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Professor DS Kothari: The Architect of Defence Science in India

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1. INTRODUCTION

Defence science in India owes its origin and early growth to Professor DS Kothari. From humble beginnings the Defence Research and Development Organization (DRDO) has grown into a major national scientific agency over the last four and a half decades.

2. BACKGROUND

The application of science to the invention of new weapons of war goes back to several centuries in history. The development by Archimedes in the third century BC of catapults for the Greek armies of Syracuse as well as his fabrication of huge concave mirrors and their installation on the coast to set on fire from at a great distance ships of the invading Italians are well known. However, the application of science to the conduct of operations of war and optimization of the effectiveness of weapons of war (operational research or operations research, as it is now called), and the direct impact science made on tactics (and even strategy) date back only to World War II.

3. THE BEGINNINGS OF DEFENCE SCIENCE IN INDIA: ADMINISTRATIVE AND ORGANIZATIONAL ASPECTS OF THE FIRST DECADE (1948-1858)

The account presented in this section is largely based on the article by Venkateswaran[1].

India had a long tradition of indigenous production of weapons and ammunition. Some of the Ordnance Factories like the Gun and Shell Factory at Cossipore and the Ammunition Factory at Kirkee were nearly 100 years old by the time of our independence. They were producing weapons and ammunition of British design to their specifications. There were some Technical Development Establishments under the Army, located in the Ordnance Factories. Their main function was inspection and quality control. They were sometimes involved in material substitution and some defect investigation. There was, however, no setup to carry out research and development in respect of weapons needed by the three Services.

It was Pandit Jawaharlal Nehru who, with his immense faith in science and technology to improve all aspects of human endeavour, felt that, following the outstanding success of the application of science to defence matters in the UK, our country should also have an organization for the application of science and Operations Research to the development of weapon systems .

Dr OH Wansborough Jones, who was then the Scientific Adviser to the UK Army Council, visited India in the middle of 1946. It was on the basis of his report to the Commander-in-Chief, submitted in November 1946, that the Defence Science Organization was set up later.

Early in 1947 the appointment of a Scientific Adviser was taken in hand, but in view of the rapid changes in the political scene that were taking place then in the country, the question was temporarily shelved.

After independence the question was again taken up, and, in May 1948 Professor DS Kothari, who was then the Dean of the Faculty of Science in Delhi University, was invited to be the first Scientific Adviser

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to the Defence Ministry. The scale of pay for the post was fixed as Rs. 2000-100-2500 (at par with the pay scale of the Directors of the National Laboratories).

Professor Kothari assumed charge as Scientific Adviser on 12 1948. He rejoined the Delhi University on 12 July 1952, but was specially requested by the Defence Ministry to continue as the Honorary Scientific Adviser, a post which he held till 1961.

Several important decisions were taken in quick succession in 1948 in the structure and policy guidance to the Defence Science Organization. A board of advisers to the Scientific Adviser, consisting of Dr HJ Bhabha, Dr KS Krishnan and Dr SS Bhatnagar, was constituted. The charter of the board (renamed the Scientific Advisory Board) was soon broadened with an enlarged membership which included the Defence Secretary, the three Service Chiefs and the Financial Adviser (Defence). Its name was again changed to the Defence Science Policy Board, with the Defence Minister as the Chairman. A Defence Science Advisory Committee was also set up with the Scientific Adviser as Chairman, and consisting of a panel of consultants, co-opted Service representatives, and co-opted civilian scientists. The Committee was entrusted with the tasks of examining the technical and scientific aspects of Service requirements, liaising with the Service technical establishments, initiating basic research in relation to Defence Science in universities and scientific research institutions, and keeping in touch with the scientific and industrial development in the country as a whole.

The Indian Government invited Professor PMS Blackett, a Nobel Laureate in Physics and the father of Operations Research in the UK, then a Professor at Manchester University, to submit a report on how scientific problems of Defence could be addressed in our country. Professor Blackett visited India three or four times and submitted his report in September 1948. His report laid firm foundations for the development of defence science in India.

It was a fortunate coincidence that Professor Blackett was a good friend of both Pandit Nehru and Professor Kothari. Pandit Nehru and Professor Blackett had nearly identical political leanings, and both were great humanists passionately convinced of the importance of science and technology in improving the economic conditions and life-styles particularly in developing countries. Professor Kothari and Professor Blackett had both worked in the Cavendish Laboratory at Cambridge with Lord Rutherford. Another fortunate circumstance was the dedication, understanding and dynamism of Krishna Menon, who, as the Defence Minister, was completely in tune with Pandit Nehru's thinking, and gave unstinted support to the growth of Defence Science; Professor Kothari had an extremely satisfactory equation with Krishna Menon also. Professor Kothari's friendship with Sir John Cockroft, another student of Lord Rutherford and product of Cavendish Laboratory, who later became the Scientific Adviser to the UK Ministry of Defence, helped evolve intimate interactions in matters of defence science between India and the UK.

A 'Fire Adviser' was appointed in September 1948. A Psychological Research Wing (now called the Defence Institute of Psychological Research) under a Chief Psychologist was set up in August 1949.

In June 1949 the Government sanctioned the setting up of a Defence Science Organization. Besides the Scientific Adviser, 40 senior scientists and 100 junior scientists, plus 25 scientific assistants, were authorized. The Defence Science Organization was originally located in 'H' Block, one of the hutments adjacent to the North and South Blocks of the Central Secretariat at New Delhi. The first batch of 15 scientists joined in October 1949. Early in 1950 the Defence Science Laboratory (DSL) moved to the second floor (containing around 25 rooms) of the National Physical Laboratory at Delhi. A workshop and a library were established and a bulk grant of Rs 15 lakhs spread over a period of 3 years was sanctioned for laboratory equipment. To create an awareness and to foster in the scientists of the universities and other civilian research institutions an active interest in defence science, Defence Science Conferences were held periodically in the early days, starting from 1949. The *Defence Science Journal* was started in 1950.

In 1953 the Government established a Defence Science Service for the benefit of the scientists working in the Defence Science Organization. While piloting the case for the establishment of a separate service for the scientists Professor Kothari was concerned that if the pay scales, particularly at the entrance level, were made high, it might attract the most brilliant of the young students away from the teaching profession at the Universities to the government service. He therefore kept the entry at the Junior Scientist level, whose salary

scale was comparable to that of the lecturer at the Universities.

Around 1953, three posts of Deputy Chief Scientific Officers were created, one each for the Army, the Navy, and the Air Force. Based on the report of Col HM Paterson from the Military College of Science in the UK, submitted in 1950, the Institute of Armament Studies (now called the Institute of Armament Technology) was established in May 1952. It has a dual role: teaching and research. Consequent on the report of Dr Keyston of the UK Royal Naval Scientific Service in 1949, a Naval Dockyard Laboratory (now known as the Naval Chemical and Metallurgical Laboratory) was set up in Bombay, and a Naval Physical and Oceanographic Laboratory at Cochin in 1953.

3.1 The First Decade: Scientific and Technical Aspects

Professor Blackett's report underlined the role of science in planning for India's defence programme and suggested that small 'non-competitive' weapons should be developed and made in India, while 'competitive' weapons be imported. Blackett defined a 'competitive' weapon as one in which its performance relative to the enemy's weapon was all important; examples were tanks, missiles, jet fighters and radar. His reasoning was that as India did not then have sufficient industrial or scientific infrastructure, it would be unwise for her to devote primary attention to 'competitive' weapons in the first place.

In consonance with the suggestions of Professor Blackett, the Defence Science Organization was mainly concerned with R&D in what were designated as 'non-competitive' weapons, and in keeping liaison with the Technical Development Establishments of the Services. (It is difficult to infer now whether Professor Blackett's advice acted as a deterrent and delayed by a decade or so the taking of bold innovative decisions on initiating R&D work on major weapons systems).

In giving a direction and a coherent shape to the Defence Science Organization, Professor Kothari had no precedents to go by. It is a tribute to his clear thinking and vision that he unerringly identified thrust areas of relevance in the country's geopolitical (both the then existing and anticipated future) context. Further, there were no ready-made specialists in any of these disciplines in the country. He carefully chose through personal contact scientists (mostly from the universities) who had the necessary interest, aptitude and competence. He guided them personally in developing these disciplines on healthy lines. He himself spared no effort to get a mastery over all these areas (most of which were new to him also). He organized weekly seminars on relevant subjects and made it a point to participate actively in each one of them, and particularly encouraged the younger scientists. He believed in humble beginnings and natural growth. He therefore started all these disciplines in a small way in corresponding 'cells', mainly in the Defence Science Laboratory, Delhi. All of them have grown over the years, and when they reached a critical size, they took off as independent laboratories or establishments located in different parts of the country. (Today there are over 45 such establishments which have developed expertise and strong infrastructures in various disciplines).

Professor Kothari realized that the main purpose of the Defence Science Organization was to serve the immediate and long- term needs of the users, namely the Armed Forces. He repeatedly stressed the vital need for the scientist-soldier partnership. He made efforts to establish rapport with the chiefs of the three Services, namely Army, Navy and Air Force. In spite of the differing ethos of the academic university professor (accustomed to an informal atmosphere) that Professor Kothari was, and the highly disciplined hierarchical structure of the Armed Forces, he was able to establish extremely cordial relations with the senior service officers at all levels, and earned their respect by his encyclopaedic knowledge, humility and the special efforts that he made to understand their requirements and appreciate their point of view.

The following were among the disciplines that Professor Kothari identified for development in the first phase: Operational research, ballistics, explosives, armaments, rockets and missiles, electronics, naval technology, engineering, food, life sciences (including medicine, environmental physiology and psychology), and problems posed by special adverse environments in the efficient operation of men and materials. He also realized the importance of a first-rate training institution for training future defence scientists. Thanks to Professor Kothari's vision, DRDO still continues to have a vital interest in all these disciplines.

Special mention may be made of his pioneering vision in starting as early as 1956 a small 'Radiation

Cell' whose charter was to study the biological effects of radiation, a subject of military medicine. But he foresaw that the expertise gained in such studies could be utilized for the alleviation of human suffering through the application of the then newly emerging discipline of 'nuclear medicine'. He therefore broke new ground in establishing the Institute of Nuclear Medicine and Allied Sciences (INMAS) at Delhi (probably the first independent institute in the world devoted exclusively to nuclear medicine), and also started a post-graduate diploma course in radiation medicine in collaboration with the Delhi university (again probably the first of its type in the world).

It is interesting to recall two instances of how Professor Kothari applied his expertise in astrophysics to solving problems specific to defence. The first relates to the physics of the 'hollow charge' or 'shaped charge' phenomenon. It was well known that if a block of explosive with a conical cavity was detonated against a plate of armour there was penetration or perforation of the armour depending on the thickness of the plate as against fragmentation achieved by a plain explosive block. This effect was known as the 'Munroe jet'. It was also established that if the cavity was lined by a metal such as copper or aluminium the penetration improved considerably. Though the principle was known for several decades, the fabrication of the actual hardware took place only during world war II, and was known as 'hollow charge' or 'shaped charge' ammunition.

When such a hollow charge is initiated by a suitable detonator the advancing shock wave makes the liner material to collapse conically axially and a very high velocity jet of the order of 7000 to 8000 m/s is formed. When this high velocity jet impinges on the armour it generates a pressure of the order of a million atmospheres. Under the circumstances the penetration becomes hydrodynamic and results in penetration of a few charge diameters. This was approximately 3 diameters at the end of world war II. Today, with fuller understanding of the factors affecting penetration and with more powerful explosives like RDX and HMX, designs are available where a penetration of 10 charge diameters has been obtained.

Today we have several computer codes based on 2- and 3-dimensional analysis to predict the penetration capability. But in the early 50s the theoretical understanding was inadequate. It was Professor Kothari who applied his theory of pressure ionization in condensed matter to the case of the Munroe jet, leading to a better understanding of the phenomenon of armour penetration.

The second relates to the fragmentation of bombs and shells on explosion. He showed that the same statistical theory can be applied, whether it be random fragmentation in star formation, or the mass distribution of shrapnel from an exploding shell.

3.2 Nuclear Explosions and Their Effects

A major contribution of Professor Kothari was his authorship of the book 'Nuclear explosions and their effects', the first edition of which was published by the Government of India in 1956 and the second (enlarged and revised) edition in 1958. The inspiration to undertake this assignment was given by Pandit Jawaharlal Nehru.

It has to be kept in mind that when Professor Kothari embarked on this task, information on the subject was extremely scanty in the open literature, most of it being kept secret by the military authorities. There was also a widespread feeling that the occasional reports from official quarters tended to understate the dangers so as to allay the fears of the public. A major achievement of Professor Kothari in this publication, for which he received acclaim from all over the world, was his ability, relying only on published information but using his scientific acumen and critical thinking, to have presented the most authoritative data concerning all aspects of the effects of nuclear weapons.

The first edition of the book antedated by over two years, and the second edition by a few months, the publication by the United States Atomic Energy Commission of 'The effects of nuclear weapons'. The second edition has 275 pages of text plus 12 appendices. Almost all pages are studded with footnotes, which give copious references to literature or elaborate on points discussed in the text.

The book was translated into German, Russian and Japanese. The preface to the German translation of the book (published by Krausskopf-Verlag, Wiesbaden) stated: 'Thus with the publication of the Indian book, a work has come out which makes history..... History-making books are those which convey decisive knowledge at the right moment in an authentic form - unobjectionable and incorruptible, objective,

consolidated and total - as the basis for the thoughts and actions of citizens and even of statesman!' Bertrand Russell, in his book 'Has Man a Future?', also referred to the admirable objectivity of Professor Kothari's presentation.

4. THE DECADE 1958-1968

This decade marked the beginning of the Defence Research and Development Organization (DRDO) in 1958. The DRDO was formed by amalgamating the Defence Science Organization with the Technical Development Establishments of the Army and the Directorate of Technical Development and Production (Air). The Defence Science Laboratory moved from the National Physical Laboratory campus to the historic Metcalfe House building on the banks of the Jamuna river, adjacent to the Old Secretariat in Old Delhi. DRDO started having an independent small budget from 1961-62 at a level of a few crores of rupees. This period marked the initiation of some small development projects for which the Services had immediate requirements. These involved minor changes to existing hardware. Major systems continued to be imported[2]

5. THE POST-KOTHARI PERIOD OF DRDO

Professor Kothari relinquished charge as Scientific Adviser in 1961. DRDO has been fortunate in having a succession of outstanding scientists as Scientific Advisers (Dr S Bhagavantam, Dr BD Nag Chaudhry, Prof MGK Menon, Dr Raja Ramanna, Dr VS Arunachalam and Dr APJ Abdul Kalam). Dr Arunachalam was the first scientist from within the DRDO establishment to be selected as SA.

6. THE POST-1969 PERIOD

The account given in the following sections is largely based on the DRDO Publication 'Towards self-reliance in defence: A silver saga', brought out on the occasion of the Silver Jubilee of the DRDO in 1983[2].

The coming of age of DRDO was in the the third decade, starting from 1969. The number of laboratories increased from 10 to 35. DRDO started entering into areas of high technology. The country also witnessed an all-round growth in the scientific and technological infrastructure, thanks to the vision and dynamism of Pandit Nehru as embodied in the Scientific Policy Resolution passed by the Parliament in 1958; this had its impact on the DRDO in terms of the availability of an advanced technological base (particularly in aeronautics and electronics) that could cater to the specialized demands of sophisticated defence systems.

The time had come for the DRDO to deliver systems to the user (the three wings of the Armed Forces) as per the latter's specifications and requirements. Krishna Menon had prophetically warned as early as 1961: 'The honeymoon period between the nation and DRDO is almost over'; he made it clear that the laboratories would soon be asked to justify their performance. The laboratories started learning their lessons: good research alone was not enough, but engineering and technological skills were necessary to transform laboratory research into realities[2].

7. DRDO TODAY: AN OVERVIEW

From modest beginnings the DRDO has grown into a major national scientific agency of over 25,000 scientists working in over 45 laboratories spread throughout the country.

The activities of DRDO cover applied research as well as design and development in a variety of disciplines such as aeronautics, armaments, combat vehicles, naval technology, rockets and missiles, computer sciences, electronics and instrumentation, artificial intelligence, robotics, engineering, terrain research, explosives safety, materials, life sciences (including high altitude agriculture, high altitude and desert physiology, food, nuclear medicine, psychology), work study, systems analysis, training, and information systems.

8. CONCLUSION

Today, 'in the national quest for a self-reliant defence posture, the Defence Research and Development Organization endeavours to provide the research, design and development base for meeting the needs of the Armed Forces—needs ranging from aircraft, missiles, torpedoes, radars and tanks to frozen foods and nuclear medicine'[2]. The nation owes a deep debt of gratitude to Professor Kothari for the seeds that he planted, the careful nurturing of the varied saplings in the early years, and the environment that he thoughtfully created for their growth, which has enabled the organization to be what it is today.

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