

## About The Chain Reaction

The title of the book has been chosen to metaphorically reflect how research in basic sciences in various institutions of the Department of Atomic Energy (DAE) has evolved over the years, closely mimicking what goes on in a nuclear chain reactor. Since, for harnessing atomic energy for peaceful uses, nuclear physics and atomic physics are the two core activities, work was undertaken in these areas during initial days at the Tata Institute of Fundamental Research. These activities then promoted the growth of major programmes in a number of areas, such as, reactor physics, accelerator physics, condensed matter physics and materials science, theoretical physics and mathematical physics, astronomy and astrophysics, laser and plasma physics, radiation chemistry, photochemistry, chemical dynamics, nuclear chemistry, radiation biology and health sciences, molecular and cellular biology, structural biology and biophysics, agriculture and food sciences etc. In turn, all these programmes have been fostering the growth in several other domains of science, engineering and technology.

This chain of scientific activities, has also led to the creation of a chain of institutes which are today addressing a wide variety of scientific needs of the country. The book provides a kaleidoscopic account of the activities in DAE institutions over the past fifty years, and, for the benefit of young readers, attempts are made to give a glimpse of the character of the man, Homi Jehangir Bhabha, who started it all, through the impressions of his early associates who have themselves made immense contributions to the growth of DAE's multifaceted programmes.

The compilation of this book has been handled by an editorial team with inputs from all the DAE Institutions engaged in work relating to Basic Sciences in various fields.



*Bhabha with his colleagues in Geneva (1955)*

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## Foreword

The Department of Atomic Energy (DAE) is a multifaceted organization comprising research institutions and closely linked industrial units providing an excellent environment for both scientific enquiry as well as technology development. This framework has enabled pursuit of programmes in a manner, which has promoted synergy between science & technology development through appropriate linkages between the laboratories carrying out research and development of the technology on one hand and the recipient industrial units exploiting the fruits of such developments on the other. A hallmark of the programme, founded half a century ago under the leadership of Dr. Homi Jehangir Bhabha, has been to achieve self-sufficiency in all aspects of applications of nuclear energy in the country. Through concerted efforts made by successive leaders over the years, we today possess know-how in almost all aspects of nuclear science and technology, which include the entire gamut of operations relating to the nuclear fuel cycle i.e., prospecting, ore mining, fuel fabrication, reprocessing and waste management, as well as comprehensive capability in design and construction of nuclear reactors of different types, production and applications of radioisotopes for industrial and medical purposes, materials development, electronics & instrumentation and many other uses of atomic energy.

In 1948, when the Government of India decided to initiate the above programme, the scientific, technological and industrial base available in the country was far from adequate. To achieve the aims and objectives of the programme, a great amount of effort had to be made to develop the infrastructure in the just-independent India, especially for the pursuit of frontline research in nuclear science and technology. The formation of DAE in 1954 gave impetus to build on the basic research in nuclear and atomic physics, already initiated by Dr. Bhabha at the Tata Institute of Fundamental Research (established in 1945 at Mumbai). The work was soon expanded and led to the setting up of Atomic Energy Establishment, Trombay (later renamed as Bhabha Atomic Research Centre (BARC) in 1967). APSARA, the first Indian and also the first Asian nuclear research reactor, was built in 1956. The nuclear

energy programme of India took off from this, and has never looked back ever since.

Over the years, the activities of the DAE have grown in strength and coverage, encompassing a wide spectrum, ranging from basic research in mathematics, physics, chemistry and biology on the one hand, to the construction and operation of nuclear power reactors on the other. The DAE family now comprises five R&D organisations, eight industrial units and seven grant-in aid institutions and three service organisations. Advanced and futuristic technologies involving accelerators, lasers, plasma are being pursued within DAE. The mandates of various DAE Centres are to execute comprehensive programmes in the areas of their respective specializations, to spot science and technology opportunities and to develop appropriate capabilities so that these technologies can be deployed through the industrial units, and thus technologically advance our country. DAE has also been working closely with other industries and academic institutions for the development of a mature industrial base within the country for the high-tech areas. This synergism has led to industrial competence to achieve leadership quality in core sectors. For instance, DAE has developed research reactors, covering all the three fuel technologies namely, uranium, plutonium and thorium, which is an unique distinction. India has been exemplary in closing the fuel cycle with its steadfast pursuit of sustainable nuclear power programme. So far, DAE has constructed and has been successfully operating fifteen power reactors. Efforts are on to improve the share of nuclear power to the national grid, with seven thermal and one fast reactors currently under construction and more power reactors planned for the coming years. The laudable performance of power reactors, built and operated by NPCIL, and the societal impact accruing from the use of the radiation and isotopes in agriculture and medicine stand testimony to the core competence of the organisation. As we celebrate the success of the first stage of nuclear power programme, the commercial phase of the second stage viz., fast breeder reactors has been launched by the Honorable Prime Minister Dr. Manmohan Singh, during the Golden Jubilee

function of the Department. In his address at the function, the PM said,

***“It is a matter of national pride that India has developed comprehensive capabilities in the entire gamut of fuel cycle operations.”***

He continued,

***“The Department of Atomic Energy has been able to consolidate and strengthen our indigenous capabilities in the face of externally imposed limitations and constraints. These have, however, spurred us to greater levels of achievement. The founding principles of “Atom for Peace” were subverted by restrictions derived from an ineffective non-proliferation regime. Despite these limitations, our scientists to their great credit have excelled time and again in demonstrating our indigenous capabilities measuring to the highest standards in the global nuclear industry.”***

The growth of DAE from a small nucleus to a chain of internationally reputed scientific institutions, has been possible by a large body of dedicated scientists and engineers and supporting personnel. In this process human resource development always received highest attention in the Department, notably with the early initiative to start the Training School at Trombay in 1957, having paid rich dividends. The Department continues to this day new initiatives in attracting young talents as well as supporting academic research in different institutions across the country.

Looking back over the past half a century, the country can rightly feel proud of the Department’s growth and evolution into

a great S&T organisation which is contributing to societal benefits. This evolution is captured in the ***three commemorative volumes*** covering Basic Sciences (titled ***The Chain Reaction***), Nuclear Technology Development (titled ***Atoms with Mission***) and Applications of Radiation and Isotopes (titled ***Atoms for Health and Prosperity***). The preparation of these volumes has been coordinated by Dr. R. B. Grover with Dr. Vijai Kumar and Shri R. K. Bhatnagar attending to all the modalities for publication with great care and attention. I am grateful to Dr. Bal Phondke, who has put in laudable efforts to review the contents of the three volumes and ensured uniformity in style. I also want to thank the Chief Editors of the three volumes, Dr. V. C. Sahni, Dr. Baldev Raj and Dr. V. Venugopal. They along with their teams have admirably handled the difficult job of collating and preparing the present volumes, covering the breadth and complexity of the activities being carried out in the DAE.

These commemorative volumes attempt to chronicle the achievements of the Department in a reasonably simple style. I hope that the general reader will come to appreciate the saga of Atomic Energy Programme in India, that started half a century ago with the grand vision of Homi Jehangir Bhabha.



**Anil Kakodkar**

Chairman, Atomic Energy Commission &  
Secretary to the Government of India,  
Department of Atomic Energy

## Outline on the Presentation on Research Programs in Basic Sciences in DAE Laboratories

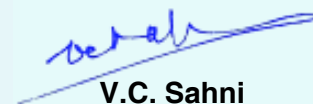
Research in basic sciences has been an integral part of all the R&D institutions of DAE right from their inception. The areas of research, where the work has gone on, include physical, chemical and biosciences. In physical sciences, DAE labs are involved in probing the structure and functioning of natural objects, with sizes varying from  $\sim 10^{21}$  m on length scale in the case of Galaxies, to below  $\sim 10^{-15}$  m in the case of hadrons and leptons or still smaller constituents of matter. In chemical sciences, different aspects of material synthesis, purification along with developments of analytical techniques has been carried out. In biological sciences, various life processes of organisms from unicellular microbes to complex plants and mammalian species under normal and stressed conditions are being investigated.

In this volume, the work carried out in all these areas is described, in the form of an overview. The major achievements in the past, as well as the current research being pursued, especially in the areas that have been nurtured for long in the different DAE institutions are presented. Some of the programmes to be undertaken in near and distant future will also be covered. For the sake of convenience of presentation, various topics are presented with focus on the subject rather than on the institutions. However, reference to institutes is made if the investigation reported upon so demands.

Consequent to the fact that the spectrum of activities pursued in DAE over past fifty years is very wide and the work done is enormously large, it is just not possible to cover the entire work in a single volume. Hence, the summary of the work given in this volume is only illustrative and not exhaustive.

This volume is divided into three parts. Part 1 is devoted to the areas of physical sciences, with which the largest number of DAE labs are associated. Parts 2 and 3 cover the work in the areas of chemical sciences and biosciences, respectively.

In this volume, throughout, the actual contents under each item have been planned keeping in mind the diverse backgrounds of the readers. So we do not plunge right away into details of the work in DAE institutions. Rather, we begin each part with a brief historical perspective and start from the roots at a level that should be accessible to the general reader, before moving to technical matters. To ensure smooth reading, wherever we felt it necessary, matter with high scientific detail or accomplishment has been segregated in the form of boxed item or through a change of font etc. We hope, this will enable the general reader to get the substance of the work done without having to digest all the details. It would have been impossible to complete this book without the enormous efforts put in by my colleagues: Dr. S.C. Sabharwal (Physical Sciences), Dr. P.N. Bajaj & Dr. Tulsi Mukherjee (Chemical Sciences) and Dr. (Smt) J.K. Sainis and Dr. K.B. Sainis (Biological Sciences). I owe them a debt of gratitude and to all the contributors from different DAE institutions who provided their unstinted support in the preparation of this book.



**V.C. Sahni**

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*No country which wishes to play a leading part in the world can afford to neglect pure or long term research*

**Homi J. Bhabha**