their military counterparts did not have either the academic qualifications, knowledge and experience in R&D to direct R&D effort. The military officers on their part considered the civilian counterparts as theoreticians who lacked administrative skills for managing laboratories and also understanding of weapon system deployment in combat which was considered by them as essential for successful hardware development.

Soon after Dr Bhagavantam took over as full time Scientific Adviser, apparently differences between the full-time Scientific Adviser and his senior deputy, the CCR&D came to the fore and strengthened the divisive forces. The Scientific Adviser was faced with the prospect of the break up of the Defence R&D Organisation and of separating the functions of the Director General of DRDO from the post of the Scientific Adviser. Major General B D Kapur, the CCR&D put up a proposal for divesting the Scientific Adviser of the direct control of the equipment oriented laboratories. He proposed that these laboratories and the corresponding Technical Directorates be made part of the CGDP, and the CCR&D becoming Additional CGDP. According to him, this would have lead to quicker decisions in production and supply and also would have enabled economy in technical manpower. In his proposal the other laboratories in the DRDO would function under the control of the Chief Scientist and the Scientific Adviser would exercise overall jurisdiction. According to General Kapur, his proposal got the approval of the government in principle but it did not become a reality because Dr Bhagavantam opposed it\textsuperscript{13}. The

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subsequent actions of the Government of India in 1963 in abolishing the post of CGDP and in creating instead, the post of Director General of Inspection and making him responsible for the activities of inspection carried out by the remnants of TDEs, effectively put an end to all efforts for dismembering of the DRDO. Soon after when Major General BD Kapur left the DRDO, another able and competent military officer, Major General JR Samson was appointed as CCR&D.

2.7 CONSOLIDATION

Dr Bhagavantam was the head of the Defence R&D Organisation for about eight years. In this period the Organisation went through a process of growth and consolidation. By the time he retired from his post in October 1969, the Organisation had made significant progress on many fronts. Some of the major issues that were addressed and solutions sought are discussed below.

2.7.1 Organisation Structure

The organization structure as shown in Appendix–II (Figure 1) remained basically the same as it was in 1959 except that additional laboratories came into existence and that a Directorate of Vehicles was formed out of Directorate of Vehicles and Engineering at the Headquarters. The approach was one of caution towards major changes in organizational structure because time had been too short and that there was not enough experience to come to the conclusion that it was ineffective and because any major change to be effected invariably required significant time and effort to negotiate through various government departments. The changes that were effected were mostly adjustments made in the duties and in the delegation of powers at the DRDO Headquarters and to the Directors of laboratories after a dialogue-discussion process.

The Scientific Adviser had two senior personnel, namely the Chief Controller R&D and the Chief Scientist to assist him in the management of the organisation. The Chief Controller was a very senior Service Officer of the rank of a Major General of the Indian Army. The post of the Chief Scientist was never filled up either during Dr Kothari’s period or during

Dr Bhagvantam’s tenure as Scientific Adviser to the Defence Minister. Dr V Ranganathan who was earlier appointed as Deputy Chief Scientist continued in that post until he moved to the Cabinet Secretariat. The Controllers under the CCR&D had been re-designated first as Group Directors and later as Technical Directors with more emphasis on coordination than control of laboratories. The important functions for which the Chief Controller was responsible to the Scientific Adviser were, coordination of research and development programmes with the Services, the efficient functioning of the technology-oriented laboratories, general administration of the laboratories, discipline and welfare of the military personnel in the department and operation of the secretariat of the Research and Development Advisory Committee. The CCR&D had five Technical Directors namely Aeronautics, Armament, Electronics, Engineering and Vehicles. In addition, the Director of Administration, the Fire Adviser, the Director of Standardisation, and the Director of Scientific Evaluation Group reported directly to the CCR&D. The laboratories under the CCR&D were, ARDE, ERDL, DMRL, IRDE, DRDL, and TBRL in Armaments; LRDE, SSPL, DLRL and HRPU in Electronics, RDE(E) under Engineering, VRDE, CVRDE under Vehicles; and ADE and GTRE under Aeronautics. The main functions for which the Deputy Chief Scientist was responsible to the Scientific Adviser were, coordination of research in the laboratories, scientific interests of the Ministry and Services Headquarters, formulation of training policy and research programmes in the training institutes, research programmes of the psychological research wing and taking care of the interest and welfare of the scientific staff. The Technical Director of Research Laboratories and the Directors of Training Institutes reported to the Deputy Chief Scientist. In addition, the laboratories and institutes that reported to the Deputy Chief Scientist were, DRL (Materials), DSL, NCML, INPL, DL (Jodhpur), INMAS, DFRL, DIPAS, DRL (Tags), IAT and DIWS. Each of the Technical Directors coordinated the work of and provided assistance to their corresponding laboratories and acted as link between them and the Services and between them and the CCR&D or the Deputy Chief Scientist as the case may be. The Technical Directors normally acted as a single window agency for the concerned laboratories for most issues concerning projects and also monitored the major projects of the laboratories on behalf of the CCR&D or the DCS. The laboratory Directors usually dealt directly with the Director of Administration in administrative matters and had the option of communicating directly with the CCR&D or the Deputy Chief Scientist as well as the Services, wherever they considered necessary. The CCR&D and
the Deputy Chief Scientist apprised the Scientific Adviser periodically and whenever he called for, the status of projects and the major issues that required his attention and action.

With the formation of the DRDO in 1958, the Government of India constituted the Defence Minister’s Research and Development Committee which was presided over by the Defence Minister. The members of the Committee were, the Scientific Adviser, the Chiefs of Staff of the three Services, senior secretariat officers and the Financial Adviser to Defence. It was a policy making body with a very wide mandate to consider any and all aspects that affected the working of the organization. Later in July 1962, this body was replaced by the Defence Research and Development Council with the Defence Minister as the Chairman. The membership of the Council was expanded to include in addition to the members of the earlier Committee, Minister of State in the Defence Ministry as Vice Chairman, Additional Secretary Defence, Director General CSIR, Controller General of Defence Production and the CCR&D. The functions of the Defence R&D Council were more specific and included, coordination, direction and review of R&D work undertaken by the laboratories, formulation of programmes for training of DRDO personnel, scrutiny and recommendation of annual budgets of the DRDO for government approval, maintaining liaison with other S&T institutions of the country and implementation of government decisions in all matters concerning R&D. According to Shri Krishna Menon, the Defence Minister at that time, the Council was an autonomous body in a limited sense and had the freedom to function without administrative impediments so that the speedy execution of defence R&D programmes that aimed at developing and producing weapon systems was made possible. To assist the Council in its functioning, a Research and Development Advisory Committee was set up with the Scientific Adviser as the Chairman. Other members were, representative from the Ministry of Finance (Defence), Senior Officers from the three Services, two leading scientists of the country, CCR&D and the Deputy Chief Scientist. The functions of the Advisory Committee were the same as that of the earlier Defence Science Advisory Committee.

2.7.2 Management Style

According to those who worked closely with Dr Bhagavantam, he did not concentrate powers in his hands. The powers of the Director General of the DRDO which could be delegated down had been passed
down to the two principal functionaries, the CCR&D and the Deputy Chief Scientist, and the Scientific Adviser expected them to exercise the delegated powers fully. Powers were also delegated to the Heads of the Laboratories and these were revised periodically after feedback from the laboratories. While most of the problems relating to the running of the laboratories and progressing of the projects were dealt by the CCR&D or the Deputy Chief Scientist, the Directors of laboratories could utilize the opportunities during their visit to Delhi or during the visit of the Scientific Adviser to their laboratories to inform him of the progress made on major projects, unresolved issues with respect to manpower, facilities and availability of foreign exchange. These occasions provided the Scientific Adviser a fairly up-to-date picture and a first-hand view of the work and issues relating to the laboratory and sometimes used these opportunities to convey his views on matters of importance and on issues relating to more than one institution. This provided him time to play his role as a scientist of eminence at the national level, steer the organization in its activities towards applied research and development, decide on the areas of growth and also be an effective spokesperson of the DRDO.

He also made full use of the mechanism of the annual meeting of the Directors of laboratories, with the Scientific Adviser, CCR&D, DCS, Group Directors and the Director of Administration instituted by Shri VK Krishna Menon from the very first year of the creation of DRDO. During these Conferences which lasted about two to three days, the Organisation as a whole took stock of the work that had been accomplished, review measures to consolidate effort and help formulating policies on major issues and problems of concern and which kept arising from time to time. He and the senior level scientists were also aware that in a conference of this nature where the Directors from very widely varying disciplines attend, more than narrow technology issues, the broader aspects of R&D management, and administrative policies affecting the functioning of the organization need to be aired before decisions could be taken or recommendations made. The published proceedings of these conferences indicate that there was a frank and free exchange of views and identification of common issues that require to be resolved. There was accountability as actions taken on the decisions of the previous conference were brought out, reasons for those not resolved were presented and were kept open for reaction of the directors. Several decisions of importance on policies relating to the organization, planning and implementation of R&D activities, and also on policies related to delegation of powers, administration and management of the laboratories, role of Technical Directors, manpower planning were taken during these
Annual Conferences. For example at the 8th Annual R&D Conference, Dr Bhagavantam announced important decisions about decentralization of responsibility and delegating authority to Directors, revision of Defence Science Service Rules, terms and conditions for Service Officers who opt for permanent absorption in DRDO, initiation of a substantial building plan for the DRDO and a five year financial plan for build up of R&D facilities\textsuperscript{15}. The process of participative decision making and the transparency of the process mitigated any feelings of partisanship or bias in decision making in matters where differences existed and fostered the esprit de corps among the diverse elements of the organization. Immediately after or preceding the Annual R&D Conference, a symposium on topics of common interest such as Equipment Oriented Research and Development, Management of Research & Direction in Defence, Defence Packaging, Defence Electronics, Optics in Defence, and so on was organized and in addition, an exhibition of products of the laboratories at a particular station was held. The conferences and seminars also brought the civilian scientists and their military counterparts nearer, gave the senior personnel a chance to be in touch with the scientists and technologists as well as technological advances in areas other than theirs, gave them a closer look at the type of work carried out, and promoted a sense of identity among them.

These occasions were also utilised to interact with the Minister, who is the political head of the Ministry and high ranking civil officials. These were necessary to provide a feedback to them regarding the reaction to the rules framed several decades back by the British for status quo of routine maintenance and running of departments and that were ill suited for the type of technological development work undertaken by DRDO. Unlike the other S&T organizations, DRDO had a major constraint of undertaking research and development work within the framework of government regulations. The venue of the conferences was shifted every year among the four cities where there were three or more DRDO establishments, namely, Delhi, Bangalore, Hyderabad and Pune.

2.7.3 Defining the Role of DRDO

Dr Bhagavantam recognised the need for the two groups, one favouring equipment orientation and the other which favoured the technique oriented approach, to work together to meet the needs of the Services. The Indian Army being the largest Service of the three and the first to be modernized after independence, was the major customer for the

\textsuperscript{15}Dr Bhagvantam, S. Opening Address, during session on General review of R&D Activities. Proceedings of the 8th Annual R&D Conference, Bangalore, April 1965, p.15-16.
DRDO. In many technology fields such as armaments, electronics, engineering and vehicles, the Indian Army had brought out their long term needs in the General Staff Policy Statements and their immediate needs in the form of Qualitative Requirements. The expansion of the Indian Air Force as an aftermath of the Chinese aggression of 1962 also contributed to the workload though not to the same extent. The requirements of the Indian Navy with the exception of armaments were being met mostly by the two DRDO laboratories namely, NPOL and NMRL which were situated in the Naval premises in Kochi and Mumbai and were working in close liaison with the Navy. Under these circumstances, the equipment oriented approach would enable the DRDO to meet the immediate needs of the Indian Army in particular and could contribute to the building up of confidence in and credibility of the Organisation. It would thus ease the pressure on the technique oriented group so that they can be more effective in development of new requirements and of the next generation equipment. Thus, together they would provide continuity in the response of the DRDO.

During his tenure as Director of the Indian Institute of Science, Dr Bhagavantam had been aware of the changes in engineering education in the developed countries towards greater reliance and sophistication in analytical techniques, and the advances that were taking place in the technology fields of electronics, aeronautics, and mechanical engineering. As a member of the Electronics Committee of the Government of India (more commonly known as Bhabha Committee), he was fully cognizant of the latest advances in electronics such as lasers, integrated circuits which would influence the next generation weapon system designs.

Dr Bhagavantam went about in closing the divide by emphasizing the need for diversity in the personnel of the DRDO by virtue of the charter of duties entrusted to it. In this he was ably assisted by Major General JR Samson who established harmonious relationship with the Service Officers and the Scientists alike by his sincerity of approach and desire to solve problems. The cordial relationship between him and the Deputy Chief Scientist (DCS) also helped. Dr Bhagavantam made it a point to acknowledge their contribution by telling the Directors that, “The Chief Controller and the Deputy Chief Scientist are the two focal points with whom I have to deal as far as the organization is concerned. They have a difficult task to perform and they are doing their best.”. Dr Ranganathan who was the DCS at that time, recalled that the Scientific Adviser delegated his powers to the CCR&D and to him and asked them to consult him only if they felt necessary.

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Dr Bhagavantam in his meetings with the Directors and at various fora he addressed within the DRDO, stressed that the activities of DRDO has to go beyond the range normally associated at that time with research and development and that to meet these obligations, DRDO has to contain personnel with diverse educational backgrounds and professional experience and expertise. He pointed out that, “.... The R&D Organisation is essentially a supporting organisation for the Armed Forces. .... We have to render scientific advice to the Services Headquarters; we have to carry out applied research to solve manifold scientific problems that confront the Services; we have to design and develop weapons and equipment for the Services as they tell us from time to time, to meet their operational requirements; we have to evaluate and carry out technical trials of any new weapons and equipment that may be designed, developed and produced in the country or acquired by the Services from abroad; and lastly we have to educate and render technical guidance to civil trade in the country to help build up its competence for development and production of items of defence weapons and equipment.....”. He described the gamut of products and services provided by DRDO in the following manner. “.... In rendering service to the Armed Forces in accordance with the above charter, most important of all, we are called upon to provide the design and know-how for producing hardware that the Services need. This hardware is of a very wide variety; it may be a gun; a rifle; a bridge; a blanket; a shoe; or even sometimes a small chocolate ration cake. Also, it may run to more sophisticated equipment like a radar of a communication set; and so on. There are many problems confronting us in this wide variety of activity flowing from the charter. Many of the problems not concerned with the hardware are also dealt with by the scientists and technologists in the Defence R&D. We deal with the physiological efficiency of the soldier when he works at heights and under low pressure and extreme cold temperature. We deal with recruitment results and constantly improve these recruitment procedures and we follow-up appropriate rations for use at high altitudes. We prepare ballistics range tables; we introduce corrections and make statistical studies. We press into use, for the benefit of our services, such new scientific technique as operations research, work study and so on. We prepare other type of services such as training, advice and application of psychology and other scientific disciplines to various problems which the Services meet and where they need assistance from R&D Organisation...”.17

He followed it up by stating that for DRDO to meet its obligation, “...we have to have in the Defence R&D Organisation, a wide and rather odd

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17Reference 12, p. 6.
assortment of ‘Scientists’. Under the heading ‘Scientists; we have physicists, chemists, mathematicians, economists, statisticians and so on. And then the scientists are mixed with the technologists. We have Army, Naval and Air force Officers and .... we have Administrative officers as well in the Organisation of Defence Research and Development. Such a motley crowd, if I may use that expression, today constitutes what the Government brought into existence some years ago...” 18

To those scientists who had earlier joined the Defence Science Organisation and were hesitant to switch away from basic research he was explicit in stating that purely basic research which has no bearing on defence is not to be pursued in DRDO. He made it clear that since the resources invested in DRDO are from the total defence budget, the work of the DRDO laboratories should have a bearing on either the immediate or long range needs of the defence. 19 A year later he reiterated by stating that “so far as Defence R&D is concerned, our main task is to carry out applied research. However, we should not neglect basic research. It should be a subsidiary activity, to the extent necessary, to keep the scientists alive, to keep their professional status at a high level and to provide the necessary backing for the objective oriented task which we have to perform...” [10th Annual R&D Conference, Hyderabad, 1967]20. Thus, he set firm guidelines for the Organisation to pursue namely, applied research and development directed towards defence applications.

It is worthwhile to note that by 1969, the equipment oriented laboratories started to veer around the need for taking up applied research before the formulation of the General Staff Policy Statement or the QR. The tremendous technological advances that were taking place in the USA in electronics and aerospace with the US Department of Defence as the technology driver, led to many new concepts mainly to improve lethality, range, and accuracy of weapons, range, resolution and accuracy of sensors and improved communications for strategic and tactical scenarios. For the electronics laboratories of DRDO the opportunity to take up contemporary equipment development came about as an aftermath of the Chinese invasion of 1962 when the Services went for modernisation of their communication systems and sensors. The technological advances in this area had made it

18 Reference 12, p. 5-8.
19 DSL Advisory Committee. R&D Digest. 1966, 6(10).
20 Reference16, p. 6.
possible for them to conceive of solutions which were not linear extrapolations of their present holdings. The Army proposed Plan, AREN (Army Radio Engineering Network) for tactical communications and the Air Force decided on the ADGES (Air Defence Ground Environment System) plan for radar coverage of the country with tropo scatter and microwave terrestrial systems for communication. The scientific and technical community participated in their deliberations for the Plan AREN (communication) for the Indian army and for the Plan ADGES (radars) for the Indian Air Force. Both of these concepts were state-of-the-art at that point of time and would provide the Services with a quantum jump in their capabilities. These were not mere extrapolations of existing equipment and to a large extent required assistance from the scientific community to link the technological advances that were taking place, their potential as well as constraints and to explore the possibilities of new architecture at the system and at the equipment levels. The projects arising out of these which were undertaken by DRDO were high value for the services, innovative in development and would result in the state-of-the-art equipment/system. LRDE which was one of the foremost equipment oriented laboratories in DRDO and which was involved in the formulation of concepts and experimentation that was being carried out for the Plan AREN for the Army, recorded the following in 1969. “In electronics, the undertaking of equipment-oriented development projects cannot entirely depend on the availability of Qualitative Requirement from the Services.... the Services cannot realistically visualize and formulate in time their futuristic requirements in detail, unless they are made aware of the potentialities and the impact of the changing state-of-the-art. This is done by demonstrating to them experimental models of equipment, systems designed by R&D as a result of their continuing system studies and simulation in the laboratory. In fact, the QRs get evolved and finalised as a result of continued dialogue between the designer and the User...” 21 The repeated emphasis by the Scientific Adviser that the work in DRDO laboratories need to be oriented to meet the needs of defence also had an impact on the techniques/research oriented laboratories. Though the scientist was still the originator of the project, the scientist and the laboratory found that higher priority and more resources would be made available if the Services showed enthusiasm and endorsed the activity. Therefore, these laboratories also shifted their stance and chose more and more projects of relevance to the Services and attempted to involve them at early stages.

On the part of the Services also, there was a growing realization that the Services would have to be guided by the expertise of DRDO for projecting the futuristic requirements of weapon systems. It is in this connection Lieutenant General KN Dubey, Master General Ordnance (MGO) urged the DRDO to considerably step up the dissemination of technical intelligence available with DRDO on the type of equipment and futuristic thinking in the more advanced countries to aid the Services in spelling out their futuristic requirements. Rear Admiral KL Kulkarni, Chief of Materials (COM) Indian Navy brought out that the Navy was embarking on a programme of warship construction for which it would need tremendous support from DRDO and urged that scientists and servicemen would have to work together and establish a two-way traffic of problems, trials, feedback and new ideas.

Dr Bhagavantam tried to put across to the politician and to the bureaucrat alike that DRDO is one link, though an important one, in the long chain of many links for design, development and manufacture of defence equipment. He outlined the modern concept of defence thus, “In modern concept, the fighting man does not have the sole responsibility for defence but he consists naturally the front or the key or what we are used to call the ‘teeth’ in this business of defence. Following ‘teeth’ comes ‘tail’ called the tail of logistics, which is concerned with the supply of all the wherewithal by which the fighting man is able to live, fight and move, i.e., the supply of food, clothing and all the munitions of war. To maintain the logistics, calls for a powerful industrial base which has to produce a lot of things to feed the channel that flows from the interior of the country to the forward areas. The industrial base in its turn, has to be kept at a certain level by the technology and engineering which flourish in the country. The scientist and technologists are produced by the universities and the technical institutions which for their proper functioning require the support of the people and the leaders. Thus, there is a long chain starting from the fighting man, going into the industrial base, the technology and engineering, the research scientists, the universities and the people, i.e., every important sector of community is drawn in this whirlpool of total conflict. We have to get fully tuned in this country to this modern concept of total defence by paying attention to every aspect of it.” In effect he was highlighting that education, training in the acquisition of both analytical and experimental skills for R&D and an industrial infrastructure which is keeping pace with technology advancement need attention.

23 Reference 12.
2.7.4 Project Selection & Planning

In the process of getting the DRDO focused on defence needs, measures were taken to reduce the number of projects and enhance the scientist/project ratio, this was met with partial success. Dr Bhagavantam drew the attention of the Directors of the laboratories and their scientists to this and brought out that individually these projects were of little significance to the Services and the sum total of their contribution was small compared to the effort needed. Though an attempt was made to reduce projects of potentially low contribution, overall the number of projects increased from about 850 in 1963-1964 to about 1050 in 1967-1968. One reason was that in this period, the number of laboratories and field stations had increased from 27 to 35 and the project plus equipment expenditure had gone up from about Rs. 1.5 crores in 1963-1964 to about Rs. 4.0 crores in 1967-1968. Thus, even though the number of projects had increased, the average expenditure per project had more than doubled. Another reason for the number of projects not having gone down was the longer times taken for Staff and Development projects to be sanctioned for the equipment oriented laboratories if the formal procedure such as the DDPIL-69 was followed24.

Simultaneously, an orderly procedure was being evolved and put in place for undertaking projects. A project could be initiated in four different ways. The first category was the laboratory/establishment projects under powers of the Director. These were small projects to gain lead time and might involve investigation/analysis or even small hardware to generate specific knowledge/data or to gain hands-on-experience on specific aspects. In this case, work could be initiated even before the staff or the development project was proposed. The next category was the development project under the powers of the Director General R&D but these had to be linked either to a long term requirement of the General Staff Policy Statement or to a potential defence application. If one of the Services expressed interest in such an application, it would get preference over others on which there had been no interaction with the Services. These projects would require higher resources and their purpose was to establish the feasibility of the technology or technique or process in defence systems. They took longer time for sanction than the laboratory projects as these would be examined by the concerned Technical Director, interest of the

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Services would be gauged by interaction and sometimes even commitments were sought. The third type of projects were the Staff Projects which were based on a Qualitative Requirement/Air Staff Requirement or a similar commitment. These projects did require greater time because sanction had to be preceded by dialogue-discussion between the DRDO laboratory and the User Service about the technical characteristics, the operational parameters and the time frame and cost of development. The fourth category of projects were the projects allotted to the DRDO by the Defence Minister’s Scientific Advisory Committee with defined system, technical and performance characteristics, specified time and funds for completion but with funding external to the Organisation. There would also be a commitment by the Service in terms of quantities for production in the form of a budget provision. By 1966, a uniform procedure for all DRDO projects was evolved so that the numbering of projects, the format and contents of documents for new project sanction and the format for reporting of progress on current projects followed a standard pattern.

The greater involvement of the Users with the DRDO, the technological advances that were changing weapon systems and the increased outlay needed for DRDO led to the activities of DRDO being subjected to planning and control and evaluation just as any other government function. This was in keeping with the global trend of recognizing that the problems and operations of basic research are different from that of development and that activities concerning applied research and development especially dealing with hardware concepts is more amenable to application of management tools for optimization of effort. As each laboratory gained more experience in dealing with the Users, the necessity for taking up projects ahead of User’s requirements forced the laboratories to be actively involved in forward planning and dovetailing the plans into the Five Year plans of the Ministry and the country. There was a growing realization within the technology and within the equipment-oriented DRDO laboratories that lead time was necessary for launching a major effort which had been signalled by Dr Bhagavantam in 1964. He laid great stress on the necessity for forward thinking and urged the Directors and the senior scientists to look beyond the current needs of the Services and prepare long term plans sufficiently in advance. Accordingly long term planning covering a five year period, 1964-1969, was first introduced in DRDO in 1964. This was a bottom-up approach to long-term planning since each laboratory was required to prepare a plan and phase it out over the period 1964-1969 on an yearly basis. Initial efforts in projecting only the

resources needed for build up of facilities, equipment and manpower had to be expanded to cover yearly outlay for current as well as for new projects proposed to be undertaken in the five year period. After further refinements to link the proposed projects to anticipated User needs and to the status of User interaction and elimination of duplication in projects among laboratories, the plans had to be again revised to cover the period 1967-1972 to synchronise with the national Five Year Plan period\textsuperscript{27-30}.

The Five Year Plans of the laboratories were finalised in consultation with the Services and the Ministry of Defence. The individual plans of the laboratories were consolidated as the DRDO plan and integrated into the Five Year Plan of the Ministry. The plan outlay was Rs. 116 crores with a foreign exchange content of Rs. 10 crores and an investment of Rs. 17 crores for laboratory buildings and residential accommodation which was long overdue. The implementation of the plan meant that the DRDO through each of its laboratories had to plan in greater detail its activities to meet the planned targets. For each of the projects above a monetary limit, the newly introduced PERT (Programme Evaluation and Review Technique) and CPM (Critical Path Method) replaced simpler time charts and also enabled monitoring of the major projects. In addition, a standardised format was introduced for budget estimated by the laboratories. The laboratories were required to submit the budget estimates six months before the beginning of the financial year and furnish justification for each facility, test equipment and machinery. This could only be done if the scientists at the laboratory carried out a systematic analysis of their project activities and worked out the manpower, material, test equipment and component needs in greater depth than hitherto. However, planning to such depth at the beginning was fraught with uncertainties and also cut into the valuable time of the senior scientists. Further, even though sanction would be obtained for the total financial resources as well as early requirements for a project, this did not guarantee that the financial resources would be made available yearly as planned by the laboratory. Yearly allocation, rupees as well as foreign exchange, was subject to changes which was not possible to predict. Hence, the paper work was burdensome especially as changes and revisions had

\textsuperscript{27} Proceedings of 7th Annual R & D Conference, Hyderabad, 1964.  
to be carried out often, due to uncertainty in foreign exchange allocation, variations in price quotations of imports, and due to changes in original goals and scope of projects.

Even as the Five Year Plans were being finalised, the Scientific Adviser at the 8th Annual R&D Conference in 1965 at Bangalore announced the decision to strengthen and expand activities in the areas of electronics, missiles and rockets, aeronautics and naval research and development. His vision and foresight in giving strategic direction to DRDO’s work and in providing resources to expand R&D activities in these four technological areas paid dividends by paving the way for the Secondary Surveillance and the INDRA radars for the ADGES Plan, the mobile digital switching systems, TIDEX (Time Division Electronic Exchange) and AES (Automatic Electronic Switch) for the Plan AREN (Army Radio Engineering Network), several generations of cipher and speech secrecy systems, the APSOH (Advanced Panoramic SOnar Hull-mounted) for the Indian Navy IGMDP (Integrated Missile Development Programme), and LCA (Light Combat Aircraft) development among others, nearly twenty years later.

It is interesting to note that at the 12th Annual R&D Conference in 1969, the topic of laser was discussed from the point of view of initiating R&D activities. During the discussions it emerged that if work in this area has to be launched then it would have to be on a wide front starting from the devices such as laser diodes, photo diodes, components such as couplers, power dividers/combiners, subsystems such as laser sources, photo-detector amplifiers and equipment design and development for a wide range of possible applications. The Conference came to the conclusion that such an effort would cut severely into the resources of the DRDO without payoff in the near future. Dr Bhagavantam therefore ruled that prior to launching any effort in this area, DRDO should prioritise the activities from the point of view of immediacy of application to the military, clarify our own ideas in such applications, and interact with the Services. This is a clear instance of participative decision making through dialogue-discussion which contributed to greater cohesion and understanding among Directors.

2.7.5 Integrated Procedure for Development & Production

Three different customers, several technology and science fields, different outputs (reports, product, process), several categories of industries (departmental undertakings, public sector and private sector)
with different requirements and conditions for technology transfer, stringent performance requirements and first generation designers was the picture of DRDO and its activities when Dr Bhagavantam took over as full time Scientific Adviser in 1962. In such a situation any problem faced would be specific to a laboratory and to a specific technology/science field. This would prevent effective communication and exchange of information among the laboratories to improve the R&D response. Design and development for a customer who is outside one’s own department and transfer of technology for bulk production to an outside manufacturer was being attempted for the first time in the country and therefore it was a new territory for all the parties involved in the process. The knowledge about the activities and the processes involved in the development and production of defence equipment in the UK due to the earlier close association of the Indian Armed Forces was useful in getting started but significant departures were necessary in many cases. For example, in the case of electronics equipment, the industry having no R&D of their own did not involve itself actively till the equipment was designed, developed and accepted by the User, whereas in the UK, the hardware was developed by the industry right from the beginning. Such departures and the inexperience of all the parties involved in the process led to many difficulties regarding rights and responsibilities, relaxations for deviations from the written document and so on. These were resolved by a dialogue-discussion process so that our own methodology for design, development and production of military equipment could be hacked out of the thickets of differing concepts, opinions and prejudices, and some measure of understanding between the Services, the DRDO, the bureaucrat at the Ministry and the public sector production agencies/ordnance factories was reached. For each industry sector such as armaments, electronics, automobile engineering, mechanical engineering and so on, there was commonality in the overall procedure for design, development, production and inspection of hardware for Defence but they differed in the details due to the industry structure, the technological expertise of the firms in the industry and the rate of technological advance in that particular sector.

One of the first technology sectors within the defence ministry to attempt codification of the procedure in the form of a guideline document was electronics. The first version of such a document was prepared in the very first year of the DRDO namely 1958. Based on the experience that was gained in the next four years a modified version came into existence in 1962. A third version was made available in 1964 and subsequently a
comprehensive document named DDPIL-69 was issued by the Ministry of Defence. Shri MM Sen, Secretary Defence Production prefaced the document in the following manner. “...The design, development, production and supply of increasingly complex electronic equipment systems will require optimum coordination of the efforts of the numerous agencies involved in such programmes. Such coordination cannot be arranged through the medium of a formal procedure, however exhaustive it is made. If all the agencies involved realized that the tax payer on the one hand and the Service on the other, are looking up to them to design, develop, produce and supply military equipment systems expeditiously and economically, the guidance provided by this procedure would be adequate...”.31 The DDPIL-69 document consists of three parts, Part I dealing with the separate procedures for design and development by the DRDO, design and development by a public sector under a development contract and design and development on a proprietary basis. Part II lays down the guidelines for production in public sector and in departmental undertakings while Part III concerns procedures for inspection. It also lays down the responsibilities of the different agencies involved and the type of documents and drawings to be prepared and the mechanism for monitoring the progress. Even though the DDPIL-69 had shortcomings, its main contributions were in the systematization of the steps, elimination of arbitrariness and lessening of confusion in the development process and in the technology transfer for production, that was prevailing in the civilian sector between R&D and the manufacturer.

Early in the 1960s, a few instances came to light where a hardware had been successfully designed and the Services had expressed their needs and were prepared to place orders but no recognised production agency could be found willing to manufacture. Mostly, the reason was that the Services order was not economical for the recognized manufacturer to launch production within the price targets. The only alternative in some of these cases was to import even if the DRDO effort had been successful. The first case that was discussed in this context was that of military store Charge Line Mine Clearing successfully developed by the ERDL (now HEMRL) which would have to be imported unless a way was found to get it manufactured within the country. In this case no production agency within the country had the necessary facilities and they would have to make

31 DDPIL-69 Document.
investments as well as need additional time for completion. A policy decision
was taken that DRDO would have to extend its activities to small scale
production to fulfil the needs of the Services in such instances lest the
development effort go waste. It was also decided that costing should include
DRDO overheads in addition to cost of materials, additional test equipment/
facilities and direct labour. Overhead was charged as production was an
exceptional activity of DRDO. Over the years many laboratories set up pilot
plant facilities and were successful in producing and completing the small
orders on the equipment developed by it for the Services within the price
limits. These activities did not occupy the centre stage in the laboratories
except that the Director and some of the senior scientists had to spend part of
their time in management and review. An idea of magnitude of the effort
involved can be gauged from the pilot plant activities of LRDE which in a
period of 18 years (1967-1984) had orders worth Rs. 9.6 crores for 32
hardware items and 17 types of Nickel Cadmium battery packs.

For the technique/science oriented laboratories, the scientist
initiated a project based on a new idea, new material, new component,
new process, new technique or new technology and after interaction with
the Service on a less formal basis if necessary. The outcome could be a
report, a process, a component or a subsystem. In the case of a process or
a hardware, the commitment of the Services to use or even to try it would
be tentative or it might not exist at the initial stage. The interaction was at
the Services echelons lower than the Services Headquarters and it would
continue till the performance of the product or process has demonstrated
its promise or the expectations did not materialise. In either case, the
scientist or the laboratory director would take the decision and the input
from the Services was one among others which helped in decision making.
In the case where the expectations were not matched by performance, the
chances of continuing it would reduce drastically and most likely the
activity would taper off. The effort would not be considered as having
failed but as a necessary step in the learning process of R&D. In case the
results are judged to have matched the expectations, DRDO would
formulate a Provisional Technical Specifications and raise the level of
interaction to Services Headquarters. Depending on the quantum of
investment to be made, the urgency of the need, and the degree of
satisfaction of the User about the performance, the formal procedure of
issuing a Qualitative Requirement might be followed or the informal

32 Reference 16

33 Past and Present Performance, Future Plans & Expectations. Electronics and Radar
approach would be continued with the Services Headquarters being fully in the picture and work continued to its logical end. Over these years, the sharp conceptual divide between the equipment oriented laboratories and the technique/science oriented laboratories in their approach to R&D began to blur as the mutual interaction between these two groups as well as their experience of dealing with the Services increased. Though no single procedure was possible for technology oriented tasks as well as equipment oriented tasks across all technology fields for design, development and production, there was a lot of commonality in the processes. Also there was better understanding within the organization about the processes involved and adapted for the different Services and across technology fields.

2.7.6 Management, Review & Evaluation

Simultaneously with the formalisation of procedures for initiating projects at the laboratory”, the management and review procedure was also being systematized. As long as the projects were small, the number of laboratories were less, the working of the laboratories dealing with technology was reviewed annually by the Chief Controller R&D along with the Technical Director and other functionaries from Headquarters who dealt with personnel, administration, and purchase. The Technical Director was kept abreast of the progress in projects by periodic project progress reports and during visits to the laboratories so that the CCR&D was briefed fully about the work that is being carried out. The problems and difficulties of the laboratories were presented, discussed and wherever possible decisions were taken at that point of time. Besides these, the high ranking officers from specific Services such as the Signal Officer-in-Charge, Army Headquarters or equivalent would visit the laboratory, and would be acquainted with the progress and discuss issues relating to their requirements. For science laboratories the Deputy Chief Scientist reviewed the progress and working of the laboratories. This was a simple and effective procedure but with increasing number of laboratories and projects this could no longer be continued. For the equipment oriented laboratories, development panels were introduced for monitoring and reviewing the progress. These had representatives from the three Services, maintenance agencies, inspection agencies, main production agencies, director of the concerned laboratory, corresponding group director of DRDO and so on. These were chaired by a senior military officer of the branch and the Services that had the maximum interaction
with the laboratory. These panels met at least once a year but more often twice. For each of these meetings, the concerned laboratories and the production agencies would prepare detailed briefing papers containing the actions taken on the earlier decisions of the panel, the progress done in period between two meetings and the difficulties that have been faced in progressing the work. The discussions mostly centred around the Development and Staff projects about progress made, the relaxations sought in specifications, conducting of the User trials and the results, documentation for production and the interaction between the different agencies. These were intense and interactive but extremely productive because in most cases decisions would be taken and these were implemented by the participants. In the case of laboratory projects the progress would be reviewed, User reaction as well as interest in continuing, foreclosing or furthering the work ascertained and the next logical step outlined. For example, in the electronics ‘area’ the Electronics Development Panel (LDP) was constituted in 1962 and held its first meeting in July 1962 with Major General BD Kapur as the Chairperson. Besides the formal development panel meetings, the periodic visits of senior ranking officers from the Services helped in clarifying difficulties and clearing bottlenecks.

For major Staff projects for which a QR had been drawn by the Services, or those which had been authorized by the Defence Minister’s Scientific Advisory Committee, Steering Committees with a top level Service Officer as Chairman and with members at the top level from the concerned Services, the production agencies, inspection agencies, the Ministry of Defence, the technical director and other functionaries in charge of finance, administration and stores the finance, and the director of the concerned laboratory, were formed. Because of top level representation, these committees were found very effective in cutting down delays that had been encountered in fabricating pre-production models at production agencies, User trials, placement of orders for bulk production and so on.

For the techniques/research oriented laboratories, Advisory Committees or Research Committees were set up with an eminent scientist as Chairperson, the membership comprising of specialists from other science and technology organisations, academic institutes, group directors and other functionaries from DRDO HQrs and representation from the three Services. The atmosphere in these meetings was more relaxed and somewhat collegial as there were fewer projects of immediate interest to
the Services and the topics discussed were also not of immediate interest to them. The periodicity and the regularity of meetings of these committees, however, varied widely. For example, in the case of the Defence Science Laboratory, the first meeting of the DSL Advisory Committee met in July 1966 with the Scientific Adviser as the Chairperson. In this case, the Committee reviewed the progress of research and development projects undertaken by the laboratory and scrutinized the requirements of the laboratory in respect of electronic materials and equipment needed for conducting R&D in this area. Dr Bhagavantam took advantage of this occasion to give direction to the work of the scientists by reminding them that purely basic research which had no bearing on defence is not to be pursued. On this occasion, he made it clear that only two types of projects could be undertaken by the laboratory and these were, “User” Projects initiated by the Services after interaction and “R&D” projects initiated by the scientists based on the forecast requirements of the Services for the next 5 or 10 years. 

Based on the recommendations of the Scientific Advisory Committee to the Cabinet, the mechanism of a Governing Council was introduced in the last years of the 1960’s for nine laboratories. The Governing Council was chaired by an eminent scientist outside of DRDO with specialist members from academic institutions, other Science & Technology Organisations, the concerned technical director and other functionaries dealing with finance, personnel and stores at the DRDO Headquarters, director’s representatives from the Services and the defence public sector undertakings.

From the point of view of top management, evaluation of the performance of each laboratory would help in locating the science and technology areas as well as the laboratories that would need more attention from the Scientific Adviser, the CCR&D and the DCS. Performance evaluation of the laboratories based on input/output ratio, that is, inputs being cost of equipment, materials, components, direct manpower employed and the output being the value of the hardware successfully developed and produced, was accepted as the starting point for equipment oriented laboratories. It was also recognized that a different evaluation method would have to be devised for technique/science oriented laboratories since there would be difficulties in quantifying their output in terms of orders placed on production agencies. In view of the
doubts expressed by some Directors that even for equipment oriented laboratories, the input/output criterion could discourage the scientists to take up projects with higher technical uncertainty even though the Services might benefit more, and that further strain would be imposed on the scientists for maintaining up-to-date and detailed records of hours spent by the scientific and technical personnel on the projects, it was decided that evaluation based on the present criterion would be applicable only to equipment oriented laboratories and a review would be carried out after gaining experience. It is not surprising that DRDO faced difficulties in evolving a common metric for the output of its laboratories. Even in the 21st century a common metric that applies across the R&D continuum is yet to be evolved.

2.7.7 Interaction with other Organisations

The integrated procedure for development and production of military store did not specifically contain provisions for involving the private sector industry in development. When such a necessity arose in 1968, DRDO had to evolve a procedure for development contract with private sector and get the approval of the Government of India. If it had not done so it would have been subjected to the normal procedure of involving the Director General Supplies and Disposal (DGS&D) of the Ministry of Supplies who were considered as the experts in contracts. The DGS&D had their own procedures and rules which were not suited for development contracts and their time schedules normally did not accord priority for development contracts of DRDO. The draft contract was discussed at the 11th Annual R&D Conference in May 1968 and finalized. The guiding principles advocated a procedure that encouraged competition and required on the part of the DRDO laboratory to make full enquiries into the capability of the firms to undertake the development work of the desired quality within the time frame and their financial soundness to manufacture the desired numbers. It also outlined the review and monitoring mechanism, the financial limits and other general conditions governing placement of development contracts. The contract also permitted the DRDO laboratory to assure the potential partners that on successful completion of development, they would be

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awarded of 80 per cent of the initial bulk orders. On subsequent orders, the government was free to encourage competition to get optimum price for the Services.

The linkages with Universities and other R&D institutions were maintained through Grants-in-Aid-Schemes which enabled the DRDO to get specific experts/specialists at these institutions to take up investigations in topics of interest to defence. During the Chinese aggression of 1962 a steering committee was set up with CSIR to carry out investigations and develop processes and products having defence applications so that indigenous production was made possible. This resulted in pilot plant production of 28 items of defence interest by CSIR. In the 11th Annual R&D Conference, the overall results of the Grants-in-Aid Schemes was reviewed and it was found that while the collaboration with CSIR was successful, it was not so with the academic institutions. Since most major projects were classified as SECRET, difficulties were experienced by the DRDO laboratories to take the investigators into full confidence and provide details. This also resulted in the dearth of worthwhile projects with clearly defined objectives for the academic specialists to work upon. In addition, there was lack of enthusiasm on the part of the investigators at the educational institutions due to the complexity of administrative procedures and consequent additional paper work. The fact that DRDO would not be able to build expertise in all areas of science and technology that was of relevance to defence, dependence to some extent on scientists outside of DRDO will be needed. Thus, it was decided to continue the Grants-in-Aid Schemes with simpler administrative procedures, clearly defined objectives, higher financial limits, and closer linkages with the DRDO laboratories.

2.7.8 Human Resources Management

The human resource at the time of incorporation of the DRDO was a motley crowd with diversity in the recruitment procedures, service conditions, training, promotional opportunities and advancement.

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2.7.8.1 Service Officers

There were two main streams namely, the personnel from the Armed Forces and the civilian stream consisting of scientists/technologists, scientific/technical assistants, skilled workers and personnel for manning administration. Of the three Services, most of the personnel were from the Indian Army who had come into the DRDO through the TDEs. At the time the DRDO was formed, the value of these Service personnel to the Organisation was in their familiarity and knowledge about the usage of current military equipment and about the immediate future requirements of the Armed Forces. In addition, there were specialists from the Armed Forces in aeronautics, explosives and medicine whose expertise was valuable for initiating R&D activities in these areas. The bulk of the Service personnel were Commissioned Officers who moved into the equipment-oriented laboratories either as heads of the laboratories or as heads of divisions with the civilian technologists at lower levels. At the time of formation of DRDO, they were on deputation and since their services were required, those who wanted to continue had their deputation period extended. By 1964, it was decided to have a complement of Service officers permanently seconded to DRDO and they were permitted to retain the service conditions and ranks of the military instead of being absorbed into the DSS. The induction of Service Officers into the DRDO on a permanent basis was also finalised. It required these officers to come on tenure in the first instance and on completion of tenure go back to their parent Service. It is only after completing at least one posting after their return to the parent Service that these officers were eligible for consideration of permanent absorption by the DRDO. Since it was envisaged that Service Officers would be needed for a long enough period into the future, a cadre of permanent Service Officers Cadre was created with adequate career advancement opportunities to attract the brighter and younger officers from the three services. The number of posts for the cadre was approximately 20 per cent of the total number of Class I Gazetted Officers sanctioned for DRDO with a disproportionate number of posts being at levels higher than Principal Scientific Officer [Scientist D]. Thus, within the DRDO, for similar responsibilities and work there would be two types of service conditions.

2.7.8.2 The DSS Cadre

The civilian qualified scientists and engineers of the newly formed DRDO were already part of the Defence Science Service (DSS) which had
been constituted in 1953. The DSS contained both Class I and Class II Gazetted Officers posts and a permanent strength of 342 posts. These covered all “appointments in various establishments under the Ministry of Defence connected with scientific research and development or teaching”. Thus, when the DRDO was formed in 1958, the personnel of the DSS were now distributed into the DRDO, the organisation of the Director General of Inspection (DGI) and the teaching institutions of the Services not directly under the DRDO. Mobility in and out of the DRDO for the DSS cadre had to be provided. As each new laboratory was set up, on promotion, civilian scientists belonging to the DSS cadre and working in organizations other than DRDO could move into it just as it would be in Indian Administrative Service or in any other similar Service. Unfortunately, as the specific skills needed in R&D are highly differentiated, the experience of those who had been serving the Inspection organization or in teaching devoid of research component was not necessarily useful in the higher job positions within DRDO where guiding, directing and managing R&D activities was paramount.

After 1958, posts higher than the Deputy Chief Scientific Officer (DCSO) were added to the DSS cadre and it was designated as Class I service so that talented scientists and technologists could be attracted to DRDO. These additional posts were aimed at getting scientists and engineers of eminence to head the laboratories, LRDE, DMRL, ADE, ARDE, and DRL (stores), DSL & Weapons Evaluation Group (later became DRDL). However, till 1970s, four out of the seven higher posts were occupied by the Service Officers. By 1965, the strength of the DSS was about 1200 mainly because as each new laboratory was formed, a Peace Establishment (PE) was sanctioned for manning it. The component of civilian scientists were made part of the DSS cadre.

When the DSS cadre rules were promulgated in 1953, it was brought under the purview of the Union Public Service Commission (UPSC) for direct recruitment and for departmental promotions of the civilian scientists and technologists. As the UPSC was the agency that was charged with the recruitment for all Class I services of the government of India, it had a very busy schedule and asked the government departments to supply the necessary information several months in advance for scheduling the examinations and interviews for selection. The agency had its hand full with recruitment drives for such major All India Services as

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40 Gazette of India Notification Issue No.15, dated April 1953, Part II-Section 4.
IAS, IPS, ITS and accommodated relatively smaller cadres such as DSS in the lull periods between their major recruitment activities. The result was a time delay of several months between the declaration of vacancies by the laboratories and the holding of the interviews by UPSC. Several more months would expire before appointment orders would reach the selected candidates as each of them had to be subjected to security clearance by the police of the state in which the candidate is resident. In 1965, there were as many as 400 posts vacant out of a total of 1200 posts in the DSS cadre. In such rapidly expanding fields as electronics, solid state physics, aerospace, several organizations within the Government as well as private sector were competing for the services of the same set of personnel and the time delay in the DRDO resulted in more than half of the selected candidates finding employment elsewhere.

The serrated pyramid (SP) system based on the fact that skills gained in the process of R&D are highly differentiated and specific science/technological skills in one field (microwave engineering) are not of much use in many others (automobile engineering), was introduced around 1962 for departmental promotions. Each scientist belonging to the DSS was allotted a specific science or technology field such as physics, chemistry, electronics and so on depending on his qualifications and experience and his promotion to higher posts would be in the same pyramid. It created greater disparity in promotional chances of civilian scientists belonging to different science and technology streams. The disparity arose because in fast growing technology sectors such as electronics and aerospace, scientists jumped ahead of their counterparts with SP subjects such as chemistry, mathematics and life sciences. Within two years of the adoption of the SP system, DRDO set up a Committee of Directors to re-examine the question of SP subjects in all its aspects. The Committee's main recommendation was to rationalize the promotion policy of the DSS by proposing a unified salary scale from Junior Scientific Officer to Principal, Scientific Officer with time scale promotions and with provision for accelerated promotion for really talented scientists up to the level of Principal Scientific Officer. However, the recommendations were turned down by the Ministries of Defence and of Finance on the grounds that there might be repercussions on other S&T organizations41.

The concept of Peace Establishment for each of the DRDO laboratories was adopted from the military services where during long

periods of peace a small standing army was maintained. During the
periods of conflict or war which would always be short compared to the
periods of peace, the small standing army could be expanded several folds
as was done during World War II for the Indian Armed Forces. In the case of
DRDO, it meant that each laboratory be staffed with a small complement of
personnel who have permanent service and form the core. When major
projects were undertaken, additional manpower had to be added for the
duration of the projects. There were two disadvantages. First, it
discouraged many talented scientists and engineers to join DRDO and
prefer other S&T organizations such as the Departments of Atomic Energy
and Space where permanent positions were available. Second, in most
cases as the duration of major projects was of the order of seven to ten
years, the additional manpower hired for the projects could not be laid off.
The laboratories were required to go through another round of paper work
to continue them on another set of projects until they were made
permanent and absorbed. The concept borrowed from the Armed Forces
of the peace establishment had to be given up in the 1980’s. The handicap
of being part of the government set up is very much evident in the delays
and denials experienced by the DRDO in many of the new processes
essential for building an innovative environment. In the eyes of qualified
scientists and engineers, the personnel policies of DRDO appeared to be
static, rigid and less enlightened in comparison to those of the
Departments of Atomic Energy and of Space.

2.7.8.3 The Non-Gazetted Cadre

The DRDO inherited two streams of technical assistants, the
Foreman downwards from the erstwhile TDEs and the Senior Scientific
Assistants downwards from the Defence Science Organisation. These two
streams could not be merged at the time of formation of DRDO because the
qualifications, the pay scales and the conditions for departmental
promotions were not the same. In the newly formed institutions which
were called establishments (for example CVRDE, VRDE) the Foreman
stream was introduced while in those institutions which were called
laboratories (for example, DLRL, SPL), the non-gazetted technical stream
was mostly formed of Scientific Assistants. There was no transfer of posts
or personnel between the two streams and even in each stream, movement
of personnel from one laboratory to another was possible only with mutual
consent of the two heads of the establishments/laboratories. Since there
was no centralised recruitment, each head of the laboratory/establishment
was authorised to advertise, recruit and appoint the non-gazetted personnel. In the early years of the DRDO, across the science/technical disciplines and depending on the location of the laboratory/establishment there were variations in the procedures and qualifications of the personnel who were recruited. Hence, a common procedure was evolved in 1968, which laid down the qualifications for direct recruitment, eligibility for promotion and the procedure for recruitment. While this was an attempt to streamline the method and qualifications for the recruitment and promotion of the NGO cadre in the organisation, it did not fully address the problems faced by personnel wanting to move from one laboratory to another or the \textit{inter se} seniority at the time of promotion in both streams to the Junior Scientific Officer post.

\section*{2.8 PERFORMANCE BALANCE SHEET}

Even as it was expanding to set up new laboratories to cover the important fields of science and technology of interest to defence, and striving to integrate the diverse streams of personnel to form a cohesive organisation, the DRDO scientists were able to take up design and developmental activities for the Services and in this process buildup the experience and expertise needed for more complex tasks. The activities ranged from minor tasks of import substitution and modifications, reconfiguring and adapting imported systems for new applications to design of new equipment. A representative sample of the equipment, processes and items that resulted from these activities in the period 1958-1969 are outlined in the following paragraphs.

\subsection*{2.8.1 Armaments}

The effort was focused on the development of a new mountain gun and explosives/ammunition for the guns and other weapons held by the three Services. The development of the new field gun for use in mountainous terrain, the 75/24 Pack Howitzer and its ammunition was a major effort. It had to be designed for towing by a vehicle and it was required to be disassembled and carried on mule backs without difficulty. The development was completed, successfully tried out by the Army and was accepted for production. As part of the development process, special range and instrumentation facilities were also established for full scale range and

\footnote{Gazette of India. Statutory Rules and Orders issued by the Ministry of Defence, New Delhi, 6th July 1968, p. 274-279.}
accuracy as well as for endurance trials. Transfer of technology to the manufacturer was effected by way of drawings, physical model and placement of the designers at the Gun Carriage Factory. Non-detectable antitank mine, and mine clearing equipment were also designed and developed. The mine clearing equipment was produced in requisite numbers by setting up a pilot plant within DRDO. In addition, the other contributions were, tracer ammunition for 7.62 mm calibre weapons, propellant for 105 mm antitank ammunition, smoke ammunition for mortars and plasticised white phosphorus for filling smoke shells/bombs. The representative list of significant contributions would be complete with the inclusion of the development of escape aid cartridges, signal cartridges, distress visual night signal cartridge for Air Force, drill mines for the Navy, drill and practice version of antitank and antipersonnel mines, indigenous propellants for light and heavy mortars, ammunition for defeating armour for different types of gun, air-to-air and air-to-ground rockets, lead-zirconate-titanate crystals for utilization in fuses for ammunition. The lead-zirconate-titanate crystals is a dual-use item, as it finds application in crystal gauges in civilian applications.

2.8.2 Aeronautics

The main thrust was in the development of facilities and expertise leading to the design and development of the power plant, the gas turbine engine for aircraft. An important contribution of this group was meeting the challenge of equipping the HAL-designed HF-24 combat aircraft for the Indian Air Force with a power plant that would enable it to meet the performance specifications. Originally, the aircraft was designed around an engine which was expected to be developed by a foreign firm to meet their requirements. In the course of the Indian project, the foreign firm dropped the programme for development of the engine and the Indian designers were left with an engine, Orpheus 703, which was under powered for the requirements, the airframe was designed to meet. In view of the shortage of time, the DRDO scientists and technologists within a record time of two years, found a solution and proved by analysis and experiment that an addition of an afterburner to the Orpheus 703 power plant, would be adequate for the aircraft to meet the performance it was designed for. An HF-24 aircraft was fitted with the reheat developed by DRDO to the power plant and successfully flown for about 250 flights. The reheat of the Orpheus 703 engine was a success.

43Interview with Lieutenant General SG Payara, Retired Former Chief Controller, R&D, DRDO.
44Interview with Shri Arun Prasad, Former Director, Gas Turbine Research Establishment, Bangalore.
2.8.3 Electronics

In the 1950's, electronics components underwent a quantum change from power guzzling vacuum devices to transistors which worked at lower voltage and consumed considerably less power. DRDO took this as an opportunity to design and develop transistorized equipment for the Army. Several types were successfully developed and then manufactured. They range from portable transistorized communication switchboards (manual exchanges), light weight VHF ground-to-air wireless communication set, a forward area HF communication equipment, two types of speech secrecy unity channel doubling units for speech, carrier communication equipment, two versions of cipher equipment for telegraph communication to VHF/UHF log periodic, mono cone and ground plane communication antennas covering the frequency range from 4 MHz to 100 MHz, among others. In addition, portable/mobile generators for prime power, and light weight portable nickel cadmium batteries were successfully developed, produced and accepted by the Army for introduction into Services.

Two types of radars for the Army were also successfully completed. These are, a mobile surveillance radar and a field artillery radar. The latter was configured out of the radar that was being manufactured under collaboration at Bharat Electronics Ltd for a different application namely, fire control. These were accepted by the Army and orders were placed on Bharat Electronics Ltd. Besides these, new projects were initiated for the development of a portable battlefield surveillance radar for the infantry, secondary surveillance radar Mk 10 for the Air Force, sound ranging system for location of enemy guns, radar distance measuring unit, VHF/UHF direction finding equipment for the Indian Air Force, a portable electronic exchange from 40 lines to 120 lines in modules of 40 and a computer controlled nodal switch (Automatic Electronic Switch) for grid communication as part of the Plan AREN equipment for the Indian Army.

These were taken up after extensive discussions with the Services and on their issuance of Qualitative Requirements. Besides these hardware activities, propagation studies in the VHF/UHF range of frequencies including the effect of vegetation were undertaken and based on this data, graphical representations were drawn for ease of utilization by the Services. In the field of devices, projects were undertaken in the areas of semiconductor materials and devices, thermoelectric generators, microwave solid state sources and microwave ferrites. The orders placed by the Services for all the electrical and electronic equipment successfully completed by the DRDO was
in excess of Rs. 15 crores\(^45\). One of the scientists of LRDE, Shri Hari Prasad Jaiswal, was awarded Padma Shri by the President of India for his leadership and contributions to the development of communication system, AREN, for the Army.

2.8.4 Engineering Equipment

The Corps of Engineers of the Indian Army was the main customer for the DRDO scientists in this area of activities. The scientists in close collaboration with the industry and the customer were able to meet the needs of the Corps.

The activities were concentrated towards the development of light metal bridges and power boats for bridging operations, development of light weight water supply pumps, prefabricated shelters for high altitude operations and other engineering equipment. Some of the representative items were, submersible pumps, pneumatic assault and reconnaissance boats, air landing mats, class 30 assault track way, centrifugal pumps, flexible shaft pumping sets, gas welding trailers, two-stroke petrol engines, and high altitude shelters.

2.8.5 Food & Nutrition

The DRDO scientists aimed primarily at developing operational and nonoperational food and rations for the Armed Forces. The operational food and rations required special attention because they have to be provided both in bulk and in packs tailored to meet specific types of military operations, land-based and space-borne, high altitude and extreme cold conditions. These have to be partially or wholly processed items requiring very little preparation before eating. The primitive infrastructure relating to presentation of food in India for hostile environments also required to be upgraded before production can be entrusted to the industry. The food technologists of DRDO had the satisfaction of successfully developing light weight 5-man composite pack rations with indigenous items of food, cocoa-based soft bar with coconut and banana flavours, light weight flexible packs using paper/aluminium foil/polythene laminates for accelerated freeze dried food stuffs instead of tins. It was not a surprise that DRDO food scientists had the unique honour of supplying processed items of Indian dietary to the first successful Indian Everest Expedition led by Lieutenant Commander MS Kohli in 1964.

\(^{45}\) Reference No. 33.
2.8.6 Infra Red Sensors & Optical Instruments

The main focus was on the Army’s requirements for enhancing combat potential in the night for tanks and for navigation of vehicles. A representative sample of the equipment successfully developed and which went into production are, Gunner’s IR (Infra Red) scope sight and Commander’s IR periscope for Vijayantha tank, IR Sniperscope for Infantry, IR Telescope for the Navy, and IR Search Light. In addition, binocular for Vijayantha tank and Universal Mortar Sight for 120 mm Brandt Mortar were successfully developed and technology transferred for production. Further, in anticipation of user’s requirement, work in the area of general purpose laser range finders was initiated. The production orders by the Armed Forces for these equipment exceeded Rs. 25 crores.

2.8.7 Materials

In the area of materials developments relating to corrosion inhibitors, parachutes, synthetics, solar heaters, helmets and so on were taken up and successfully completed. Vapour Phase corrosion inhibitors for protection of small arms, gauges and hand tools, corrosion inhibition treatment for jute and hessian used in packing metallic items, corrosion inhibitor for water cooled engines, and cathodic protection of underground fuel storage tanks were some of the items and processes that were developed successfully. In the area of textiles, flame proofing for olive green cellular shirting, glass reinforced polyester for use in light weight bullet proof helmets, various types of parachutes, container and slings for para-dropping supplies were the major contributions. A solar room heater based on the principle of thermal-siphoning was developed for use in high altitude and extreme cold environments, so that a room of moderate size could be maintained at 20 °C. A series of meteorological stations were set up along the border including at Ladakh. This technique won international recognition.

2.8.8 Medical Research

Some of the important investigations that were carried out are, effect of prolonged stay at high altitudes on physiological parameters, acclimatization to cold and altitude, tolerance and rationalization of military food rations under different operational environments, establishment of sound procedures in radiation safety and radiation

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hygiene. Further, a one year post graduate diploma course in collaboration with Delhi University was started. It had the distinction of being the first such course anywhere in the world.

2.8.9 Missiles

The development activities included missiles and its components. The components taken up for design and development were gyroscopes and accelerometers. In addition, the design and development of rockets up to a diameter of 125 mm was attempted.

‘A wire-guided antitank missile’ was developed and nearly 400 guided flights were carried including 100 flight tests as part of User trials.

2.8.10 Naval Research & Development

The main thrust has been towards design and development of items and processes for the Navy. In the area of devices and systems, sonar range finder, monitor panels for fire control systems and a sono-buoy were successfully designed and developed. The requirement of the Navy for the sono-buoy was met by pilot plant production. On the material side, the successful development of anticorrosion and antifouling heavy duty underwater paints and transfer of technology to the industry considerably eased the maintenance of seagoing vessels. The paints based on oleo resins offered corrosion-and fouling-free life of around 9 months and were immediately introduced in the Services by the Navy in 1966. Antifouling paints based on organic toxins instead of conventional cuprous oxide and anticorrosion paints containing magnesium were also developed. Another significant contribution was the development of a cathodic protection system based on aluminium metal alloy anodes for protecting the hulls of naval ships from corrosion. These contributions led to the Navy designating the NMRL as the agency for formulating national specifications for paints to be used by the Navy.

2.8.11 Psychological Research

Important investigations carried out relating to psychological tests were, development of psychometric tests for assessing leadership potentiality in Service Officers, psychodynamics of courage in operational contexts, selection of technical trades in the Army, effects of high altitude and low temperatures on mental performance, scales for assessment of flying failures in Air Force pilot training, new schemes for administration of PAB tests at the Air Force Selection Boards, and aptitude tests for categorization of cadet trainees into technical and nontechnical groups. Experiments were conducted to determine the optimum duration of watch for radar plotters and ASDIC operators, and to devise an improved procedure of branch formation of artificer apprentices in the Indian Navy.
2.9 SUMMING UP

In the twelve years after its formation, DRDO was transformed into a cohesive organization of professionals dedicated to the application of science and technology to defence. This was no mean task because being a department of the government it had to operate within the frame work of government rules which did not suit research and development activities. In addition, the large span of the technical and scientific disciplines, the geographical separation of the laboratories and the primitive communication infrastructure impeded free flow of information necessary for a new organization to cohere. In spite of these factors, Dr S Bhagavantam with Major General JR Samson as Chief Controller R&D and Dr V Ranganathan as Deputy Chief Scientist, steered the DRDO skilfully in the firm direction of applied research and development for meeting defence needs. By the end of the first decade of DRDO, the laboratories in the organisation were at different state of preparedness to move away from routine tasks towards more innovative and challenging assignments. The status of readiness depended on the rate of change in each technology, quality and capacity of industrial infrastructure of the country and the quality of manpower that was transferred from TDE and of those that were subsequently recruited. However, some of the DRDO laboratories specifically in electronics, made the switch from import substitution of equipment to development and delivering of contemporary solutions for the Services. Innovation was in evidence in many of those solutions because they differed in form, fit and function and were not replicas of what was available abroad. The next twelve years will be more eventful because the impact of rapid changes taking place in the landscape of technologies and of the step up in activities to contemporary systems development. This would be a challenge and an opportunity for the DRDO.
OVER TO SYSTEMS DEVELOPMENT
CHAPTER 3
OVER TO SYSTEMS DEVELOPMENT

3.1 INTRODUCTION

When 1970 dawned, DRDO was without a head as the appointment of an eminent scientist/technologist as Scientific Adviser to the Defence Minister had not been made. The uncertainty persisted even as eight months passed and June 1970 approached. It was common knowledge that many eminent scientists were reluctant to take up the post because it did not carry the same authority and powers as the heads of the other two scientific departments, namely Atomic Energy and CSIR. Further, it was well-known in the scientific circles that after the exit of Shri Krishna Menon, Dr Bhagavantam had experienced difficulties in pushing new initiatives and projects. Dr V Ranganathan, who was the Deputy Chief Scientist during Dr Bhagavantam’s tenure, reminisced that early in 1970, Dr BD Nag Chaudhuri, one of the top scientists who was Member (Science) Planning Commission, enquired of him about the problems and the challenges faced by Dr Bhagavantam as the Scientific Adviser1. The possibility of Dr Nag Chaudhuri being appointed as the Scientific Adviser was soon talked about within DRDO and the delay in the announcement of his appointment was understood by most of us to be due to his reluctance to accept the responsibility without the post being vested with the powers of the Secretary to the Government of India. The 13th Annual R&D Conference was held in May 1970 at Pune, with the uncertainty about the appointment of the Scientific Adviser very much in the minds of the Directors2. There was anxiety and concern about the forces at work that would attempt to deny the

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1 Interview with Dr V Ranganathan former Deputy Chief Scientist DRDO. He gave Dr Nag Chaudhuri an account of the working of the DRDO in the Defence Ministry and also the difficulties the Scientific Adviser faced in pushing new ideas and programmes. Dr Ranganathan had left DRDO in 1970 and joined the Cabinet Secretariat as Secretary, Scientific Committee to the Cabinet.

2 The 13th Annual R&D Conference was held in Pune from 16th to 18th May. In all these thirteen years the Conference had been held in the period March to May of each year.
Dr BD Nag Chaudhuri
(01 July 1970–01 July 1974)
Over to Systems Development

post of the Scientific Adviser the authority and powers of the Secretary to
the Government. There was also hope and confidence that Shrimati Indira
Gandhi, the Prime Minister of India would rule in favour of the head of the
DRDO being at par in power and in authority to the Secretary to the
Government of India. Finally, the uncertainty ended with the
announcement that Dr BD Nag Chaudhuri, would be the next Scientific
Adviser to the Defence Minister, Director General DRDO, and would have
the ex-officio status of Secretary to the Government of India. He assumed
charge on July 1, 1970.

3.2 Dr BD NAG CHAUDHURI – THE SCIENTIFIC ADVISER

A Short Biography: Dr Basanti Dulal Nag Chaudhuri obtained his
B.Sc (Hons) degree from the Banaras Hindu University in 1935 and Master's
degree from the Allahabad University, in 1937. He proceeded abroad to the
University of California, USA for continuing his studies in nuclear physics
under the Nobel Laureate Professor Ernest O Lawrence, the inventor of
cyclotron during the period 1938-1941, and was awarded the doctorate
degree. On his return to India, he joined the University of Calcutta in 1942
and continued his work as leader of the Cyclotron Project. In 1947-48 he
returned to the University of California as a postdoctoral fellow to pursue
research work in his area of interest. In 1953, he was offered the Palit
Professorship at the University of Calcutta as successor to Professor M N
Saha. He was appointed as the Director of the Saha Institute of Nuclear
Physics, in 1956, a post he held with distinction till 1967. The Saha Institute
of Nuclear Physics during his tenure as Director, expanded its activities
and grew up into a pioneer research institute in Nuclear Physics in the
Country. The work of the Institute as well as the research activities of Dr
Nag Chaudhuri in Cerenkov radiation gained national and international
recognition.

In 1967, he was invited by the Government of India to join the
Planning Commission as Member (Science). In addition to science and
scientific research, he was also entrusted with the subjects of education,
health, social welfare, housing and urban development technology. In a
short period of time, he was also offered the Chairmanship of the Committee
on Science and Technology, which had the responsibility for policy making
and coordinating all efforts aimed at the advancement of science and
technology in the country. During his tenure as Member of the Planning
Commission, he acquired a very good understanding of the working of the
Government of India and the process of decision-making within the
Government. In addition, he had the rare opportunity as a scientist to gain
insight into the management and utilization of science and technology in
the service of society and to understand in depth the innovation chain starting with research at academic institutions and ending with a product utilizing the industrial infrastructure.

Dr Nag Chaudhuri had a wider view of the potential of R&D and the role it had played in the developed countries in ushering an era of unprecedented economic expansion. He was aware that the uninterrupted economic growth experienced in the developed nations for nearly two decades was showing signs of abatement in the form of slowing down of capital investment for new plant and machinery for industrial expansion. Consequently in those countries, more resources were being diverted to industry to incremental innovations with shortened time horizons. In effect, it meant that in product R&D, industry was beginning to concentrate more on improvements and widening the applications and in process R&D, the focus was on increasing efficiency. R&D managers were being made aware of the importance attached by management to return on investment (ROI), higher accountability, and short-term results. In effect, efforts were on in those countries to align short-term R&D activities with the current business and products. A new R&D management paradigm came into existence with the objective of integrating technology with business strategy. He was also cognizant of the crucial role that the Department of Defence in the United States was playing in accelerating the pace of technologies in the electronic and aerospace industries for establishing military superiority over their Cold War rivals.

3.3 INITIAL STEPS

When Dr Nag Chaudhuri assumed his Office, there was a heightened sense of expectation within the DRDO of enhancing the scope of development activities, of greater freedom for keeping pace with technological changes and advancements. As the 13th Annual R&D Conference had been held earlier in May 1970, he did not have the opportunity to meet the heads of laboratories to ascertain their views. Therefore, he took upon himself to visit some of the major laboratories to interact with the Directors and other scientists of the laboratories. The purpose was twofold. Firstly, like any scientist he wanted to obtain first hand information from other scientists and technologists about their work.

The author had the pleasure of receiving Dr BD Nag Chaudhuri on 7th July 1970 at the Defence Electronics Research Laboratory in the absence of the Director who was abroad. The Scientific Adviser was fully briefed about the current projects of DLRL, immediate future plans and about the personnel and their working as well as service conditions. He also went round the laboratory, met the scientists who explained, the genesis, the technical aspects of the projects and their interaction with the User Services.
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and working conditions. Secondly, he wanted to signify his break from the hierarchical mould on which DRDO had been patterned. The visit of the Scientific Adviser to the laboratories at such a short notice and the way he put the scientists and others at ease and invited their suggestions during meetings with him, paved the way for better communication. He also made it a point to meet the heads of the public sector industries and of the ordnance factories to ascertain their views and opinions for collaboration with DRDO for the major system projects that would be accorded higher priority for development in the Organisation.¹

His immediate attention was drawn to the type and nature of activities undertaken by the Organisation and to its personnel policies. He assessed that the Organisation had been busy in providing response to short-term needs of the Services which enabled the scientists to learn the profession of equipment development and also to gain credibility with their customers. In this process, the hardware/engineering-oriented laboratories had acquired a good understanding of the working as well as the technologies of existing equipment so that modifications, improvements, and substitutions could be handled with confidence and assurance. In some cases where technological advances were rapid, equipment and systems were made modular in architecture, substitution also led to improvements in performance, such as higher reliability, lower power, and lesser cooling needs, and so on. He was convinced that DRDO had to graduate from these short-term responses to systems development to achieve self-reliance in defence equipment. However, the leap to system development would only be successful if the Organisation could take the route of technology development of subsystems and acquire competence to configure not one system, but a wider range of systems. The evolutionary approach that he had in mind, envisaged continuity from the current-generation to the next-generation systems. It followed then, that prior to undertaking next generation systems development, building competence in the technologies of major subsystems/modules would be necessary. Each of the newly developed subsystem would be substituted in the current system, and by this process, the knowledge on trade-off would be understood and built up. The starting point would be the infrastructure building, for which investments would have to be made and because of budget limitation, prioritising the technology areas would be necessary if DRDO was to make

¹ He was clear in his views about the absolute necessity for greater understanding and cohesion between the R&D and the production agencies. In his talk on "Defence of India in the 1970s" on 15th November 1973, he stated that "... defence R&D efforts are related to the total infrastructure of science and technology and the capabilities of the industry within the country ...."
Defence Research & Development Organisation (1958-82)

a greater impact. Therefore immediately after assuming the Office, he changed the budgetary allocations earlier made for the laboratories for 1970-71 and apportioned about 60 per cent of the budget to the thrust areas of aeronautics, electronics, missiles and submarine technology. The priorities for electronics and aeronautics reflected the national concern for undertaking R&D for self-reliance. The missiles, in his opinion, were efficient and cost-effective weapon systems that could provide a superior force-multiplier effect so that fewer number of fighting men could be effective against aircraft, tanks and so on. The message was clear that system development in these thrust areas would have the priority in the coming years.

The Scientific Adviser envisaged that the laboratories in the thrust areas would be the nodal laboratories responsible for systems development and that other laboratories of the Organisation working in allied science and technology fields would take up activities related to development of components/subsystems that would fall in their areas of specialisation. This would mean pooling of the available resources and expertise within the Organisation through a large number of inter-laboratory projects. Thus, multiple specialist laboratories would be involved in any weapon system development so that development time was reduced and the optimum use of the infrastructure and skills would be possible. He, therefore, made it known that if the laboratories specialising in other technology areas, which are allied to electronics, missiles, aeronautics and naval technologies, orient their activities to match the needs of the laboratories in the thrust areas, these could expect higher funding levels.

3.4 THE DIRECTORS’ ANNUAL CONFERENCE

The 14th Annual Defence R&D Conference held at the Proof and Experimental Establishment (PEE), Balasore in April 1971, was the first

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6 Interview with Dr ID Gaba who was staff officer to the Scientific Adviser, Dr BD Nag Chaudhuri in that period.
7 The Bhabha Committee Report on electronics and the C Subramanian Committee Report on aeronautics.
occasion for him to interact with and address the group of senior scientists and Service officers of the DRDO manning the 35 institutions and the Headquarters. The Conference was inaugurated by the Defence Minister, Shri Jagjivan Ram, who pointed out that DRDO was “yet to make a distinct and powerful impact in our overall defence capability…. The contribution of R&D has therefore to increase considerably. The Defence R&D should endeavour to develop indigenous system in our Country so that we may become increasingly self-reliant in all of our defence capability”. He further stated that, “There are certain areas of technology, such as aeronautics, rockets and missiles and electronics which are sophisticated and predominantly of defence interest. They need high priority in our national development programme”10. The Defence Minister’s address put the seal of approval to the changes that were already taking place in the DRDO and his emphasis on systems development coupled with the remark that DRDO was yet to make a powerful impact, was a total endorsement of Dr Nag Chaudhuri’s drive to shift the emphasis towards systems development by the evolutionary route.

The Scientific Adviser in his address to the senior scientists and Service officers of DRDO gave his perception of DRDO and expectations for the future. He stated that,

(a) The expenditure on DRDO was too low in comparison to the expenditure on defence R&D of any developed Country. For example Sweden, which was not even involved in the Cold War, spent 1.23 per cent of their GNP in research and development related to defence while the Government of India spent only about 0.056 per cent of the GNP on DRDO. The budget for the financial year 1970-71 was Rs. 17.52 crore, which was spread over 35 institutions and on 1186 projects. There were practically no multi-laboratory projects. Thus, the effort was either too insignificant on problems/projects of importance to the Services or the Organisation was preoccupied with trivial problems.

(b) The DRDO would have to redirect its efforts so that the major focus would be toward development of new and future products based on evolutionary development, current technology and concepts.

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In view of limited manpower and finances, thrust areas with a clear sense of priorities were missile, electronics/radar, aircraft systems and submarine technologies.

(c) The personnel at the technical headquarters situated in Delhi were to re-orient their work to have more technical and scientific content in bringing the Services and the laboratories closer and also reduce the current administrative burden at Delhi. To this end the powers delegated to the laboratories would be enhanced and this would cut down delays in taking decisions.

(d) There was a need to observe a strict balance between the two main streams, namely the civilian scientists and the scientists in uniform by using the yardstick of competence and performance. Seniority should be counted, but only after full credit has been given to competence and performance. Therefore, the present annual confidence reports would have to be suitably amended.

3.5 SETTING A STRATEGIC GOAL

He set the strategic direction to the organisation as contemporary system development, but left the pace of implementation to the laboratories as the engineering/hardware oriented laboratories in the Organisation were at different states of preparedness depending on the rate of change in each technology, quality and capacity of industrial infrastructure of the Country and the quality of manpower of the laboratory. Some, like the electronics group of laboratories had already moved into contemporary system development in view of their active participation in the Plan AREN of the Indian Army and Plan ADGES of the Indian Air Force.

The interaction between the senior scientists, Service officers at the helm of the laboratories on the one side and the Scientific Adviser with the Chief Controller, Chief Scientist and the Technical Directors at the Headquarters on the other side, was free, frank, thorough, and detailed during the 14th and 15th Annual R&D Conferences. The discussions covered all important issues, such as the type of activities to be undertaken by the laboratories, the role of technical directors at the headquarters, delays in the development-production cycle, delegation of powers to the heads of

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the laboratories, personnel policies including recruitment and promotion, governing councils, R&D panels and their effectiveness, stores procurement procedures, and civil works services.

In particular, the Scientific Adviser’s directive that laboratories should move away from import substitution tasks to contemporary systems development, was the subject of intense discussion and after considerable exchange of views, the consensus emerged that while DRDO would build credibility with the Users by delivering hardware which meets their immediate needs, the Organisation should not set itself at a technologically lower level by merely reproducing the existing hardware in the name of import substitution. In addition, it should take up technology development tasks, leading to design of contemporary systems with infrastructure building and acquisition of competence preceding actual system development. The difficulties faced earlier to get approval for technology development tasks with large financial outlay would be very much reduced if the activity was related to a known or anticipated requirement of the Services. Over the years it was found that if the technology development programme was linked to a known or anticipated need of the Users, or if it was part of a national investment plan/policy, or if the track record of the laboratory/senior scientists was outstanding, the programme would find a place.

3.6 MEASURES TO STEP UP ACTIVITIES

The Scientific Adviser was able to persuade the Ministry of Defence to examine the proposed switch in the activities of DRDO from their perspective. The Ministry concurred with Dr Nag Chaudhuri that, “product development as well as product improvement where quantum jump in the performance characteristics was required involving major redesign and development activity would be the responsibility of the Defence R&D Organisation”. In the case of military stores that were in service, the responsibility for product improvement, for giving better performance and tasks of indigenisation of equipment produced under license, would not be that of the DRDO but of the production agencies. Thus, the decks were cleared for DRDO to move away from import substitution activities to technology development and contemporary military systems design.

At the instance of DRDO, two other measures were introduced by the Ministry of Defence to facilitate and speed up the introduction of military stores (equipment/systems) developed by DRDO into Service. The first one was to streamline the procedure for encouraging private sector firms to work with DRDO in the development of military stores. It was decided that any firm in the private sector, which participated with DRDO in the successful development of military stores, would get the first order for bulk production. Subsequent orders for manufacture of the same stores would follow the procedure laid down by the Ministry of Defence. The second measure was about the advance action to be taken by the User Services before the requirement was reflected to the DRDO for development. The Ministry stipulated that, “The User Services will concretise their futuristic requirements and get financial approval in principle for all overall outlays involved for the development and quantity production of the equipment.” It was also decided that a procedure for design, development, production and inspection of the military stores in each technical sector like armaments, aeronautics etc., would be drawn up on the lines similar to that already in use in the electronics sector (DDPIL-69) so that the respective agencies can initiate advance action for speedy transition from one stage to another.13

On his part, the Scientific Adviser adopted a three-pronged approach to accelerate the movement of the DRDO towards the strategic goal. Firstly, priorities were set and enhanced resources were allocated for building up infrastructure and competence in four specific technology sectors namely, aeronautics, missiles, electronics and naval science and technology. Secondly, he persuaded the Government to enhance the DRDO budget as a percentage of the defence budget from 1.31 per cent in 1969-70 to 2.05 per cent by 1973-74 and in absolute value from Rs. 14.43 crore in 1969-70 to Rs. 34.39 crore in 1973-74. Those laboratories, which were in associated technology sectors, were assured of enhanced resources when these moved toward the strategic direction. Thirdly he selectively placed research-minded persons of proven ability and proficiency in their fields as heads of laboratories when the posts fell vacant due to retirement or by transfer14. His address at the Indian Institute of Administration, Mussoorie,

13 Reference 12, p. 32-33.

14 Some of the important placements that took place as heads of laboratories during the period 1970-74 were as follows. Dr WD Patwardhan became Director ARDE, Dr SK Sinha assumed charge as Director HEMRL, Dr BK Banerjea took over as Director Defence Science Centre, Mr NS Venkatesan became Director TBRL, Dr MP Murgai officiated as Dean Institute of Armament Technology, Dr RP Shenoy assumed charge as Director LRDE. When the post of Director DRDL fell vacant by virtue of retirement of the incumbent, Dr Nag Chaudhuri, selected a serving Indian Air Force Officer 14... contd...
would reveal his thought process in making such changes. In that address he stated that, “management functions cannot be carried out without an understanding of the relevant technologies and their role in the enterprise. This understanding involves some knowledge of the science and technology that is involved...... A generalist administrator without a feel of the problem he is dealing with, without an adequate knowledge of the facts and techniques which are crucial and an appreciation of relative importance of these can be now misled into wrong decisions. In our Country there have been a number of instances in the past of such bad management decisions because of inadequate appreciation of relative importance (Kolar, Zinc mines). This does not mean that one has necessarily to know in great detail the technology or whatever discipline of science is involved...... But a poor knowledge of technology of his industry is dangerous to his enterprise. What is needed in his appreciation of the subject, ability to discriminate between what is crucial, what is relevant and what is peripheral. To this extent he must not only know but able to understand the expert’s view and use his own judgment. He needs a fairly clear and systematic understanding of what he is dealing with and not just a superficial knowledge of the terminology used...”15.

Consequently, there was a step up in activities from short-term responses to equipment/system development, though the laboratories did not follow the same trajectory. CVRDE interacted with the Armoured Corps in the formulation of the QR for the tank needed by the Indian Army. Thereafter, a study group in 1972 looked into the feasibility of developing the main battle tank and suggested the optimum solution. It was followed up with a proposal to the Political Affairs Committee of the Cabinet and a major project for the development of the main battle tank MBT-80 was sanctioned to CVRDE in March 1974. GTRE which was trying to improve the dry performance of the Orpheus engine, launched research projects in the areas of compressor, combustor, turbine, engine control system, heat transfer to build up the competence to develop power plant for a future combat aircraft. DRDL with a new Director in place, was in the process of building infrastructure for missile development. Dr Nag Chaudhuri encouraged the laboratory to initiate work on liquid propulsion technology and also explore

the possibilities for undertaking the development of an indigenous surface-to-air missile system using the latest technology. For this purpose, the engineering and functional analysis of an existing missile system was carried out to derive the functional specifications necessary for the subsystem development. DLRL undertook the development of the radar system for the surface-to-air missile. With the placement of a new Director at LRDE, a different approach to the development of the radar system for the detection of low flying aircraft for the Indian Air Force was taken up and a feasibility study was initiated. DEAL initiated the development of the troposscatter communication system to meet the functional specifications of the Indian Air Force.

The participation of DRDO in the first nuclear explosion of the Country (1974) and the part played by the Scientific Adviser, has been placed on record by Dr Raja Ramanna. According to him, the DRDO’s contribution was significant and pertained to the development of the lenses and fabrication of the explosives. He has also recorded that, “Prior to 1972, the Bhabha Atomic Research Centre (BARC) and the DRDO had never worked together on any project involving high level secrecy. This collaboration was thus surprising as the two were culturally opposed but thanks to Dr Nag Chaudhuri, things went smoothly on the Pokhran project.” It goes without stating that the armament group of laboratories were involved in the development of the high explosives, in the shaping of the lenses, and in carrying out experiments for calibrating the lenses so that nuclear explosion could take place. Prior to the explosion, emphasis was given at TBRL for modernising and improving the instrumentation facilities at the TBRL for terminal ballistics.

3.7 HUMAN RESOURCES DEVELOPMENT

The Scientific Adviser was fully aware of the unhappiness throughout the Organisation about the delays in recruitment of scientists, about the infrequent and irregular holding of promotion boards, uncertainty in career prospects, and the need to revise the annual confidential reporting of performance. DRDO was finding it difficult to attract and retain top scientific and technical talent whereas other Government agencies, such as Department of Atomic Energy, Department of Space, public and private sector industry were not hampered. He found that specific attention and quick resolution of issues could not be provided by an omnibus Directorate of Administration. Therefore, he decided to

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16 Years of Pilgrimage: An Autobiography by Raja Ramanna, Penguin Books India (P) Ltd, New Delhi, 1991, p. 90-91. He has lauded the courage displayed by another DRDO scientist in rectifying the earthing problems after the installation of the nuclear device.
create a separate directorate of personnel and persuaded Mr AN Bhattacharya, Deputy Director, IRDE, Dehradun, to move to Delhi and organise the Directorate of Personnel.

Mr Bhattacharyya as the first Director of Personnel (DOP) had his task cut out. First, he got the approval of the Scientific Adviser to rescind the earlier order of listing the seniority of scientists and declaration of vacancies for departmental promotions discipline-wise [serrated pyramid] to reduce the disparity that existed in the opportunity for next promotion among the scientific/technical disciplines. Next, he attempted to find ways and means to get around the delay in recruitment as well as in the holding of the departmental promotion boards due to the non-availability of the member from the UPSC. The reduction of the delay was achieved after a series of meetings with UPSC officials and he finally persuaded them to nominate one UPSC Member exclusively for looking after the needs of DRDO. By this measure, even in extreme cases the delay was brought down to about one year. However, this improvement did not last long because the UPSC could not afford to have one member exclusively earmarked for DRDO and after some time, DRDO found its recruitment/departmental promotion work being sandwiched between the regular work for other All India Services. There were other irritants due to the lack of transparency to DRDO of the process of screening of applicants and selection of the experts for interviewing the candidates. These could not be resolved easily with UPSC but would have to be sorted out over a longer period of time.

In order to bring DRDO at par with other S&T departments/bodies of the Government of India, the Scientific Adviser held discussions with the Chairman, UPSC for getting exemption from UPSC for recruitment and promotion of scientists. The proposal was turned down by the Chairman of the UPSC. Subsequently, the Scientific Adviser approached the Prime Minister who approved a set of guidelines to be followed by DRDO for taking it out of the purview of UPSC for recruitment and promotions. The Director of Personnel at the 15th Annual R&D Conference presented to the Directors, the proposed new personnel policy by which, “the recruitment to DRDO will not be through UPSC but through Selection Boards constituted by DGR&D. The promotions will be independent of the availability of vacancies and a scientist will be promoted in situ if necessary. The Scientific Adviser will have the powers to transfer or freeze a post. The existing Defence Science Service [DSS] will be bifurcated and a separate cadre i.e., DRDS will be formed of scientists engaged on research and development work. The general recruitment will be at SSO II [present Scientist B] level and made through a training-cum-assessment scheme. A small number of
posts will be earmarked for scientists on deputation from universities and other research organisations. Similarly it will be possible for scientists from DRDO to work outside institutions for short periods. There will also be provision to appoint some retiring scientists as Emeritus Scientists. The new personnel policy was received with great enthusiasm and the suggestions made by the Directors in respect of entry into the DRDS cadre of the non-gazetted officers holding the posts of foreman and senior scientific assistant, was accepted for inclusion in the new personnel policy. Due to the opposition by the UPSC and the procedural hurdles that had to be overcome, DRDO had to wait for seven long years, before the policy could be implemented.

The DOP also streamlined the departmental promotions to the cadre of non-gazetted officers (senior scientific assistant downward and foreman downward) by getting the laboratories to indicate in advance the vacancies to be filled up and by getting them to complete the annual confidential reports and dispatch these on time so that the promotion boards could be convened once in a calendar year. Changes in the annual confidential reports of the scientists were also introduced to include comments by the immediate supervisor, making the scientist aware of adverse remarks and stipulating the criteria for grading a scientist “outstanding”. The career prospects were improved but these still fell short of the expectations of the scientists. The migration from DRDO slowed down in most technology areas except in computers, communications, radar, including microwaves and antennas, and signal processing.

3.8 HEADQUARTERS REORGANISATION

The functional chart of the Organisation at the time Dr Bhagavantam became the Scientific Adviser did not envisage any administrative duties to the technical directorates. Instead, the duties of the technical directorates were broadly termed as “research, design and development in their field of specialisation and rendering technical advice to Staff (Services Headquarters) on such matters”. However, in the functional chart of each technical directorate, the responsibilities were mostly of coordination, organisation and attending of meetings related to development, supply or purchase of equipment for the Services. By the time Dr Nag Chaudhuri arrived on the scene, the duties of the personnel
manning the technical directorates did not require high technical expertise which led the Scientific Adviser to consider them as "file pushers". The perception of the laboratory directors about the role played by technical directors varied considerably from that of helpfulness and cooperation to that of obstruction and interference. At the 14th Annual R&D Conference, the Scientific Adviser led the discussion stating that he wanted the technical directorates to take up, as one of their major activities, the study of futuristic trends in their technical areas and preparation of position papers which would describe critically and correctly the state of technology within the Country as well as in the rest of the world. There was considerable discussion at the end of which it was decided that a clear delineation of responsibilities of the DRDO Headquarters would help in removing the irritants. As far as the preparation of position papers on the technologies and systems was concerned, the participants of the Conference were of the opinion that with the increase in project activities and with the enhancement of powers delegated to the laboratories, Headquarters would have its hands full with monitoring and evaluation for ensuring that the progress on all projects, infrastructure and competence building activities were proceeding according to the plan.

In December 1971, the Functional Chart of the DRDO Headquarters was published. It got first revision in May 1973 with the strengthening of the Headquarters by the appointment of an additional Chief Controller (R&D), re-designation of the Chief Scientist as Chief Controller (R&D) and with a Joint Secretary working full time for the DRDO. In his communication to the DRDO the Scientific Adviser stated, "... the needs of the Defence Services are getting more and more sophisticated day-by-day. But the resources placed at the disposal of the Defence Research & Development Organisation are limited. In order to optimise the resources, the R&D Headquarters has to play a significant role in the process of analysis and decision-making and in the allocation of tasks. It has also to monitor progress and remove difficulties of laboratories/establishments and assist these in all possible ways to speed up the progress of assigned tasks. It has to systematically analyse the

Contd... Electronics the typical duties of one of the deputy directors are indicated as, coordination of development activities of LRDE, development planning targets, technical advice to Services, project’s development coord meetings with potential manufacturers and DPI(L), production schemes, planning and provision of resources and facilities, LDP meetings, Radio Cable Board, GS Policy Statements/GS Policy Sub-Committee and Committee Progression of projects.

need and to delegate authority to the laboratories/establishments in various matters and to review the manner in which the delegated authority is being used so that corrective action where necessary can be taken with quick time. In addition, the Headquarters must periodically forecast technological development areas, collect, collate and disseminate information so that development programmes are consistent with current and future trends and do not significantly fall behind. The role of Headquarters, as spelled out by the Scientific Adviser, was one of support to the laboratories who would be the backbone of the Organisation and monitor their performance for rendering service. The functional chart as well as the duties and responsibilities of the three Chief Controllers, one Joint Secretary, and the directorates under each of them were laid out in detail. The Scientific Adviser also stipulated that the three Chief Controllers and the Joint Secretary would not only be responsible for the activities in their own areas but will work as a team and help each other in all important, technical, scientific, personnel and administrative matters.\(^{21}\)

The Functional Chart of DRDO as indicated in the letter is shown in Appendix–II (Figure 2). The three Chief Controllers, the Joint Secretary and the Director of Administration reported directly to the Scientific Adviser. The distribution of responsibilities and duties of the three Chief Controllers was such that one Chief Controller had the technical directorates and the laboratories/establishments primarily oriented to Army projects under his jurisdiction, the second one had technical directorates and laboratories oriented to Naval and Air Force tasks, while the third Chief Controller had the Headquarters directorates and laboratories involved/working in applied sciences and the Directorate of Personnel. The duties of the Joint Secretary were to interact with the Ministry and pilot the paper work for all schemes and proposals requiring Government approval/sanction. He was to be associated from the early stages of the proposals. The Director of Administration had the responsibility on all administrative matters such as planning and preparation of budget, interacting with Ministry for foreign exchange allocation, and ensuring progressive allocation to the laboratories, processing papers on procurement of stores sent by the laboratories for approvals at DRDO Headquarters at Delhi, planning and implementation of civil construction to meet residential and laboratory needs, security and

\(^{21}\) The re-organisation of the DRDO Headquarters was circulated to all laboratories/establishments/units of DRDO vide the Scientific Adviser’s letter No. 92957/A/SA dated 22nd May 1973.
vigilance. Three Committees were formed for taking decisions on all important technical and administrative matters and they would meet periodically to review the progress made in the major areas of activities. The Technical Committee ‘A’ consisting of the SA to RM, three CCR&Ds, Joint Secretary, and Director of Administration would meet every alternate Monday to consider all policy and important matters. Technical Committee ‘B’ with SA to RM, three CCR&Ds, Director of Administration, Director of Personnel and other technical directors (on need basis) would review the progress on all important projects, consider all other technical and administrative matters related to specific projects, and would need detailed consideration at higher levels.

The third committee called the Capital Equipment and Procurement Committee, would comprise the three CCR&Ds, Director of Administration, and technical directors (on need basis). The work of the Committee was to scrutinize the need for the procurement of all stores requiring foreign exchange, capital equipment and creation of major facilities. The duties of the technical directors at the Headquarters were divided into four broad categories-general duties, staff functions, technical functions and line functions. In the category of technical functions, the work involved arranging and reporting on prototype trials of equipment/systems developed by the laboratories, keeping a watch and progressing development-to-production and induction into services of equipment to safeguard R&D interests, and writing position papers in their field on various subjects, upgrading these from time-to-time and anticipating advancing technologies and techniques. These three Committees would synergise the capabilities of the top management to resolve difficult issues. The reorganisation laid in clear terms the duties and responsibilities with little or no overlap up to the level of Headquarters directors so that confusion was minimised and accountability was enhanced. It was effective in reducing the delays within the DRDO. However, the technical functions of writing position papers on various subjects was, by and large, not carried out by the technical directors with the exception of a few.

3.9 DELEGATION OF POWERS TO THE LABORATORIES

As the laboratories were well spread out geographically and these also dealt with a wide spectrum of science and technology fields, the
Scientific Adviser expressed that there should be more autonomy than hitherto by delegating more powers to them. This measure would cut out considerable paper work on matters which could be dealt at the laboratory level. Thus in June 1971, the Defence R&D Organisation issued letters enumerating the delegation of financial powers to establishments/laboratories. In some cases, these orders enhanced the powers of the heads of the laboratories to the extent held by the Scientific Adviser and in others additional powers earlier held by the Scientific Adviser were delegated down. Similar action was taken in respect of extending the financial powers of the heads of the laboratories. It was later found that in effect it reduced the correspondence between the laboratories and the Headquarters by about 25 per cent to 30 per cent.

3.10 STORES PROCUREMENT PROCEDURES

The procedure followed for the purchase of test equipment, machinery, or any other sophisticated facility that would enhance the capability of the laboratory was antediluvian because the Government rules that were applied, were by and large framed by the colonial rulers at the beginning of the 20th century. The expansion of the infrastructure in the thrust areas was hampered by the elaborate procedure of the Government which required as many as 82 complicated and time-consuming steps involving diverse agencies like the DGTD (Director General of Technical Development), DGS&D (Director General of Supplies and Disposal), India Supply Mission, Department of Electronics, and so on. In view of the enormous administrative burden that would be imposed on DRDO if it took over procurement from DGS&D, it was decided not to disturb the present arrangement. However, in special cases recommended by the Organisation, DGS&D was persuaded to permit DRDO to purchase directly. The uncertainties and delays in procurement of equipment/machinery, either from indigenous sources or foreign imports, continued throughout the 1970s.


24 Reference 18, Page 22. Most of the regulatory and procurement agencies of the government were overwhelmed with paper work and thus delays were endemic. Coupled with this was the fact that DRDO HQrs did not accept estimates of cost at the planning stage, as a result of which for each equipment or machinery quotations had to be obtained so that the price reflected in the budget was accurate. However, because of
3.11 GOVERNING COUNCILS

Governing councils had been constituted in the 1960s for the laboratories with participation from academies and industry to provide independent expert opinion on technical as well as other matters to the scientists of the laboratories. The contributions and the impact of the governing councils on the laboratories varied considerably from negligible to significant. In the case of the governing council dedicated to one laboratory and the activities of the laboratory led to new processes, materials and devices, the impact was, by and large, significant. However, for equipment-oriented laboratories, the contribution of the governing councils was negligible. Most of their input and decisions came out of the development panel meetings where DRDO interacted with the User and associated production agencies. Similarly in the case of governing councils constituted for multiple institutions, the contributions were not significant. In the light of these it was decided to discontinue the practice of constituting governing councils for DRDO laboratories. Instead, the development panels and the Project Steering Committees were found to be better and true mechanisms for monitoring and reviewing the work carried out by the laboratories.

3.12 IMPACT ON THE ORGANISATION

Four years to the day, on 1st July 1974, Dr BD Nag Chaudhuri moved out of South Block where he had been the Scientific Adviser to Raksha Mantri, and donned the mantle of an academician by becoming the Vice Chancellor of Jawaharlal Nehru University in Delhi. In that short period, he set the DRDO for the new direction or vision of contemporary system development for the Services. He created the department of personnel to look into the problems of recruitment, promotions and career prospects of the personnel and initiated a sequence of actions which would ultimately take DRDO out of the purview of UPSC. He also decentralised the decision process by initiating the delegation of powers of the Scientific Adviser to the Directors of the laboratories.

the long delays between the time the quotations were obtained and the time the foreign exchange was released prices would escalate which would start the process all over again if it exceeded a certain percentage. The other option was to reflect the demand to the India Supply Missions abroad for procurement. Delays of two to three years was not unusual. Similarly, as the direct purchase powers of the Directors were limited, even equipment/machinery which was available on rupee payment had to be purchased through the DGS&D as a result of which more than 50 per cent of the machinery or equipment of any year would materialise two years later.
Prof MGK Menon
(17 August 1974–10 July 1978)
Over to Systems Development

3.13 PROFESSOR MGK MENON BECOMES THE SCIENTIFIC ADVISER

The departure of Dr Nag Chaudhuri to the Jawaharlal Nehru University as Vice Chancellor was a surprise to most heads of the laboratories in the DRDO. Most of them hoped that the post would be filled up shortly as it had been vested with the powers of the Secretary to the Government of India. While a small minority within the DRDO wanted that scientists from within the organisation to be considered, the general consensus was that an eminent scientist from outside the Organisation would most likely be the next the Scientific Adviser. The formal announcement that Professor M Govind Kumar Menon, an internationally known physicist and who was Chairman, Electronics Commission and Director, Tata Institute of Fundamental Research (TIFR), Mumbai, would be the next Scientific Adviser made most of the scientists happy. Professor MGK Menon assumed the Office on 17 August, 1974.

A Short Biography: Professor Menon had his early education at Jodhpur after which he was awarded M.Sc (Physics) of Bombay University while working at the Royal Institute of Science, Mumbai25. He was enrolled at the Bristol University, England for advanced studies in physics and was awarded the Ph.D degree by the University of Bristol in 1953. At Bristol, he worked with Nobel laureate Professor CF Powell. During the period 1953-55, he held the highly coveted senior award of the Royal Commission for the Exhibition of 1851, for two years. In 1955, he decided to return to India and joined the Tata Institute of Fundamental Research (TIFR) Mumbai, as Reader. For his outstanding work on cosmic rays, he was awarded the Shanti Swarup Bhatnagar Memorial Award for physics in 1960. He was also made Professor and Dean of the Physics faculty at the TIFR in the same year. In 1961 his contributions to physics were recognised by the President of India with the award of Padma Shri. In 1964 he rose to the position of Senior Professor and Deputy Director, and took over the mantle of the Director of TIFR two years later.

Under his inspiring stewardship, TIFR grew into a pioneer research centre that was internationally recognised. He made significant contributions in developing the technology of fabricating and flying very large balloons under tropical conditions, through very low temperatures of the equatorial tropopause, thus enabling cosmic ray work to be carried out at high altitudes, close to the geo-magnetic equator. His work in the field of elementary particle physics, particularly relating to strange particles,

defended the existence of muons of varying energies, of mono-energetic high energy pions, and of electrons of varying energies, as secondaries in the decay of heavy mesons. He demonstrated the scattering phenomena involving K-mesons and contributed to the development in the nuclear emulsion technique, particularly the use of large stacks of stripped emulsions, which led to significant results relating to the decay modes and interactions of the heavy mesons and hyperons. He pioneered deep underground studies in India relating to muons, neutrinos, weak interaction and nucleon decay; this included establishing the feasibility of experiments on neutrino-induced interactions and related new phenomena at great depths underground; first observations and analysis of natural neutrino interactions and observations of Kolar events; and from the late 1970s the first major dedicated experiment in the world to look for nucleon decay with life times up to $10^9$ years, with important observations on nucleon events, limits on magnetic monopoles, etc. The nation recognised his significant contributions to physics by the Presidential award Padma Bhushan in 1968. In 1970, the Fellowship of Royal Society (FRS), UK, was conferred on him. At the time of his appointment as the Scientific Adviser to Raksha Mantri, he was also Chairman of the Electronics Commission and Secretary to the Department of Electronics of the Government of India. In addition, he was the Chairman, Cosmic Ray Commission of International Union of Pure and Applied Physics, Indian National Committee for Physics, and was on UN Secretary General’s Advisory Committee on Application of Science and Technology to Development. After Dr Vikram Sarabhai passed away in December 1971, he was for some time, Chairman, Indian Space Research Organisation.

As one of the world’s top physicists and as one who had contributed to the growth of application of electronics in India to meet scientific and societal needs, the Professor brought to his new post his rich experience which would be an invaluable asset to DRDO. It was the hope of every scientist in the Organisation that he would give a significant fillip to their activities and lead them further along the path of self-reliance.

Professor Menon was known to most of the senior scientists of DRDO as they would have come into contact with him at one or more of the science and technology activities he was involved in. On his part, DRDO was no stranger to him. Many of us who had the benefit of listening to him, admired him for his grasp, for the wide range of his knowledge, for the way he could effortlessly analyse the most difficult situations, for his clarity of thought and the power of expression.
Professor Menon had a wide reach in the political, bureaucratic, military and scientific circles, and as the Scientific Adviser to Raksha Mantri, he would have a significant role to play in large military purchases from abroad. In addition, as Chairman Electronics Commission he had a decisive role in the promotion of indigenous R&D as well as manufacture of electronic component/equipment/systems. The scientists and technologists of DRDO were happy that with his appointment as the Scientific Adviser, DRDO would continue to have its voice heard at the highest level of decision-making, and that there would be a better understanding and appreciation of their efforts towards self-reliance in defence.

On his assuming the office of the Scientific Adviser, he reviewed the activities with the Chief Controllers and senior scientists to chalk out a plan and set the priorities. He recognised that DRDO in its role as an Organisation, solely dedicated to meet the needs of the Services, would have two types of project activities. The first one would be those that are relatively small and not spectacular, but nevertheless, necessary because of the need expressed by the Services. In these types of projects, it was essential to ensure success and a faster turnover so that the overall contributions of DRDO were high. He found that there were far too many small projects, each costing less than Rs. 20,000, neither linked to any major development programme, nor to any expressed need by the Services. He closed these and brought the number of projects down from 600 to 350.

The second type of projects were big and high visibility projects dealing with weapon system hardware. These would get his attention, guidance, and direction to minimise the chances of failure. Therefore, it would appear that he set his priorities as the development of the MBT-80 tank at CVRDE, the building up of the capabilities of GTRE for aircraft engine development, and that of DRDL for missile development, the activities at DMRL for the development of special metals and alloys with particular application to Kanchan armour and aircraft brake pads and those of the three electronic laboratories involved in the development of sensors, communications and electronic warfare equipment; DLRL was specially designated as EW Laboratory. He was clear that the personnel policies of DRDO need to be changed as these were inferior to those prevailing at the Departments of Atomic Energy and Department of Space. The succeeding paragraphs bring out some of the important developments that took place during his tenure as the Scientific Adviser.
3.14 MBT-80 TANK PROJECT

He was briefed on the MBT-80 tank project by the Director and the scientists of the CVRDE and also by the brass of the Army so that he could make an assessment of the magnitude of the task undertaken by the Organisation, the capability of CVRDE and other laboratories involved in the project, and the developments taking place in this area and their likely impact. By 1974, CVRDE had a strength of 400 and was in the process of completing the design and development of modified guns, armoured personnel carrier, and the improvement of Vijayanta tank. It was clear to the Scientific Adviser that it was the vision and drive of Mr DP Mukherjee that was responsible for the scientists of the CVRDE to undertake the development of the MBT-80s. His presence at CVRDE would be essential for some more years for guiding the development effort. Since, Mr Mukherjee had reached the age of superannuation, he re-employed him as Consultant so that he could concentrate fully on the project. The MBT-80 development envisaged the use of 110 mm to 115 mm bore gun, an integrated fire control system, night vision device, hydro-pneumatic suspension, nickel-chrome armour steel for hull and turret, and a 1500 HP engine. With the exception of the engine, all other features and subsystems were within the competence of DRDO for design and of the Indian production agencies for fabrication. Therefore, CVRDE’s determination to develop an air-cooled 1500 HP diesel engine to be fitted within the specified space in the tank, was a bold venture, especially as Indian automobile industry was totally dependent on imports for their vehicle models and also for the automobile engines. The Scientific Adviser approved the development plan and the proposed methodology. Keeping it in mind, he appointed Brigadier KN Tandon as the Director of the Laboratory so that he could provide the necessary support to Mr Mukherjee by his management capabilities which were needed to form the team of engine, transmission and suspension specialists within the Laboratory to work on the indigenous engine. While the existing industrial infrastructure would be used to the maximum possible extent, there was a lack of adequate machining and test facilities. This was remedied by deciding to expand the Mechanical Systems Laboratory and also to establish test facilities for engine, transmission, fuel injection pump, etc., at CVRDE so that testing of engines up to 1100 kW capacity would be possible. In this way, the Scientific Adviser gave a concrete shape to the project and to the organisation of the effort by combining the system expertise of Mr Mukherjee, which enabled him to spot the technology trends in each of the
major subsystems of the Tank ahead of others, with the management capabilities of Brigadier Tandon, who would ensure that the changes are smoothly incorporated into the design.

3.15 AIRCRAFT BRAKE PAD & KANCHAN ARMOUR

Way back in the 1970s, a decision had been taken that as a consequence of the work done at the DMRL on a variety of special metals and super alloys required for defence applications, exploitation of the know-how generated by the Laboratory should be taken up. Accordingly a plant for manufacture of these strategic and sophisticated metals and alloys required for electronics, aeronautics, rockets and missiles was proposed to be setup in the vicinity of the Laboratory. Since the demand picture was not encouraging economically, the proposal was in the process of being put in the cold storage. Professor Menon, in his capacity as Secretary Department of Electronics, was successful in arguing the case for the new enterprise so that in 1973, the Ministry of Defence could register at Hyderabad a new Public Sector Undertaking (PSU) called Mishra Dhatu Nigam Ltd (MIDHANI) with an authorised share capital of Rs 20 crore on a 75 acre site adjacent to the DMRL. The strategic importance of the new PSU could be gauged by the fact that only a few manufacturers in the world had the capability and capacity to supply these products. By establishing the production unit, the Country would not be subjected to the pulls and pressures of the Cold War which otherwise would come into the picture.

With the setting up of MIDHANI, the Scientific Adviser decided that the activities of the DMRL in the future would be towards R&D on other critical and advanced materials like friction materials, heavy alloys for armaments, steel projectiles, and armour, ultra-high strength low alloy steel, electro-steel castings, titanium and titanium-based alloys, technologies like hot isostatic pressing and so on26. He brought in Dr VS Arunachalam who was at the National Aerospace laboratories (NAL) in Bangalore and whom he had known earlier quite closely at the Department of Atomic Energy, to head the Laboratory. The work of DMRL in the next few years comprised mainly of R&D programmes, commissioning of facilities for production of quantities bigger than laboratory-scale and fabricating specific hardware in its support role for the laboratories, such as

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26 Dr RVTamhankar was made full time Chairman & Managing Director of MIDHANI in July 1975 and Dr VS Arunachalam took over as Director DMRL from August 1975. Dr VS Arunachalam would be appointed in 1982 as the Scientific Adviser to the Defence Minister, Secretary to the Department of Defence Research & Development and Director General Defence Research & Development Organisation.
ARDE, CVRDE, GTRE, DLRL, DRDL, and so on. The faith of the Scientific Adviser in the new Director of DMRL was vindicated when the Indian Air Force informed the Prime Minister that their MIG aircraft fleet would have to be grounded soon due to the irregular and interrupted supply of brake pads for the aircraft from Russia. The nation turned to the Scientific Adviser and to DRDO in this crisis and DMRL rose to the occasion and solved the problem expeditiously and produced the brake pads in numbers in-house for the IAF to test and evaluate their product. These brake pads had better performance in terms of number of landings superior to that obtained with Russian brake pads. At that point, the Russian supply of the brake pad was resumed and they were willing to part with their manufacturing know-how to India. The Scientific Adviser persuaded the Ministry of Defence to turn the Russian offer down. Instead, DRDO know-how was passed on to HAL for the manufacture of brake pads. Over a period of time all the brake pads needed for the Indian Air Force fleet were manufactured in India based on the DMRL technology.

3.16 AIRCRAFT ENGINE DEVELOPMENT

In the early 1970s, GTRE had embarked on research projects in the area of compressor, combustor, turbine, engine control system, heat transfer, and so on, so that the input from these projects would provide valuable data for configuring a viable indigenous propulsion system. In the mean time, the work on the integration of the single-stage transonic compressor with six subsonic stages of the Orpheus 703 engine had been completed and the performance level achieved during the static tests in May 1974 proved the reliability, repeatability, and mechanical integrity of the design and gave considerable confidence to the GTRE team to take on the development of a power plant for the military aircraft. As the cost, the generation of skills, acquisition of expertise and the accumulation of data was expensive and time-consuming (tens of crores of rupees and about fifteen years) the Scientific Adviser took the decision to support this activity at GTRE for the development of the GTX engine specially configured to deal with the high ambient temperatures of the tropics.

27Brake pads are essential for landing and take off of aircraft. The estimates made by the IAF about the quantity they would need annually for their fleet was lower than the actual numbers used and since the Russian economy was a planned economy, the latter were not able to bridge the gap because they would not have planned the additional numbers into their production programme earlier.

28After successful completion of development and at the time of introduction into service, the radars developed by LRDE for the detection of low flying targets against the background of heavy clutter were named INDRA, an acronym for INdian Doppler RA dors.
3.17  **INDRA RADAR DEVELOPMENT**

The feasibility of using the moving target detector for the detection of low flying aircraft targets in the presence of heavy ground clutter as a solution was completed shortly after Professor Menon became the Scientific Adviser. A presentation was made to him and he was convinced that this would meet the operational requirements of the Indian Air Force which had been searching world wide since 1967 for a radar system with capability to detect moving targets of low cross section against the background of heavy ground clutter. In his capacity as Chairman of the National Radar Council, he provided a forum for the LRDE scientists to make presentations of the new concept to the top technical officers of the three Services. Initially, there was a high degree of skepticism about the practical realization of the approach but Professor Menon’s backing of LRDE considerably softened the opposition and gave an opportunity for the DRDO to come abreast in surveillance radar technology with the rest of the world. He also ensured that two staff projects were sanctioned to LRDE for undertaking the development of radars for the Indian Air Force and for the Indian Army. He went further and allowed LRDE scientists to explore the possibility of getting critical subsystems, such as the high stability transmitter and the radar data processor outsourced for reducing the uncertainty and for compressing the time for development. The major success in the field of electronics were the self reliant implementation of Plan Adges for the Air Force (led by TIFR and supported by Electronics Commission) and Plan Aren for the Indian Army with the key switch developed in parallel at LRDE and TIFR.

3.18  **MISSILES DEVELOPMENT**

While Professor Menon who was in accord with the policies followed by Dr Nag Chaudhuri in respect of the priority for building missile development capability at DRDL, he desired other scientists within the country who had expertise in the fields of rockets and missiles, aerodynamics, propulsion, control and guidance, radar, to critique these activities from a strategic perspective. Therefore, he constituted a committee in 1974 with Professor Brahm Prakash of the Department of Space as Chairman for the purpose of assessing the progress of development activity, competence generation, infrastructure and facilities build-up. The Review Committee while recommending further release of funds to DRDL, held the view that from the strategic perspective, systems analysis needed to be

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28 The Brahm Prakash Review Committee was constituted in December 1974.
given greater emphasis in the next phase of the project by DRDL, the nodal laboratory. Accordingly, the activities of development of the existing missiles on a one-to-one basis as well as the strategic buildup of the infrastructure and that of technology development at DRDL were fully backed by the Scientific Adviser during his tenure. He was totally supportive of the technology development programme in liquid fuel propulsion for missiles.

He was also instrumental in effecting a step change in the mind set of the Ministry from the narrow perspective of looking at the missile requirements of each Service in isolation to the other (that had resulted in the imports of the individual missile systems for each purpose), to the more strategic perspective of formulating a total picture of the needs of the Country. The Defence Minister then constituted a Missile Policy Committee with Professor Menon as Chairman to analyse and determine the likely needs of the Services in the future and also outline further investments needed to be made by the Government. The Report was a comprehensive document that stated in detail the likely requirements in all classes of missiles, the class of missiles to be developed within the Country, the technologies to be developed and/or acquired from abroad, the needs of production and that of DRDO for such development to be effective. This document would help later in the 1980s in drawing the blue print for the Integrated Guided Missile Development Programme (IGMDP).

3.19 PERSONNEL POLICY REFORMS

The personnel policy of DRDO continued to remain inferior to that of the Departments of Space and Atomic Energy. The combination of small and compact peace establishments (PEs) for the laboratories, the non-periodicity and delays in direct recruitment/departmental promotions, and the increased demand for additional manpower contributed to the problems of unhappiness about poor career prospects, of tension due to highly unequal opportunities, and of high turnover.

The anomaly of a small peace establishment (PE) with a large number of temporary posts created for the duration of the projects undertaken in most of the equipment/hardware-oriented laboratories was generating enormous paper work and taking considerable time and effort of senior persons, both at the laboratories and at the Headquarters. Every time, a project got extended or completed/terminated, the urgency to retain the
experienced personnel appointed against the project would crop up and piloting the papers, either for revision of the peace establishment or for their continuation through finance personnel even within the Ministry of Defence would more often than not hit a road block and the process would have to be started all over again. The Scientific Adviser, realising the frustration of senior scientists, organised a meeting of the senior scientists with the Internal Financial Adviser (IFA) to evolve the concept of core PE for each laboratory and the norms that would be applicable. Guide lines were then issued to the laboratories and each case was argued on file, corrected, and modified, sometimes more than once, before it got the approval of the Government. In this way, the pool of permanent posts of the DRDS cadre was enlarged and was made to reflect the ground reality so that the acceptance of the Flexible Complementing Scheme would be high among the scientists when a large number of them (larger than ever before) would likely to be promoted in the early years of the Scheme.

The more than doubling of the DRDO budget from Rs. 17.52 crore in 1970-71 to Rs 40.00 crore in five years had resulted in expansion of facilities and manpower in the laboratories of thrust areas like radar, communication, electronic warfare, guidance and control, aerospace where the additional scientific/technical and industrial manpower approved for the projects became comparable to their PEs. Since Finance officials targeted higher scientific posts (Scientist E equivalent and higher posts) for drastic reduction, the hierarchical structure was needle-like at higher levels, with a bulge at Scientist B and C equivalent levels and tapered-off upwards at Scientist D equivalent and downwards at Junior Scientific Officer. In the NGO (scientific assistant/foreman) and industrial categories, there was also significant expansion compared to the original strength in the PE. The scientists were mostly recruited through UPSC to whom the vacancies were released twice a year on a regular basis. The delay in filling up the posts varied from eight months to two years. Since the qualifications for the recruitment to the NGO category included Master’s degree in science or a BE/B.Tech degree in engineering, and since the recruitment could be done at the laboratory, these posts for technicians were filled up by young engineers and scientists, a significant percentage of whom worked for two to three years to enhance their market value and left the Laboratory for better prospects. Those who had met with success when UPSC interviews were held and it was not unusual to find a number of them jumping two levels to become Scientist B equivalent from Assistant Foreman, and laterally from
one laboratory to another in a matter of three to four years. The picture was not as bright for scientists working in the non-thrust areas or in the inspection organisation where the opportunities for promotion were limited and were through departmental promotion committees which met not so regularly or as frequently. These factors led to unequal career opportunities and unhappiness among the scientists within the organisation, and tension between DRDO and the inspection organisations. The younger and brighter scientists and engineers, and also those who had joined DRDO at the level of technical assistants, moved from one laboratory to another as the project posts for Scientists B or C equivalent were advertised and selections were made. Teams broke up as skilled personnel migrated on promotion or through direct recruitment and affected the system development programmes of the laboratories.

The vexing question of DRDO getting out of the UPSC for recruitment and promotion required a lot more attention from the Scientific Adviser. A number of meetings were held by him with the Chairman UPSC and these were followed up by one of the Chief Controllers and the Director of Personnel. Concessions like DRDO sending the list of vacant posts for recruitment twice a year, having a say in the screening of candidates to be called for interview, nomination of specialists for serving on the panel of experts for examination of the candidates, and inclusion of a representative from the laboratory to serve on the selection boards for the posts advertised by the laboratory, were made but the basic problems of uncertainty and delay in recruitment and promotion of scientists continued. The publication of the Third Pay Commission Report in which the Pay Commission had recommended flexible complementing scheme for scientists and technologists provided the trigger for DRDO to get out of the inflexible and static personnel policy. The Scientific Adviser pursued it vigorously, by first getting the approval of the Minister for Science and Technology to include DRDO as a scientific department. Next, he utilised the recommendation of flexible complementing for scientific services to get the application of flexible complementing to DSS accepted and approved at a high level meeting of the Secretaries and the Chairman UPSC. The DRDO would no longer be bound by vacancy-constrained promotion which had caused so much unhappiness and migration of scientists from DRDO. Even after the approval Ministry of Finance, the flexible complementing scheme

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30 Flexible complementing is budget constrained personnel policy instead of vacancy constrained. Under this scheme, eligibility for consideration for promotion was prescribed and the promotion of eligible candidate was based solely on his performance.
could not be implemented during Professor Menon’s tenure as the Scientific Adviser because the details of bifurcation of the common cadre of scientists between the DRDO and DGI organisations, the circulation of the new rules to the scientists etc., had to be completed first.

3.20 CONSOLIDATION OF DELEGATION OF POWERS

The shift of DRDO from short-term responses to contemporary system development meant that the number of large projects with significant investments would be on the rise and there would be a greater need for taking decisions closer to the point of action. In effect, it would mean more decisions would have to be taken at the level of the heads of the laboratories for which powers of the Scientific Adviser and the Director General R&D would have to be delegated. Accordingly, Professor Menon delegated some more of the financial powers of the SA to RM and that of DGR&D to the heads of the laboratories in July 1975 and followed it up with a consolidated list of such powers delegated to heads of laboratories in April 1976. For example, full powers of the Scientific Adviser were delegated down in the case of placing of indents, disposal of surplus stores through the central purchase organisation like DGS&D, ISM London/Washington, placing of purchase orders on firms who have a DGS&D rate contract, purchase of material under limited tenders, direct purchase of materials/equipment not handled by central purchase organisations or not covered by DGS&D rate contract, advance payment on orders, sanction of expenditure for airlift of materials/equipment, contingent and miscellaneous expenditures. These steps reduced the paper work at the DRDO Headquarters and also eliminated one of the irritants that had bedevilled the working relationship between the laboratories and the Headquarters.

3.21 REFORMING DRDO HEADQUARTERS

The Scientific Adviser took the step of having an Internal Financial Adviser (IFA) attached to the DRDO so that most of the files with respect to revising the peace establishment of the laboratories, financial approval for projects, foreign visits, equipment purchase, would be processed and scrutinized in-house through the office of the IFA before these were sent

31 DRDO letter No. F21(2)/Coord/74 dated 10 July 1975 and Government of India Letter No. 98916/RD-26/3466/D(R&D) dated 7th April 1976. The consolidation provides at one place the powers of the Scientific Adviser that were delegated to heads of laboratories under different headings such as sanction of manpower, sanction of development projects, purchase and disposal of equipment/material, write of losses and audit objections, sanction of contingent and miscellaneous expenditure and lists the procedure to be followed for disposal of surplus stores.
outside the Department for sanction, concurrence, and other related activities. This avoided the repetitive movement of files to and from the department and reduced the delays in getting approval of the higher authorities\(^\text{32}\). The Scientific Adviser who was not fully convinced of the necessity for DRDO Headquarters to grow to the numbers it had, constituted a committee under JP Kaicker, who was Additional Secretary Defence Supplies, to examine the duties and activities of Headquarters personnel versus their growth in numbers. He found that the special allowance paid to personnel serving at DRDO Headquarters might also have provided incentive for personnel from the laboratories to move to Headquarters. Kaicker’s committee’s recommendations reduced the number of personnel at Headquarters significantly and also cut out the special allowance. In this way the number of personnel available at the laboratories increased to the extent it was reduced at DRDO Headquarters.

3.22 FOREIGN DEPUTATION & VISITS

Unlike other science and technology departments of the Government of India, the scientists of DRDO found it very difficult to travel abroad on Government account even for presentation of papers or for attending important international seminars. While foreign visits by the personnel from the Ministry of Defence for purchase of arms or for training on arms and weapons were accorded permission, scientists and technologists of the DRDO were routinely denied permission as it was considered by financial officials that these visits were not necessary. Professor Menon convinced the Expenditure and Finance Secretaries of the Government of India, the necessity for scientists and technologists of DRDO to attend such important international conferences and seminars and visits including stays at laboratories abroad for exchange of information about the latest trends in techniques and technologies, and the benefits that would accrue to the Country. Thereafter, the situation eased for visits abroad for DRDO scientists.

3.23 IMPACT ON THE ORGANISATION

Professor Menon’s main contributions were two fold. The first contribution was giving thrust to projects where DRDO could contribute effectively and make a significant impact. Typical examples would be, the

\(^{32}\) The first IFA was Mr BM Prabhu, an IDAS officer who was helpful in handling these matters for the DRDO outside the department. Since all important papers like the ones needing Cabinet approval would have to be routed through the Financial Adviser to Defence and the Finance Minister, the inclusion of IFA earlier in the chain improved the chances of acceptance.
Over to Systems Development

MBT-80 tank project which he put in shape, the Indra Radar, the microwave component development effort and stress on electronic warfare systems, and the Plan AREN communication projects, which he actively encouraged and supported, the projects of DMRL and the activities in the area of missiles including the strategic perspective on the new technology of missile warfare. The other contribution was in disentangling the sorry state of affairs in personnel policy of the DRDO and putting it on the correct path so that the rigidity and inflexibility by which they were earlier characterised, was eliminated and a methodology for an enlightened and flexible policy could be put in place. This came about in the years after he had left notably under the leadership of Dr Ramanna.

3.24 DR RAJA RAMANNA ASSUMES OFFICE OF THE SCIENTIFIC ADVISER

The transition from Professor Menon to Dr Raja Ramanna as the Scientific Adviser to Raksha Mantri was unlike the previous changes. It was known ahead of time that Professor Menon would be leaving the post of Scientific Adviser and that Dr Raja Ramanna had been appointed in his place. A Conference of the Heads of the Laboratories, the chief controllers and the Technical Directors was convened and over a period of two days, the incoming Chief was briefed about the accomplishments, current status of projects, and on issues and problems that needed his attention.

Biographical Sketch: Dr Raja Ramanna had his early education in Bangalore and took his Honours degree in physics from the University of Madras, and Ph.D degree from the University of London. Following a brilliant academic career, he joined the TIFR, Mumbai, in 1949 where he held the post of a professor at the time of his appointment as the Scientific Adviser. He was transferred to Bhabha Atomic Research Centre(BARC), Mumbai as Head of the Nuclear Physics Division. He made significant contributions in the field of neutron thermalisation, reactor design, experimental and theoretical studies of low energy nuclear reactions with special reference to nuclear fission. India’s first reactor Apsara was designed under his guidance. He became the Director of the Physics group in December 1962 and was awarded the Shanti Swarup Bhatnagar Memorial Award for physical sciences in 1963 and Padma Shri in 1968. In June 1972, he became Director, BARC, Mumbai and Member for Research & Development, Atomic Energy Commission. He was in-charge for the utilisation of three reactors, Apsara, Cirus and the fast reactor Purnima as well as of the 5.5 MeV Van de Graaff accelerator. He also headed the group working on the
Dr Raja Ramanna
(10 July 1978–15 February 1982)
inelastic scattering of neutrons for the study of the condensation of matter and recording and interpretation of seismic events, including the underground and atmospheric nuclear explosions. For his continuing contributions, Dr Ramanna was awarded Padma Bhushan in 1973. He was the prime architect of our first peaceful nuclear explosion in 1974. The Country recognised his contributions with Padma Vibhushan in 1975. At the time of his appointment to the post of the Scientific Adviser to the Minister for Defence, he was Chairman, Board of Governors, IIT Bombay, and held membership of the National Committee on Science and Technology, of the Executive Council of Jawaharlal Nehru University, and of the Indo-Soviet Joint Commission. Besides these, he was also Chairman of two international committees Nora Committee of IAEA with Norway, and India-Philippines Agency Project Committee.

Though in the beginning of his tenure as Scientific Adviser, Dr Ramanna, who was still Director of BARC, commuted between Mumbai and Delhi regularly but soon he became full-time Scientific Adviser. Besides being a scientist of eminence, Dr Ramanna, is also a great musician and musicologist, an excellent piano player who regularly gave concerts. He was also interested in comparative study of Indian and western musical styles. He made it a point to visit all the laboratories and field stations of the DRDO more than once and this gave him opportunity to explore different manifestations of nature in places like Kumaon, Lahul, Pygmalion Point, Andaman-Nicobar islands, and feel rejuvenated. In this process, he had the time and opportunity to appreciate the good work being done by the small laboratories and the field stations at Manali, Almora, Jodhpur and other places. The scientists of these institutions were encouraged by the visits and interaction with the Scientific Adviser, and showed it with an upward trend in quality and quantity of their output. His passionate desire to preserve the Nation’s historical heritage found expression in the renovation and maintenance of the historic building in Delhi, the Metcalfe House.\(^3^3\)
Dr Ramanna was not a stranger to DRDO. His first acquaintance with the Organisation was around 1957 when he attended the Defence Science Conference convened by Dr DS Kothari the Scientific Adviser at that time. He had close interaction with Dr BD Nag Chaudhuri, and Mr NS Venkatesan, who was Director, TBRL in the pre-1974 days when DRDO collaborated with the Department of Atomic Energy for the peaceful nuclear explosion. From these experiences, he was well aware of the essential cultural dissimilarities between the DRDO and the BARC/DAE.

The DRDO Conference of the senior scientists and Service officers convened by Professor Menon and also attended by Dr Ramanna, alerted him to some of the outstanding issues which required immediate attention and action.

3.25 DRDO HEADQUARTERS AS COORDINATING AGENCY

Immediately after assuming the office of the SA to RM, Dr Ramanna swung into action and in about a fortnight, issued a letter to all the laboratories and field stations of DRDO about the restructuring of DRDO Headquarters and distribution of work among the CCR&Ds to reduce the bureaucratic overheads and ensure faster response to the needs of the laboratories. The revised organisational chart is shown in Appendix-II (Figure 3). On technical activities, the link between the Heads of the Laboratories and the Director General R&D would be direct. The Heads of Laboratories would keep their respective CCR&Ds in the picture so that the latter would be able to effectively interface with the Services. The CCR&Ds would be the single point contacts for their laboratories on all issues requiring clarification/action from multiple directorates at DRDO Headquarters. The role of Headquarters personnel would be to assist the laboratories in all possible ways by providing scientific and administrative support and data not available to the laboratory personnel. In addition, they would keep the Scientific Adviser informed of all the modern developments in their respective areas and effectively liaise with the Services and concerned Ministries of the Government. Two Committees were formed of which the Headquarters Committee consisting of the three CCR&Ds and IFA and chaired by the SA to RM would deal with all problems faced by the laboratories. The Committee would meet every week. The second committee was called the Technical Committee with two CCR&Ds other than CCR&D(A), all Headquarters directors and laboratory

heads who were present in Delhi and chaired by the SA to RM would review progress on projects, deal with requirements of the Services, slippage of completion dates of major projects, and problems of procurement. This Committee would meet once a month. To improve communication and integration of work between the laboratories working in the same or allied disciplinary areas, the CCR&D would chair an Advisory Committee with the respective heads of the laboratories of each group as members to bring an interdisciplinary perspective on the projects pursued by the group. In addition, the directive from the SA to RM contained specific instructions for laboratories to promote participation of younger scientists in decision-making and their training to improve their skills. It is a tribute to Dr Raja Ramanna’s managerial acumen that the Advisory Committee and the Technical Committee continued to function for many years after he had left the Organisation.

3.26 NEW PERSONNEL POLICY

There were apprehensions in the minds of many scientists at DRDO Headquarters and at the Laboratories about the impact of new personnel policy on their careers, the methodology of implementation, and the delays that might arise due to legal challenges. Speed was of essence and here again, Dr Ramanna showed his penchant for action to reduce the agony of uncertainty. In September 1978, a communication was issued by the Director of Personnel forthwith forbidding the Heads of Laboratories from recruiting Master’s degree holders in science and BE/B.Tech graduates in engineering for posts in the non-gazetted cadre, and banning direct recruitment to the post of Foreman. This put a stop to creation of more posts of foreman (highest echelon in the non-gazetted cadre)\textsuperscript{35}. The communication effectively reserved the NGO cadre for diploma holders and graduates in science thus preventing entry in future into the scientists' cadre through the departmental route. Second, the measure ensured better chances of career advancement for the serving non-gazetted officers at lower levels by stopping direct recruitment at the Foreman level. If the scientists' cadre of the future, Defence Research and Development Service (DRDS) had to be Class I service, then the post of junior scientific officer (JSO) would have to be abolished and a means would have to be found whereby the existing personnel could have an opportunity to move into the scientists cadre. Further, since the existing Defence Science Service (DSS), was common for scientists serving in DRDO and Inspection Organisations, it would be necessary to delink the two cadres, especially as the earlier efforts

\textsuperscript{35}D.O. Letter from Director of Personnel No. 87360/RD-22, dated 30 September 1978.
by Professor Menon had indicated that the Department of Defence Production was not enthusiastic to adopt the flexible complementing scheme for promotion of the scientists serving in their organisations. Further interactions at the levels of DGI and Secretary, Defence Production resulted in their not standing in the way of DRDO to opt out of DSS and form the new Service, DRDS, with provision for one-time option for the scientists serving in the inspection organisations to enter the DRDS. The decks were cleared after the scrutiny by Government legal experts and a detailed communication was sent to all laboratories/establishments, field stations, detachments, and technical directorates at the DRDO Headquarters in January 1979. The die was cast and there would be no looking back. The DRDS rules were clearly a step forward and a way out of the morass that the DRDO had slipped into in the 1960s. No doubt, the response from the scientists of DRDO was by and large enthusiastic and

36 Letter from the Director of Personnel No. 0744/Pers/RD-21(a)/79 dated 15 January 1979. The communication from the Director of Personnel indicated that DRDS as "finally approved in consultation with all the offices concerned are being published in the Gazette of India 13 January 1979 as SRO No.8." A copy of the DRDS rules was forwarded to the each of the formations of DRDO and the heads of the units were asked to communicate the document to all serving Group A scientists and only those scientists who do not want to be absorbed in the new Service were to be asked to exercise their option in the format provided. The DRDS rules form a 22 page document.

37 The salient points of DRDS rules as communicated in January 1979 are as follows. The DRDS excluded the Junior Scientific Officers so that the entry point to the Service was at Scientist B level. The mode of entry was direct recruitment through an open competitive examination the scheme for which would be decided by the UPSC. The minimum entry level qualification would be either a bachelor’s degree in engineering or a Master’s degree in science. The post of Junior Scientific officer was abolished. However, those who were in service and had the minimum entry level qualification were eligible for promotion to Scientist B till they are wasted out with the stipulation that at no time would the percentage of promotees exceed 50 per cent. The filling up of the posts higher than Scientist B could be by promotion, direct recruitment, deputation or transfer from other departments of the government, or absorption of Service Officers. The post of Scientific Adviser was included in the DRDS but the selection to the post would be made by the government in consultation with the UPSC. The mode of promotion from Scientist B upwards would be on the basis of individual merits or accomplishments evaluated by an Assessment Board chaired by a UPSC member and consisting of two to three departmental members and two or more experts from outside the DRDO, nominated by the UPSC. The minimum specified period of service in any grade for appearing before the Assessment Board varied depending on the grading of the scientist over the period. Promotion would be in situ and the required number of posts would be upgraded under the powers of the DGR&D with the proviso that the budgetary ceiling was not exceeded. Another restriction was that the total number of Scientists D and E shall not exceed one.
positive. They could all look forward to merit based promotions, no vacancy-based constraints, regular and annual holding of assessment boards and all promotions given effect to from a specified date.

The Scientific Adviser made certain that the promise held forth by DRDS to the scientists was fulfilled at the earliest. The effort needed was enormous but the Directorate of Personnel lived up to the expectations of the Scientific Adviser and of the scientists with help from senior scientists in preparing the panels of experts in each discipline for clearance by UPSC and in ensuring that annual confidential reports were updated and despatched on time for assessment boards to be held. The DOP on its part had to decide on the centres for the Assessment Boards, on the laboratories in each centre where the Boards would assemble, decide with selected laboratories on the dates, days for assessment and the daily lists of candidates to be assessed, the total logistics of getting the relevant experts for each day, intimating the laboratories and the scientists about the dates and so on. It was an effort of herculean proportions but it was accomplished with minimum disarray and confusion. In 1980 the exercise of completing the assessment of more than 1000 scientists in five centres was begun and the promotions across the Organisation were made effective from 1 July, 1980.

The terms and conditions of service of the Service Officers permanently seconded to DRDO was also revised. The non-gazetted cadre too benefited considerably as a result of the quick implementation of the DRDS.

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third the number of Scientists B and C together and that the number of Scientists E shall not exceed 50% of the number of Scientist D’s. The DRDS rules also stipulated that the Assessment Board met at least once a year and that all promotions would be given effect to on the same date. Scientists belonging to the DSS but working in the DGI and DTD&P(Air) were given an option to shift to DRDS on condition that they exercise the option within 90 days and their suitability for absorption in DRDO would be determined by a Screening Committee chaired by UPSC member with SA to RM, two Chief Controllers and one senior scientist working in the discipline concerned as members. In order to eliminate litigation by those who had opted for absorption but were not selected, the decision of the Screening Committee was made final and binding on the scientists.

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38 Annual Report of DRDO to the Ministry of Defence, 1979-1980. In consultation with the Chiefs of Staff Committee and with the approval of the government the age limit of active service for Service Officers was extended up to 57 years with review and screening at the ages of 52 and 55 years. A cadre review was carried out and their career opportunities at the level of Colonel equivalent and above were improved considerably.

39 The stagnation that had occurred in the non-gazetted cadre of Foreman down to Assistant Chargeman, Senior Scientific Assistant to Junior Scientific Assistant was
Defence Research & Development Organisation (1958-82)

The combined efforts of three Scientific Advisers spread over a period of nearly ten years bore fruit. Dr BD Nag Chaudhuri initiated, Professor MGK Menon actively pursued and Dr Raja Ramanna firmly put in place the new personnel policy for which the scientists of DRDO owe them a debt of gratitude.

3.27 DEPARTMENT OF DEFENCE RESEARCH & DEVELOPMENT

Even though the Scientific Adviser enjoyed the status of the Secretary to the Government of India, DRDO was put under the Department of Defence Production from the days of Dr Nag Chaudhuri. Dr Raja Ramanna took the step of creating the Department of Defence Research & Development so that the important papers requiring approval/concurrence from the Cabinet, the Prime Minister, Raksha Mantri or Raksha Utpadan Mantri or other Ministers could be sent straight to the destination. In all cases of development of major weapon systems, direct communication with the political head of the Government would be necessary because it involved strategic decision-making. If such important papers were to be routed through channels who had no immediate interest in the matter and who were not aware of the strategic nature of the issues, they would in all probability introduce delays with queries of short-term nature which would clutter the picture and more often than not stifle the creative process. The creation of a separate department helped in reducing the paper work on important issues and the corresponding delays for DRDO. The enormous prestige Dr Ramanna enjoyed with the political establishment of the Country as the prime architect of the peaceful nuclear explosion stilled any action to stall the creation of a separate department for research and development. The main areas of responsibility for the department were rendering advice to the Defence Minister and the three Services on all scientific aspects of military operations, equipment and logistics, reduced considerably with several measures. The first was that of extending age limits to departmental candidates who had the minimum qualifications and who were in the ranks of JSO and in non gazetted officers' cadre to appear for direct recruitment at entry level of DRDS. The second was the reservation up to 50% by promotion of the vacancies at the entry level of DRDS to Junior Scientific Officers. The third was holding of limited departmental competitive examination for JSOs who did not possess the minimum entry level qualification for entering into DRDS. The number of promotions from Foreman/Senior Scientific Assistant to JSO created chain vacancies down the line so that the non gazetted cadre too got the benefit from DRDS. Next the departmental promotion for the non-gazetted cadre was decentralised so that departmental promotion committee could be regularly held locally with the head of the laboratories in the Chair, every six months. The visibility of upward movement every six months of persons who had earlier stagnated for years in the lower rungs of the non-gazetted cadre had a significant positive impact.
formulation of research and development plans, administration of DRDS Rules, framing of personnel policies and providing the backup for the Defence Research & Development Council.

3.28 STREAMLINING THE OPERATIONS WITHIN

Dr Ramanna demanded and got from Headquarters the type of service that he needed, namely data about the projects undertaken, their discipline wise distribution, the financial resources required for the projects in each discipline, the distribution of minor, R&D and staff projects, the number of projects and the financial liability for each Service and so on, for streamlining the operations inside the Organisation and to decide on further action.

The analysis revealed that the laboratories of DRDO in major disciplines had reached a stage where the Organisation was confident of taking on development of major systems for the Services. He found that the cost of Navy’s projects was a distant third to the other two Services as Navy did not have any major weapon system or sensor system projects at the laboratories dedicated exclusively to meet their needs. He decided to increase the budget for NSTL so that the laboratory could accelerate the

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40 The creation of the department of defence research and development with the areas of its responsibilities was communicated to the laboratories vide Head Quarters Routine Order No. 10/80 24th July 1980. The creation of the department eliminated the need to route papers on important issues needing concurrence or approval of the Cabinet, Prime Minister, Defence Minister or other Ministries through the Secretary of the Department of Defence Production within the Ministry of Defence to reach the intended destination. Normally since that department would not be fully in the picture on issues of strategic nature relevant to defence R&D, they would query DRDO and seek clarifications and details before the papers were sent to the intended destination. This entailed further paper work, delays and stifled the creative process.

41 The project activities of the DRDO could be classified into two broad categories namely Staff projects and "RD" projects. Staff projects were taken up against definitive qualitative/operational requirements of the Services while "RD" projects were initiated by the laboratory for competence building through technology development and for building infrastructure in order to complete the Staff project to the satisfaction of the customer Service within the stipulated time. The break up of the resources among these two categories indicate that sixty percent of the resources are dedicated to Staff projects and the rest to the other category. The Air Force staff projects needed the most resources with their share of the cost being 47%, while the Army’s was close with 41%. The Navy staff project needs were a distant third with 9% and the cost of the inter-services projects was only 3%. Of the projects that were actively progressed, large projects (costing Rs 1 crore and above) accounted for 55% of the total cost, middle size projects (between Rs 10 lakhs and Rs 1 crore ) needed 34% of the cost. A large number of small projects (costing less than 10 lakhs) were accounting for 11% of the project costs. Discipline wise, Materials and General Stores and Armaments had a large number of small projects, while Rockets and Missiles, Aeronautics and Electronics had more large projects and fewer small projects with engineering, naval systems and vehicles having almost an equal number of small and large projects.
process of building infrastructure and test facilities for development of naval weapon systems. He supported the Director NPOL in improving the laboratory facilities for signal processing activities which were essential for developing modern sonar systems. In addition, when Dr VK Aatre, an electronics engineer with specialisation in signal processing expressed a desire to return to India after a long stay abroad, the Scientific Adviser encouraged him by offering him a senior scientist’s position at NPOL. He then turned his attention to laboratories in the Armament, and Materials & General Stores groups. These had the largest number of smaller projects. He conferred with Mr NS Venkatesan, Director ARDE and his senior scientists after which ARDE agreed to change from the reactive mode of response to a more pro-active mode so that ARDE in future would have a small number of larger projects. The laboratory would also take up technology development so as to be ahead of the User’s needs in armament and guns. In the Materials Group, he found that DMRL was already very active and interacting with other laboratories in respect of their needs and had very good interaction with the production agencies. With the other laboratories in the Materials Group, he urged them to drop as many smaller projects which could be handled by institutions other than DRDO and try to focus on bigger issues.

In the case of the Aeronautics Group, he got ADE to terminate a large number of small projects and switch over to work on a major programme of developing Pilotless Target Aircraft (PTA) for meeting the Services requirements. He found that the inter-laboratory collaboration between CVRDE, the nodal laboratory for development of tank and IRDE the specialist laboratory for weapon sights, required to be improved. Therefore, he got the activity of development of sights taken up by CVRDE to be transferred to IRDE which had the expertise and knowledge for such development. Director, CVRDE was asked to focus on the in-house development effort for the engine, transmission heat transfer and suspension systems besides improving the coordination.

He was not happy with the missile development activities at DRDL because he found that the emphasis was towards the building of infrastructure without a clear cut technology development and missile system programmes. As a result of the serious differences of opinion, the incumbent Director DRDL parted company with DRDO in March 1980.

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42 Dr VK Aatre who is currently the Scientific Adviser to Raksha Mantri joined NPOL in 1980 after his return from abroad.
Even though a senior scientist within the Organisation was made head of the laboratory, Dr Ramanna was on the lookout for a scientist who had a good track record and who was dedicated and committed to his work and profession. He found his man in Dr APJ Abdul Kalam who was at the Department of Space and persuaded him to take up the challenge of building the missiles for the country.

Way back in 1973, three laboratories setup under DRDO, namely INMAS, DIPAS and DIPR had been transferred out of the Organisation to Director General Armed Forces Medical Services since they needed very close interaction with the Armed Forces and the activities were in science and technology areas related to medical sciences. However, since the emphasis in the DGAFMS organisation is towards operational issues and short-term solutions, the culture of R&D would not be robust and the research aspect would have taken a second place. Further, since the promotion in DGAFMS organisation is vacancy limited, and DRDO was opting for flexible complementing, there would have been difficulties in retaining scientists promoted by DRDS in the DGAFMS organisation. Hence on two counts the transfer of INMAS, DIPAS and DIPR back to DRDO was accepted by Dr Ramanna in 1980.

3.29 LIGHT COMBAT AIRCRAFT

The aircraft industry in India were devoid of any major aircraft development programme. The Indian Air Force, a major customer in India for aircraft industry, was buying aircraft from Russia and West European countries to meet their requirements. However, when the Indian Air Force indicated that they would need replacements in 1990s for the ageing fighter fleet, Dr Raja Ramanna in his capacity as the Scientific Adviser, took the lead in February 1980 by communicating to the Prime Minister of India that he was forming an internal group of scientists to conduct a detailed study of the various aspects of the light combat aircraft (LCA) and related engine development programmes. The study would also include the assessment of the resources and technologies from within the Country. Further, the report would bring out the technology areas for which inputs from abroad would be necessary. Nearly 18 months later, Dr Ramanna, in his second communication to the Prime Minister detailed the progress that had taken

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43 Dr A PJ Abdul Kalam joined DRDO as Director DRDL in 1982. He would be known as the father of missiles in India and in 1992 he became the Scientific Adviser to Raksha Mantri. At the time of writing this book, he is the President of India.
place in advancing the cause of indigenous development of the light combat aircraft. He informed the Prime Minister that preliminary design configuration studies based on a number of available engines including the indigenous GTX of GTRE were completed. The concept as envisaged by the committee of the future fighter aircraft and the new advancements likely to find a place in the proposed solution to the Air Force’s needs were enumerated. He also mentioned that any estimate of time and resources would only be inexact as the Country had no expertise in the new technologies that would find place in future aircraft. The note concluded with a draft paper for approval of the Cabinet Committee for Political Affairs (CCPA) of the proposed plan of action. The seeds of the LCA programme which would be taken up a few years later were sown.

![GTX engine](image)

**Figure 3.1. GTX engine**

### 3.30 FOSTERING INTER-LABORATORY INTERACTION

Dr Ramanna was surprised at the low inter-laboratory collaboration among the DRDO laboratories. His own experience of the peaceful nuclear explosion had brought home to him the interdisciplinary nature of modern weapon systems. Therefore, he set about in improving the collaboration among the laboratories in a three-pronged manner. First, he setup Advisory Committees for each group of laboratories with Chief Controllers in the chair to bring interdisciplinary perspective on the activities of each laboratory. Second, he discouraged nodal systems laboratories, such as CVRDE, DRDL and others from setting up specialist groups and facilities in areas for which expertise already exists within DRDO. It is in this context that on the MBT-80 project, he transferred the
weapon sighting development activities undertaken by CVRDE to IRDE. Third, he fostered the concept of laboratory complexes in Bangalore, Delhi, Hyderabad and Pune so that optimum use of the facilities and sharing of expertise would be possible among the laboratories. Therefore, when he took over as the Scientific Adviser, he stopped the permanent building project of LRDE at High Grounds in Bangalore. Instead, he wanted the permanent location of the laboratory to be shifted to the area where the other two laboratories, namely ADE and GTRE were situated (presently called CV Raman Nagar). With this in view, he obtained additional land from the Karnataka Government adjacent to GTRE and permitted LRDE to have its laboratories situated on that site. On the land contiguous to LRDE, he allowed the present residential complex for all DRDO institutions of Bangalore to be constructed44.

3.31 IMPACT ON THE ORGANISATION

Dr Raja Ramanna brought home to us three important aspects of leadership. First, use analysis or analytical power of the intellect as a tool for timely and decisive action. Second, it is important to keep channels of communication open with the decision makers at User end and with those in the political establishment. Third, team building across the Organisation is necessary and nodal laboratories in major systems development must reach across to other laboratories in the organisation. When it was known that he would be shortly moving out of DRDO because of his being appointed as Chairman of Atomic Energy Commission, Dr Raja Ramanna persuaded the Government not to look outside the Organisation for his successor. He considered that there was more than one senior scientist within the DRDO who could head the Organisation. Dr VS Arunachalam, Director DMRL became the first DRDO scientist to assume the office of the Scientific Adviser to Raksha Mantri.

3.31 SUMMING UP

In these twelve years, DRDO was transformed into a more challenging workplace. The predominant activity of catering to the short-term requirements of the Services was replaced by technical activities, leading to contemporary systems development. Thrust areas were clearly

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44 Dr Raja Ramanna laid the foundation stone at CV Raman Nagar in Bangalore in May 1982 for the laboratory accommodation for LRDE and for residential accommodation for employees of all DRDO institutions in Bangalore. The CV Raman Nagar complex was inaugurated by the Prime Minister of India Shri Rajiv Gandhi in March 1987.
identified and prioritisation of the resources was accordingly carried out. A programme for the development of next generation tank weapon system was initiated. The personnel policy was also changed to conform to the "flexible complementing" policy adopted by other S&T departments. Steps were taken to promote inter-laboratory interaction and cooperation for better utilisation of resources. Dr VS Arunachalam became the first DRDO scientist to head the DRDO and also to assume the office of the Scientific Adviser. In the next decade, under his leadership, the Organisation would expand and excel.
DEFENCE RESEARCH & DEVELOPMENTAL ORGANISATION

INTERIM FUNCTIONAL CHART (As on 1st Sept 1962)

SCIENTIFIC ADVISER & DIRECTOR GENERAL
Defence Research & Development
Dr. S. BHAGAVANTAM (Tel: 31519)

CHIEF CONTROLLER RESEARCH & DEVELOPMENT
Major General BD Kapur (Tel: 32796)

AD (COORD)
Maj MM Talwar (Tel: 35742)

DIR OF ARMAMENTS
Brig JR Samson (Tel: 31424)

DIR OF STANDARDS
Col DS Roy (Tel: 32264)

CONTROLLER R&D (Engg)
Col NB Grant (Tel: 34148)

DIR OF ELECTRONICS
Brig BJ Shahaney (Tel: 32369)

DIR OF RESEARCH (Labs)
Dr V Ranganathan (Tel: 31424)

FORMULATION OF POLICIES AND PLANS for technical Projects relating to design, development, manufacture of aircraft, aeroengines and associated stores, including electronics, telecommunications and radar, required by the Services, research in the field of aeronautical problems, including gas turbine research, inspection of aircraft stores and liaison with scientific agencies abroad on aeronautical matters.

AIMED and Applied research in the field of avionics; research in materials (other than metals), defence food research, overall HQ co-ordination of Scientific Research Programmes (including psychological, biological and nuclear medicine); research programmes of Field labs; liaison with scientific agencies abroad (i.e., CACDS and others).

DIVISIONAL CHIEF SCIENTIST

SCIENTIFIC ADVISERS TO SERVICES HQ

SCIENTIFIC ADVISER TO WESTERN COMD
Shri PS Cheema (Tel: 32286)

SCIENTIFIC ADVISER TO NAVY
Defence Secretary (Tel: 31519)

SCIENTIFIC ADVISER TO AIR
Defence Secretary (Tel: 31519)

PSYCHOLOGICAL ADVISER
Shri SF Lakhani (Tel: 31860)

FIRE ADVISER
Shri SF Lakhani (Tel: 31860)

DEFENCE R&D COUNCIL
Chairman: Defence Minister, Vice-Chairman: MMD

Members:
DG, CSIR
Defence Secretary
Chief of the Air Staff
Addl Def Secretary
Chief of the Naval Staff
Scientific Adviser
CGDP
Financial Adviser
CCR&D

SECRETARY R&D COUNCIL
Shri MP Belliappa, Deputy Secretary, M of D (Tel: 31383)

DEFENCE R&D COUNCIL
Chairman: Defence Minister, Vice-Chairman: MMD

Members:
DG, CSIR
Defence Secretary
Chief of the Air Staff
Addl Def Secretary
Chief of the Naval Staff
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SECRETARY R&D COUNCIL
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REFERENCE

Figure 1. Organisational Chart-1962
ORGANIZATIONAL CHART OF DEFENCE RESEARCH & DEVELOPMENT ORGANIZATION

Scientific Adviser to Raksha Mantri

TECH 'A' - FOR ALL POLICY DECISIONS AND GUIDELINES MAJOR INTER-DISCIPLINARY PROBLEMS
CHIEF CONTROLLERS R&D (S) (E) & (G) AND JOINT SECRETARY (R&D)

Figure 2. Organisational Chart-1973
Figure 3. Organisational Chart-1978
MARCHING FORWARD
CHAPTER 4
MARCHING FORWARD

4.1 INTRODUCTION

In Chapters 2 and 3, the growth of the DRDO as an Organisation under the helmanship of four eminent physicists of the country has been traced. The DRDO was established in 1958 and it took nearly a decade to transform a collection of individuals and laboratories with diverse backgrounds into a single Organisation dedicated to apply science and technology to the needs of the Services. The first decade was one of learning by doing and the response of the DRDO was to meet the short-term requirements of the Services in their effort to maintain, substitute or improve the major weapons, sensors and other equipment procured from outside sources. In the second decade, the goal was set higher to undertake contemporary system development. Competence to do so would be generated through activities related to technological advancements of the components/subsystems as well as of the system. In this chapter, the progress made by some of the major laboratories of the Organisation towards the goal are described.

4.2 AERONAUTICS

In the field of aeronautics, there are two laboratories namely the Gas Turbine Research Establishment and the Aeronautical Development Establishment, both at Bangalore which are focussed on aircraft as the weapon platform.

4.2.1 Gas Turbine Research Establishment

The charter of GTRE is to carry out research on gas turbine components with a view to design and develop gas turbine engine systems to meet military aircraft requirements. In the early 1960's, the development

1 The selection of the laboratories whose progress is detailed in this chapter is based on the Annual Reports of DRDO to the Defence Ministry in the period 1958-59 to 1981-82.
programme launched by M/s HAL for Hindustan Fighter HF-24 (Marut) had generated a lot of enthusiasm and hope that this was a forerunner of many more opportunities and challenges to come in aeronautics in the future. Though the proposals for the development of HF-24 was based on an engine which was being developed abroad, the move to shift GTRE to Bangalore to be nearer to the aircraft manufacturer was to prepare itself for the day when it might be called upon to develop a power plant for a military aircraft. Thus, at this stage, the main thrust of GTRE was in the building of the facilities and expertise in the area of gas turbine engine technology.

However, as the aircraft development progressed at HAL, the promised engine from abroad did not materialise. The development of the engine was halted by the foreign manufacturer and M/s HAL had the difficult choice of either abandoning aircraft development programme or searching for an available engine and accept the shortfall in the performance of the aircraft. HAL chose the latter and a search was on for a suitable candidate engine. GTRE was called upon to re-engineer one of the possible options, namely RD-9F of Russian origin. But the aircraft designers preferred the Orpheus-703, a non-reheat engine which rendered HF-24 at best an underpowered transonic fighter. DRDO through GTRE offered to take on the development of a reheat for the Orpheus-703 whereby the engine could boost its thrust by another 35 per cent for short crucial bursts. For GTRE, it involved the design, development, and fabrication of prototypes of the complete reheat system including changes on the basic Orpheus engine. Theoretical studies and experimental verification of the efficiency of combustion, flame stability, fuel injection, regulation, resistance of parts to high temperature, etc., were carried out to develop the reheat system. The success of a limited reheat system tried out on Marut led to the development of the full reheat system. Eleven prototypes were built and extensive bench testing of over 2000 hr under extreme tropical conditions were also carried out. The reheat engine Orpheus 703-1700K was fitted on a prototype of Marut and over 250 hr of flight testing were completed. These tests indicated that there was substantial improvement in performance by the Orpheus 703-1700K engine in respect of takeoff, run, climb, acceleration, maximum speed etc., over the non-reheat engine. The Orpheus 703-1700K engine was type certified in December 1973.

The aircraft designers launched the *Marut* MK II design around the GTRE-developed Orpheus-703 reheat engine (Fig 4.1). Subsequently GTRE took up the design and development of Orpheus 703-2000 K reheat system. Two prototypes were built, successfully bench tested for about 160 hr and then subjected to simulated flight testing at the Altitude Test Facility in UK. It was a pity that the crash of the redesigned *Marut* fitted with the reheat engine in one of the early development flights put an end to the *Marut* Mk II and the Orpheus reheat engine programme. As future events unfolded, the crash of *Marut* MKII was a set back of catastrophic proportions to aeronautics in India because no effective programme for the development of either civil or military aircraft would be undertaken in the country till the mid of 1980’s. The silver lining for GTRE was the valuable experience and inputs its scientists gained for design of afterburners and in the area of altitude testing of aero gas turbine engines. Simultaneously with these activities, GTRE made an attempt to improve the dry performance of HF-24 by integration of a transonic compressor to the basic engine without resorting to afterburner operation. It involved the replacement of the first stage of the seven-stage subsonic compressor of the Orpheus with a transonic stage and matching it with the rest of the subsonic stages. The
integrated research engine system was test run in May 1974 and the results were encouraging.

Besides these tasks, the scientists carried out a number of basic studies and initiated work on a number of competence building tasks for gas turbine components so that an adequate technology and knowledge base would be built and would enable GTRE to evolve a family of advanced gas turbine technology engines that could meet the whole range of power plant requirements of futuristic military aircraft. The absence of a viable aircraft development programme was considered as an opportunity to build up the competence and expertise in this area so that some time in the future when a programme for design of aircraft materialised, an indigenous engine system could be developed to power the aircraft. Such a project would however, have a long gestation period of the order of 10-15 years, and hence the engine system would run the risk of becoming obsolescent unless there was an ongoing research and development programme on the major components of the engine system. The long time scale and massive investment was necessary because the process of development involved technology exploration, concept proving, design validation, full-scale development, and finally qualification of the engine system. In 1974, GTRE embarked upon the programme of designing and developing an engine demonstrator programme based on a straight jet engine. The plan called for development of important subsystems incorporating latest technological advances for the demonstrator engine. The laboratory adopted the flat rating concept presently well known as high throttle ratio so that the configured engine system would be optimised at high forward speed and high ambient temperatures.

The starting point for design and development of the gas turbine engine would be aerothermodynamic design followed by mechanical/structural design. Once the aerothermodynamic design for a given performance requirement was arrived at, techno-economic considerations would play a major part in deciding the structural design. Thus, the aerothermodynamic design of the main components, namely, compressor, combustor, turbine, afterburner, etc., was the first step to obtain the gas flow path geometry of the engine. Therefore research and development activity focussed on the important areas of compressors, combustors, highly loaded turbines, engine control systems, catalytic ignition systems and heat transfer.

Marching Forward

transfer with the objective of putting a full-scale gas turbine engine. In addition to being a technology demonstrator, the engine would also serve as a technology acquisition and design validation test bed.

In the decade of the 1970’s GTRE had to tackle the problems related to materials, hardware manufacture, measurement, testing and validation of hardware. Side by side with development, establishment of aerothermodynamic experimental facilities for validation of the major components singly as well as the full-scale engine, was taken up. Single-stage and multi-stage compressor testing, low pressure air supply, high mass flow high pressure air supply, and full-scale engine facilities capable of measuring up to 15000 kg thrust with afterburner and with automatic data acquisition, were planned and implemented. A cost-effective setup was designed using grounded aero engine exhaust to drive the free power turbines so that adequate motive power for testing of components was available. A number of component test facilities were established in areas of compressors, turbines, combustors, reheat systems, fuel system, nozzle system, and so on. An expandable fabrication facility which would be versatile, sophisticated and technologically in the forefront, in order to process materials from conventional to exotic was also included in the plan. In collaboration with Bhabha Atomic Research Centre (BARC), National Aerospace Laboratory (NAL), HAL Koraput Division, electron beam welding, electrochemical spark erosion techniques with precision casting blades were implemented. The setting up of such a facility was fully justified later when it turned out that an estimated 0.25 million to 0.5 million man-hours were invested for manufacture of about 25,000 components per engine. As these engine components would have to pass the stringent military standards of performance, durability and life, several highly specialised test facilities, such as vibration fatigue, thermal fatigue, shaft torsional fatigue, gear box test facilities, which were unique to engine development and which were not commercially available, were also planned, designed in-house and rigged up for design validation and mandatory certification tests. Computational facilities were also set up and commercial standard software packages were purchased to facilitate computation of stress and life of the engine components.

Hardware-wise, in the area of compressors, design studies had been carried out in the 1960’s of a seven-stage subsonic compressor. This would form the basic core compressor for the proposed engine to be built. As mentioned earlier, the design and testing in the early 1970’s of a transonic compressor ahead of the multi-stage subsonic compressor on the
Defence Research & Development Organisation (1958-82)

Orpheus 703 engine provided valuable design inputs for resolving matching problems. The single stage transonic compressor which developed a pressure ratio of 6.5:1 had the variable stators carefully designed to provide better stage matching. The success of the design showed the way in the 1960’s for the design of the six-stage transonic compressor which would form the core compressor for future engines. In the area of combustors, since the combustion phenomena was complex function of fuel spray droplet dynamics and evaporation, air flow pattern, and chemical kinetics, it was not readily amenable for analysis. Hence for progress in the design and development of combustors, analysis had to be augmented with experiments involving waterflow visualisation and combustor model tests. In addition, testing methods and test rigs were set up in order to realise viable and efficient combustors. Analysis backed up by experimentation and testing in the 1970’s led to optimization of the design of the annular combustor for the proposed GTX engine, with an L/D ratio of 3 and an exit temperature of 1500K. The atomiser for the GTX-17U combustor was pressure jet type, the diffuser was aerodynamic and dump type and the material used was Nimonic 75. Close interaction was maintained with Mishra Dhatu Nigam (MIDHANI) for development, evaluation of specification and type test schedules of a number of alloys needed for gas turbine materials. Type approval was also accorded to an alloy – MDN 3214 developed by MIDHANI.

The turbine was axial flow type and the design was based on free vortex models for the GTX. The performance analysis of turbine stages being crucial for engine operation as a whole, the criticality of operation was due to the vane and blade throat area which controlled the swallowing capacity as well as the operating line of the engine. This necessitated setting up of a full-scale model test rig of capacity 2250 kW for conducting the experiments. The initial design of the turbine blade elements accommodated 5 holes and subsequently increased to 8 holes which were drilled radially for the coolant to pass through the blade span from root to lip. This arrangement proved inadequate from the point of view of creep and fatigue and would be replaced in the early 1980s by a better mechanism which would provide a good creep and fatigue life.

The aero gas turbine engine, being a high speed rotating machine with a heavy weight rotor, rotor dynamics, secondary flows and the lubricating system required attention right from the beginning for the reliable operation of the engine. The rotor dynamics was mainly carried out using conventional single shaft analysis procedure for prediction of critical
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speeds even though the shafting was essentially a two spool configuration supported on rolling element bearings with shaft interconnection at intershaft bearing location. This would be replaced in the next decade by sophisticated dynamic analysis codes. The vibration behaviour of the rotor, being a direct consequence of quality of manufacture of the rotor, balancing of the rotor and alignment of rotor components during assembly had to be built into hardware design. Vibration problems were experienced in the GTX engine and were solved by introducing uncentralised squeeze film dampers. The secondary flow system required modification since there was leakage of hot air from the gas flow path into the cooling and sealing system. Three technology development programmes were proposed to address the problem. In effect by the end of the 1970’s, the technology status of the core turbine was axial flow turbine engine GTX-37U, stage loading factor of 1.4, TET of 1400 K with convective cooling (Fig 4.2).

GTX incorporated all components /subsystems, such as transonic compressor, annular combustor, shrouded cooled turbines, fully variable exhaust nozzle, digital control system and sophisticated materials and metal-forming techniques. The engine was test run successfully bringing to an end the demonstrator phase of engine development. In 1980, discussions

Figure 4.2. Demonstration model of GTX 37–14U engine
were held between GTRE and M/s Rolls Royce of UK to examine the feasibility of developing a viable engine designated GTX-Adour which would integrate the core of the Adour engine used in the Jaguar with the components of GTX design. The collaboration did not materialise and it was decided to go ahead with the full-scale development of the GTX engine. This engine would serve as a highly effective and useful test vehicle for validating advanced technology design features.

4.2.2 Aeronautical Development Establishment

The major activities of Aeronautical Development Establishment (ADE) in the 1960’s was to provide support to on-going acquisition of equipment for the Indian Air Force and carrying out type approval of aeronautical equipment/components offered by the industry. In addition, ADE carried out design and development studies on Hovercraft, Dart Target System and Stall Warning System. The Hovercraft lifted-off the ground supported by a cushion of air formed by forcing a large volume of air through ducts in the lower periphery of the craft. The Hovercraft was able to negotiate obstacles of 120 cm to 150 cm height easily and heldforth promise as a good negotiating vehicle in swampy or otherwise impassable terrain.

The Dart Target system consisting of a target of composite construction, a hit recorder and a para recovery device, was aimed to provide a realistic target for air armament practice. The Stall Warning System provided warning to the pilot through shaking or buffeting of the control column of an impending stall condition with a predetermined margin of safety.

The Subramanian Committee Report on Aeronautics, which was made public in 1969, had made the Ministry of Defence as the nodal ministry for aeronautics. As far as ADE was concerned, the recommendation about the high priority to be accorded to develop a new ground attack fighter for the Indian Air Force did not translate into a major project activity. Thus, in the beginning of the 1970’s ADE found itself to be one of the few system-oriented laboratories of DRDO which had no major project activity, current or planned even though aeronautics was a thrust area for the Organisation. As the uncertainty about the ground attack fighter continued, it was decided that ADE would get into the area of flight

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5 R&D Digest, Vol.9, August 1969, Pages 67-68.
simulation and develop flight simulators that would help the IAF in their training of pilots. In 1972, DRDO tasked ADE to plan a flight simulator centre which would be the first of its kind in the country.

The Flight Simulation Centre was envisaged to aid at the system definition phase, the performance and acceptability of a complete flight vehicle or its systems/subsystems. The facility would help the designer to evaluate and optimise the performance of the aircraft and thus reduce the time and effort that would be spent in assessment of hardware at a later stage. The heart of the facility was an analogue-cum-digital hybrid computer which would be coupled to a cockpit capable of free movement for simulating a flying aircraft. The computer would also be coupled to a visual system to provide visual cues to the pilot seated in the cockpit. This facility would simulate aerodynamic configuration, control layout, stability augmentation systems and so on. The Centre was commissioned by the end of 1977. Subsequently, ADE initiated design, development and fabrication of simulators for Ajeet and Kiran aircraft of the IAF. These would be used to train pilots on ground without actually flying the aircraft on various flight exercises. Development work for various subsystems of the prototype simulator, such as the motion system, instrumentation, data generation, weapon system, navigation and communication system and software development system was progressed as the decade came to an end. ADE’s plans envisaged to have the prototypes of the simulators to be ready by December 1980 for evaluation.

In addition, the development of a reusable rocket pod, missile target, and a technology development project on Head Up Display were also taken up. The reusable rocket pod was an underwing rocket launcher developed for air-to-ground roles and was expected to be reused for about 100 firing sorties. It was designed to have universal adaptability to fighter aircraft of Soviet and western origin. By the end of the decade, reusable rocket pods for all current aircraft of IAF were designed and were cleared for introduction into Service after a series of static, ground firing, flight carriage and firing/jettisoning trials from aircraft. HAL was the production agency for the reusable rocket pod. Work on Head up Display system, which would enable an aircraft pilot to have a visual view of the important flight parameters of a flying aircraft like altitude, speed, etc., continued into the 1980’s. IRDE was associated with ADE for the development of the optics module for the Head Up Display. As the 1980’s dawned, ADE initiated a major programme for development of Pilotless Target Aircraft (PTA) for meeting Services requirements. In view of the high attrition rates, and high
cost of military aircraft, ADE scientists visualised that PTA would play a very useful role, particularly in training activities.

4.2.3 Light Combat Aircraft

By 1980, it was evident that aircraft industry in the country was maintained by importing technologies and products for manufacture. The best talents in the field of aeronautics in the country were looking for challenges outside our borders and with the induction of Jaguar and MIG-23 aircraft in the Indian Air Force fleet there was scope for indigenous development in only one class of military aircraft namely the light combat fighter aircraft to replace the ageing fleet of Ajeets.

Since the Indian Air Force indicated that they would need the new light combat fighter aircraft in the 1990, in his capacity as Scientific Adviser, Dr Raja Ramanna, took the lead in February 1980 by communicating to the Prime Minister of India that he was forming an internal group of scientists to conduct a detailed study of the various aspects of the light combat aircraft and related engine development programmes. The study would also include the assessment of the resources and technologies from within the country. Further, the report would bring out the technology areas for which input from abroad would be necessary. He concluded his communication with the information that DRDO was examining a joint proposal from two companies namely an aircraft manufacturer and an aero engine manufacturer for a combined feasibility study with DRDO on the aircraft and the engine development programmes.

Nearly eighteen months later, Dr Ramanna, in his second communication to the Prime Minister, detailed the progress that had taken place in advancing the cause of indigenous development of the light combat aircraft. He informed the Prime Minister that preliminary design configuration studies based on a number of available engines including the indigenous GTX of GTRE, were completed. The light combat aircraft as envisaged by the Committee of Internal Experts would be a highly manoeuvrable high speed lightweight multi-mission aircraft powered by an advanced technology engine with adequate growth potential. It would incorporate design provisions to adopt advanced technologies like fly-by-wire, modern avionics and weapon systems. The aircraft would be initially developed around a proven engine which would be replaced by the indigenous GTX variant when the latter would be available. The estimated cost and the time frame were also indicated but with a remark that a realistic estimate would be possible only after further discussions with aircraft
designers from abroad and subsequent studies. The note concluded with a
draft paper for approval of the Cabinet Committee for Political Affairs
(CCPA) of the proposed plan of action. It specifically mentioned that the
country had taken no major aircraft development programme for the last
two decades and since vast advancements in the field have taken place,
input from abroad on selected areas of technology would be necessary. The
seeds of the LCA programme which would be taken up a few years later
were sown.

4.3 ARMAMENTS

The Armaments group of laboratories comprise of ARDE, HEMRL,
Pee and TBRL. ARDE was formed out of the erstwhile Technical
Development Establishments of Weapons at Jabalpur and of Armaments
at Khadki in September 1958. Pee, Balasore was also set up at the same time
as ARDE but Explosives Research and Development Laboratory (later
renamed as HEMRL) as a full-fledged laboratory came into being in 1963
though its antecedents can be traced as far back as 1908 to the Chemical
 Examiner’s Office in Nainital.

4.3.1 Armament Research & Development Establishment

In the early years, ARDE was located within the campus of the
Ammunition Factory, Khadki with rudimentary facilities for R&D. Even
though the ordnance factories had been in the business of manufacturing
ammunition for the Indian Armed Forces since the early days of the British
empire, the drawings and designs of their products were of British origin. A
primitive manufacturing base was available for conventional high explosive
projectiles at the time of Independence. The TDE personnel were entrusted
with the inspection of finished product, which included proof firing, defect
investigations, as well as substitution of imported raw materials with those
of Indian origin without altering the original specifications issued out of the
UK. In the period 1958-69, the development efforts were reverse engineering
of ammunition and warheads in production, to reduce the dependency on
imports. A large number of small projects with limited scope were undertaken
to graduate from import substitution of materials and components to that of
import substitution of ammunition and warheads. Through this time-
consuming and laborious process, the knowledge base was built and
expertise was acquired for design and building up of test facilities. In the case
of weapons, a modest production base for production of howitzers, mortars
and small arms existed at the time of Independence but the technological base
Figure 4.3. 75/24 Pack howitzer
was practically absent.

The period 1958-62 was a period of transition for change of mind set from inspection activities to design and development and organising the laboratory with recruitment of personnel and establishing basic facilities. The progress was slow due to the marginal design capability at system’s level, little or no access to knowledge bases available abroad with respect to armaments development and poor infrastructure in both defence and non-defence industrial sectors of the country. However, with the concluding of several projects for Transfer of Technology (TOT) and license production of complete equipment from overseas sources in the early 1960s, notably the 40 mm L-70 Air Defence Gun, 81 and 120 mm Mortars and later the battle tank Vijayanta, including its 105 mm Gun and Ammunition, the tempo of activities of the laboratories in the Armaments Group picked up mainly because these were involved in the evaluation and later technology absorption.

The first challenge to the scientists of ARDE in the field of Conventional Armament Technology came in the wake of the 1962 Chinese Operations, especially when Indian Army was faced with an acute need for modern replacement for its mostly World War II vintage weapons and equipment. The need for the development of a mountain gun and that of the self-loading rifle became inescapable.

The development of the mountain gun, the 75/24 Pack Howitzer, with an investment of about Rs 70 lakh, was a major activity ranging from the development of the weapon, different types of ammunition, as well as the preparation of the range tables (Fig 4.3). It was the first venture of ARDE into large-calibre weapon development, even though it was not an ab-initio project. It was based on initial design carried out for the British Army by Canadian Armament R&D Establishment (CARDE). While the original contract for development between UK and Canada was cancelled, the sketches and drawings of the incomplete design were passed on to DRDO who pursued it to the logical conclusion, namely development of the Mk I version, which met the basic requirements laid down in the GSQR by the Army. This was manufactured at the ordnance factories to equip the mountain divisions of the Army. Based on the experience gained by the Directorate General of Ordnance Factories (DGOF) during technology transfer and production of the Mk I, a Gun Development Team (GDT) was constituted in July 1964 for further improvements at the Gun Carriage Factory, Jabalpur, which was the nodal factory for the final assembly of that equipment. This was the first-ever interdisciplinary team with specialists.
Defence Research & Development Organisation (1958-82)

drawn from DRDO, Ordnance Factories, Directorate General of Inspection (DGI) and the Users - in fact GDT was headed by a veteran Gunner Officer - to minimise the lead-time and for seamless technology transfer. We were ahead of the global trend by at least two decades in implementing concurrent engineering, and cross-functional team concepts and it bears testimony to the readiness of DRDO to try novel methods for speeding up the development process. The Mk II had to be designed for towing by a vehicle and it was required to be disassembled and carried on mule backs without difficulty. The design and development included among other activities, complete new design of carriage and the recoil system, new types of muzzle brakes, breech and firing mechanism and design of accessories for pack role. It was successfully developed and the first prototype was user tried in November 1965 and was accepted for introduction into the Services. As part of the development process, special range and instrumentation facilities were also established for full-scale range, accuracy as well as for endurance trials. The 75/24 Pack Howitzer would remain in service for nearly 25 years.

The 1962 Chinese conflict also highlighted the inadequacy of the Lee Enfield bolt action rifle as an infantry weapon. The Army’s decision to replace it with self-loading rifle on a priority basis triggered ARDE to develop jointly with ordnance factories the 7.62 mm self-loading rifle which came to be known as the Ishapore rifle. Ammunition for the rifle was also developed simultaneously. The gamut of activities ranging from design, development, trials and establishing bulk production were completed in the shortest possible time as a result of high degree of coordination between ARDE and the Ordnance Factories. More than one million rifles have been produced and these have been put to good use during the 1965 and 1971 conflicts with Pakistan.

In the areas of ammunition and warheads, the contributions of ARDE were, non-detectable antitank mine, tracer ammunition for 7.62 mm calibre weapons, 105 mm antitank ammunition, smoke ammunition for mortars, drill mines for the Navy, drill and practice version of antitank and antipersonnel mines, indigenous propellants for light and heavy mortars, ammunition for defeating armour for different types of gun, air-to-air and

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7 Interview with Lieutenant General SG Payara (Retired), former Chief Controller R&D, DRDO.
8 Bread and Butter (DAL ROTI)- Notes prepared by NS Venkatesan, Former Distinguished Scientist & Director ARDE, Pune on the working of the Armament Group.
9 ARDE, A Profile. Latest Brochure published by ARDE, Pune.
Marching Forward

air-to-ground rockets. Most of these development activities where aimed to reduce our dependence on import from abroad for our Armed Forces. These were not simple substitutions but also required the study of high energy materials, the interaction between gun and the projectile, the ballistics of projectiles with shape explosive charge and so on. In addition, incorporation of maintainability, durability and reliability required the designer to relate technology at the design stage to operations so as to build the confidence of the User. The experience gained and the knowledge base built in this period enabled ARDE to take up more sophisticated projects in the succeeding decades.

The representative list of significant contributions would include the development of escape aid cartridges, signal cartridges, and distress visual night signal cartridge for the Air Force. The development work on Seat Ejection and Escape Aid Cartridges had been initiated when the supply of these for aircraft of UK origin was stopped by the Government of UK during the 1965 conflict with Pakistan. As a trained pilot is an important asset of any Air Force, measures to save his life even under the most adverse conditions of flight, had to be incorporated in the aircraft. All combat aircraft were therefore provided with crew escape aid systems which demanded the highest degree of operational reliability. Escape aid cartridges would be fitted in the ejection seat system of the aircraft and since the aircraft would be grounded without them, ARDE took up the development with all speed. After they were approved by the IAF for introduction into Service, production on a pilot plant basis by ARDE had to be resorted to since the requirements were small for each aircraft and not attractive for industry. The development effort and the pilot plant would continue even after the IAF switched over to aircraft of Russian origin.

The decade of the 1960’s was also the period of adjustment and understanding between the design and production agencies. There were ups and downs in the interactions between the agencies, namely DRDO and the Ordnance Factories, mainly because the designers on their part focussed on technological innovation and gave lesser importance to production worthiness, while the production agencies straight away rejected designs that could not be produced with the existing machinery, tools and fixtures. Another difficulty was that of finding manufacturers who would participate in the development process which required production of ammunition in small lots for trials at short notices before zeroing in on the final design. The Ordnance Factories were not interested
in such experimental activities and would come into the picture after the placement of orders by the Services for the store. All requirements of parts and components during development, including the numbers needed for evaluation before finalisation, and those needed for user evaluation and trials had to be procured from small-scale private sector manufacturers. The government rules required that bulk production orders for ammunition and weapons systems would have to be placed on ordnance factories, which discouraged participation from the private sector. Modification of the existing rules was not easy but with persistence by the designers, the rules were changed to accommodate small scale entrepreneurs in the private sector to participate in the development process with the provision that the 80 per cent of the first order of parts and components for volume production would be placed on the agencies participating in the development process.

The development of a variety of warheads for gun and mortar application and the involvement of ARDE in technology absorption of a range of new products in the earlier decade provided the knowledge base and the confidence to develop a new range of products with increasing performance levels and higher technology content. The major contributions of the 1970’s were,

(a) 105 mm Indian field gun for the field artillery

(b) Several stand-alone projects in the areas of gun and mortar ammunition, fuses, land mines, air and naval armaments.

(c) 51 mm infantry platoon mortar and its ammunition family

(d) Pilot Plants in the vital areas of PZT piezo-ceramic materials and pyro power-cartridge for life/mission-critical aircraft escape-aid and stores separation systems.

The 105 mm Indian Field Gun was developed as a replacement to the 25 Pounder gun used by the Indian Army (Fig. 4.4). The initial development activities were carried out at ARDE in the 1960’s and later transferred to the gun development team that was earlier involved in the development of the Howitzer. The activities included the design and development of the carriage for the gun, the associated ammunition namely HE (High Explosive), High Explosive Squash Head (HESH), smoke and star shells, modification of the prime mover and design of a new gun barrel using the existing breech and muzzle brake for extending the range of the weapon to the desired value. The gun with its ammunition was tried out by the Artillery, accepted for introduction into Service and the units started
rolling out of the production line in early 1970’s. This was culmination of close interaction between ARDE, the Army and the Ordnance Factories and demonstrated the continuity of the R&D effort in area of guns over more than one product and in a time period of about one and a half decade.

Another important activity of ARDE was the upgunning of the Russian tank T-55 which had been acquired from Russia. The Indian Army had in its arsenal a large number of T-55 tanks with 100 mm gun as its main weapon. With this calibre and firing Armour Piercing (AP) and High Explosive Anti Tank (HEAT) shells, the tank was clearly outgunned in comparison to the tanks of Western origin. ARDE proposed to mount the indigenously produced 105 mm gun for the Vijayanta tank on the T-55 so that it would be equipped with excellent fire power. This programme was carried out in close collaboration with the 502 Army Base Workshop, Cooper Engineering Works and two ordnance factories. The close coordination among the user, design agency and the manufacturers ensured free interchange of information and data between the agencies and to its success. For ARDE, this was also an excellent opportunity to gain insight into the problems the gun designer would face in designing the weapon for a tank.
The variable-time (VT) fuze was an important contribution of World War II and it was the first ever attempt to introduce electronics in armament. While the Indian Navy was using fuses imported from the UK, the Indian Army did not possess these. Since its aerial burst was effective against ground troops, the development of the fuze was undertaken by ARDE. It was the prime contractor and was responsible for the development of the explosive train. The electronics part was concurrently developed by two R&D agencies, namely the Bhabha Atomic Research Center (BARC) of the Department of Atomic Energy and by the Solid State Physics Laboratory (SSPL) of DRDO. The BARC was involved in the development of the VT fuze for the 25 Pounder gun while the SSPL’s involvement was for the development of the VT fuze for the 75/24 Pack Howitzer. The VT fuses for the 105 mm IFG and the 75/24 Pack Howitzer were successfully completed and they rolled out of the production line in 1973. For this project, ARDE had two customers, namely the Army and the Indian Navy, two associate R&D agencies in development namely BARC and SSPL, and three production agencies, namely Electronics Corporation of India (fuze for 105 mm IFG) and HAL, both in Hyderabad and an ordnance factory. It was no easy task for ARDE to finalise in association with the agencies involved in development and production and with the User Services, the modalities for testing and proofing the rounds and quality acceptance procedures. The development work on fuses was continued with BARC and SSPL and was crowned with success, with BARC involved in the VT fuze for the 76.2 mm gun for the Navy and SSPL for the VT fuses for the 130 mm Russian gun for the Army and the 4.5 inch gun for the Navy. In addition to these, ARDE developed and got a wide variety of ammunition manufactured for the three Services. Some of these were, illuminating ammunition, antitank mine, improved tear gas grenade and triple-chaser for the police, limpet mines, chaff dispensing warhead, IR cartridges, practice and operational pods for IAF, plasticised white phosphorous filled ammunition for 120 mm grenade and 81 mm mortars, sub-calibre inserts for 105 mm Vijayanta and for 20 Pounder Centurion tank guns, launching device for 36 mm grenade, photoflash cartridge for low-level night photography, training ammunition and so on.

ARDE had also undertaken the development of a new mortar with higher range and better lethal terminal effects for Infantry platoons. These were smooth bore muzzle-loaded weapons and would replace the World War II vintage 2 inch mortar held by the Indian Army. The development of the 51 mm mortar had as its objective, doubling the range without unduly increasing the weight. For increasing the range, the gun had to be fired at
higher pressures which called for a forged base plate integral with the breech. As this had not been incorporated in the earlier 2 inch mortar, a period for learning by doing was necessary. Initial trials in the 1970’s were very promising.

Another venture was the development of the nondetachable mine Mk III which could be laid with a mechanical mine layer. This would be a long mine with nearly double the explosive component and a pneumatic fuze which would activate the mine even when a small portion of the track passed over the body of the mine. The development had been completed and was cleared for initial trials phase by the Services.

There were other project activities, such as the development of the 7.62 mm Pashan Light Rifle (PLR) and that of the 105 mm SP Gun, though not culminating in production, nonetheless, provided invaluable experience and helped build up competence in Small Arms and Main Armament Systems for Armoured Fighting Vehicles, respectively.

From its inception till the mid 1970’s, ARDE was responding reactively to the requirements of the Services. This was necessary because the implicit or tacit component of knowledge, which is essential for independent design and development as against derivative development, could only be acquired patiently over the years by a process of learning by doing through import substitution of materials, components and complete ordnance of the items in Service. In addition to developing the competence in this field, it also brought the scientist of ARDE into close interaction with the Services as well as with the manufacturers. Every successful effort shored up the confidence level of the Services and of the manufacturer in the competence of ARDE scientists, and every other attempt which was not accepted for introduction by the Services added to the tacit component of knowledge. At this juncture ARDE had a large number of small projects, about 150 of them, with sanctioned funds of less than 10 lakh for each, to accommodate requests from the Services for indigenous development and supply of one or other type of ammunition imported by them along with the weapon system.

Instead, the Laboratory decided to have a pro-active approach and take a smaller number of projects of higher magnitude and include research and development to build newer competence to meet the challenges of the 1980’s and beyond. The influence of electronics, the emergence of missiles and rockets and the new types of projectiles developed as part of the armour
and anti-armour race would be the area for ARDE to focus on. In addition to taking up pro-active type of R&D projects, induction of additional manpower and building up of infrastructure was also planned.

The first among R&D activities was that of building up the competence for taking up design and development activities of the main armament system for the Main Battle Tank. This is explained further in Section 4.12.2 of this chapter as part of the effort of DRDO for the development of the tank.

In the area of ammunition, the development of the Fin Stabilised Armour Piercing Discarded Sabot (FSAPDS) ammunition in the early 1980's deserves special mention. For the designer of the ammunition, defeat of armour is the crowning achievement and in the seesawing battle of armour and anti-armour ammunition, victory was always transitory and alternating between the two. During the World War II, the development of Armour Piercing Discarded Sabot (APDS) appeared to have given an edge to anti-armour ammunition since it combined the best of both worlds, namely, the advantage of a large diameter (full calibre) from the internal ballistics point of view and very high muzzle velocity up to 1800 m/s. On the other hand the very dense reduced diameter projectile that emerged after the sabot was discarded, led to a sizeable drop in air resistance which permitted the projectile velocity to remain very high at long ranges. The reduced diameter ammunition consisted of tungsten carbide for APDS and for soft core FSAPDS a tungsten alloy of high specific gravity of over 18 with aluminium alloy sabots, nylon driving band, rubber seals, etc. The ammunition was fired from a gun at about 600 MPs (Mega Pascal) pressure, 3000 °C temperature and at about 1400 to 1800 m/s muzzle velocity. The development of the ammunition called for mastery over high precision engineering coupled with sophistication in design and fabrication. ARDE produced FSAPDS ammunition for the 105 mm gun with the assistance of DMRL which developed the super-heavy alloy material and produced the penetrator based on powder metallurgy techniques. FSAPDS ammunition development in other calibres would follow in the mid of 1980’s and ultimately it led to the setting up of a fully automated Heavy Alloy Penetrator Project (HAPP) plant based on totally indigenous technology (from ARDE, HEMRL and DMRL) and with full cooperation from ordnance factories.
4.3.2 High Energy Materials Research Laboratory

The importance of High Energy Materials Research Laboratory (HEMRL) arises due to the fact that all weapons use high energy materials for their terminal lethal objective. It is a matter of fact that in every project that ARDE undertook, HEMRL had a role in providing the necessary propellants and explosives. In view of the strategic use of high energy materials and from safety considerations, import of such materials is highly involved and complicated. Therefore in 1960, TDE Explosives, Pune was bifurcated and personnel with a research mind-set were segregated to form Explosive Research and Development Laboratory (ERDL). However, due to constraints of space, the physical separation between the R&D and the Inspection functions did not take place until ERDL moved to the Pashan campus in 1963. In those early days, the motivation for development was import substitution of explosives as the country at the time of Independence had manufacturing facilities for conventional gun propellants, high explosives, as well as for primary and secondary explosives.

The initial efforts of the Laboratory were to work on the processes for realising double-base that is, nitroglycerine and nitrocellulose (NG+NC) and triple-base (NG+NC+picrite) propellants to UK specifications. Later, the Laboratory successfully developed the processes for different gun and rocket ammunition and for mortars. These propellants were used in ammunition designed by ARDE for small arms, for the mountain gun, for the antitank operation of the 105 mm IFG, for heavy and light mortars. A pilot plant was established for producing plasticised white phosphorous for smoke ammunition. Safe initiatory compositions were established and electro-explosive devices required for various applications were also formulated. HEMRL also initiated work on Extruded Double-base technology for solid rocket propellants. HEMRL demonstrated that it had the competence to start from quantities as small as a few milligrams, and build up to one-to-one scale propellants in pilot plants for use in rockets, missiles and other applications.

In the decade of the 1970’s, HEMRL successfully established the techniques for casting double base propellants and produced on semi-pilot plant scale, different types of grain required for trials. A new initiatory composition having most desirable properties of storage stability and compatibility with metals and a new gelling agent were developed. A new double salt of diazomide tetrazolic acid and styphnic acid was used as it combined the most desirable properties of storage stability and compatibility with copper. Since the superior properties and performance
of this new initiator had enormous prospects for its application to civil and military application, the process was released for commercial exploitation through NRDC 10.

In the case of guns, propellant was developed for 106 mm RCL HEAT ammunition, 100 mm HE full charge, reduced charge and sub-charge ammunition for use over service range of temperature, i.e., -20°C to +57 °C. The Laboratory had also developed propellant for the 105 mm IFG for firing at high ambient temperature. When the use of metallic cartridge cases for high calibre ammunition was being questioned due to disadvantages of high gun wear, higher volume and weight and the presence of toxic gases in the confined space inside the tank, the development of semicombustible and combustible cartridge cases became a necessity. HEMRL kept pace with this trend and undertook in the late 1970’s to develop the technology. It was successful in establishing the manufacture of semicombustible cartridge cases for 75/24 Pack Howitzer, 105 mm APDS and HESH. Further, the Laboratory was successful in developing additive liners which are wear-reducing agents for guns so that their life could be extended with reduced wear per round of ammunition. The user evaluation of the additive liners appeared to be positive as a result of which production on a pilot plant scale was under consideration.

In the area of high explosives, a powerful plastic explosive based on RDX and for use at subzero temperatures, was developed by HEMRL and found acceptance for introduction into the Service. Later, HEMRL developed a continuous process for the manufacture of HMX, an explosive more powerful than RDX. A pilot plant with a capacity of 5 kg/h was set up and the design of a bigger plant to meet the requirement of Army was underway.

Work on various pyrotechnic compositions, such as candle for target indicating bomb with different delays, and replacement of various metal components with plastics in ammunition continued at a vigorous pace.

HEMRL successfully established the complete process for making nitrocellulose plastisol propellants which met the requirements of high energy and performance for use in rocketry and missiles. The propellant was made by the slurry process, a versatile, simple and inexpensive technique with lower plant investment. The process offered the advantage of not imposing any limitations on the size of the rocket grains and also

permitted incorporation of metallic powders for high impulse rocket propellants. Initially the Laboratory made propellant grains of different sizes and compositions and evaluated these for their ballistic characteristics. Later, the Laboratory scientists produced grains of different sizes and compositions, both in composite and double-base systems in pilot plant scale\textsuperscript{11}.

The Laboratory also developed a new family of weapons called Fuel Air Explosive (FAE) system with a damage potential superior to conventional explosive weapons. When fuels like ethylene oxide, propylene oxide, heptane and methane were dispersed in air these formed detonable aerosols which produced very high impulse blast waves on detonation due to higher heats of combustion. These aerosols would be FAEs and owing to their gaseous state before detonation, they covered large areas irrespective of the land contour or protective buildings. FAEs were found very effective against soft targets like antipersonnel mines, ships, aircraft, bridges, missiles, troops and jungle clearance. HEMRL went further to explore the feasibility of developing a rocket-delivered FAE warhead for utilisation by multi-barrel rocket launching system.

Several pilot plants were set up in this decade for producing in bulk, propellants for a large variety of artillery and tank ammunition. The Laboratory was also in the process, setting up additional pilot plants for the manufacture of explosive composition for the Navy, various propellant cartridges and power cartridges. Setting up of more pilot plants were also under consideration for low-temperature plastic explosive, tear smoke ammunition, propellant for 100 mm, HE ammunition and anti-submarine rocket. The Laboratory was in the process of establishing a pilot plant for Air Regenerating Composition (ARC) for sailors working in submarines or soldiers operating at high altitudes, where the atmosphere would be of rarified oxygen. ARC, when in contact with moisture, would generate oxygen and absorb the exhaled carbon dioxide, thus providing relief. The ARC provides a self-contained breathing apparatus.

To back the extensive development activities, HEMRL established a strong research base in areas of high explosives, propellants, high energy materials, detonics of explosives, combination mechanism and ballistic modification of propellants. In 1970’s HEMRL built capability to scale up from pilot plant level to full-scale production on a turn key basis.

\textsuperscript{11} R&D Digest Vol. 15, December 1975, Page 172.
Currently, HEMRL is the only laboratory of its kind in the country dealing with the entire range of high energy materials for use by military, starting from small rounds, mortars, high energy solid propellants for guns, rockets and missiles, to tailor-made high explosives, pyrotechnics and so on. The knowledge and expertise it has built resulted in the country being totally self-reliant in the field of explosives, propellants and pyro devices.

4.4 ELECTRONICS

There were five laboratories in the field of electronics namely Electronics and Radar Development Establishment (LRDE) at Bangalore, Defence Electronics Research Laboratory (DLRL) at Hyderabad, Solid State Physics Laboratory (SSPL) at Delhi and Defence Electronics Applications Laboratory (DEAL) at Dehradun. However, in the 1980’s two more laboratories in electronics were set up. These were, Microwave Tubes Research and Development Centre (MTR&DC) and Centre for Artificial Intelligence and Robotics (CAIR), both at Bangalore. During 1958-1982, the major activities of LRDE were development of generating sets, radars and terrestrial communications for the Services. At DLRL, the focus was on electronic warfare, cipher systems for telegraph, and radars. SSPL was dedicated to research and development of solid state materials for electronic applications and devices, and DEAL was engaged in radio propagation, troposcatter/meteoric burst communications, and millimetre wave systems.

4.4.1 Electronics & Radar Development Establishment

At the time of formation of LRDE in 1958, there were only a handful of qualified personnel whose experience was mostly in defect investigations and/or carrying out import substitution for the existing electronic equipment to keep these in operation. In some rare cases, minor modifications were also being carried out mainly because exact equivalents of obsolete components were not available. Thus, the first five years were devoted to recruitment of qualified scientists and engineers, organisation of the Laboratory for development and to initiate activities which were a mix of import substitution and improvements to equipment held by the Services. This was a period of learning by doing during which greater insight was gained into the complexities of design and development of equipment for meeting the stringent performance specifications laid down by the Armed Forces. The quantum change in electronics components technology that
had taken place, from power guzzling vacuum devices to transistors operating with low voltages and power levels, virtually eliminated replication of older generation equipment. Instead, DRDO seized this opportunity to design and develop transistorised equipment meeting the functional characteristics of the older equipment. Several types were successfully developed by LRDE and then manufactured. Some of the more important ones were, portable transistorised communication switchboard (manual exchange), light weight VHF ground-to-air wireless communication set, a forward area HF communication equipment, two types of speech secrecy units, channel doubling unit for speech and carrier communication equipment. In addition, portable/mobile generators for prime power, and lightweight portable nickel cadmium batteries were successfully developed (Fig 4.5). As the electrical industry had the technological capability, it was decided that developments in portable/mobile generators would be carried out by the industry with the technical direction from LRDE and after evaluation and approval by the Armed Forces, these would be manufactured by the firms which had developed these. In the case of nickel cadmium batteries which were needed for operations at subzero temperature and high altitude regions, industry did not take up the development as they did not foresee its commercial viability in the immediate future. LRDE took up the work as a challenge and developed the indigenous active plates and materials, non-spillable power packs with long storage and service life. In addition, a pilot plant was
established at LRDE for the manufacture of nickel cadmium batteries and chargers. Pilot plants were also set up for production of other communication equipment which were required in small numbers.

In the aftermath of the 1962 Chinese invasion of the country, there was a realisation that modernisation of our Armed Forces was overdue and also that electronics technology would have an important role in contributing to our capability to deter such aggression. The Plan ADGES (Air Defence Ground Environment System) for the Indian Air Force and Plan AREN (Army Radio Engineered Network) were sanctioned so that the country would have radars along our borders to provide us early warning of any attack and the Army would have a tactical communication network that would link the forward units with each other and with the rear echelons. DRDO participated in the formulation as well as in the design and development for both the Plans. In both cases at the insistence of the Services, indigenous development activity was assigned to two R&D institutions of which one would be a DRDO laboratory. LRDE would be fully involved in the development of transmission, switching and speech secrecy equipment for Plan AREN for more than a decade. The Laboratory would undertake development of radars for the Indian Army as well as the Air Force.

In the 1960’s, the radar projects of immediate concern for LRDE were the development of two mobile radar systems for the Artillery; one for surveillance and the other for location of mortars and other projectile launching weapons. As there was no readily available mobile surveillance radar meeting the Artillery’s performance requirements, LRDE was vested with the responsibility of developing the system. Ab initio development and configuring it for mobile application did not fit the time frame for development, and thus major subsystems were imported from radar manufacturers abroad and the system was configured in a designated vehicle. The radar was evaluated by the Artillery and was accepted for production at Bharat Electronics Ltd. Since Bharat Electronics Ltd, the Public Sector Unit was in the process of producing a fire control radar with foreign collaboration, LRDE decided to develop the field artillery radar with the subsystems of the fire control radar. The analogue computer used for fire control purposes had to be redesigned for field artillery purposes. The field artillery radar was developed by LRDE, evaluated by Artillery for the role and was accepted for production at Bharat Electronics Ltd. In the second half of the 1960’s, the R&D work on radar systems to detect targets flying at low altitudes against the background of heavy clutter, was taken up primarily to meet the requirements of the Indian Air Force. LRDE’s
approach was based on the use of continuous wave system for moving target detection and sine wave modulation for ranging the detected target. The other two major development efforts of the radar group of LRDE was the development of the Radar Distance Measuring Unit (Fig 4.6) and the development/fitting of a moving target indicator (MTI) to an existing fire control radar held by the Army for improving its tracking performance against low-flying targets which tried to take advantage of ground clutter.

In the area of communications, LRDE had been involved in and contributed to Plan AREN for the Army at the time of its formulation. Plan AREN was revolutionary because it marked a changeover from linear communications to grid communications, at the same time as it was being introduced in defence forces in developed countries. The Laboratory provided technical input to the Army by way of analysis of their requirements,
the likely impact of new technologies on communication networks, the concept of modularity that would lend itself readily for capacity expansion, the concept of adaptive routing within the network, and newer modulation techniques that were ideally suited for military networks (Fig 4.7). In addition, LRDE configured a skeleton network to clarify the concepts and clear technical issues\textsuperscript{12,13}. Further, LRDE took up the development of the basic module of the automatic electronic exchange with (40+12) lines. It was a space division exchange using the concept of \textit{wired programme} digital processor to control the speech network for establishing speech path between the subscribers. Reed relay cross-points were employed as speech path switching elements. The architecture was modular with control processing unit, switching matrix, line and trunk interface unit, operator console, and the power supply as the major subsystems.

\textsuperscript{12} LRDE Annual Report, 1969 at page (i) states the following:” The feasibility models of these equipment [Semi-electronic exchange, electronic exchange, TDM/PCM multiplexer and speech secrecy equipment] have already been developed and demonstrated during the 2\textsuperscript{nd}(69) meeting of our Governing Council. A skeleton communication set up utilising these equipments along with the existing introduced equipments had also been shown to the Chief of Army Staff...”

\textsuperscript{13} In the early 1970’s, Plan AREN Directorate was set up in the Army to foster close interaction between the User, the development agencies, the production agencies and the Ministry so that issues regarding technology, techniques, testing and evaluation, production and deployment could be resolved as system development progressed.
Besides the activities related to Plan AREN, the other major activities of the communication group were the development of the wireless set HM30, the speech secrecy unit Coding And Decoding of Digital Speech (CADDIS), transistorised metallic mine detector, and sound ranging system for location of enemy guns. These were taken up after extensive discussions with the Services and on their issuance of qualitative requirements. The development of the manpack wireless set HM30 was taken up in 1965 in response to an urgent need expressed by the Army for regimental communication sets up to a range of 30 km. Since it was to be productionised with minimum delay, the development was centred around available mechanical sub-assemblies and parts and used indigenously available electronic components to a large extent. Needless to state, the development was completed, evaluated, and production was launched in record time so that the urgent need of the Army was met. CADDIS, the speech secrecy unit was developed to provide secure voice communication over an existing simplex radio link with manpack sets as terminal units. The development was successful and the required numbers were fabricated for the Army at the LRDE pilot plant. Another activity was the development of the transistorised metallic mine detector. The operation of the equipment was based on the principle of regenerative amplification and the completed equipment was lightweight. The metallic mine detector was user evaluated and approved for introduction into Service by the Army. The necessary numbers were supplied to the Army by the private sector on whom the orders were placed and to whom LRDE successfully transferred the technology. The Sound Ranging System for location of guns, employed a number of sound ranging microphones spread over a distance to pick up the acoustic signals from the enemy guns that were firing. These signals were transmitted by cable or by radio for further processing to determine the location of the gun (sound emitter). The system was required to be highly mobile and speedy in deployment and in dismantling. In this case, the sensitive grids for the microphone were developed by the Defence Science Laboratory, Delhi (Fig 4.8).

LRDE demonstrated its capability to go beyond import substitution/indigenisation to design contemporary equipment to meet the needs of the Services. In the 1970’s, the scorching pace at which technological advances in electronics were taking place, required originality in thinking as the vacuum tubes were replaced by transistors, which in turn were being replaced by integrated circuits. Even in integrated circuits the transition from SSI, MSI, and LSI which denote the integration density of circuits in ascending order was rapid. Consequently, obsolescence of electronics components was a factor that had to be taken into account in all system designs. The advancements in digital techniques were equally rapid as a result of which...
Figure 4.8. Sound ranging system
the scope and range of signal processing applications in the military equipment appeared almost unlimited. Thus, the response of the DRDO scientists in the area of electronics was in keeping with changes in circuit miniaturisation and advances in digital techniques that were taking place, so that the equipment offered to Users was contemporary.

As 1970 dawned, at LRDE there were two projects which were continuation of development from the earlier years. The first was the development of the Distance Measuring Equipment. The system operated in the X-band and was based on the active radar transponder principle. It provided an accuracy of 10 cm in the measurement of distance between any two geographical positions separated not more than 50 km. The DME was tested and evaluated by the Artillery at Devlali in 1973. It was accepted for production and technology was successfully transferred to ECIL, Hyderabad for supply to the Artillery, and in addition to the Survey of India.

The second was the development of the moving target indicator for fitment to the fire control radar of the Army. The development was successfully completed and after testing and evaluation, an order was placed on the pilot plant of LRDE for fabrication of the required number of units.

Six additional projects on radar systems were initiated during this period by LRDE. The first two were aimed at providing the Air Force and the Army with state-of-the-art short range mobile surveillance radars for detection of moving targets in the presence of heavy ground clutter. The Indian Air Force had floated this requirement in 1967 and had searched worldwide for a system but had drawn a blank, as no radar existing or under development at that time had the capability to meet the target visibility conditions. The Artillery too had a requirement for a radar with the same stringent condition for target visibility but with reduced range. Both radars were required to be vehicle mounted. For the Air Force, LRDE proposed to base the radar on the concept of moving target detector, which was a combination of a ground clutter map, moving target indicator, and a bank of Doppler filters all in digital mode14, but was greeted with skepticism because many well known radar manufacturers did not have it on their drawing boards. LRDE had to prove the performance capability and physical realisation feasibility by analysis and simulation of the signal processor15. The physical realisation

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14 LRDE’s proposal was based on the research work carried out at Massachusetts Institute of Technology, USA, that a combination of MTI and a bank of Doppler filters would be the ideal anti-clutter filter. At that point in time, it was not known whether the signal processor had been physically realised and how it performed in the field when used with a radar.

15 Analysis and simulation studies were carried out in collaboration with Indian Institute of Technology Madras so that the growth of the moving target signal and the decimation
The solution for the Army radar was a simpler signal processor based on digital filtering. The radar system proposed by LRDE had a number of other features that were not available in any single surveillance radar system offered at that time by other countries to India\textsuperscript{16}. A state-of-the-art coherent transmitter, digital signal processing, moving target detector, software based radar data processor for providing track-while-scan capability and multicolour displays with synthetic video sum up the effective transformation brought out by LRDE in the field of surveillance radars to raise our capabilities to be at par with the developed countries (Fig 4.9).

\textsuperscript{16} Fast Fourier Transform techniques was just being introduced as a powerful tool in engineering and the only known application for radar at that time was processing data in a batch processing mode that is, in integrating pulses of the order of 1024 or more. On the other hand for LRDE application, pulses less than 100 were to be processed in a continuous mode and in real time. The other advanced features were, an antenna with lower side-lobes without compromising mobility, a coherent doppler transmitter in master oscillator power amplifier configuration with a state-of-the-art highly stable microwave source, a three coloured display where the raw video as well as the computer generated radar picture complete with symbols and numbers would be available, and automatic target detection with track-while-scan capability by means of a software based radar data processor.
The third project was in response to a new qualitative requirement put forward by the Army for a lightweight field artillery radar which would have the capability to locate launch points of multiple projectiles such as the mortars in the shortest possible time. Since electron scanning radars at that time were not lightweight and also very expensive, the state-of-the-art systems employed electromechanical scanning, manual detection and located one weapon at a time. LRDE proposed a unique solution based on automatic detection, operator-aided extraction of trajectory and an algorithmic innovation of trajectory association from intercepts through snapshots of multiple projectiles taken at two distinct time intervals by the radar. This would then provide the launch and impact points in real time of the projectiles for which association could be established. The activities involved the development of the scanner antenna, a compact magnetron-based high power transmitter, automatic detection with constant false alarm rate provision, on-line computing, synthetic display and real time software for digital display, operator interaction, training and estimation of launch and impact points. In addition to the design, fabrication, assembly, and integration of the hardware and software, user-assisted data collection at the ranges in Devlali for verification and modification of algorithm for multiple weapon location was carried out more than once. User evaluation and trials were planned for the first quarter of the 1980’s.

The next three radar projects were aimed at acquiring competence in techniques and technologies that would find place in next generation systems. One was an airborne radar and the other two were for shipborne operations. The Indian Air Force had projected an Air Staff Requirement (ASR) for fitment of indigenously developed radar systems to the imported fighter aircraft. After an extended dialogue between DRDO, Air Force and HAL, it was decided that LRDE’s effort would be aimed at developing a roof top (technology demonstrator) model of a passive airborne phased array radar while HAL would develop its system based on mechanically scanning antenna. Phased array technology was the most advanced radar technology of the time and it was necessary for DRDO to initiate activities with a specific goal in mind for advancing the state-of-art in the country. The LRDE technology demonstrator would be a coherent airborne phased array system with advanced features. The design of the phased array antenna was initiated based on the data and dimensions of a phase control

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17 The Technology Demonstrator multi mode radar system proposed by LRDE was aimed to be a test bed for trying out new techniques and technologies that were likely to be introduced in the next generation systems of that period. The radar would have ferrite based phase control modules which would have to be imported for electronic scanning, high performance monopulse feed, coherent transmitter and three channel monopulse receiver, programmable digital signal processor, synthetic display with
module that was selected for import\textsuperscript{18}. The emergence of sea skimmer missiles as a viable threat against ships required a search radar which would detect a high speed target with very low radar cross-section skimming over the sea surface and a tracking radar with high angular resolution to track the missile before it could be destroyed. LRDE undertook to carry out investigation of techniques for detection and tracking of targets of very small cross-section in sea clutter\textsuperscript{19}. Hardware for a C-Band search radar and a tracking radar operating in the dual-frequency bands (X- and Ku) for Naval applications was initiated. In the early years of the 1980’s, design of the major subsystems was under way.

The activities of the Laboratory were thus directed toward passive phased arrays instead of mechanically scanning reflector type antennas, high range resolution waveforms, high angular resolution beams, digital signal processors, multi-microprocessor-based radar data processing, improved algorithm for the tracker performance, and man-machine interface, multi-moding in radars and multi-target tracking capability. In the field of communications as the 1970’s opened for LRDE, two projects in this area, namely the Sound Ranging System and the Automatic Electronic Exchange ((40+12) lines), were ongoing activities. The Sound Ranging System development was completed, the System was evaluated by the Army and on approval for introduction into Service, technology was transferred to M/s ECIL, Hyderabad for manufacture and supply.

\textsuperscript{18} Solid State Physics Laboratory would take up the development of the ferrite for the phase control module, IIT Delhi would be involved in the design and development of the phase control module and Central Electronics Limited a public sector undertaking would manufacture the IIT design so that an indigenous base for this critical component was established.

\textsuperscript{19} The technological challenge in the search radar was in the design of a high average power transmitter with wide band transmitter waveforms to provide high range resolution and in the design of the antenna with very low side lobe levels for detecting the sea skimmer. In the tracking radar the technological challenge was in the design of dual frequency monopulse antenna and in the technique for tracking the moving target at very low elevation angles.
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The Automatic Electronic Exchange (40+12 lines), was the first of the developments to be undertaken by LRDE for Plan AREN. In this decade as well as in the next decade, a major part of the development activities of LRDE would be directed toward the design and development of Plan AREN equipment. LRDE was in the unique position of being the developing agency for three distinct families of switching systems, namely, manual switchboards, automatic electronic switches for local calls, and integrated switches for trunks. In each category, the developmental activities were aimed at integrating progressively and at the earliest, relevant technological advancements as they were taking place.

In the manual switch boards, the emphasis was on increased reliability with reduction in weight, size, and power consumption. A solid state 15-line manual exchange with push button control, CMOS devices for low power consumption, solid state cross-points for reliability and compactness, was developed, user evaluated, and technology was transferred to BEL, Bangalore for re-engineering and production (Fig 4.10).

In the automatic electronic switching systems, the designs progressed from wired, program-controlled space division multiplexed analog switching matrix to time division multiplexed digital switching matrix, using advanced control concepts and component technologies. The first of the development projects in this area was the Automatic Electronic Exchange (40+12 lines) which was taken up for development in 1968. In this pre-microprocessor era, wired program control was implemented using

![Figure 4.10. Manual switch board](image)
Defence Research & Development Organisation (1958-82)

discrete devices. A three-stage solid state switching matrix was employed with reed relay crosspoints in the early version as speech path switching elements. As technology advanced, reed relays were replaced by silicon-controlled rectifiers, and still later, by CMOS crosspoints with very low power consumption. For the first time in the country, an Exchange provided the subscribers with sophisticated facilities such as multi-level priority, conference, and call-transfer. The design of the exchange was modular in that by adding an identical switching matrix the capacity was doubled, i.e., [80+24] lines. In 1972, the Army evaluated the laboratory model of SWITEL, preferred LRDE’s equipment to that of our indigenous competitor and cleared it for industrial prototype and manufacture by M/s ITI, Bangalore.

The modularity of the SWITEL was not extended to the Corps level electronic exchange with [160+48] lines because by the time SWITEL was productionised, component technology had advanced to a point where time division switching of digitised speech signals could be considered. The development of the time division switch TIDEX, was sanctioned in 1978 with basic modularity of (40+12) lines and expandable up to (160+48) lines (Fig 4.11). TIDEX was modular with a processor and switch (PAS) unit, a subscriber unit, an ac/dc power supply unit and a derived power supply module. For expandability, only the subscriber unit was added up

Figure 4.11. Tidex
to a maximum of four. PAS, the core of the equipment, contained a digital switch and dual microprocessors operating in a load-sharing mode. The digital switch was a single-stage time switch with four input and four output TDM highways, each having a gross bit rate of 2 megabits and 64 time slots. The subscriber unit contained the trunk and line interface for 40 lines and 12 trunks. TIDEX offered all the call processing facilities of SWITEL. Facilities were provided for the operator through his console to carry out diagnostics, isolate faulty circuit modules, and reconfigure the Exchange. Call processing, diagnostic, as well as man-machine interaction software were also developed for the Exchange. The changeover to digital switching resulted in smaller size, lesser weight, greater flexibility and higher reliability for the Exchange. The laboratory model was evaluated by the Army in 1982 and cleared it for industrial prototype and manufacture at M/s Bharat Electronics Ltd, Bangalore.

For the trunk switch, LRDE had persuaded the Army in 1968 to opt for the futuristic digital time division multiplexing instead of space division, as the former would provide an integrated facility for voice, data and teleprinter and also would reduce the complexity of the switching network. The Automatic Electronic Switch (AES) as it was called, was designed as a real-time stored, programme-controlled, time division multiplexed (TDM) trunk exchange catering for 192 voice circuits/32 data channels/256 teleprinter channels. It was a full availability communication system centred around a time-space digital switch with capability to handle 16 TDM highways of 12 channels. AES system comprised synchroniser, front-end processor, digital switch, main processor, local switchboard and system monitor. Two new design concepts were implemented in the digital switch. To ensure process integrity and operational reliability, dual processors were employed in hot stand-by mode with module-level synchronisation between the processors. The other novel concept was the use of hardwired, front-end processor for extracting signalling information from the TDM highways and passing the reduced signalling data to the main processor. The software was modular in nature with watch dog timer for programme sanity checks and included real-time hardware/software diagnostics. The AES had the following additional features namely, adaptive routing, priority pre-emption, fail-soft networking, and operator’s command memories. Thus, the design of AES by LRDE incorporated functional modularity, processing integrity, operational reliability, and ease of operation and maintenance. The laboratory model of AES was given the "go ahead" signal for industrial prototype to be fabricated by BEL, after its operation with other Plan AREN equipment was demonstrated in 1979. The industrial prototypes based on LRDE design along with that of our
indigenous competitor were extensively tried out over a period of six months of User and troop trials before the LRDE design was recommended for production by BEL, Bangalore in November 1982.

Two more Plan AREN projects namely, the development of Radio Trunk Extension (RTS) and Radio Local Extension (RLS) systems, were undertaken for development in this period. RTS was expected to provide to mobile subscribers (Gypsy) access into the Plan AREN grid network. It was a duplex, digitised voice radio telephone system. It was also capable of operating in the stand-alone mode. The RLS was also meant to connect a mobile subscriber to the Plan AREN local exchange. The system was designed to operate in the VHF band using demand-assigned pooled channel approach to a maximum of 10 subscribers in clear as well as in secure voice modes of working. The hardware was under development in the first quarter of the 1980’s.

LRDE was equally active in the development of transmission and secrecy equipment in keeping with the technological advancements. LRDE was the first to propose time division multiplexer with speech/data based on Adaptive Delta Modulation (ADM) coding. This would particularly suit military networks because of its tolerance to high transmission error rates. The technology was progressively updated in this period so that by the end of the 1970’s, the design was based on CMOS technology and active filters and provided expansion capability in 6 channel steps. LRDE also developed a family of speech secrecy equipment using both analogue and digital encryption. Time domain analogue scramblers based on rolling codes, digital encryption employing crack resistant codes were developed for single-channel, multichannel, frequency division and ADM multiplexers. A number of these were evaluated by the users, accepted for introduction into the Services, and were under production in the required numbers at the LRDE pilot plant. Some of the other project activities of LRDE were, the development of the commutated Aerial Direction Finder for the Indian Air Force, Radio Frequency Suppression Kits for vehicles, avalanche-victim detector, and emergency firing unit for Vijayanta tanks. All of these were taken up at the instance of the Services. These were evaluated by the Users, accepted for introduction into the Services and technology was successfully transferred to production.

LRDE and DRDO had the satisfaction of having contributed greatly to the indigenisation of the Army’s tactical communication network. It would not be out of place to mention that but for the vision and courage of

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conviction of the Army Signal Corps, the Plan AREN based on cutting-edge technology of that period would not have materialised from indigenous efforts. Contrast these developments for the military with the corresponding developments in switching systems on the civil side\textsuperscript{20}. The technology of the civilian telephone exchanges in the 1970's and 1980's was either strowger or cross bar in our country.

4.4.2 Defence Electronics Research Laboratory

Defence Electronics Research Laboratory (DLRL) which was set up in 1962, found that the growing application of electronics in defence gave ample scope for its scientists to gain experience and build expertise in electronic warfare which was in its infancy, on-line ciphers for teleprinter traffic, HF/VHF/UHF communication antennas (Fig 4.12), and radars. Since LRDE’s focus was on speech secrecy, DLRL found a niche in secrecy systems for teleprinter traffic which was being increasingly used by the military. In the first five year period, namely 1962-67, DLRL like LRDE, had to build its human resource, organise the Laboratory for undertaking R&D work, and go through learning by doing of import substitution/indigenisation and improvements to existing equipment.

Figure 4.12. HF/VHF antennas
Defence Research & Development Organisation (1958-82)

Figure 4.13. DLRL radar building
The main radar activity at DLRL in the 1960’s was the de novo development of the Secondary Surveillance Radar under the ADGES Plan of the IAF. This was the ground-based radar that interrogates through coded transmission of pulses from all airborne transponders within its coverage volume. The new generation IFF Mk 10 which was under development in developed countries had new features, such as sidelobe suppression through interrogation and control patterns of the antenna, active and passive decoding, degarbling, defruiting, interlacing of interrogation pulses, and so on. The system when completed would be modern and comparable in features and performance to any system available in the world. Thus, in the field of radars, by the second half of the 1960’s, DLRL was offering innovative and competitive system solutions.

The major activity in the field of communications at DLRL in the 1960’s was the development of On-line Cipher machines which replaced the World War II Typex machines for clearing large volume of classified traffic on teleprinter channels. An innovative design approach based on digital techniques for complex key generation, real time encrypting and decrypting algorithms, and synchronisation provided a machine which was competitive on a global basis. Two versions of on-line cipher machines were successfully developed and introduced in the Services. These were produced in numbers at the pilot plant established by DLRL in 1965.

Unlike radar and communication systems, electronic warfare systems are characterised by large bandwidths for which octave bandwidth microwave components are crucial. Right from the beginning, since the laboratory found that procurement of such components from abroad was not easy, DLRL had no choice but to build competence and expertise in the design, development and fabrication of these vital components. The Radar Augmentation Plan of 1965 provided financial resources and additional manpower so that an additional 18,000 square feet of area was available for housing microwave circuit, microwave antenna, and radar EW laboratories (Fig 4.13), which would be equipped with test and measuring equipment and staffed with young, qualified engineers/scientists. Scientists were also deputed for training abroad and on their return, they were gainfully employed in design and development of waveguide, coaxial and strip line passive components and active modules. Besides these hardware activities, DLRL undertook propagation studies in the VHF/UHF range of frequencies including the effect of vegetation and based on this data, graphical representations were drawn for ease of utilisation by the Services.

In the first quarter of the 1970’s, the development of the secondary surveillance radar was completed (Fig 4.14). It was evaluated, accepted and the technology was successfully transferred to Bharat Electronics Ltd,
Defence Research & Development Organisation (1958-82)

DLRL undertook two more projects namely, Indigenisation of the SA-75 System – code named Project DEVIL, and Analog Moving Target Indicator for the Radar used in SA-75 system, and the Infantry Battlefield Surveillance Radar (Fig 4.15). The DLRL effort on the SA-75 radar was part of the overall import substitution exercise undertaken by DRDL. The indigenous design had to conform operationally to the specifications, but in view of the fact that technology had shifted from vacuum tube to integrated circuits, the detailed circuit designs of the missile radar were totally Indian. The main technical challenges for DLRL scientists were in the design of the high power transmitter and electromechanical scanning antenna. The laboratory collaborated with SAMEER in Bombay which had the required
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competence for high power transmitter development. As the information on
the antenna was very sketchy, considerable effort was devoted towards the
analysis of the intricate design by which the scanning was achieved. A
simplified design from the point of view of fabrication and a more efficient
electromechanical scanning was attempted. The development of the
Analogue Moving Target Indicator for SA-75 was taken up to improve the
performance of the original imported system against ground clutter and
chaff\textsuperscript{21}. By the end of the decade, DLRL had designed and developed most
subsystems of the missile radar and that of the analogue MTI. However, the
closure of the main project on the indigenous development of the imported
missile system required DLRL also to discontinue the development work on
the missile radar. Both the projects were stage closed but the experience and
insight gained through these projects was of great help in the development
of radars for the Integrated Guided Missile Development Programme and for
development of high power jammers.

The Battlefield Surveillance Radar (Fig 4.15) was the other project
undertaken for development in mid 1970’s by DLRL in response to the
qualitative requirements of the Army for a battery-operated man-portable
system for the infantry\textsuperscript{22}. The challenges in using the pulse Doppler
approach were, detection of very low Doppler targets, such as crawling
men, ease of operation, the need for the system to be man-portable, and
ensuring low primary power consumption by the radar station. The
requirement of man-portability set an upper limit of 15 kg for weight for the
radar station and the other limit was at least 4 hr of operation with a
given battery pack. To satisfy both the limits, innovation in circuit design
and operation was necessary. A novel way of correcting frequency drift of
the transmitter over time and a search procedure which would enable the
operator to detect anywhere in the search zone the moving target in a very
short period of time, were evolved. Special efforts had to be made for getting
the rechargeable battery pack designed and developed so that 4 hr of
continuous operation was met. The systems were field evaluated by the
Infantry at their School in Mhow. Subsequently, the systems went through
evaluation by the Infantry in jungle, mountainous ranges, desert, high
altitude terrains successfully and by the end of 1981, introduction into the
Services was decided and orders were placed on M/s HAL, Hyderabad.

\textsuperscript{21} The fitment of the analogue MTI to the missile radar required modification of the local
oscillator to improve its frequency stability, incorporation of a delay line canceller and
changes in the B-scope display for presenting moving target information.

\textsuperscript{22} The salient features desired by the Infantry were that the weight of the radar station should
be within 15 kg, and the installation or closing down should be within 5 minutes. The radar
was required to give a range of 800 metres for crawling men, 1.5 km for a group of walking
men, 3 km for vehicles with a range resolution of 50 metres and an angular resolution of 6
degrees.
The technology was successfully transferred from DLRL to HAL, Hyderabad and the radars were supplied to the Army.

The focus of DLRL in non-radar areas was on microwave circuits, cipher machines, and electronic warfare equipment/systems. In the area of microwave components, passive microwave components in waveguide configuration, ferrite devices, low noise tunnel diode parametric and transistor amplifiers, and YIG filters and oscillators were designed, fabricated and used in DLRL’s own equipment designs as well as supplied to the Services on request. In addition, as strip line and microstrip line structures replaced waveguide and coaxial structures, DLRL kept pace with these technology advancements by setting up a Microwave Integrated Circuits (MIC) laboratory so that thick film hybrid circuits would be fabricated in-house and used in their own equipment. The success of the first two cipher machines, ECL Mk-I and Mk-II brought in more orders for better machines, such as ECL Mk-III for on-line and off-line operations.
Further, as component technology advanced and as small scale and medium scale integrated circuits became available, DLRL scientists developed ECL Mk-IV incorporating digital techniques, complex key stream generators and real-time powerful encryption algorithms (Fig. 4.16). The customers list went beyond the Services to include law and order agencies of the Ministry of Home Affairs. Instead of the pilot plant, Bharat Electronics Ltd, Ghaziabad, to whom the technology was successfully transferred, manufactured the equipment.

In the area of electronic warfare, DLRL’s activities covered the three Services and ranged from receiver systems for electronics intelligence, communication intelligence, electronic support mission to jammers and electronic counter-countermeasures for enhancing the immunity of operational radar systems. The Laboratory also initiated work on electrooptical warfare systems. The first QR-based project for the Army was the development of a panoramic adapter in HF band for displaying radio frequency emissions with channel identification parameters in any selected sub-band. The adapter was to be fitted to an existing receiver of the Army to improve the speed of response. The next project was the development of a VHF jammer of high power covering net radio band. Since the jammer was required to carry out automatic search by monitoring the channels sequentially and then jam the required channels, the EW system had a receiver for search and monitor purposes, a high power transmitter, a control unit to carry out the sequence of operations, a display unit for the human operator to monitor and initiate action, and an antenna unit for
covering the band of operation. Both these systems were evaluated by the Army, accepted for introduction into the Services and manufactured at the pilot plant of DLRL. When the requirement for a vehicle-mounted electronic and communication intelligence (ELINT and COMINT) systems was reflected to the DRDO in 1974, DLRL took up the development of ELINT/COMINT systems operating in the band, 0.5 GHz to 18 GHz and having the capability to search, intercept, acquire, analyse, determine direction of arrival, and record the important parameters of emissions (Fig 4.17). It required on the part of the Laboratory to develop nine major subsystems, assemble these in two vehicles and integrate these to achieve the desired receiver performance. This was the first electronic warfare system in which a microprocessor-based controller was employed to command the various subsystems to operate in a programmed manner. It was also the first step taken by the Laboratory toward modular multi-port computer controlled system. The receivers were superheterodyne broad band, which necessitated the laboratory to design and develop frequency synthesizers. For the radar band direct frequency synthesis was employed while for the communication band a hybrid between indirect frequency synthesizer and Direct Digital Frequency Synthesizer was developed. In the radar band rotary Direction Finding (DF) technique was implemented with Log Periodic Antennas (LPAs) as feed. For the communication band eight LPAs giving 360 degree coverage were electronically switched for amplitude
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comparison and estimation of Direction of Arrival (DOA). The broadband microwave components and the antenna were designed and fabricated in-house. Even though the system performance was demonstrated, the effort did not result in production. But it laid the foundation for greater interaction between the Users and DLRL.

The requirement of a high performance search and monitoring system for operations in the VHF/UHF bands for the Army was taken up by DLRL for development in 1977. The receiver was required to analyse the interference, categorise it as AM, FM, CW and pulse type of signals and display all the relevant information in panoramic/sector and manual modes, with each mode displaying information specific to that mode. Digital techniques were employed in the design to tune and control the functions of the receiver. The salient features of the equipment were high frequency stability, high spurious rejection, switchable IF bandwidth, IF analysis, signal-level indication, remote operation and digital read-out. After evaluation, the equipment was accepted and the technology was successfully transferred to M/s ECIL for manufacture.

The Electronic Support Measure (ESM) system to be fitted on fast patrol boats of the Navy, and which was required to intercept, analyse, locate, and estimate relevant signal parameters, was taken up for design and development by DLRL in 1979. A frequency coverage of more than three octaves, starting from the low microwave frequency region was stipulated.

The system was to provide simultaneous warning capability for multiple threats, display about half of the unidentified ones and also provide audio alarm for the first-time interception of the warned threat. In addition, it was required to be fitted on to the boat in such a way that the three main subsystems namely, the antenna unit, the ESM cabinet, and the display with associated circuitry would be physically separated with antenna unit on top of the mast for maximum line of sight and the display in the operator’s cabin. DLRL developed a digital system with a wide-open crystal video receiver with eight LPA’s for DF purposes and an omni antenna for band warning. The specific technical challenges were in the placement of antennas for minimising interference from own radar; design, fabrication and testing of the antennas with radome, and of the DF receiver for optimum accuracy through amplitude comparison; algorithm for DOA estimation based on antenna pattern, for signal de-interleaving and for minimisation of multi-path effects. For determination of the position for co-location of the antennas of the ESM receiver system, the expertise of the faculty of IIT, Madras was sought for prediction by analysis of the electromagnetic field at different
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locations on the ship. These were verified by experiments. Since it was a de novo development, reworking/iterations could not be avoided. Until 1982, fabrication of the laboratory model was under way. The Navy also wanted a heliborne ESM system covering 1 GHz to 18 GHz frequency band, with capability to provide 100 per cent probability of intercept, direction of arrival, parameters of radar emitters and an automatic warning. In view of the non-availability of gain-tracked multiplexers, omni antenna for base band identification was preferred to distributed antennas with multiple receivers. On acceptance of this approach by the User, in 1982 studies were initiated for choice of antenna location and also for determining the effect on the aerodynamics of the helicopter.

Two projects were initiated at the instance of the Indian Air Force; one for providing frequency agility for an imported missile guidance radar and the other for adding ECCM capability to an imported surveillance radar. For the missile radar, the proposal of DLRL to develop a frequency agile transmitter was accepted by the Indian Air Force. The Laboratory initiated the development of the hardware and by 1982, it was in the process of being assembled. The second proposal for adding ECCM capability to an imported surveillance radar was taken up in 1974. The DLRL proposed to develop and configure ECCM receivers to counter a variety of jammers, an interface unit which accepted 30 MHz IF signal from the radar, local/remote control unit, and an IF simulator capable of generating jamming scenarios for testing the effectiveness of the ECCM receiver configurations. The ECCM receivers comprising of a linear IF amplifier with CFAR and IAGC, a logarithmic IF amplifier, a Dicke-Fix IF amplifier, a pulse length discriminator and a video integrator with the control network providing preprogrammed selectable receiver configurations, were designed and developed. The system was subjected to extensive field trials against different types of emitters such as CW, noise, slow sweep and fast sweep jammers and the ability of the operator to track a moving target in the presence of these jammers with and without the ECCM receivers was evaluated for arriving at the efficacy of the system. The system was accepted for introduction by the Services and the number of ECCM systems required were fabricated and installed successfully.

The use of infrared and optical spectrum for weapon aiming and guidance prompted DLRL to undertake studies in characterising military lasers and active infrared emitters for design and development of effective countermeasures. Further, methods of detection and estimation of the direction of arrival of these emissions were also investigated. In addition, investigations were also undertaken to explore various countermeasure techniques against passive IR guided missiles.
4.4.3 Solid State Physics Laboratory

Solid state Physics Laboratory (SSPL) is dedicated to the development of solid state materials and devices for applications in the electronic equipment and systems designed by LRDE, DLRL or any other laboratory in the DRDO (Fig 4.18). In the 1960s, the laboratory initiated work in silicon and gallium arsenide, two most important materials out of which integrated circuits, solar cells and microwave devices were being created and manufactured. At the very outset, facilities were created at the Laboratory for the growth of silicon crystals, slicing them in wafers and characterising them. It is a matter of record that SSPL was the first Laboratory in the country to initiate work on crystal growth of semiconductors and the extensive work carried out by the scientists of the laboratory led to indigenous development of techniques for growing dislocation-free single crystals and also of those with controlled doping. Once the infrastructure was in place, the Laboratory focussed on developing unit processes such as diffusion, lithography, contact and packaging, and testing of devices. As far as gallium arsenide was concerned, work was initiated in the late 1960s on epitaxial growth by vapour phase epitaxy. Besides these two materials, SSPL initiated work on microwave ferrites, out of which isolators, duplexers and circulators would be fabricated for use in radar systems. Recognising the strategic importance,
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feasibility experiments on synthesis of the material was started, useful data was collected and analysed so that future requirements could be met.

The work carried out by SSPL in the 1960s on devices and components can be gauged from the following six projects, which are representative of the activities of the laboratory. The first one was sanctioned in 1965 and was concerned with the development of special-purpose devices, such as varactor diodes, silicon point contact diodes, tunnel diodes, and so on. SSPL developed the silicon point contact diodes in standard microwave cartridge and the know-how was transferred to two private sector firms through NRDC for manufacture. Varicap was the other device which was developed in chip form for encapsulation and use by BEL, Bangalore in a specific radio equipment under production. The project on the development of microwave ferrite isolator was sanctioned in 1965 and was aimed at building the competence in microwave ferrites and then developing specific high power ferrite components. The laboratory achieved success in the preparation for magnesium ferrites of various grades, nickel-copper and nickel-zinc ferrites (Fig 4.19). A major user of magnesium ferrites, was M/s ITI, Bangalore to whom large quantities in the form of slabs were supplied for manufacturing microwave ferrite components used in their communication systems. In addition, SSPL developed a high power X-band isolator which was evaluated for use in X-band radars under production at BEL, Bangalore. About 50 numbers of these high power isolators were fabricated and supplied to the Company. The project on development of solar cells taken up in 1965 was aimed at the standardisation of the phosphorous diffusion process in p-type silicon and

Figure 4.19. Microwave ferrites
design/test typical solar cell-nickel cadmium cell power system for application in communication sets. The project was successful, an array of 180 solar cells was tested for high altitude performance at Leh with a wireless set in use with the Army. Solar cells were also supplied to Space Science and Technology Centre for their use as photosensors. Two other projects, one on the development of laser sources and the other on microminiaturisation techniques, were aimed to build competence in these two important areas of interest to defence. The sixth project was on setting up a pilot plant facility for growing semiconductor-grade silicon.

The major activities and contributions of SSPL in the 12 years beginning from 1970 were the development of VT-fuze and silicon solar cells for space applications; investigations on IR devices and semiconductor epitaxial growth; infrastructure building for characterisation of silicon and gallium arsenide materials and devices; continuation of work on ferrite material, initiation of development work on complex integrated circuits, and discrete semiconductor devices for Missile Applications. The successful development of VT-fuses by SSPL for the Russian 130 mm gun and the Navy’s 4.5 inch gun has already been brought out under Armaments. Suffice it to state that the technology was successfully transferred to M/s HAL, Hyderabad for supply to the Armed Forces. The development of space quality solar cells as per the specifications provided by Indian Space Applications Centre (ISAC), required setting up of facilities for diffusion, evaporation metal-semiconductor contact, and evaluation. The project was successful, more than 300 solar cells were delivered to ISRO, which flew a panel of 10 of these solar cells in the satellite BHASKARA (Fig 4.20). The performance of SSPL panel was compared to that of the imported panel also flown on the satellite, and the SSPL cells delivered to ISRO were declared as space qualified. The other major activities were the development of gunn diodes of about 200 mW CW power at X-band; specific integrated circuits such as diode matrix, clock, voltage-controlled oscillator, analogue switch, high frequency high gain block; microwave field effect transistors. In all these projects, the broad objectives set at the beginning of the activities were met. In some cases, efforts to productionise some of the developed items did not succeed because of lack of orders for commercially viable quantities. However the activities pertaining to the development of poly crystalline garnets and microwave substrates need further elaboration. They covered development of the process to synthesise poly crystalline YIG and aluminium substituted YIG process for fabrication of MIC substrates of substituted magnesium-manganese ferrites and lithium ferrites; and process for substituted lithium ferrites of saturation magnetisation between 1000-3000 gauss with square loop
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characteristics and of torroidal shape. The substituted lithium ferrites were a critical material for developing an important subsystem namely, the Phase Control Module (PCM) for a passive phased array radar that was under development at LRDE. It would be later transferred to M/s CEL, Ghaziabad for production of the PCMs.

4.4.4 Defence Electronics Applications Laboratory

The activities of Defence Electronics Applications Laboratory (DEAL) in the 1970s were focussed on tropospheric communication systems, airborne/satellite command control and communications. The first major task undertaken by the Laboratory was the development of a 24-channel quadruple diversity troposcatter communication link under the ADGES Plan. The system was designed to meet the requirements of the Indian Air Force so that on completion of development, testing and evaluation, it could form part of the tropscatter communication network of the Indian Air Force. The most challenging task was the successful development of the 1 kW klystron amplifier. The technology of the high power transmitter was transferred successfully to M/s Bharat Electronics Ltd, Ghaziabad for production and supply all troposcatter communications links that were being manufactured by them. The

![Solar cell panel](image)

**Figure 4.20. Solar cell panel**
tropscatter communication link developed by the Laboratory was set up between Delhi and Agra for evaluation. It was later accepted by the Services.

In the area of command, control and communications using space as the medium, three R&D projects were undertaken by the Laboratory in the period 1975-80. These were, Door Drishti, Transportable Small Earth Station, Airborne and Ground Segment of Multi-Spectral Scanner System. The aim of the project Door Drishti was to investigate the performance of a link between an airborne reconnaissance vehicle and the ground control station. For this purpose, the Laboratory had initiated design and development of the necessary ground-based as well as the airborne hardware. The project on the development of a Transportable Small Earth Station was to investigate the feasibility of its use for troops on the move. It involved the development of critical subsystems such as up/down converter, BPSK modem for interfacing with the 6-channel multiplexer of Plan AREN. By 1982, the system was being assembled for integration. The project on the development of Multispectral Scanner aimed at developing an airborne system with real-time data transmission and display of images. A linear array of 2048 charge control devices were used in the 0.5 μm to 1 μm wavelengths and a linear pyroelectric array of 256 elements were used in the 8 to 12 μm band. Push broom mode of scanning was proposed because it needed no moving parts for image scanning in contrast to conventional scanning. The hardware for the airborne scanner was designed, fabricated, and assembled. By 1982, testing was being carried out. In addition, two projects were initiated before the end of 1982 and these were, initiation of image processing activity and development of digital VLF system for the Indian Navy. For the project on image processing, DEAL proposed to install the hardware but to develop its own software in close interaction with IIT’s, IISc, ISI and NRSA. The project on the development of a digital VLF system was taken up to meet the requirements of the Indian Navy for a low level MSK transmitter and MSK-based VLF.

4.5 ENGINEERING

Two establishments are grouped under the discipline, engineering and these are – Research & Development Establishment Engineers, R&DE (Engrs), at Dighi, Pune, and the Snow and Avalanche Study Establishment (SASE), at Manali. R&DE (Engrs) was setup in 1962 with the bifurcation of TDE (Vehicles) and moved to the present location at Dighi, Pune, in 1962. The activities of the Laboratory are engineering-oriented and cover weldable aluminium structures, portable and mobile bridges, portable and mobile masts for radar and communication systems, habitats for cold regions including Antarctica, pressurised chambers and life saving equipment for high altitude and fluid power-based systems. From the very early days, the
R&DE (Engrs) worked jointly with industry to take up the fabrication and assist in translating the designs into hardware.23

The genesis for the setting up of the Snow and Avalanche Study Establishment (SASE) was the difficulty faced by the Armed Forces in the 1949 and 1965 conflicts when they had to combat the hazards of snow and avalanches in the mountainous regions of the Himalayas. The DRDO set up a new laboratory namely, the Snow and Avalanche Study Establishment (SASE) at Manali in 1969 with the specific aim of carrying out scientific and systematic investigations to combat the hazards of snow and avalanches so that the roads and lines of communication are kept intact throughout the year, and thus, enable the Services to live and fight in the mountain regions of the Himalayas. SASE is one of the select institutions of the world and only the one of its kind in south east Asia, devoted exclusively to the study of snow and avalanches.24

4.5.1 Research & Development Establishment (Engineers)

The major activities of Research & Development Establishment (Engineers), R&DE (Engrs) in the 1960s were the development of light metal bridges and power boats for bridging operations, development of lightweight water supply pumps, prefabricated shelters for high altitude operations and other engineering equipment.

One of the problems that the Laboratory had to face and resolve during the development of lightweight structures was the inadequacy of indigenous aluminium alloys for military use. These alloys were either not weldable or in case welding was possible, the composite structure lost strength after welding. The Laboratory had to take up investigation about the composition of the alloy and with the assistance from Indian Aluminium Company and in collaboration with Ordnance Factory, Ambernath, experiments were conducted to arrive at a new alloy composition to achieve better strength and stress corrosion resistance. By 1969, welded components of Class 3 Bridge were found to have the desired strength. Experimentation on alloy composition was continued from the point of view of corrosion resistance and ageing characteristics into the 1970s till a self ageing weldable aluminium alloy was established.25

23The developments carried out by R&DE(Engrs) and described in this volume are based on the volume, Research & Development Establishment (Engrs), Dighi. Pune 411 015 prepared by the laboratory at the request of the author to the Director, Mr MR Joshi.

24The activities of the SASE described in this volume were communicated to the author by Dr A Nagaratnam, former Director, Defence Laboratory, Jodhpur, who was compiling the data.
Another major activity was aimed at replacing the heavy and bulky pneumatic and conventional electric tools used by the Army engineers in the field by corresponding tools and 400 Hz power supply which would be less bulky and lightweight. This involved evaluation of the high frequency tools for field use, estimating the power requirements in the field, liaising with industry to develop high frequency generating sets and corresponding tools for use by the Corps of Engineers. The activity would spill over into the 1970s.

The development of a Class 30 Assault Trackway to permit Class 30 wheeled vehicles to cross soft areas especially approaches at bridge and ferry sites, class 60 tank approach to support movement of tanks over soft ground, punched tape, which is electro-galvanised carbon steel strip with sharp barbs for replacing bulky barbed wires used by the Army, and transportable water purification set were some of the other contributions of the Laboratory. R&DE (Engrs) also assisted other DRDO laboratories in their projects by designing, developing and supplying specialised equipments and components. For example, portable lightweight antenna mast capable of withstanding winds up to 160 kmph and weighing less than 150 kg was designed and fabricated for use by DLRL for mounting HF Log Periodic Antenna up to heights of 22 metres. Another example was the development and fabrication of a tower of 47 metres length with an inclination of 20° to the vertical to ARDE for testing indigenously developed cartridges used for emergency ejection of seats in military aircraft. A specialised development work carried out by the Laboratory was to design and fabricate a recompression chamber which was 2.44 m long and 0.7822 m diameter cylinder capable of withstanding 150 psi pressure for the Indian Navy for their diving operations.

The activity on the development of aluminium alloy reached a logical conclusion in 1976 with aluminium alloy D 745, which was found to be self-ageing and weldable. Consequently, design, development and fabrication of a series of bridges, such as the assault bridges-class 13, class 19 and class 50T, assault floating bridge-class 19 were successfully completed. In addition, assault bridge-class 9, fixed bridge class 3, were also developed and fabricated. Consequently, military bridge development became a major activity in this period. The search for better aluminium alloys for the next generation of military bridges with greater strength and stress corrosion resistance was continued. Varying percentages of zinc, magnesium, manganese and chromium for the composition was initiated in 1977. Small quantities of the alloy with different compositions were extruded by Ordnance Factory, Ambajhari and were tested for stress corrosion, susceptibility to heat treatment cycle, composition variation at
grain boundary and matrix, precipitate distribution, and electrochemical effects. Welding trials were carried out at the Bhabha Atomic Research Centre, Trombay. Simultaneously with the expertise that was gained in military bridges, a major effort was initiated for developing mobile bridges involving sophisticated powering systems so that the country would be self-reliant in this area.

The development work on high frequency generator system and powered tools was continued. The replacement of the 50 Hz electric and fluid power in such applications as lighting, welding, heating for surgical tools, ventilation and air conditioning, water pumping, sawing and felling of trees, drilling for boreholes and surface breaking, winching, grinding and machining by the 400 Hz high frequency power would have the advantage of high power-to-weight ratio (Fig 4.21). The other features to be incorporated were, good efficiency with low power consumption, safety, constant speed, robustness, reliability, and ease of maintenance. The power range covered portable tool requirements and operations in the type of environments found in our country. Under the direction of the Laboratory, 3-phase generating sets of capacity 12.5 kWA and 5 kWA with 208 volt output along with such tools, as medium breaker hammer, rock drill hammer with pressure blower, light demolition hammer, heavy concrete breaker, portable electric drill, portable electric chain saw and centrifugal pump, which met the various GSQR’s (General Staff Qualitative Requirements) of the Army, were successfully fabricated by the industry.

Figure 4.21. High frequency generator set (400 Hz)
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In 1971, the Army floated a GSQR for a universal assault boat (BAUT) with capability to carry 16 fully armed men, 2 crew and a cargo of 2000 kg. The GSQR also specified the load that two coupled boats and six to eight coupled boats would have to carry. The intention of the Army was to replace the current multiplicity of floating equipment used during the initial stages of an assault river crossing with one standard system. Accordingly, the BAUT was designed and fabricated using aluminium alloy sheets and extrusions in riveted/welded construction. Detachable links were provided for coupling the boats and suitable ramps with anti-skid surface were also developed for loading and unloading (Fig 4.22). Splash panels were attached to prevent water entering the boat when it was travelling at high speed. The boats could be propelled manually or by an onboard motor. The BAUT was accepted for introduction into service by the Army and a few thousands were manufactured.

Besides BAUT, R&DE (Engrs) had also designed other boats such as the Boat Reconnaissance 3 Men 2A which was a pneumatic rubber dinghy made of nylon fabric with neoprene coating on both sides. The boat could carry 3 fully armed men with stores or a distributed load of 340 kg at a free board of 254 mm. It could be propelled manually by one person with a pair of folding oars and collapsible rowlocks, or by an outboard machine of 6.5 HP power. The boat was provided with double nozzle foot pump that could inflate it in about 7 minutes. The hull was cylindrical in shape with four buoyancy compartments and could retain buoyancy even with two (one on either side) punctured. The boat with accessories weighed less than 46 kg and in deflated condition, could be packed in 3 canvas bags. The boat had been introduced in service by the Army.
In response to the development of non-detectable mine and bar mine at ARDE in the 1970s, R&DE (Engrs) initiated activities for the development of a Mechanical Mine Layer (Fig. 4.23). It would provide mechanised laying of round non-detectable Mk I mines as well as bar mines in mine fields, which were the most vital and efficient obstacles against enemy armoured attack. The Mine Layer could lay mines on any type of terrain ranging from soft sandy or desert terrain to hardest soil of plains. The mines could be armed automatically and laid as fast as any other contemporary system available. These could be laid on the surface or at any mine depth not exceeding 250 mm below the surface. The average rate of laying was several hundreds per hour with a crew of four. It was simple to fabricate and simpler to operate and had a safety device in case of buried boulders in the soil. It was a pure mechanical contrivance with no hydraulic, pneumatic, or electric components. It was accepted by the Army for introduction into service and was manufactured.

Another important activity was the development of prefabricated shelters to provide living, storage and workshop accommodation in the plains, semi-mountainous regions, high altitude and snowbound areas (Fig 4.24). The shelter was semi-cylindrical with a base width of 5 m, height of 4.6 m at the centre and a length of 10 m. The shelter was designed to withstand wind velocities up to 135 kmph and snow loading up to 60 mm depth over the roofing. The shelter could accommodate one 3-ton (4 x 4) lorry, one Amx tank or one 25 Pounder gun at a time.
For training of divers, a recompression chamber was developed and transferred to Navy for use. The chamber was a single-compartment surface-type gastight chamber which could accommodate 7 to 8 men at a time. The internal pressure could be increased or controlled to the working pressure of 7 kg/cm². Intercommunication facilities from inside the chamber to the outside, safety relief valves for emergency release of pressure and a chamber control panel with depth pressure gauges, control valves and external loudspeaker were also provided. For the Air Force, a chamber for high altitude indoctrination of pilots and aircrew was successfully developed and handed over to them for installation.

In the area of fire fighting equipment, a mechanical foam extinguisher was developed successfully. For combating fires involving reactive metals, a dry powder of special composition was developed and its commercial production was organised to meet the requirement of Defence Services. An indigenously developed fire extinguisher for use at high altitudes was developed. It was accepted for Service use. To meet the urgent requirement of the IAF and Civil Aviation, a fire crash tender was successfully developed and cleared for bulk production.

A number of other items of equipment developed by the laboratory to meet the requirements of Armed Forces personnel in difficult terrain and
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forward areas, were, pillow-type portable water tank, water purification set with a capacity of 13,500 litres which could deliver filtered and chlorinated water to troops from any natural source and survival kit for extraction of water.

4.5.2 Snow & Avalanche Study Establishment

Immediately after the formation of the Snow and Avalanche Study Establishment (SASE), Manali in 1969, the Establishment undertook systematic surveys on the Manali-Leh axis and later during winter of 1971, on the Srinagar-Leh axis. These studies culminated in a report recommending control measures to mitigate avalanche hazard along these two highways and kept these open for most times of the year. From 1971 to 1977, the Establishment steadily grew in terms of manpower, infrastructure and other facilities based on the recommendations of an Advisory Committee with the Engineer-in-Chief, Corps of Engineers, Indian Army as the Chairman. Some of the activities of this period include, avalanche forecasting based on simple and effective methods; artificial triggering of avalanches using weapons; de-icing of roads with common salt and calcium chloride; convening the First International Workshop on Snow and Avalanche in 1976 and organising the First Regional Training Seminar in 1978. Avalanche prediction initiated earlier on an experimental basis was expanded in 1981 to include areas of Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh and a network of manned observatories upto a height of 6500 m were set up covering most of the areas in these three states to make avalanche forecasting more precise and timely. To encourage personnel to join these activities, Avalanche Pay was granted from 1978 to the personnel participating in this activity. Avalanche forecasting proved very useful in saving valuable human lives and by end of 1982, arrangements were made for broadcasting warning bulletins by AIR.

4.6 FOOD & AGRICULTURE

Defence Food Research Laboratory (DFRL) at Mysore, the Field Research Laboratory (FRL), at Leh, Defence Agricultural Research Laboratory (DARL) at Pithoragarh and the Defence Laboratory (DLT) at Tezpur are the institutions in DRDO that are concerned with food and agricultural products.

4.6.1 Defence Food Research Laboratory

The activities of the Defence Food Research Laboratory (DFRL) are aimed primarily at developing operational and nonoperational food and rations for the Armed Forces. The operational food and rations require special attention because these have to be provided both in bulk and in
packs tailored to meet specific types of military operations, land-based and spaceborne, high altitude and extreme cold conditions. These have to be partially or wholly processed items requiring very little preparation before eating. The scientists had to bear in mind that the infrastructure relating to preservation of food in India for hostile environments was primitive in 1960s and unless the industry was upgraded, production of the processed foods developed by the Laboratory could not be manufactured and the benefit of their labour would not be available to the Services. Hence, side by side, with the development, upgrading of the plant, processes and hygiene at the producers had to be attended to.

Some of the early attempts of DFRL scientists were the development of lightweight 5-man composite pack rations with indigenous items of food, cocoa-based soft bar with coconut and banana flavours, lightweight flexible packs using paper/aluminium foil/polythene laminates for accelerated freeze-dried foodstuffs instead of tins. It was not a surprise that DRDO food scientists had the unique honour of supplying processed items of Indian dietary for the first successful Indian Everest Expedition led by Lieutenant Commander MS Kohli in 1964. Since then, the Laboratory has been supplying food items to nearly every expedition.

The activities of the Laboratory in 1970s were principally directed into three areas of processed foods, namely frozen foods, dehydrated foods and ready-to-eat or retort process foods. As pre-cooked AFD meat was reported to have low acceptability in view of its woody texture, DFRL evolved a process to improve the quality of the freeze dried mutton. In the new process, the mutton was first deboned and defattened with a solution containing 10 per cent sodium tripolyphosphate with or without 1 per cent sodium chloride for two hours. Subsequently, it was cooked at 60°C for three hours and then freeze dried in the normal manner. This was found to have better rehydration capacity, juiciness and acceptability. It was also observed that pretreatment with additives, such as agar-agar, native potato starch and a mixture of wheat gluten-autolysed yeast improved the quality and texture of pre-cooked AFD mutton. The second aspect was the developing of suitable flexible packaging to replace the tin containers which were expensive and heavy. A systematic evaluation of the suitability of various flexible packaging materials for packaging processed foods was undertaken (Fig. 4.25). Out of the several materials selected and tested, a lightweight flexible pack, consisting of maplitho/aluminium foil/polythene with casein latex as laminating adhesive was found quite suitable for packing. The container had three components namely, a flexible pouch made of maplitho/aluminium foil/polythene to prevent entry of moisture and air, an inner liner to protect the
pouch from damage by sharp edges of meat chunks, and an outer carton to protect the pouch from external damage. The shelf life of the flexible pack was the same as that of the tin container, i.e., 9 months but it was 25 per cent less expensive and 33 per cent lighter in weight. After extensive large-scale transportation trials including air dropping as well as User trials, it was accepted for introduction into the Services. DFRL also collaborated with a firm in the private sector to manufacture the flexible containers.

Figure 4.25. Processed food

The activities on ready-to-eat convenience foods and dehydrated foods were aimed at the possibility of including these in the Pack Rations for different types of requirements of the Services. Such foods would be lightweight and would have a shelf-life of one year. They would be either in a ready-to-eat form or could be quickly reconditioned in a few minutes with the addition of water and without losing the original taste. In addition, these foods would lead to reduction in bulk, economy in transportation, in storage space and in packaging material. These were also resistant to microbial attack. The ready-to-eat foods were prepared by the High Temperature Short Time Retort Drying process which was developed by the Laboratory. It was a single-step process in which cooking, forming and drying was achieved by high speed mixing, shearing and extruding under pressure to impart any shape. The resulting product would be crisp, crunchy, lightweight and ready-to-eat. DFRL developed a variety of compressed ready-
to-eat food formulations, such as the vegetarian and the non-vegetarian savoury bars, cardamom-flavoured sweet bars, porridge bars, cereal bars based on banana, mango, tomato and curd-rice bars. In these formulations, cereals (rice or wheat), pulses, vegetables, fruits, skim milk, curd and processed or dehydrated meat could be added. The ready-to-eat foods were in the form of tablets of 100 g each and were suitably packed for ensuring a shelf life of more than 12 months under ambient and field conditions. Based on the results of field trials, compressed ready-to-eat bars were recommended for introduction into service by the Armed Forces.

DFRL also developed compact dehydrated foods with high caloric content in the form of conventional items of a normal meal suiting the Indian palate. For example, an instant omelette mix consisting of egg powder, dehydrated onion, green chillies, salt and oil hydro was developed. It could be reconstituted by mixing with double its weight in water, allowing five minutes for soaking and shallow frying on a greased hot plate in the normal manner. It could be conveniently packed either in flexible foil laminate or in cans (Fig 4.26). The product had a shelf-life of more than 6 months. A second example of the dehydrated food developed by the Laboratory was the fruit-flavoured milk and lassi powders. The method of preparation consisted of spray drying clarified fruit juices in admixture with milk or lassi in a spray drier. In the case of pulpy fruits such as banana, mango and guava,
clarification could be obtained by using pectic enzymes and the milk was concentrated under vacuum prior to use. Alternatively, clarified fruit juices could be freeze-dried and their powders mixed with spray dried milk or lassi powder. The beverages reconstituted readily in cold water with natural aroma with a minimum shelf life of six months under ambient conditions when packed under nitrogen. Their inclusion in Service rations, therefore, greatly improved nutritional quality besides providing variety. It goes without stating that the processes developed by the Laboratory were transferred to the industry for supply of rations to the Armed Forces.

The main objective of developing processed foods was to provide the Armed Forces with a nutritionally balanced, lightweight, ready-to-eat food with adequate calories and catering to a variety of tastes. The first step in this direction was taken by DFRL with a study on rationalisation of Army Ration Scales for Peace and Field Areas with special reference to calorie and nutritional requirements of troops at high altitude where soldiers faced extreme climatic conditions. Similarly, DFRL took up the dietary requirements of submariners in the Navy who were subjected to high stress environment. The scientists developed Pack rations based on fresh and processed foods, which were approved for introduction into the Service. In addition, DFRL came up with new scales of rations based on the processed food for use by naval personnel during operations and these have been introduced by the Navy.

Chapathi, the staple diet of a large percentage of our country men did not escape the attention of the DFRL scientists. Since the consumer put a premium on the freshness of the preparation, DFRL began the development of an automatic chapathi making machine which could produce these at a fairly rapid rate. The original design went through a few transformations before a prototype could be fabricated in collaboration with industry with capability for producing $20 \pm 5$ fully baked chapathis per minute. The prototype machine consisting of two units, one for dough making and kneading and the other for rolling, baking and puffing was under testing and evaluation.

DFRL also undertook troubleshooting for the Armed Forces. When the serious problem of de-emulsification of tinned butter was posed by the Army, DFRL provided the solution of adding milk solids. It was proved by laboratory scale that the tinned butter remained good/fresh in all climates and the taste of the butter did not change. It also launched efforts to study the feasibility of incorporating milk powder by the industry during the
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processing stage. Similarly, the Laboratory scientists found a solution to extend the short shelf-life as well as to retain the bland taste of the refined groundnut oil by adding 25 per cent polyunsaturated fatty acid.

4.6.2 Agricultural Research Laboratories

The three agricultural laboratories comprising of the Field Research Laboratory (FRL) at Leh, the Defence Agricultural Research Laboratory (DARL) at Almora (later shifted to Haldwani) and the Defence Research Laboratory (DRL) at Tezpur were set up to solve a major problem faced by the armed forces personnel stationed in inhospitable terrains, such as high altitudes where fresh, varied, tasty as well as nutritious food was unavailable. FRL and DARL focussed on assessing and enhancing the agricultural potential of high altitude Himalayan areas as well as the development of suitable agricultural practices for increasing production. DRL, Tezpur focussed on the northeastern region. In animal husbandry, the stress was on improvement of animal breeds and to find ways and means to increase the milk/meat yields and acclimatisation to high altitude conditions. A major mission common to all the three laboratories was to liaise with civil agricultural authorities as well as with the Army units to establish model farms for demonstration, training, consultancy and to render help to local problems of environmental interest. The activities carried out by the FRL, Leh are typical of the work carried out by them.

Leh, where the Field Research Laboratory is located is one of the districts of Ladakh which is a high altitude area with altitudes varying between 2900 m to 5900 m and with temperatures as low as −50 °C. The majority of the inhabitants of Leh depended on agriculture for their livelihood but the arable irrigated land was limited and farming was possible for only 3-5 months in a year. Agriculture was primitive and traditional and was based on sustainable organic farming. The scientists of FRL made attempts to grow suitable varieties of vegetables at these high altitude areas. FRL introduced trench cultivation for raising nursery of vegetables in the early years to overcome the major handicap of a small farming season. Seedlings were raised in polythene covered trenches during April and were transplanted as soon as cropping season started. Green vegetables like coriander, mint, lettuce, celery, parsley, fenugreek and palak were grown by following polyhouse and trench cultivation. FRL introduced polyhouse type of crop cultivation in which crops were grown inside a closed enclosure made of wood with the roof covered with an ultraviolet stabilised white polythene film. The crop inside was covered overnight with a black film. This technique helped in winter cultivation of vegetables and flowers,
when minimum ambient temperature sometimes went down to 
–33 °C. FRL assisted the local farmers in adopting these techniques by 
liaising with local agricultural authorities, setting up model farms for 
demonstration, arranging training programmes, providing consultancy and 
rendering help in solving local problems of environmental condition. FRL 
succeeded in production of seeds of several vegetables to help the local 
farmers to get reliable seeds of specific variety suitable for the region. The FRL 
was also responsible for providing the much needed varieties and nutrition 
to the restricted local diet of barley and tea.

Thanks to FRL, the economy of the region was transformed and 
Ladakh, instead of buying vegetables for its needs not only met its needs and 
that of the Army, but was also able to sell its surplus crop. It not only reduced 
the strain on air transport for supply of fresh vegetables, but also resulted in 
a saving of substantial amount annually by way of reduction of transport 
charges. Giant-size vegetables like 1 kg potato, 8 kg radish, 14 kg cabbage 
and 25 kg pumpkin were setting records in vegetable production. FRL also 
developed the technology for the exploitation of high market value crops like 
hop and saffron. A horticultural garden of temperate fruits was established, 
at a height of 11,500 feet for pilot-scale studies in Ladakh. The cultivation of 
Choti-lerna wheat variety which was about 2-3 times more productive than 
that of the local Fort variety, was introduced. Work on breeding short-
duration, cold-resistant varieties of vegetables, suitable for high altitude 
border areas, was initiated and the response to these varieties was very 
encouraging. Several local germplasm were collected and improved with 
hybridization techniques. The seedlings were cultivated by the farmers 
which revolutionised the cultivation of vegetables like cabbage, cauliflower, 
turnips, carrots, potato, onion, tomato, peas, beans and radish in the area 
where hitherto nothing was grown. Similarly, cultivation practices and 
varieties of cereal crops which were standardised, were adopted by the local 
farmers for general cultivation at these high altitudes.

Improved breeds of poultry birds were reared under subzero 
temperature conditions without use of external heat. Studies of incubation 
under low oxygen content at high altitudes was also undertaken to evolve a 
suitable technique for large-scale hatching of eggs to meet the growing needs 
for poultry birds in Ladakh. For higher egg production, it was found that 
underground system of housing was the most ideal method. Initially, three 
exotic breeds of broilers were inducted in the Ladakh areas. Hybrid broiler 
strains of chicken were cultivated and methods of quick identification and 
containment of infectious and nutritional diseases were developed. As a 
result of crossbreeding with the local stock, crossbreed strains most ideally 
suited to local conditions were evolved. In addition, the laboratory
popularised the use of nonconventional energy sources, such as wind-powered pumps, solar photovoltaic systems for lighting and biomass gas plants among the local population. Training was imparted to a number of Service personnel in poultry farming and broiler chicks were distributed to the army units so that the units even in remote locations could have their own poultry farms. Follow up to study the performance of these broilers at different altitudes was taken.

Research studies in the field of upgrading of local cows were initiated. FRL crossbred Holstein Freisian cattle with the local Sahiwal variety to breed cows that gave a yield of 9 litres of milk per day. These cattle could be maintained during prolonged subzero temperatures without artificial heating. It was thus conclusively established that crossbred cattle of Friesian and Jersey performed very well in milk yield in the high altitude region of Ladakh. Artificial insemination centres were opened to effect general improvements in cattle and also to improve their production potential.

Defence Agricultural Research Laboratory (DARL) at Pithoragarh, is situated in the hilly terrains of the Central Himalayas with an inhospitable climate and porous acidic soil. Consequently, the region had minimal production of food crops and vegetables. DARL has achieved breakthroughs in protected agriculture. Through the continuous process of selection and hybridisation, the Laboratory succeeded in developing varieties of high-yielding vegetables like brinjal, tomato, capsicum, cabbage and bittergourd. It developed greenhouse methodologies that had the advantages of early raising of nursery, quicker crop maturation, growth of off-season vegetables, low incidence of disease, 3-4 crops per year and vegetable produce at twice the normal yield. Nonavailability of land mass due to steep slopes and snow in high altitudes, made the Laboratory to introduce hydroponic technology. Tomato and cucumber could now be grown throughout the year. Entomological investigations were carried out to identify 60 insect species that caused crop damage. Techniques for application of farm yard manure, fertilizers and poultry manure were standardised for various seasons and for different agro-climatic areas of the region.

4.7 INSTRUMENTATION

There is only one laboratory in DRDO whose activities fall in the area of optical instruments and optical systems for the military. It is the Instrumentation Research & Development Laboratory, (IRDE) at Dehradun. The role of IRDE has been that of designing optical, infrared (night vision) and electrooptical systems in aid of the Artillery and of the Armour Corps to improve the fire of accuracy.
In 1960s, the only established technologies used by gunners and tank crew were that of optics in the day and of infrared in the night for sighting of their weapons before aiming and firing. Therefore, the main focus of IRDE was on the Army’s requirements for enhancing combat potential in the night for tanks and for navigation of vehicles (Fig 4.27). A representative sample of the equipments successfully developed and which went into production were, Gunner’s IR (Infra Red) scope sight and Commander’s IR periscope for Vijayanta tank, IR Sniperscope for Infantry, IR Telescope for the Navy, and IR Search Light. In addition, binoculars for Vijayanta tank and Universal Mortar Sight for 120 mm Brandt Mortar were successfully developed and technology was transferred for production. Further, in anticipation of user’s requirement, work in the area of general purpose laser rangefinders was initiated. The production orders by the Armed Forces for the equipment exceeded Rs 25 crore.25

Figure 4.27. Night observation device

In 1970s, there was a shift in the activities of IRDE towards lasers for ranging and passive night vision devices. Investigative R&D tasks were initiated and test and evaluation facilities were acquired as part of the process of building the competence in these technologies. In June 1969, the Laboratory was sanctioned a project on the development of general purpose laser rangefinder with the twin aim of containing its size and weight for shoulder mounting and providing it with a capability of ranging targets from 500 m to 10 km with an accuracy of ±10 m. In the course of developing the laser rangefinder the scientists built up competence in the selection and use of laser material, the pumping source, design optimization of laser cavities, the Q-switching techniques, techniques and devices used for low level signal detection, heat exchangers, and mechanical housing. This laid a good foundation for the development of Nd glass and Nd-YAG lasers around which the Laboratory would develop future laser rangefinders. The first opportunity to utilise their expertise materialised in March 1979 with the sanction of a staff project to develop a laser rangefinder for T-55 tanks with capability to range targets from 400 m to 4 km.

R&D activity was also initiated in 1974 for development of passive night devices with the sanction of a project for the design and development of passive night sight for 106 mm recoil gun. The competence in night vision technology lay in the trade-off of the various relevant parameters such as range, magnification, field of view, size and weight and the selection from among the different options of Image Converter, Image Intensifier, Low Light Television (Fig 4.28) and Intensified Charge Coupled Devices for the design.

Figure 4.28. Low light TV system
Expertise in innovative optical designs for effective filtering functions would also be necessary. In the course of development, IRDE was required to design high speed/aperture and catadioptric systems and also devise techniques for adjustment of the imaging mirror to an accuracy of 0.25°. In addition, a major facility with capability to test image intensifier tubes and measurement of its parameters such as resolving power, radiant sensitivity and so on was established. A long dark hall with target models and resolution patterns, and with facility to simulate night illumination conditions for evaluation and adjustment of night vision devices was under installation at the beginning of 1980s. The process of learning by doing was attempted to build the expertise in this vital area. The process required more iterations in design which resulted in the project activity continuing beyond the 1970s. The second activity in this area was the design and development of Commander's Passive Night Sight for Vijayanta Tank which was sanctioned as a staff project in 1976. It would also spill over into the 1980s.

Another R&D activity was the design and development of Optics module for Head Up Display system for use in military aircraft. The objective was to design the optics module which would have a field of vision of 15° in azimuth and 8° in elevation in such a way that the pilot could see in head up position the display of primary flight data and also navigation and weapon-aiming information. The requirement would be met with an optics module that would be a special type of bioptic system with a large aperture and low F number. The surface would be dichroic. The electronic circuitry for the flight data and for navigation and weapon aiming was being developed at ADE.

In addition to these activities, IRDE also undertook the development of a gyro-land navigation system for Vijayanta tank, recalibration of graticule marking on periscopic sight AFV30 Mk, muzzle bore sights for artillery guns, night-aiming devices for the mountain gun, gun rule for 75/24 Pack Howitzer, 25 Pounder and 5.5 inch gun for high angle fire, direct sight and indirect sight for 105 mm IFG, collimator type parallel scope and devices for identification of tanks and fire control plotter for field artillery. Most of these products developed at IRDE were accepted for introduction into the Services.

Besides development, modernisation of facilities for fabrication of precision optical components to high degree of surface angle and dimensional accuracies was also being carried out so that the project needs for a wide range of optical components, starting from simple lenses and
prisms to more complex designs such as Q-switching prisms, laser rods etc., would be met.

4.8 LIFE SCIENCES & HEALTHCARE

DRDO undertakes extensive research on several aspects of human health encompassing physiology, biochemistry, nutrition, toxicology, psychology and nuclear medicine. The laboratories in the Life Sciences and Healthcare group are, the Institute of Nuclear Medicine and Allied Sciences (INMAS), Defence Institute of Physiology and Allied Sciences (DIPAS), Defence Institute of Psychological Research (DIPR) all situated in Delhi. INMAS, DIPAS and DIPR were transferred in 1973 to Director General, Armed Forces Medical Services (DGAFMS) and were reverted to DRDO in 1980.

4.8.1 Institute of Nuclear Medicine & Allied Sciences

The main charter of INMAS is to promote, develop and train in radioisotopic and related modern techniques in medical research, diagnosis and therapy and in allied sciences such as medical radiation biology and health physics. Nuclear medicine involves close integration of knowledge and expertise in several scientific and technical areas, like nuclear physics, radiobiology, radiopharmaceuticals, health physics, electronic instrumentation, clinical and experimental medicine, all oriented to the use of ionised radiation.

INMAS had its origins in the Radiation Cell set up at Defence Science Laboratory in Delhi in 1956 for the purpose of developing a programme of applying radiation medicine for better healthcare of both Armed Forces and civilians. Because endemic goitre was prevalent along the entire Himalayan range, running approximately 2500 km from east to west, the sub-Himalayan belt as well as isolated pockets in almost every state of our country, due to deficiency of iodine in water and other foodstuffs, it was decided that the first application of radiation medicine would be to treat thyroid disorders. In 1958, a field unit was setup at

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26 The author is thankful to Dr A Nagaratnam former Director, Defence Laboratory Jodhpur, for providing extensive background notes on the laboratories working in the field of life sciences and healthcare.

27 Lieutenant Colonel S K Mazumdar of the Army Medical Corps (rank held at that time) who had been sent to UK for training in radiation medicine was posted as Specialist Medical Officer to Defence Science Laboratory in August 1956.

28 About two hundred million of our population were estimated to be exposed to iodine deficiency and out of this about 50-60 million were sufferers of iodine deficiency disorders like mental disorders and cretinism. Even the troops from non-endemic areas
Safdarjung Hospital in Delhi and radio iodine was used for treating thyroid disorders. This was the first ever application of nuclear medicine in our country and the good work carried out by the Radiation Cell led to the establishment of the Institute of Nuclear Medicine and Allied Sciences in Delhi in June 1961 under the Defence R&D Organisation. The clinical work continued at the Safdarjung Hospital until 1971, when the clinical outpatient department was set up at the Institute.

**Investigations and Treatment of Goitre** – In 1960s, the thyroid clinic of INMAS at Safdarjung Hospital witnessed remarkable growth and even today the INMAS clinical outpatient department draws annually about 50,000 to 60,000 patients from all over the country. The Institute has, over the years, developed a battery of radio isotopic, conventional biomedical and pathological tests to obtain a better understanding of the aetiopathology of the disease. The scientists studied the influence of familial and socioeconomic factors, age, sex, possible presence of goitrogen in the soil, water and foodstuffs. For example, the goitrogenic potency of some common vegetables with high thiocyanate content like okra (*bhindi*), radish (*mooli*), and yam (*arbi*) were demonstrated by chemical analysis and by animal studies. As early as 1962, INMAS recommended that an adequate dose of iodine should be ensured for the troops stationed in endemic areas as a prophylactic measure. Based on the findings of INMAS and other centres, the Government of India promoted the use of iodised salt throughout the country.

Hyperthyroidism which is the result of excess activity of the thyroid gland was also the subject of clinical investigation by the Institute. The scientists of INMAS pioneered the methodology of employing smaller fractionated doses of radio iodine, a few times at suitable time intervals instead of the more common method of large doses of the radioisotope to deliberately destroy the functioning of the thyroid gland partially and restore it to its normal status. In this manner, they brought down the incidence of late onset of hyperthyroidism to about 3 per cent.

**Radiation Biology and Health Physics** - The study of radiation burns had attracted the attention of INMAS scientists right from the 1960s. It is one of the four centres in the country working actively on radioprotectors. The goal of these investigations was to discover substances which offer efficient radioprotection with least toxicity. Early investigations led to the use of an ointment, from an indigenous plant *aloe vera* for accelerated healing of radiation burns. Subsequently, several chemicals were screened when posted to these regions were found to acquire goitre if they stayed long enough. Iodine deficiency disorders are thus not only a major public health issue but are also of relevance to the health of our defence forces.
and two nontoxic long acting effective radioprotectors have been developed to prevent radiation-induced injuries. At the same time, studies were also conducted on the basic mechanism of regulation of DNA repair processes in radiation-induced and chemically-induced lesions. Based on theoretical considerations and a variety of animal model systems, the scientists have discovered that 2-deoxy-D-glucose (2DG) acted both as a radioprotector of normal healthy tissue and as a radio sensitizer (radiation damage enhancer) for tumour cells under exposure to radiation. Confirmatory trials combining 2DG and radiation were being planned at Delhi and Bangalore in the first quarter of the 1980s.

In the area of health physics, the concern about exposure to radiation led to the setting up of a compact and competent group of scientists who carried out research on internal dosimetry and critical review of the recommendations of the International Commission on Radiological Protection (ICRP). Significant contributions were made in the area of whole body counting for radiation protection and clinical application to establish physiological norms for total body potassium and iron plus vitamin B-12 absorption in the Indian population. Over a period of time, several types of whole body counting systems and calibration techniques were designed and a new whole body counting geometry (Buddha Posture) was evolved to suit Indian conditions.

Since the Reference Man used by ICRP for establishing radiation exposure safety limits was based on the Caucasian living in temperate conditions in North America or Europe, straightforward application of these limits to Indians would not be accurate and correct. Therefore, work on providing input to the development of Reference Indian with well defined anatomical and physiological characteristics applicable to our population was initiated and preliminary recommendations were made for the parameters of the Reference Indian.

Radiopharmaceuticals – Radiopharmaceuticals are the substances used to give radiation doses to patients and are therefore essential for the practice of nuclear medicine. The radio nuclide of choice was the short half-life (6 hr) $^{99m}$Tc which gave minimum dose to the patient and could be conveniently tagged on to a variety of pharmaceuticals. The emphasis of INMAS scientists was on indigenous modifications to several widely used $^{99m}$Tc-labelled pharmaceuticals, development of newer radio-pharmaceuticals and evolving simplified quality control procedures. Several new $^{99m}$Tc tagged pharmaceuticals such as Cu-mannitol for renal dynamic function, Cu-GHA for spleen, DMSA for soft tissue tumours and metastases,
etc., were developed. In addition, many $^{99m}$Tc-labelled Mix and Use kits were designed to instantly produce radiopharmaceuticals of high quality.

4.8.2 Defence Institute of Physiology & Allied Sciences

DIPAS is primarily engaged in research for increasing the operational efficiency (physical as well as mental) of Armed Forces personnel in relation to the diverse micro-and macro-environments. DIPAS owes its origin to the small physiology group of scientists at the Defence Science Laboratory, who initiated studies in 1952 on the physiological factors that would lead to increase in fighting efficiency, safety and comfort of the Armed Forces personnel under varying operational conditions. For the Army, problems associated with hot environmental conditions under which the jawan had to live and work, for the Navy it was the habitability conditions in the ships, which had been designed to operate in cold and temperate climates and for the Air Force, it was the effects of the hot environment on the air crew, that were to be attended to and resolved by the scientists. To cope with the workload, the small group had expanded into two large divisions in 1960 and the Parliamentary Committee which was visiting the Physiology Division in 1960-61, recommended the establishment of a separate institute to look into the problems of physiology related to Defence Services. Consequently, the Defence Institute of Physiology and Allied Sciences came into being in September 1962 at Chennai. Meanwhile, the aftermath of the Chinese incursions at our borders shifted the focus of physiological studies to high altitude and cold environment. In view of the difficulties experienced for efficient functioning from the south of the country, the Institute was shifted back to Delhi on the recommendations of a committee appointed by the Ministry of Defence. In 1970, the Government of India decided that DRDO should take over the Physiology Research Wing of the Himalayan Mountaineering Institute, which was re-designated as Physiology Research Cell, DRDO at Darjeeling.

*Early Investigations and Findings* – One of the earliest assignments was the study of energy expenditure by a soldier carrying a load in different terrains and environments. Studies and experiments by DIPAS scientists showed that a load up to 50 per cent of the weight of the soldier as against the conventionally accepted norm of 30 per cent, could be carried without any disproportionate increase in energy expenditure. Marching speeds for soldiers with different loads and for different terrain conditions were worked out and the influence of load distribution along the body length was also determined. Efficiency of a soldier was found to improve with lighter
footwear. Similarly, hand carriage of such loads as school bags was shown to require thrice the energy than if it was carried on the back in a rucksack.

The aversion of Indian troops to drink water laced with salt during summer months was taken up for investigation to check whether it posed health hazards. DIPAS scientists found that Indians unlike the Europeans, were more accustomed to heat and since salt in their sweat was not high, the heat casualties among Indian troops were more due to water depletion or heat hyperpyrexia. This was easily remedied by replacing water losses in sweat on an hourly basis. Thus, the issue of extra salt to troops in summer months was dropped.

The cause of death of some divers during ascent from shallow dives was referred to DIPAS by the Navy. DIPAS scientists were able to point out the limitations of the accepted theory that it was due to release of excess nitrogen into the blood vessels during decompression caused by the ascent, and postulated that the cause was actually rupture of lung alveoli and capillaries during ascent, due to expansion according to Boyle’s law. These research findings were published in the *Proceedings of the Royal Society* and are referred to in text books on submarine medicine.

*High Altitude and Cold Environment Studies* – The physiological problems of high altitude include acute mountain sickness (AMS), high altitude pulmonary oedema (HAPO), high altitude cerebral oedema (HCO), high altitude hypertension (HAPH), high altitude retinopathy (HAR), snowblindness, chilblains and frostbite. Investigations were conducted among three types of personnel namely, fresh inductees, acclimatised low landers and high altitude natives. Their findings are outlined in the succeeding paragraphs.

Acute mountain sickness, which occurred among nearly 50 per cent of the mountain trekkers, produced only minor symptoms for 2-3 days, and required no treatment in a vast majority of cases. In a small minority of cases, where it could turn into a severe form, rapid ascent was found to be the cause and exercise on arrival at high altitude (HA) might be a predisposing factor.

A common complaint of troops arriving at HA was disturbances in the sleep pattern, particularly above 3500 m. Investigation by DIPAS revealed that reduction in slow-wave sleep and frequent arousals were adaptive responses that prevented accentuated levels of hypoxaemia due to sleep hyperventilation.
The more serious disease was the HAPO which occurred in more than 2000 cases among our troops during the Chinese incursion in 1962. The incidence was found to be about 0.6 per cent amongst troops within 45 minutes of their being inducted by air from the plains to altitudes of 3500 m and above. The symptoms were cough, chest pain and breathlessness which occurred within 3-4 days of arrival. If it was not taken care of, the patient would become dangerously ill very quickly and some even died by literally drowning in their own secretions. Those troops who after HA exposure came down to the plains for 3-4 weeks and again returned to HA were more prone to HAPO than the fresh inductees. DIPAS drew an acclimatisation schedule to be strictly followed by the Army personnel going on tenure at altitudes of 4,500 m and above. Since there was a noticeable drop in efficiency at 3,500 m altitude and a significant loss at 5000 m altitude and above, optimal work capacity, load carriage, marching speeds and maximum period of tenure were also prescribed for different altitudes. As a result of the investigation on the thermogenic needs at HA, DIPAS recommended a uniform scale of 4800 calories for all high altitudes. The investigations of the Institute also indicated that systematic physical training for 8 weeks at moderate altitudes as well as yoga exercises resulted in improvement in maximum oxygen uptake and lesser margin of increase in cardiac and respiratory frequency on induction to high altitudes.

Exposure of extremities to severe cold for prolonged periods would lead to cold injuries, resulting in loss of digits of hands and feet if treatment was not given on time. Since rehabilitation of frostbite victims was difficult, susceptibility tests were devised for cold injuries. Studies also showed that exposure to cold environments for 3 weeks significantly increased adaptation and parasympathetic dominance. Thus deliberate exposure to cold during the first three weeks with gradual discarding of heavy items of clothing was recommended.

DIPAS conducted investigations for identification of soldiers who would be susceptible to AMS, HAPO and frostbite before they were to be inducted into high altitudes. It devised a chemoreceptor sensitivity test which appeared promising. The cold-induced vasodilatation (CIVD) response and heat output of the extremities during cold immersion under controlled laboratory conditions were found effective for screening individuals. Those with poor CIVD response had a low heat output and suffered more than the others.
Heat Stress - Heat stress would not normally be a serious threat to our countrymen under normal resting conditions because of natural adaptation to some extent. However, for soldiers performing physical work in summer in desert and other hot areas, for tank crews, for aviators working in aircraft cockpits, for sailors toiling in engine compartments of ships, the metabolic heat would add to the strain on the thermoregulatory mechanism of the body. To compensate for the loss of fluid and electrolyte, DIPAS worked out optimum water and salt requirements as well as work schedules for different levels of thermal stress. It was found that under field conditions, 55 per cent of the heat illness was due to exercise-induced heat exhaustion and 25 per cent was due to heat pyrexia. Heat exhaustion due to salt/water deficiency and heat cramps was extremely rare. Potassium supplementation was found beneficial and replenishment of fluid was imperative. While heat-adapted soldiers could be moved to cold areas, it would be preferable to avoid rapid movement of soldiers from cold to hot regions. Studies on the effects of repeated calorie deprivation for troops on long patrol duties showed no cause for alarm due to recovery without adverse effects. Drinking brackish water found in Rajasthan for periods up to about 2 years did not reveal any ill effects.

4.8.3 Defence Institute of Psychological Research

The Defence Institute of Psychological Research (DIPR) is one of the oldest institutions under the DRDO, having been established in August 1949 to carry out research and develop procedures for the selection of personnel at Service Selection Boards, to maintain records and relevant statistics, and to train the assessors for effective functioning at the Service Selection Boards. Over a period of time, its charter was extended to study problems related to morale, motivation and operational efficiency of the Armed Forces. Over more than four decades of its existence, it has completed over 700 projects and published over 470 research reports which have a wide circulation.

The Institute developed over the years an elaborate training system for the assessors, such as Interviewing Officers, Group Testing Officers, Psychologists in the Services Selection Boards, Armed Forces Selection Boards and Recruiting Centres. A number of projects in the field of psychology were aimed at monitoring of selection systems and development of selection tests for officers at Services Selection Boards and for classification of other ranks for allocation of specialised trades in the Army, Navy and the Air Force. In addition, developmental tests for use in selection and classification such as Nurses Aptitude Test, tests for selection...
of students for admission to AFMC, Pune, Word Association Test, Thematic Apperception Test for use by Services Selection Boards, various techniques for evaluation and aptitude tests for selection of various trades for airmen and sailors, new schemes for administration of PAB tests at the Air Force Selection Boards, and aptitude tests for categorization of cadet trainees into technical and nontechnical groups, were also designed. Expertise was also developed in the standardisation of personality, intelligence and aptitude tests for use in selection and task allocation of the officers of the three Services. To provide feedback for improvement of selection procedures, follow-up studies were conducted, investigating causes of wastage during training and assessing the job performance level.

Another important research area was on the mental health of the soldiers including mental depression, suicides, boredom, isolation, study of aetiological factors in the adjustment of men in the Armed Forces with a view to identify the potential breakdown cases at the selection stage, factors that promote successful adaptation, physio-psychological effects of prolonged duties concerned with watchkeeping in high altitude pickets, problems like huge dropout rates among trainees and morale of disabled soldiers. Valuable work was also carried out on issues related to leadership, organisational effectiveness, morale, motivation, job satisfaction, discipline, group processes, sociometry, team building activities, training for adaptation to change, development of psychometric tests for assessing leadership potentiality in service officers, psychodynamics of courage in operational contexts, effects of high altitude and low temperatures on mental performance and techniques for interrogation of prisoners’ of war.

DIPR conducted in-depth studies on the dynamics of training at the Services training academies like the National Defence Academy, and the Indian Military Academy. Improved training techniques were devised for instructors and the behaviour of pupils were evaluated through instructional feedback. It also conducted courses for DRDO for the senior scientists on self-development as part of the continuing education programme.

4.9 MATERIALS

A wide variety of metals and nonmetals are required for the development of the hardware that form military equipment and systems. The range is almost limitless and even a small sample, such as light alloys for structures, high temperature materials for turbines, high strength materials for armour, plastic and synthetic/composite materials for aerospace, materials for radar invisibility, and now smart materials provides us an estimate of the expertise necessary to exploit these in defence
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systems. Often, these materials have to perform reliably under exacting and extreme conditions of temperature, environment and mobility which characterise military weapons and equipments. Two laboratories of DRDO namely, the Defence Metallurgical Research Laboratory (DMRL), Hyderabad and the Defence Materials and Stores Research and Development Establishment (DMSR&DE), Kanpur are devoted to the study and development of these critical materials for defence applications.

4.9.1 Defence Metallurgical Research Laboratory

With the formation of DRDO in 1958, TDE (Metals) at Ishapore was bifurcated into an R&D entity called DMRL and the rest as Chief Inspectorate of Metals. Both the new entities were housed in the same premises of TDE (Metals) till 1962 when a decision was taken to expand DMRL by infusion of personnel, equipment and buildings to bring it at par with modern metallurgical R&D institutions. The location was shifted to Hyderabad (Fig 4.29) and a reputed Indian metallurgist was appointed as the Director and was entrusted with the task of building the Institution.

The move from Ishapore to Hyderabad, and the setting up a new laboratory, including construction of buildings, placement of personnel, installation of plant, machinery and other equipments, was completed by 1969. Even before this, the Laboratory started functioning from rented buildings. The initial focus was to build the competence of the scientists in the area of strategic materials which are of interest to defence.

The activities for the development of metals and alloys required for aircraft, electronics, tanks and missiles continued in the 1970s. A powder metallurgy plant was set up for research on various applications of powder metallurgy for defence applications. The major application area was towards rendering help to the defence PSUs/factories in specific products. One such area was anti-armour ammunition. In the 1970s, a requirement was reflected to DMRL to develop the core for a particularly lethal type of projectile, the high velocity armour piercing (AP) projectile, which by its kinetic energy was able to penetrate deeply into the tank armour. The effectiveness of the AP (armour piercing) ammunition against the tank was

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29 The author is greatly indebted to Dr A Nagaratnam, former Director, Defence Laboratory, Jodhpur who undertook the task of gathering the data from the laboratories, analysing the contents and communicating the essence of their work in the form of two communications namely, DMRL - Salient Activities and Achievements and DMSRDE - Activities and Achievements. In addition to these reports, I have also drawn on the DRDO Annual Reports from 1970-71 to 1981-1982 in the preparation of the material.

30 Dr RV Tamhaakar was appointed as the Director of DMRL in 1963.
Defence Research & Development Organisation (1958-82)

Figure 4.29. DMRL – main building
due to the core, which for the first generation was a long-rod penetrator of tungsten carbide with a specific gravity of 14. DMRL succeeded in developing the processes and fabricating the tungsten carbide core. It even set up a pilot plant for supplying these and the nose cones. In addition, DMRL also set up pilot plants to provide shatter alloy, lighter alloy castings for sighting and vision instruments for tanks/AFVs and permanent magnets of various types for use by the microwave industry. Further, development of magnets for magnetrons that power radar systems and recovery of tungsten and cobalt was also undertaken.

In 1973, it was decided by the Ministry of Defence to set up in the vicinity of DMRL, a public sector company, Mishra Dhatu Nigam Ltd. (MIDHANI) for exploiting the technology that had been developed by DMRL in a variety of special metals and superalloys required for defence applications. The strategic importance of the work of DMRL lay in the fact that only a few manufacturers in the world had the capability and capacity to supply these and their availability to us in times of war and even in times of peace was subjected to the pulls and pressures of the Cold War.

With the setting up of MIDHANI, the activities of the DMRL in the future were shifted towards R&D on critical and advanced materials for defence applications. Over the years, DMRL’s activities would cover friction materials, heavy alloys for armaments, steel projectiles and armour, ultrahigh strength low alloy steel, titanium and titanium-based alloys, superalloys, investment casting of superalloys for aircraft applications, magnetic materials, electro-steel castings for guns and so on. The work of DMRL in the next seven years comprised mainly of R&D programmes, commissioning of facilities for production of quantities more than laboratory scale and fabricating specific hardware in its support role for laboratories such as ARDE, CVRDE, GTRE, DLRL, DRDL and so on.

A number of facilities for building up competence and taking up tasks of a challenging nature were set up. These included, successful installation and commissioning for the first time in the country of a Hot Isostatic Press (HIP) for production of aero-engine components out of superalloy atomised powders. In addition, facilities for conducting studies on Hot Isostatic Pressing for fabrication of components to near-net shapes, die shop for making different types of dies and punches and facilities for taking up major projects in the field of reinforced composites and silicones.

31 Dr RV Tamhankar was made full-time Chairman & Managing Director of MIDHANI in July 1975 and Dr VS Arunachalam took over as Director DMRL from August 1975. Dr VS Arunachalam would be appointed in 1982 as the Scientific Adviser to the Defence Minister, Secretary to the Department of Defence Research & Development and Director General Defence Research & Development Organisation.
Defence Research & Development Organisation (1958-82)

were also installed. Further, facilities to produce titanium metal and for development of gas turbine components made out of high temperature alloys were in the process of being set up.

One of the first R&D efforts was directed towards the indigenous design and development of brake pads for aircraft. Since aircraft could not takeoff or land without brake pads and as their attrition rate on Russian aircraft were higher than earlier estimates, a crisis situation appeared to be looming when the matter was referred to DMRL. The Laboratory rose to the expectations of the nation, experimented with steel and copper and then developed ceramic disc pads through powder metallurgical techniques for the particular aircraft, with service-life higher than the original component, initially fabricated and supplied these and successfully transferred the technology to M/s HAL so that our dependence on imports was eliminated (Fig. 4.30). In addition, various types of friction materials, viz., cupped brake pad for AVRO 748, bimetallic stator pads for aircraft brakes and clutch discs for different aeronautical applications were developed. Subsequently, transfer of know-how to HAL for fabrication of bimetallic stator pads for

Figure 4.30. Aircraft brake pads
aircraft was also carried out. Regular production of these at the Bangalore, Koraput and Hyderabad units of HAL continues. An extension of this activity was the development and subsequent production of iron-based friction clutch pads for the synchronised turbines of the SNF-class ships of the Indian Navy.

Another activity pertains to the development of armour and armour piercing projectiles in antitank warfare, which progressively used advances in science and technology to surge ahead. With ARDE, DMRRL collaborated to develop the second-generation armour piercing ammunition which had a core or long-rod penetrator of tungsten alloy of specific gravity 17 to 18. For CVRDE, it was developing the armour for the main battle tank under development. This long-rod penetrator was formed by DMRRL using powder metallurgy techniques. The fin stabilised armour piercing discarded sabot ammunition developed by ARDE was a success. DMRRL also developed an alloy of steel with significantly improved properties as compared to the imported variety for the penetrator. In addition, DMRRL later developed process for two other parts of the FSAPDS round namely, sabot and tail unit. The sabot was developed using closed-die forging and the tail unit through star shaped extrusion technique, resulting in material savings as high as 45 per cent for the sabot and 85 per cent for the tail.

For the tank, initially the armour was required for providing protection against kinetic energy ammunition and by 1978, DMRRL had developed 5 per cent nickel-steel armour which gave 10 per cent more ballistic immunity than the armour used on the Vijayanta tank against kinetic energy ammunition. Another approach pursued by DMRRL was based on electro-slag refining (ESR) technology which would improve ballistic immunity of monolithic armour in the direction of attack by reduction of inclusions. In both cases, DMRRL had the public sector and private sector steel companies taking up the work of fabrication of proof plates for conducting trials to evaluate their ballistic immunity. However, in 1979, Army reassessed the threat and wanted that the armour should withstand not only the kinetic energy but also chemical energy ammunition. DMRRL agreed to develop composite armour similar in performance to the Chobham armour of UK which was considered a breakthrough in armour technology. In view of the scanty information available about the sandwich-type construction of the composite armour, DMRRL scientists had to work out on their own about the composition, the spacing and the thicknesses that would provide the desired performance.
By the middle of 1980, the DRDO could announce a breakthrough in armour with the initial encouraging results obtained during laboratory-scale firing of the composite armour, named Kanchan developed by DMRL (Fig. 4.31). Subsequent trials against kinetic energy and chemical energy ammunition proved the ballistic immunity of Kanchan against the type of threats envisaged by the Indian Army and also its superiority in performance to the earlier versions developed elsewhere.

Figure 4.31. Kanchan armour

While the current requirements of defence in armour and armaments were being met, basic studies on chemistry-structure-property relationship for improvement in materials of interest to defence were pursued. The investigations focussed on modifying the chemistry of iron and steel alloys through small alloying additions and their effect on fracture resistance of steel. This would lead to the development of a new steel alloy at laboratory scale, with very low percentage of alloying elements but with toughness and strength equivalent to marraging steel.

Besides iron and steel, R&D activities on other metals like magnesium, nickel and titanium were pursued. Work on magnesium alloys, with applications to rockets and missiles in mind, on atomised nickel powder for application in fuel filters for missile and aeronautics, and titanium alloy development for airframes and aero engines to utilise the vast titanium resources of the country, were also initiated. Magnesium alloy vibration
fixtures were developed and supplied to Indian Space Research Organisation in this period. Further, special electronic ceramics components, like steatite rings, piezo shell components and chip resistors made out of alumina ceramics etc., were developed and supplied to other laboratories.

4.9.2 Defence Materials, Stores Research & Development Establishment

DMSR&DE came into existence in 1976 after two other DRDO laboratories, Textiles and Stores Research & Development Establishment (TSRDE) and Defence Institute of Stores Preservation & Packaging (DISPP) were merged with Defence Research Laboratory (Materials) Kanpur, which was originally formed in 1962 after the bifurcation of Defence Research Laboratory (Stores) into two separate entities. The establishment undertakes R&D in nonmetallic materials, textiles, light engineering and general stores.

The main focus in the 1960s was in the area of materials developments relating to corrosion inhibitors, parachutes, synthetics, solar heaters, helmets. The Laboratory was quite successful in developing these materials out of indigenous raw materials. Vapour phase corrosion inhibitors for protection of small arms, gauges and hand tools, corrosion inhibition treatment for jute and hessian used in packing metallic items, corrosion inhibitor for water-cooled engines, and cathodic protection of underground fuel storage tanks, were some of the items and processes that were developed successfully. In the area of textiles, flame proofing for olive green cellular Shirting, glass-reinforced polyester for use in lightweight bullet-proof helmets, various types of parachutes, container and slings for paratrooping supplies, were the major contributions. A solar room heater based on the principle of thermal-siphoning was developed for use at high altitude and in extreme cold environments, so that a room of moderate size could be maintained at 20 °C. Based on this, a series of meteorological stations were set up along the border, including at Ladakh. The technique won international recognition.

In polymer science, the thrust was on synthesis, characterisation, compounding, moulding and modification of high polymers for specific defence requirements. In the 1970s, synthesizing polyurethane foam from indigenous raw materials was carried out successfully and the technical know-how was released for commercial exploitation. Further, research on the synthesis of novel high temperature-resistant resins was carried out for
applications to aircraft radomes, aircraft engine components, rockets and missiles. Efforts were also directed towards the development of rain erosion-resistant coating materials for protection of radome surfaces on aircraft.

Fibre-reinforced composite materials based on polymer matrices, generally known as fibre-reinforced plastic (FRP) was another area of research activity for the Laboratory. Initially, the activity was limited to glass fibre reinforcement and conventional polyester and epoxy resins, but the effort was steered towards building up competence in high temperature and protective armour applications. It paid off when the Laboratory developed a honeycomb core sandwich of glass fibre phenolic composite for use in Kanchan armour that was under development at DMRL for the main battle tank. Some of the other products developed by the laboratory in the area of composite materials were, transparent laminates for winds shields and windows for bullet-proof automobiles, fibre glass combat helmets and FRP ceramic composites for ballistic applications.

In the areas of fuels and lubricants, DMSR&DE focussed on developing synthetic oil-based lubricants and greases for use in land-based, sea and airborne systems over a wide range of temperatures. In electrochemistry, the activities of the laboratory resulted in the development of a large number of anti-corrosive materials for different kinds of recoil fluids for guns, coolants for vehicles, rust converters, corrosion inhibitors for submarine engine, and for ferrous and nonferrous components of diesel engine cooling systems of the Navy. A stop-off phosphating technique was developed for ambient temperature phosphatisation of small arms, which could be carried out by troops at the field workshop level.

In the area of textiles, DMSR&DE was responsible for the development of complete range of textile stores, including footwear for the Services. A major step was the introduction of cotton and polyester-wool blends for combat uniforms for comfort during extreme summer months and during the rest of the year, respectively. For combat duties, camouflage for green belt as well as for desert terrains in the form of disruptive printing in four shades or colours using dyes with high light fastness and wash fastness properties was prescribed.

The Laboratory’s approach to Service materials preservation is multi-disciplinary for identification of the causes of deterioration and in the formulation of preventive measures. A suitable preservative was developed for the prevention of microbial degradation of foam compounds used in extinguishing fires, an inhibitor compatible with aviation turbine fuel was
developed after the contaminant microorganisms were identified, and microbiological tests were evolved for assessing the biodegradation of electronic components.

**Anti-G suit – The Aero Bio-engineering Unit** – This unit, later merged with DEBEL, took up in the 1970s, the import substitution of anti-G suit, which was being imported\(^{32,33}\). The anti-G suit was a critical life saving for the pilots of combat aircraft. It protected them from the ill effects of G forces which they were subjected to during the manoeuvring of aircraft at high altitudes. These G forces tend to drain the blood from the brain to the stomach and to the legs, which resulted in the gradual loss of vision of the pilot and eventual blackout as well as mental and physical fatigue. The anti-G suit had to be designed to automatically apply pressure to the abdomen, thigh and calves in proportion to the forces experienced by the pilot and thus avoid the ill-effects. The Unit developed an indigenous anti-G suit that was similar to that imported by IAF but scored over the import in providing better comfort to the wearer in the hot and humid conditions prevailing in our country. The basic fabric in indigenous design was terycotton which had higher permeability and better water vapour diffusion properties than the nylon fabric used in the imported suits. After extensive physical evaluation in a human centrifuge, the item was accepted for introduction into the Service. Subsequently, four versions of the anti G suit in five different sizes were developed to suit our air crew.

### 4.10 MISSILES

#### 4.10.1 Defence Research & Development Laboratory

Defence Research & Development Laboratory (DRDL) is the nodal laboratory in DRDO for the development of rockets and missiles for defence. In 1956, a small team known as Special Weapons Development Team (SWDT) came into existence in the Defence Science Organisation with a complement of eight scientists and a few technicians to study the science and technology of rockets and missiles. In 1960, the Government of India approved the expansion of the team into a full-fledged laboratory and by 1961 the present laboratory, viz., Defence Research and Development Laboratory came into existence within the campus of the Defence Science Laboratory at Delhi. In 1962, the Laboratory was moved to Hyderabad where it was located in barracks and in rented accommodation.

During the 1960s, DRDL, which had a complement of 300 personnel that included 100 scientists and Service Officers, attempted the


\(^{33}\)Reference 3, Page 45.
development of an antitank missile to meet the requirements of the Indian Army. A wire-guided antitank missile was developed and a total of 373 guided flights were carried out (Fig. 4.32). In addition, 100 flight tests were conducted as part of user trials intended for evaluation by the Army. The development however, did not go into production. Apart from missiles, the Laboratory also developed indigenous rockets of diameter up to 5 inches and proved them in flight. Besides rockets and missiles, the laboratory undertook the development of missile components like gyroscopes and accelerometers.

Figure 4.32. Wire-guided anti-tank missile

In 1968, it was proposed to the Government of India that a study needed to be made by DRDO for indigenous support and replacement of the SA-75 medium range surface-to-air-missile system to progressively reduce the country’s dependence on import from USSR. The study was conducted by DRDO and its findings were that indigenisation was feasible, but in view of the very early stages of missile development in the country, indigenisation without foreign assistance would have better chance of success with one-to-one substitution. The study further concluded that by
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such a step, detailed knowledge of all the design parameters of a proven
missile would be available and in the process of development, the
necessary infrastructure would also be built. In the mean time, a
consensus emerged that before actually embarking on the development
programme of indigenising the SA-75 missile system, effort should be
made to acquire technical know-how from other countries so that DRDO
would start from a higher level.

There was more than eight month’s gap between the time
Dr Bhagavantam retired as Scientific Adviser and Dr BD Nag Chaudhuri
assumed the office. Since he had already perceived missile as a force multiplier
of high order and as a cost-effective weapon system, Dr Nag Chaudhuri identified
it as one of the thrust areas for DRDO. On retirement of the incumbent Director
of DRDL, the Scientific Adviser appointed a serving officer of the Indian Air Force
as the Director. The newly appointed Director of the laboratory took as his
immediate objectives, the massive task of building the infrastructure,
technology development in two areas namely liquid propulsion and inertial
navigation, and the development of the SA-75 surface-to-air missile system on
a one-to-one substitution basis to improve our self-reliance34.

Infrastructure Building – In establishing the infrastructural
facilities, DRDO was guided by the engineering and technology involved
in the current system, as well as those which were known to be under
development and about which details were available. In the course of the
next ten years, DRDL would establish test facilities for aerodynamics,
structures, electronics, telemetry, propulsion, control, fabrication of metal,
rubber and fibre-reinforced plastics components, forging, non-destructive
testing, and a computer centre. In the context of small budgets and
limited free foreign exchange, such a tilt in diversion of resources from
other disciplines attracted criticism within the Organisation about the
wisdom of these investments when the current workload of the
Laboratory did not warrant these. However, the Integrated Guided
Missile Programme (IGMDP) that was launched in the 1980s and the quick
start it got, justified the earlier investments.

Liquid Propulsion – The competence building activities on liquid
propulsion were initiated in the 1960s35. The development of liquid-fuelled

34 Air Commodore VS Narayanan (rank held at the time of appointment) was appointed
as Director, DRDL in February 1972. As Joint Director of Missiles at Air Headquarters,
he had the responsibility to look after the introduction, installation, operations of
missiles and also the training of personnel. His interest in missiles led him to propose a
methodology on how to become self-reliant in missiles, which came to the notice of Dr
BD Nag Chaudhuri. The Scientific Adviser offered him the post of Director, DRDL
which had fallen vacant on the retirement of the previous incumbent.

35 Wing Commander R Gopalswamy initiated the work on liquid propulsion system at
DRDL in the 1960s.
engines for missiles continued throughout the 60s. However, with the sanction of the project for the development of SA-75 code named Devil, the activities got a boost with the surfacing of requirements for liquid fuel motors.

Simultaneously, a programme was initiated at Defence Science Laboratory (DSL) by Dr Nag Chaudhuri for the development of fuels for liquid propulsion. The first one was Unsymmetric DiMethyl Hydroxide (UDMH), the development of which was taken up as a challenge by the group of competent chemists at the Laboratory. The Director, DSL, a physicist by profession, also relished the challenge posed to the Laboratory and plunged forthwith into the programme. The chemists who worked in the programme even after thirty years recall with a sense of nostalgia, the leadership provided by Dr Bannerjee. The process was developed, initial laboratory testing was carried out on a small scale, after which a pilot plant for 20 kg was set up. It was later transferred to DRDL, Hyderabad where further work had to be carried out to improve the efficiency of the process and to reduce the pollution. The same group at DSL was entrusted in 1976 with the development of G-fuel for the missiles. In this case, a high explosives factory of the Ordnance Group was closely associated with DSL so that after proving the process at the laboratory scale, know-how was transferred. According to one chemist, who was involved in the development, the process of scaling up of the plant for operation by relatively less skilled personnel, was an eye opener and the scientists learned a good about the problems faced in the transfer of know-how. In this case, these were successfully resolved and regular production was established. The technology developed by the liquid propulsion group of DRDO paid handsome dividends in the IGMDP programme.

Project DEVIL – When the exploration for a higher technology takeoff in missiles did not materialise, the project for indigenisation of the SA-75 missile was initiated in 1972 at the earlier estimated cost of Rs.16 crore to be completed within a period of about 7 to 8 years. In this process, the necessary infrastructure and test facilities were created. The philosophy of one-to-one substitution led to the designer creating at the major units level a hardware/software which would be different in composition from the original but functionally identical. The major units of the SA-75 SAM system were assigned to specialist groups for determination of theory of operation, physical parameters, and the material/components. Wherever possible, the design of replacement units was based on current technology/components. Prototype engineering drawings were prepared, fabrication processes were stipulated and production agencies were approached for assistance in fabrication. The

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36 Interview, Dr BV Ramani, former Chief Controller R&D, DRDO. In the nineteen seventies he was working at the Defence Science Laboratory.
changeover from the old system hardware into the new system hardware was done by unit-by-unit substitution during the regular training flights of IAF (Fig. 4.33).

Some within the Organisation were not happy. They held the opinion that unit-by-unit substitution did not really enhance capability for new system development, because the system constraints of the original design due to older technology, would be retained whereas the route of technology development and then system upgrading though slower initially, would definitely be more effective in developing next generation systems. In August 1974, when Professor Menon became the Scientific Adviser, he decided to resolve the issue by constituting a Review Committee with Professor Brahm Prakash of the Department of Space as Chairman for the purpose of assessing the progress of development activity, competence generation, infrastructure and facilities build up\textsuperscript{37}. The Review Committee made its findings known to the DRDO with respect to systems analysis, system specification, technology development, hardware, facilities that were established, computer centre, testing facilities, quality assurance and project management. The Committee was of the opinion that hardware design and engineering was truly of a high order. The comments of Dr APJ Abdul Kalam, who was a member of the committee and who would later head the DRDL in

\textsuperscript{37} The Brahm Prakash Review Committee was constituted in December 1974 vide letter R&M(RD-152)/1129/761672/S/D(R&D) dated 24 December 1974 with Dr RP Shenoy, Dr APJ Abdul Kalam, Professor I G Sarma, Mr B R Somasekhar, Wing Commander B S Solanki and Wing Commander P Kamaraju as members and with Wing Commander R K Mehra of DRDL as non-member Secretary.
the IGMDP, programme reflected quite accurately the opinion of the Committee. He has stated that, “at DRDL, ....one-to-one substitution philosophy had taken precedence over the generation of design data. Consequently, many design engineers had not been able to pay adequate attention to the necessary analysis which was the practice followed by us at VSSC. The system analysis studies carried out up to then had also been only of a preliminary nature. In all, the results accomplished were outstanding but we still have a long way to go... . The Committee made a strong recommendation to the government to give Devil a further go-ahead”38. Overall, it was the opinion of the Committee that while the progress on the project was excellent in respect of hardware fabrication on a one-to-one basis, systems analysis needed to be given greater emphasis in the next phase of the project. It lauded DLRL for having achieved the twin goals of hardware fabrication and systems analysis in the design and development of ground electronics. The Committee’s recommendation for further release of funds to DRDL to bring project to successful completion was accepted by the Government.

Figure 4.34. Blunt anti-tank missile

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The development and testing activity continued at DRDL and seven flight trials were conducted in which three were with indigenously developed fully integrated DRDL missiles. Of this, one was completely successful and the other two were partially successful. By the time the trials were completed, that is by 1979, the Indian Air Force had taken the decision to phase-out the SA-75 system, as a result of which there was no requirement to continue further development.

Besides building the infrastructure, the major spin-offs from the project were supply of SA-75 booster propellant grains by Bhandara Factory and propellant grains for Pechora missiles; automatic checkout facility for SA-75 autopilot, RCRS and radio fuze; and development of batteries for VT fuze, silver oxide-zinc battery for P-15 missile.

Project Blunt – In 1969, DRDL had proposed a competence building project, which would ultimately result in the development of semi-active homing head for the K-13A air-to-air missile system as a demonstrator. The scope of the project had to be enhanced to develop an operational homing head for getting the consent of the Indian Air Force for the development to begin. The work involved the development of the semi-active seeker, radome, microwave receiver, muting antenna for the system, modification of the aircraft launcher, modifications in the cable looms and wiring of the aircraft. The institutions closely associated with DRDL in this project were DLRL and the Hyderabad and Nasik units of HAL. On completion of the development, four modified K-13 missiles were fitted with indigenously developed homing heads. During the trials, the missiles worked well in the height band 5 km to 12 km at an acceleration of 3 g and speed of 0.7 Mach. The reliability of the performance of the homing heads was proved in these trials. Before two more missiles with indigenous homing heads and two with infrared could be tested, the project was closed.

Missile Policy Committee Report – In December 1974, the Ministry of Defence voiced concern at the level of the Raksha Mantri about the workload for Bharat Dynamics Ltd, which was founded in 1970 to manufacture missiles with foreign collaboration. According to the Ministry sources, the Services had not put forward their requirements and this would cause the Factory to be out of work in about two years. Professor Menon, who was the Scientific Adviser and who was present at the meeting, opined that, “the temporary lull in production at the factory should not blind us to the reality that missile was a whole new warfare technology and weapon system and therefore, a strategic perspective of the strike capability that the Services do need from the new weapon system should first be decided upon before details of individual requirements were taken up”. The Raksha Mantri fully concurred with this view and constituted a Committee with
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Professor Menon as Chairman to analyse and determine the likely needs of the Services in the future and also outline the further investments needed to be made by the Government. The Committee Report is a comprehensive document that stated in great detail the strike capability that was desirable to be achieved, the translation of the capabilities into likely requirements for all classes of missiles, the type of performance characteristics these weapon systems should possess, the class of missiles to be developed within the country, the technologies to be developed and/or acquired from abroad, the needs of production and that of DRDO for such development to be effective. This document was of great help later (1980s) for drawing the blue print for the IGMDP programme.

Besides the activities enumerated in the earlier paragraphs, the Laboratory continued the buildup of competence in various technologies related to rockets and missiles as well as in systems analysis. Competence building in development of inertial navigation system, solid and liquid propulsion systems, control systems, lasers, short range rockets and missiles and warheads, etc. were undertaken. Simultaneously, augmentation of range test facilities, general buildup for development of rocket and missile technology was taken up. The setting up of sophisticated and high-precision fabrication technology, like vacuum brazing, flow turning, electron beam welding, high-precision machining, metrology and other inspection facilities were completed. Test and evaluation facilities were also built-up.

4.11 NAVAL SYSTEMS LABORATORIES

Three laboratories in the DRDO namely, Naval Materials Research Laboratory (NMRL) at Ambernath (earlier at Mumbai), the Naval Physical and Oceanographic Laboratory (NPOL) at Kochi, and the Naval Science and Technological Laboratory (NSTL) at Vishakapatnam, work exclusively on science and technology solutions for the problems encountered by the Indian Navy. The Indian Navy is amongst one of the most conscious users of the sea who fully recognise and understand the difficulties and problems associated with this environment and has therefore been working very closely with the three laboratories. NMRL (as Naval Chemical &

39 The Missile Policy Committee was set up with Professor MGK Menon as the Chairman and with Secretary, Defence Production, DCOAS, VCNS, DCAS, Joint Secretary (P&C), Joint Secretary (O), Joint Secretary(N), Joint Secretary(A), CCR&D(S) and Director, Rocket & Missiles, DRDO as members. The Committee had four sittings and submitted its report in November 1977.

40 Interview, Air Commodore R Gopalswamy by Mr NS Venkatesan, Dr RP Shenoy, Dr A Nagaratnam and Dr SS Murthy.
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Metallurgical Laboratory) and NPOL (as Indian Naval Physical Laboratory) antedate DRDO whereas NSTL came into existence in 1969\textsuperscript{41-44}.  

4.11.1 Naval Materials Research Laboratory

The main objectives of NMRL are providing protective measures against marine corrosion and bio-fouling growth, conducting investigations related to pollution of both marine and atmospheric environments, developing marine materials with reference to piezoelectric transducer (PZT) materials, acoustic polymers and welding technology of exotic metals like titanium and rendering scientific support and consultancy to the Naval fleet.

Right from the early 1950s, it was recognised that the twin problems, namely, marine corrosion and marine bio-fouling were very severe in Indian tropical waters and that the protective coatings which were imported from abroad were not fully meeting Navy's requirements. The development of anti-corrosive, antifouling coatings, therefore, received top priority, and by mid 1960s, the laboratory had successfully developed paints based on oleo resins. These were immediately introduced in service by the Navy in 1966. These coatings offered, corrosion-and fouling-free life of 9 months, which was better than the performance of those imported from abroad. The know-how was transferred to the industry and the maintenance of seagoing vessels was considerably eased. Antifouling paints based on organic toxins instead of conventional cuprous oxide and anti-corrosion paints containing magnesium were also developed. These contributions led to the Navy designating the NMRL as the agency for formulating national specifications for paints to be used by the Navy. It greatly helped the industry in meeting the requirements of the Navy. Another significant contribution was the development of a cathodic protection system based on aluminium alloy anodes for protecting the hulls of naval ships from corrosion. In the field of services to the Navy, the Laboratory carried out assessment on the serviceability of paints, quality assurance of paint samples and supply of marine paints developed by it, till the formal production base was established.

\textsuperscript{42} DRDO Annual Reports, 1970-71 to 1982-83.  
Marine Corrosion and Bio-fouling – In the early 1970s, with the expansion of the fleet and with the limitations of the dry-docking and shore facilities which remained almost unchanged, the Laboratory recognised the need for developing coatings that would offer longer protective life. The second generation effort in this direction led to the development of coatings based on synthetic (vinyl) resins. These coatings helped to enhance the inter-docking period from 9 months to 18 months to the great advantage of the users. NMRL also successfully developed the next generation marine antifouling ship-hull paint based on tributyl tin methacrylate copolymers which made it possible to extend the fouling-free life to three years and thus reduce frequent dry-dockings. These paints were self-polishing, have low toxicity and are compatible with other paints. The Laboratory transferred the know-how to industry so that commercial production and supply to Navy would be possible.

To provide better and longer protection against corrosion and fouling, the Laboratory carried out investigations and developed paints based on chlorinated rubber resin and coal tar. These were found to have good adhesion over chipped and wire-brushed surfaces and after evaluation, were accepted by the Navy for introduction into service.

NMRL also developed a solvent-less epoxy two-pack trowelling compound for application to wet steel substrates against corrosion. For example, the steel sheet pilings, which extend from below the mudline of harbour to above the intertidal zone, exhibited greatest corrosion in the splash zone and maintenance by means of in-situ application of protective coatings was not satisfactory due to intermittent splash and wetting by the tidal movements. NMRL’s coating has been found to withstand most rigorous conditions of splash at the pilings, where the assessed corrosion was as high as 25 mils per year. The most important characteristic of the NMRL coating was its firm adhesion on wet surfaces due to the curing agent developed at the Laboratory. Other characteristics included, fast drying (4 hr drying time), higher dry film thickness per single coat (about 10 to 12 mils per average), corrosion resistance to alkaline and acidic solutions, resistance to diesel, fuel oil and common organic solvents, resistance to sea water splash, good flexibility, impact resistance and scratch resistance.

During the two decades, NCML developed a variety of coatings based on indigenous raw materials. Some of the paints were ship primers, anti-condensation paints, anti-skid paints, mica-based fire-retardant paints and chemical-milling primers used in aviation industry. All these coatings were widely used, not only by the Indian Navy but also by the shipping and aviation industries in the public sector.
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Cathodic Protection System – With a view to augment the corrosion protection for submerged surfaces of seagoing vessels coated with anti-corrosive paints, the Laboratory developed the cathodic protection system using galvanic systems and the impressed current systems. The structure to be protected would act as a cathode and the material used for protecting the surface would undergo dissolution by galvanic action. Generally, commercial magnesium, zinc, or aluminium in alloy form would constitute the anode. The cathodic protection of NMRL was based on aluminium alloy anodes from indigenously available high purity aluminium. The advantage of aluminium over other metals arose out of its high energy capability, long life, lightweight and low cost. The cathodic method using aluminium anodes provided protection to the underwater hull and sea water systems of patrol boats and other vessels from marine attack and increased their active life by preventing corrosion. In general, a galvanic anode would be economical when used in conjunction with paints, since a painted surface by itself would not afford complete protection. The impressed current cathodic protection (ICCP) system was a sophisticated technique and as developed by NMRL consisted of inert anodes, reference electrodes, dielectric shield, and automatic control system. It would provide optimal protection against corrosion even under deteriorated paint conditions. Underwater hulls, inlet systems and sea water systems of missile boats, submarine and the supply ship would be protected better by the ICCP systems. The ICCP system found wide use in the vessels of the Indian Navy, including the Leander frigates constructed at Mazagaon Docks, Bombay. Efforts were launched to get the industry to fabricate the ICCP system and to install it on the vessels. Interest was also shown by a foreign Navy in getting the ICCP fitted to its fleet.

The variety of paints and ICCP system for protection of ships’ hulls and other underwater structures successfully developed by the laboratory resulted in operational benefits to the Navy. The spin off from these technologies were also utilised by Oil and Natural Gas Commission, Shipping Corporation of India and the Coast Guard.

Use of Chlorine as an Anti-foulant – In some marine applications such as coolant water intakes of thermal or nuclear power stations, where the use of marine coatings to prevent the growth of marine fouling organisms was not possible, the Laboratory found the use of chlorine as more appropriate. Whereas, chlorine is effective as an anti-foulant, it may, when released in large quantities in the marine environment, could adversely affect the life of economic value in the marine biota. The introduction of chlorine in the sea,
therefore, needed to be executed very judiciously. Based on experiments, NMRL generated a good deal of information on the chlorination in the marine environment, particularly with relevance to the life of economic value.

**Corrosion and Bio-fouling Mapping** – The data on marine corrosion and fouling growth was considered very useful before designing any major structure in the sea water environment. While industrially advanced countries had collected the data in temperate waters, researchers in India were handicapped by the lack of data on behaviour of metals and other materials. Therefore NMRL set up a number of field stations on both sides of the Indian Peninsula as well as in Andaman Islands. Very valuable information on the corrosivity of metals and alloys was generated. Data was also collected on the marine bio-growth and the behaviour of marine structural timbers.

**Titanium Welding Technology** – Titanium was being increasingly used both in aerospace and marine industries. Titanium also found applications in power generation plants. The Laboratory developed welding technology with a view to weld, repair and fabricate titanium-made structures and components. The studies on fatigue crack growth on titanium and its weld were also being carried out. Techniques for in-situ weld repair of titanium under controlled conditions were developed and titanium weld repair of certain critical components of naval ships was achieved.

**Ceramic Materials** – Ceramic transducer materials having high dynamic strength, low dielectric loss factor, better stability and linearity in behaviour, were required for designing advanced high power sonar systems for longer range anti-submarine warfare. Materials having longer piezoelectric voltage coefficient were also required for the development of highly sensitive sonar receiver sets (Hydrophones). Therefore, NMRL focussed its efforts on techniques to effect an increase in the intrinsic dynamic strength of piezoelectric lead zirconate titanate ceramic materials used for sonar projectors and hydrophones. In addition, the possibility of developing the transducer ceramic material by fine particle technology was undertaken.

**Atmospheric Pollution** – The need for the management of environment at Indian naval bases was recognised on account of their proximity to chemical industries and port activities. NMRL took up the work related to air quality monitoring in the year 1979 with a view to ascertaining the environmental status. The work carried out uninterruptedly over a period of three years not only helped to reduce the level of pollution but had created
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awareness, both amongst industries and public about pollution hazards. A nucleus was created at the Laboratory to carry out antipollution work. A variety of techniques to ascertain the values of gaseous and particulate pollutant species were evolved and standardised.

Sea Water Pollution (Microbial Corrosion) – The problem of accelerated corrosion as a result of organic pollutants in the near harbour water was identified by NMRL in the mid 1970s. The discharge of untreated sewage, leading to the development of anoxic conditions and the consequential growth of the sulphate-reducing microbes in the near-shore waters was recognised as one of the factors responsible for the accelerated corrosion of harbour structures. The Laboratory, which monitored the water quality parameters as an ongoing programme, succeeded in culturing other microbes under laboratory conditions. An adequate competence was built at NMRL that enabled the Laboratory to investigate harbour water pollution problems and to suggest remedial measures.

Oil Pollution – The problem of possible oil pollution in the sea as a consequence of the nation’s offshore oil exploration programme as well as due to increased oil transportation along our coasts, was recognised by the Laboratory a few years ago. The Laboratory developed a standard method for assessing the bio-toxicity of oil-dispersants which were considered to be most suitable for dispersing the errant oil from the surface of the sea water. NMRL recommended the correct surfactants, whose efficiency as nontoxic dispersants could be assessed by the bio-assay technique developed at the Laboratory.

Fleet Support – The Laboratory developed and standardised several techniques which enabled it to undertake numerous investigations related to POL, metallurgy, rubber and plastics, and a number of other marine materials for the Naval fleet.

4.11.2 Naval Physical & Oceanographic Laboratory

The primary task of NPOL is to develop underwater detection systems—primarily sonars, to be fitted on ships, submarines or aircraft, or to be laid on or moored to the ocean bottom, to provide surveillance and detection capabilities in the ocean areas. In addition, the activities of the Laboratory included study of the ocean and its interaction with sound waves.

The main thrust in the 1960s was towards physical oceanography, ocean acoustics, marine instrumentation and rendering service to the Navy. The ocean is a complex medium in respect of sound transmission because of random variations of its characteristics in time and space and the bounds at
the surface and bottom. Variability of the ocean environment critically influences the performance of underwater sensors, weapon systems and platform navigation during naval warfare as well as during routine naval operations. Acoustic transmission loss and probable detection ranges for both active and passive sonar systems depend on this oceanic variability, which manifests itself through eddies, fronts, internal and inertial waves, wind mixing, free convection, fine structure and so on. Extensive data would have to be collected for study and analysis on the distribution and variation of relevant ocean parameters, on the acoustic propagation characteristics, such as transmission loss, reverberation and on the ambient noise in the sea with a view to build an acoustic model for prediction of the variability. The effort to collect data, design and use of better instruments and analysis for improved predictions of the variability of the ocean would be an ongoing process due to its vital importance for naval operations in our ocean environment.

Therefore, from the beginning, NPOL turned its attention to developing instruments for collecting data in respect of speed and direction of ocean currents, attenuation of visible light in the sea, sea-wave and tidal records and the profile of the velocity of sound. Two current meters—one using a photovoltaic cell for counting the impeller rotation and the other based on Hall effect—were developed and used for measuring the speed and direction of ocean currents in the coastal waters. An electronic sea-wave recorder as well as a pneumatic-wave recorder were developed and used for collecting wave data off Trivandrum, Cochin and Port Blair. A pneumatic tide gauge was developed and used for obtaining tidal records off Bhavnagar and Cochin. A transparency meter was developed for measuring the attenuation of visible light in the sea up to depth of 100 m. A modified version of this instrument was used for measuring the concentration of silt or suspended particles in the sea. For detection of underwater noise sources, passive sonobuoys were successfully developed for use in conjunction with a naval aircraft, which would carry a multichannel receiver that would demodulate the signal received from the hydrophone, which would be dropped from the aircraft to a preset depth (Fig 4.35). The Laboratory also undertook to produce one hundred of the sonobuoys by setting up a pilot plant.

Apart from the development of oceanographic instruments, NPOL built facilities for calibrating some of these, e.g. the mechanical bathythermograph (Fig.4.36), reversing thermometers and wave recorders. NPOL scientists also took a leading part in all the cruises of INS Kistna and the cruises of some foreign ships during the International Indian Ocean
Figure 4.35. Sonobuoy

Figure 4.36. Expandable bathythermograph system (XBT)
Expedition of 1962-65. The results of oceanographic studies were made available in the form of reports, atlases, monographs and charts to the Navy for their planning and operational purpose. Also, it was useful to the scientists of the Laboratory for design of sonars.

In the 1970s, oceanographic studies and instrument development continued for improving the predictions of oceanic variability. Towards this end, the second version of the current meter was completed and the development of the expandable bathythermograph for sensing and recording the vertical temperature profiles and that of the sonic ray plotter was initiated. On successful completion of these activities, the know-how for the Expandable Bathythermograph (XBT) was transferred to M/s ECIL, Hyderabad for manufacture to meet the annual needs of institutions including defence and others like Central Marine & Fisheries Research Institute (CMFRI), India Meteorological Department (IMD), National Institute of Oceanography (NIO), Oil & Natural Gas Commission (ONGC). These XBTs were also extensively used during Monsoon, Monex-79 and other expeditions. Technical know-how for manufacture of an earlier instrument, namely the sonobuoy, was transferred to M/s HAL, Hyderabad to meet the needs of Navy and for other applications, such as remote sensing, avalanche prediction, and so on.

Some of the other activities, which were successfully completed and accepted by the Navy, related to the development of Diver-held Sonar for use by the divers to locate submerged bodies in the ocean bottom, passive listening and harbour sonars used for detecting torpedoes and submarines, echo injector for training sonar operators, equipment for meeting the user’s requirements for demagnetising mine sweepers, and an instrumentation unit to provide independent strolling and range display for naval radar. In addition, a feasibility project was taken up in 1974 for developing a medium-range sonar for Petya class ships, where critical support systems like signal processing, display and signal conditions were developed and interfaced.

Besides the oceanographic studies, the activities of the Laboratory were directed towards the development of electro-acoustic transducers and sonar systems. The transducing material converting electrical energy into acoustic energy and vice versa was lead zirconate titanate (PZT). The development of the indigenous transducer was completed for operation in the frequency band starting from a few Hertz to a few hundred kilo Hertz with varying capabilities for power handling, receiving sensitivities and for the areas of insonification. Transducers of sizes varying from disc of a few centimetres to a cylindrical array of 1 m radius and 1 m height, and operating
from a few Hz to KHz, and MHz, were fabricated. A pilot plant was set up for the quantity manufacture of the transducers. NPOL built up a high degree of competence so that the Laboratory could tailor the size, shape and other design features to the specific needs of each application in the frequency range of operation. The need for building specific expertise in this area arose because the transducer consists not only of PZT discs but also of a large variety of passive materials, such as plastics, elastomers, metals, alloys, fibres and even composites for absorption, reflection or windowing to meet the different performance requirements. In the design of underwater transducers, some of the important parameters that had to be taken into account were, resonance frequency, operating frequency range, power handling capacity, source level, impedance, receiving acoustic sensitivity, acoustic phase, directivity pattern and acceleration sensitivity. In addition, other factors, such as hydrostatic pressure, mechanical stress, vibration isolation and so on would have to be taken into account for decisions on the basic transducer element configuration, packaging and encapsulation. Transducer encapsulation was critical from the long-term reliability point of view because of its role in ensuring electrical insulation, in acoustic impedance matching with and in protection from the water medium. The Laboratory also had to build competence in underwater seals, connectors, cables as well as in junction boxes to be used in various underwater systems. Thus, a high degree of expertise was established in the design and fabrication of piezoelectric transducer elements and arrays as a step towards the design of sonar systems to meet the desired specification for specific applications.

To prove the transducer element as well as the array after fabrication and assembly, test facilities for measurements were set up. An in-house Open Water Acoustic Tank with automatic positioning system and associated measuring instruments and with capability to simulate water pressures to 1500 ft. was fabricated for testing the underwater devices. Different types of calibration techniques were evolved to calibrate the sonar system transducers. For calibration of transducers at very low frequencies and for underwater propagation and reverberation studies, a test barge operating in the Idukki reservoir (about 100 km from Cochin) was set up.

In one sense, these activities were a prelude to the undertaking of a sophisticated modern sonar system development for frigates, APSOH (Advanced Panoramic SOnar Hull mounted), for the Navy in 1980s. The system features and capability were contemporary to the best of this class available in the developed world at that time. The system that was proposed
and subsequently developed, was based on the LSI/VLSI hardware, multi-microprocessors for control, digital techniques for transmission, waveform generation and memory backed raster scan display, which were state-of-the-art at that point of time. The project was monitored by a Steering Committee with the VCNS as the chairman and right from the beginning the production agency, Bharat Electronics Ltd was closely associated with NPOL. The plan of action was to modularise the system, interface the electronics subsystems with a transducer of an operational sonar and adopt concurrent engineering practices to produce, assemble and integrate the hardware at the premises of the production agency. The hardware was assembled and tested at the production agency with the involvement of the Laboratory scientists. The system development was completed and installed on INS Himgiri in a remarkably short period of about 4 year, that is 1981, and sea trials were begun.

4.11.3 Naval Science & Technological Laboratory

The main objectives of NSTL are development of underwater weapons/mines, underwater test ranges, noise and vibration studies, underwater explosion studies, marine navigational aids, and scientific support to Eastern Naval Command.

A warship is a complex system which is called upon to provide multi-mission capability with a good degree of survivability in the marine environment against man-made threats and nature's upheavals. The ship's survivability is enhanced if the hit probability of anti-ship weapons and torpedoes are brought down. The ship's characteristic emanations in the infrared, acoustic and magnetic domains signature being an important factor for its survival. NSTL undertook to study noise and vibration in ships, machinery and submarines, and magnetic signatures of ships with a view to create a databank. Facilities for analysis of noise and vibration, data were also built up so that a methodology for mitigation of noise and vibration could be evolved so as to be of help in new naval craft design. In addition to underwater noise mitigation, shock survivability and design optimization for ease and speed of navigation and manoeuvre, require hydrodynamic test facilities and model studies to be carried out. NSTL carried out studies on various hydrodynamic test facilities and proposed creation of a test facility for evaluating performance of indigenously developed major systems.

The initial activities of the Laboratory in the field of underwater weapons were the modifications carried out to an existing underwater homing weapon to update its technology. The development was a success and the know-how for the modifications was passed on to the production agency. It led
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further to the development of a portable anti-submarine target, which manoeuvred like a submarine at great depths and responded to sonar transmission of various kinds. The deep mobile target was able to operate at low speeds with engines operating on compressed air or batteries. Another effort resulted in the successful transponder system which could be used as a sonar target by ships’ operators as well as in torpedo firing. Several types of transponder systems were successfully developed for evaluation of underwater weapons and for training of operators and were produced in numbers. A project to design and to meet the user’s requirements for demagnetising mine sweepers periodically was also successfully completed. The work on the development of weapon launchers to meet the indigenous shipbuilding programme was underway and was being progressed to the satisfaction of the Users.

4.12 VEHICLES

There are two major establishments under this discipline and these are, Vehicles Research & Development Establishment (VRDE) and the Combat Vehicles Research & Development Establishment (CVRDE).

4.12.1 Vehicles Research & Development Establishment

VRDE was formed out of TDE (Vehicles), Ahmednagar, in 1965 as a result of the separation of R&D and inspection activities. Within a short period, that is in 1966, DRDO decided to station a team from VRDE, at Avadi where the Heavy Vehicles Factory (HVF) was situated, for production of tanks for the Army with collaboration from Vickers of UK. The DRDO nucleus was to assist the HVF team in their absorption of technology from Vickers with the necessary R&D backup. In a very short time, the responsibilities of the R&D team from VRDE at Avadi went beyond design and development issues and extended to trial evaluation, not only of Vijayanta tank but also of other fighting vehicles handled by the Indian Army. By 1969, the involvement of the VRDE detachment at Avadi thus changed to a longtime commitment to take up design, development and evaluation of fighting vehicles for the Indian Army. The detachment was made into an independent laboratory in 1969 and was renamed in 1976 as the Combat Vehicles Research & Development Establishment (CVRDE). A clear demarcation of areas of work was made so that design, development and evaluation activities of wheeled vehicles would be at VRDE, Ahmednagar and the design, development and evaluation of all tracked vehicles would be shouldered by CVRDE, Chennai.
In the automobile sector, the basic industrial infrastructure as well as the ancillary in the country was primitive, and narrow in scope. The activities of the first few years at CVRDE as well as at VRDE were thus limited to one of defect investigations, and improvements in the fighting vehicles held by the Services. Several projects were taken up in the 1960s and these were based on utilisation of available vehicle chasses, but changing the superstructure to suit the roles for which these were planned to be utilised. A few of these are described. Armoured patrol car, which was conceived as a scout car for protection to the Infantry while patrolling forward areas, was designed with an armoured shell around the chassis and automotives of a one-ton vehicle with four-wheel drive. The vehicle was fitted with a machine gun turret with 360 degree traverse. It was intended to be a replacement to an existing vehicle. Armoured recovery vehicle on Vijayanta (Fig. 4.37) which was also intended as replacement to the obsolescent Sherman and Centurion armoured recovery vehicles, was the first Vijayanta tank variant. The heavy recovery vehicle involved
power takeoff/pump drive, hydraulic winch and crane, the architecture of which had to be evolved keeping in mind the weight limit and ease of operation. The 130 mm self-propelled gun was the first of the artillery equipment of its kind developed in the country. It was a tracked vehicle non-turreted system with gun platform, crew stations, hydraulic suspension lock for stability during firing and supporting equipment. The Vijayanta chassis was used with additional support on either side of the gun to withstand the high firing stresses and also to cater for longer recoil length. The project on the development of Bulldozer kit for Vijayanta (Fig. 4.38) was one more effort to extend the scope of the chassis for use in the field. It was the first tank-mountable system and the configuration evolved required minimum changes to be made to Vijayanta so that adaptation and manufacture can be carried out with minimum difficulties.

By the mid of the 1970s, the projects for the development of armoured patrol car, the armoured recovery vehicle and the Bulldozer kit on Vijayanta were successful and orders were placed on the manufacturing agency to produce about 100 units of each for introduction into the Services (Fig 4.38). The project on the development of a self-propelled 130 mm gun on the Vijayanta chassis was completed in the second half of 1970, evaluated and found useful by the Army who placed orders for about 50 units (Fig 4.39). The existing facilities in mechanical engineering were upgraded so that it would be possible to undertake building of prototypes. Studies were also carried out for improving the operational effectiveness of Vijayanta tank with respect to fire power, kill probability, mobility and night fighting capabilities and corresponding modifications were proposed for implementation. These would be taken up in the 1980s.
In the field of wheeled vehicles, development of new series of vehicles for the Army with high mobility in cross country and desert/sandy terrains to meet the futuristic requirements were taken up. A number of prototypes were fabricated and were subjected to evaluation by the Services.

4.12.2 Combat Vehicles Research & Development Establishment

With the insight gained on Vijayanta during the period of technology transfer and defect investigation, with the engineering knowledge acquired during the successful execution of the projects launched in the 1960s, CVRDE was ready for the next challenge of tank development. Even as Vijayanta was in series production, a strategy to build the concept of next generation tank was discussed and debated between the Services and DRDO so that a Qualitative Requirement (QR) was generated in August 1972. Worldwide, the technological advancements taking place in the field of guns and ammunition, armour, and sights/sensors resulted in pursuing multiple options so that a change could be effected with minimum delay and difficulty, once a specific trend is sensed. In order to narrow the options so that the process of design and development can be set in motion, a Steering Committee was constituted by the Government of India with Secretary, Defence Production as the Chairman with a high level representation from the Services, DRDO, DGOF, and public sector industries for dialogue, review and direction. The project for the development of the next generation tank was assigned to DRDO in May 1974 and by November 1974, the system design was initiated. The decisions about weight and dimensions of the tank, the engine and its transmission,
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the suspension, the armour, the sights and vision and the main armament were arrived at in a series of sittings and CVRDE was designated as the nodal agency with collaboration from ARDE/HEMRL on guns and ammunition, DMRL on armour, and IRDE on sights and sensors. The only grey areas, i.e., areas where the competence did not exist or where competence would have to be built or acquired, were that of the engine, smooth bore gun and the missile with its launching mechanism. The missile option was dropped. The main armament was decided to be 115 mm gun with rifled bore, the engine would be liquid-cooled diesel engine to be imported for the first few prototypes from one of the three countries namely, UK, France or West Germany. The engine being the power pack and hence the core, it was decided to have a fallback option, i.e., indigenous engine development with air cooling at CVRDE as the automobile industry in the country had not developed IC engines for the vehicles that were in production. The armour would be 5 per cent nickel armour. IRDE was required to develop weapon stabilised fire control system with the perisopic main sight integrated with laser range finder, a separate night vision device based on image intensification devices and a third sight on the cupola for the commander. Since laser technology was just getting introduced in tanks, to aid IRDE in their development, import of two suitable systems from abroad was accepted. The time frame indicated by DRDO was brought down by two years. Thus, DRDO with the Government in concurrence, chalked out a development strategy which reduced uncertainty, while at the same time kept its options open with respect to the technological advances in the weapons area. This was the first multi-institutional project for DRDO in systems development.

By the end of the 1970s, the design of major subsystems was completed and the hardware was being fabricated for the prototypes so that the first prototype with 115 mm gun would be ready by the end of 1981. The status of the four major subsystems, namely the engine, the gun and its ammunition, fire control and vision instruments, and armour would be a fair indicator of the pace of development.

The import of an engine of adequate power from abroad did not succeed mainly due to political reasons and the fallback option of indigenous development turned out to be the only option available. It was commendable that CVRDE with no prior experience succeeded in designing and developing an air-cooled engine with an output of about 1500 HP and had assembled the first prototype. This would be subjected to tests and evaluation and would be tested for full output with the turbocharger, the development of which was entrusted to GTRE.
As far as the gun was concerned, the firing performance of the first 115 mm prototype gun firing soft core APDS ammunition gave results far superior to the Vijayanta which was encouraging. If the guns were autofrettaged at higher pressures, then still higher performance would be possible. The accuracy of firing was as good as that of Vijayanta even though the range was double. One gun barrel was tested and proved for pressures that might develop during firing. A second barrel intended to be used in the first prototype of the tank would be modified in length to meet the requirement of CVRDE for fitment. The recoil system was also improved to prevent leakage. Low pressure ammunition, such as HESH and smoke would be supplied with brass cartridge cases whereas APDS ammunition would be with semicombustible cartridge cases. Several batches of high energy propellant for the ammunition were produced so that adequate quantities would be made available by HEMRL by December 1980. The technology for semicombustible cartridge case was already established by HEMRL and the Laboratory was ready to transfer the technology to ordnance factory. As far as the fire control and vision systems were concerned, all the necessary hardware and subsystems were already developed except for the thermal imager. The software development for the ballistic computer was awaiting ballistic data about the new gun. As far as armour was concerned, the monolithic armour namely 5 per cent nickel steel armour, was being progressed by DMRL at three manufacturers and proof plates for trials would be made available by December 1981.

As the hardware was getting ready for assembling and integration of the first mild steel prototype, winds of change had already begun to blow. DRDO and CVRDE initiated the development effort when the armed forces of the world were between two generations of tanks. The obsolescence of the current generation was clearly understood but the configuration of the next generation was yet to emerge out of the clouds of uncertainty. For DRDO it was Hobson’s choice and so it accepted the prevailing uncertainty and started the development. Six years later, it accepted the changes and promised to move ahead.

4.13 RETURNS & REWARDS

The question, whether R&D can generate its own resources has been posed to many of us, both by lay persons and by the cognoscenti. It would mean that the input/output ratio has to be less than one. By that criterion, if the input is represented by the annual budget of DRDO and the output by the orders placed by the Services on production agencies for the
products developed by DRDO, then in our case, the ratio is about 1.86 as the input is Rs 520 crores and the output Rs 280 crore\(^4\). However, worldwide, R&D for defence is subsidised by the State in one form or the other. Therefore, the input /output ratio has always been greater than one. The main reason is that in defence, the customer seeks systemic change which translates into a distinct change for the better in performance parameters, like radius of action, accuracy, lethality, mobility and so on. The complexity of the system rises and makes it difficult for us to break it down to subsystems of manageable complexity (modularity) so that most, if not all of these, can be simultaneously designed and developed. With increasing complexity, modularity can no longer be taken for granted and the probability of rework increases, leading to time and cost over runs.

For the scientists and technologists, the returns for their effort is in terms of the peer recognition. Awards at the national level by a group of peers is generally considered as recognition by the peers. Many DRDO institutions and scientists have been awarded national awards like Salwan Award, Import Substitution Award, and Invention Promotion Award. In addition, the nation has recognised the contributions made by our senior scientists by the Padma Awards. In 25 years of its existence, the President of India was pleased to confer Padmashri to the following for their contributions to defence.

*Lt Col Santosh Kumar Mazumdar – INMAS (1964)*

*Dr Nautum Bhagwanlal Bhatt – SSPL (1969)*

*Mr Hari Prasad Jaiswal – LRDE (1972)*

*Dr Waman Dattatraya Patwardhan – ERDL(now HEMRL)/ARDE(1974)*

*Mr Nagapattinam Sambasiva Venkatesan – ARDE/TBRL (1975)*

*Dr Brojendra Kishore Banerjea – DSL (now LASTEC) (1976)*

*Mr Debi Prasad Mukherjee – CVRDE (1976)*

*Mr Vakkaleri Narayan Rao – DLRL (1982)*

*We salute all of them.*
EPILOGUE

More than twenty years have passed since the last event described in the book took place. DRDO has passed many significant milestones in its march towards progress, and therefore, a short account of these would be in order.

Firstly, from 1982 onwards, the Scientific Advisers have been from within the Organisation, a clear sign that the organisation has provided adequate opportunities and challenges for the scientists to excel and be recognised. Dr VS Arunachalam followed Dr Raja Ramanna in Office and had a tenure of about ten years, a period during which the Organisation expanded and excelled. Dr APJ Abdul Kalam was the Scientific Adviser from 1992-1999 during which period the tempo of activities was maintained. Dr Kalam today is the President of India and it is a matter of pride to the defence scientists of the country that one amongst us became the first citizen of India. Dr VK Aatre took over from Dr Kalam as Scientific Adviser and has maintained the tradition of excellence and accountability.

In this volume, a mention of the seeds of two major programmes being sown has been made. These were, the Integrated Guided Missle Development Programme (IGMDP) and the Light Combat Aircraft (LCA) programme. The Integrated Missle Development Programme was a major effort and involved development of five missiles, Prithvi and Agni, which are surface-to-surface missiles, Akash and Trishul, which are surface-to-air missiles and Nag, which is an antitank missile. It is indeed a matter of great pride to all of us that Prithvi and Agni have entered into Service for the Army and for the Indian Air Force. It is the goal of the DRDO scientists that the other three missiles, which are in the advanced stages of development, will find their way in the armoury of our fighting forces. The light combat aircraft development programme, which was considered too ambitious a programme to embark upon, especially as the country had no real R&D programme in aircraft for more than fifteen years and had relied on imports from the West and from Russia for meeting the needs of the military and the civil aviation, has put us in the ranks of the select few in the comity of nations. The aircraft was designed and developed with
advanced features, such as composites for the fuselage and fly-by-wire, has been successfully flown and has completed more than 200 flight trials. It is a reliable fighting machine and will join the Indian Air Force with a modern indigenously designed and developed radar which is under evaluation.

Another major system development programme mentioned in the volume is the development of the tank. Subsequent to 1982, a clear QR emerged in 1985. Prototypes were built for integration, testing and changes/modifications were progressively incorporated. The tank was named ARJUN and was inducted into the Army in 1993 with pre-production models, which were subjected to gruelling tests by field formations. After evaluation and assessment of the performance by the Army, order for its production was placed in 2000 on the Heavy Vehicles Factory, Avadi.

The development activities of the Armament group of laboratories in weapons and ammunition have resulted in production orders worth about Rs 2000 crores. Similarly, the electronic group of laboratories carrying out development activities in radar, electronic warfare and communication equipment and systems have contributed more than Rs 2000 crores to the output of DRDO. The INDRA radar, which was mentioned in Chapter 3, was successful and both the Army and the Indian Air Force have introduced it in Service. INDRA radar was followed by INDRA Mark II, for which repeat orders have been received from the Indian Air Force recently. In addition, DRDO developed in fairly quick time, a short-range battlefield surveillance radar for the Army which successfully withstood competition from abroad. The Army was happy to place an order for a large number of these, and currently, it is under production. The Central Acquisition Radar has found favour with both the Indian Navy and the Indian Air Force. They have placed orders for supply of multiple number of these. The development effort of DRDO on radar has generated a total order of about Rs 1000 crore. In electronic warfare, considerable expertise exists at the component, subsystem, and system levels within DRDO; equipment and systems have been developed, evaluated, and accepted for introduction by the three Services. Systems with ELINT and COMINT functionalities, self-protection jammers, radar warning receivers are typical of the hardware that has been designed and with software added, supplied to the Armed Forces. Suffice it to state that
the production agencies associated with these programmes have orders worth more than Rs 1000 crore for these products developed by DRDO. In the last few years, both the Army and the Navy have further demonstrated their confidence in the capabilities of DRDO by joint funding of their respective EW programmes of truly massive proportions.

The communication group of DRDO which was the first in the country to develop an entire range of mobile electronic switching systems has kept pace with their colleagues by ensuring that the Services place an order to the tune of over Rs 400 crores on production agencies for manufacture of equipments developed by them for Plan AREN and subsequent updated network. In addition, production orders over Rs 100 crores have been generated by the speech secrecy systems developed by them.

All of these are high-tech military systems where the value added is very high compared to the raw materials and component costs. The agency responsible for value addition is R&D and it is precisely the reason why these systems have been effectively used as instruments of foreign policy by advanced nations by selective denial or access to their high-tech military systems. Defence R&D, thus will continue to play an important role for the three Services in the years to come.
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About the Book

The book is an authentic description of development of Defence R&D in India and first of its kind which traces the origin of military research, its need under British rule in India in early twentieth century, the R & D during two World Wars, the independent India and defence strategy at that time to inception of Defence Research Organisation, appointment of first Scientific Adviser and evolution of separate Defence Research & Development Organisation for catering to needs of Armed Forces in India. The book vividly describes the birth pangs of the organisation, the hurdles faced and contours of current organisation as envisaged by the founding fathers of Independent India, and the milestones achieved during 1958-1982 and makes an engrossing reading.

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