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

Preface

The image of the magnificent reactor domes shimmering in the dusk and the majesty of a satellite launch vehicle billowing smoke and fire, rising gracefully in the clear blue sky, are images indelibly etched in public imagination. In an ancient nation, in the throes of development, these evocative images are not merely representations that showcase our achievements in technology. These are powerful symbols of our abiding faith in self-reliant development, our determination and ability to succeed amidst all odds and the strong commitment to the national causes that underlie these efforts. As the Department of Atomic Energy (DAE) celebrates the Golden Jubilee of its existence, we go back in time, trace the origins of DAE, pause to admire the daring and visionary foresight of our scientific leadership, take stock of how far we have come and reflect on how much further we have to go. Far from being self-congratulatory, through this commemorative volume, we hope to provide an accessible *albeit* a scientific and technological account of our activities, their importance for the energy security of the nation and the continued relevance of the self-reliant approach.

The remarkable fifty-year saga of the Department of Atomic Energy has its genesis in the audacious dream of Dr. Homi Bhabha for harnessing nuclear energy and making India a self-reliant nuclear power. The humble beginnings at "Kenilworth" the ancestral home of Bhabha was the nucleus from which DAE evolved with the full and complete backing of Pandit Jawaharlal Nehru, the first Prime Minister of independent India.

The centerpiece, the very crown jewel of the Department of Atomic Energy, is the "three stage power programme" brilliantly conceived and articulated by Dr. Homi Bhabha. Apart from thorium utilization, the three-stage programme envisages the optimal use of the available fissile and fissionable material and the recycling of radioactive fuel discharged from reactors — a strategy that greatly mitigates the burden of radioactive wastes and aims to provide a sustainable source of nuclear energy to our countrymen. The concerns over radioactive wastes are currently fundamental considerations even in developed countries with large inventories of uranium. Burning of plutonium in reactors is seen as the most viable strategy to address this issue. It is indeed a tribute to Bhabha's prescient genius that five decades after its conception, the inevitability of nuclear power and the compelling necessity of the three-stage programme are being fully appreciated the world over. Towards fulfilling this dream, DAE has grown at a fast pace over the decades and has matured into a strong, vibrant, multi-faceted and multi-institutional science and technology organisation.

This commemorative volume "*Atoms with Mission*", one of the three volumes being brought out on this occassion, discusses the implications of this strategy, and details the successful development of different types of reactors and the establishment of large scale facilities for the fabrication and reprocessing of nuclear fuel dovetailed to the "closing of the fuel cycle" as it is called in nuclear parlance. Consistent with this approach, the complete fuel cycle in terms of exploration, mining, fuel fabrication, reprocessing and waste management has been mastered by the various units of DAE. Apart from these aspects, the emphasis of this narrative is equally on the development of advanced technologies related to nuclear power generation. From the very outset, the farsighted political leadership of Pandit Jawaharlal Nehru and the visionary zeal of Homi Jehangir Bhabha laid great emphasis on self-reliance. This insistence, coupled with prolonged regimes of technology denial by the outside world, have not deterred but on the contrary have empowered the department in spearheading technological excellence in the country. Over the decades, DAE has pioneered activities in mining and metallurgy of special materials and rare earths, development of supercomputers and sophisticated electronic control systems, reprocessing of radioactive fuel, developing remote handling tools, evolving and applying non-destructive testing techniques on an industrial scale, setting new quality assurance standards of critical components, production of heavy water, development of desalination technologies and much more. There are 15 nuclear reactors in operation currently and the journey into the second stage of nuclear programme has also successfully commenced. Many of the reactors, being operated and maintained by NPCIL, have received international appreciation and awards, as being

amongst the best CANDU type reactors in operation anywhere in the world, based on their performance, availability and safety considerations. DAE has also pioneered the indigenous development of high powered lasers, particle accelerators, synchrotron light sources, plasma and fusion technologies. Remarkably, the Department of Atomic Energy has been the incubator of several successful organizations such as Board of Radiation and Isotope Technology and the Departments of Space and Electronics.

The spin-offs from our activities to the industry and contributions to areas of high societal value go substantially beyond nuclear energy. DAE has significantly contributed to the industrial sector through the development of technologies for the manufacture of large and precision engineered components made to exceedingly high levels of tolerance and reliability. It would not be excessive to claim that DAE through its emphasis on unprecedented levels of quality assurance and its active participation in developments of technologies towards this end, has ushered in new levels of manufacturing standards in the industry. Large scale, commercial production of radioisotopes and their applications to medicine and agriculture, development of desalination technologies, training of technical manpower, interaction with universities through the University Grants Commission - Department of Atomic Energy - Consortium for Scientific Research, are but a few examples of such contributions. In summary, the DAE is a model for the indigenous development of cutting edge technologies and large-scale project management requiring multifarious inputs.

Through our successful model, it is our intent to demonstrate to the scientific community and other interested audience that through grit and determination, India can successfully meet technological imperatives of the developmental paradigm and that through the vast pool of immense talent and native genius, we are capable of overcoming all vicissitudes and challenges in our quest for development and economic prosperity. In keeping our narrative technical yet hopefully comprehensive, we wish to reach out to the techno-savvy younger generation and motivate them towards a larger national cause.

In order to appreciate the vast extent and rationale behind the various activities of our department, it is essential to understand the unique context of our programme and the evolution of the organizational structure and this is where the story of “Atoms with Mission” begins.

I wish you an enjoyable reading and look forward to receiving your valuable impressions, which would be a true reward for our efforts.

Baldev Raj
Chief Editor
Director,
Indira Gandhi Centre
for Atomic Research, Kalpakkam

Atoms with Mission

A Golden Jubilee Commemorative Volume

(1954 – 2004)

Government of India
Department of Atomic Energy

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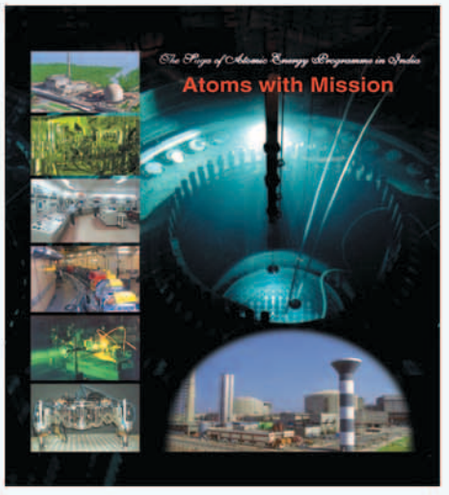

Atoms with Mission is a saga of the technological evolution of the Department of Atomic Energy (DAE), towards harnessing nuclear energy for providing energy security to the nation, as well as developing advanced technologies for societal benefit.

Centre : Reactor vessel of Tarapur Atomic Power Station (TAPS)-1 (top); Recently commissioned TAPS-4 unit, power capacity of 540 MWe (bottom).

Left (Top to bottom): Panoramic view of CIRUS and DHRUVA research reactors, invaluable assets of the Department; Lead Mini Cell, the first Indian facility for fast reactor fuel reprocessing; Instrumentation and control panels of the full scale training simulator, for reactor operation; Synchrotron beam line of INDUS-2, heralding advanced light sources for novel investigation of materials; Prototype grazing-incidence grating dye laser oscillator, for diverse applications in the nuclear fuel cycle; Four-legged sophisticated robot, for remote inspection of reactor components.