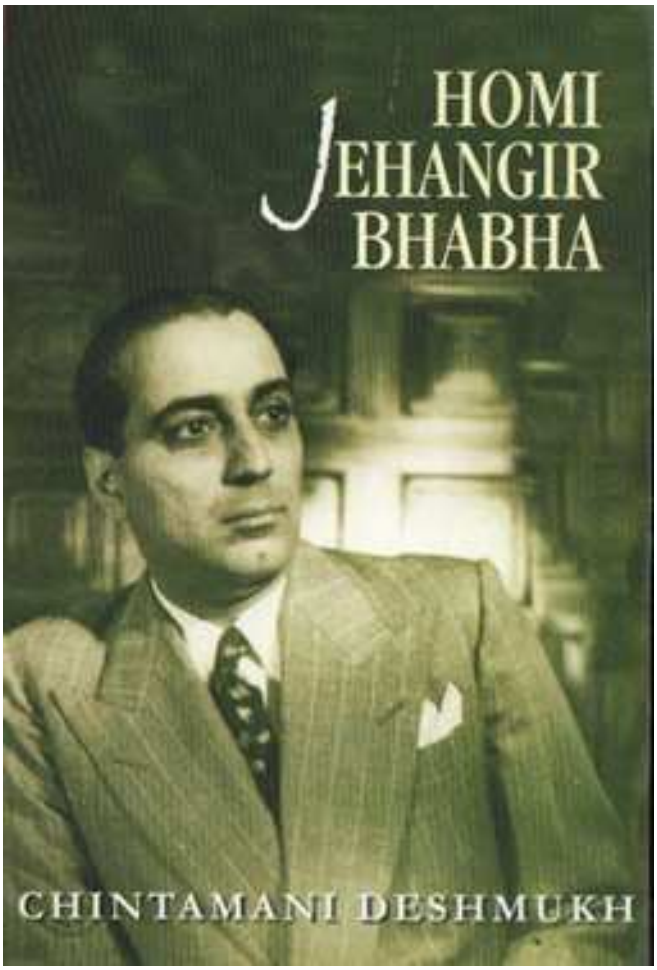

HOMI JEHANGIR BHABHA

CHINTAMANI DESHMUKH

The present biography of Bhabha presents the legendary scientist not only from the perspective of his contribution to Indian Science and Technology but also deals with his other areas of interests and concerns. The reader through these pages gets to know an institution builder, an administrator, a diplomat a dreamer, a painter, a music lover, a sensitive man that Bhabha was, besides also getting an insight into the joy and pain of the aspirations and limitations of a newly independent nation.

Chintamani Deshmukh did his M.Sc. from Bombay University and taught Physics at the V.J.T. Institute Mumbai for thirty years. He has been a science communicator and was associated with Lok Vidnyan Sanghatana and Vidnyan Granthali in Maharashtra for a number of years. His books include biographies of Damodar Dharmanand Kosambi and Homi Bhabha in Marathi published by Granthali. He lived in Mumbai. He passed in 2006.

CONTENTS

ACKNOWLEDGEMENTS

A lot has been written about Bhabha over a period of more than fifty years. Occasional articles and reminiscences by a number of scientists, who worked with him, abound. A number of short and full-length biographies have been written in English and other Indian languages. I have read some of these in Hindi, Marathi and Gujarati. In 1993, I myself wrote a biography of Bhabha in Marathi after interviewing a number of persons. These have proved useful in writing this book. Some of the more important writings are mentioned in the references given at the end of the book.

In addition, a number of persons have extended valuable help in the task of writing this book, and I am very grateful to them. Dr. Anil Kakodkar, Chairman, AEC, was gracious enough to grant me audience, and made possible my visit to the BARC complex. Dr. A. P. Jayaraman, Head, Media Relations and Public Awareness, BARC, provided valuable insights and interesting material. Prof. S. G. Dani and Shri. M. H. Jadhav (PR) from TIFR helped me see the art collection in the Institute, and the Director, TIFR, kindly supplied photographs of paintings in their possession. Shri. Kekoo Gandhy helped in revealing Ehabha's role in the world of art in India. Shri. Dilip Mahajan and Dr. Sudhir Patwardhan helped in arranging some of the interviews. My wife, Shailaja Deshmukh, contributed substantially, in the preparation of the final manuscript. Finally I am grateful to NET and its Editor Shri. Subba Rao for making this book possible.

INTRODUCTION

Homi Bhabha is widely regarded as one of the chief architects of post-independence science and technology (S & T) development in India. He stands head and shoulders above other eminent, and even senior, Indian scientists of the time. He was solely

responsible for establishing and expanding the large atomic energy programme in our newly independent and largely underdeveloped country.

A first rate young physicist, who had already made his mark in the exciting 1930s in Cambridge, UK, he was stranded in India in 1939 at the outbreak of World War II. During this enforced extended holiday at home, he was deeply affected by the turbulent period at the dawn of the independence. In a way, the young boy who had left India at the tender age of 18 and had spent twelve action-packed, creative years in the UK and Europe, discovered his Indian roots and saw the vision of independent India, a modernised and self-reliant country earning her due place in the comity of developed nations.

Bhabha had a difficult choice before him. He could return to Europe and resume his purely scientific career that was almost certain to reach great heights. Alternatively, he could stay back in India and contribute to the development of Indian science. It was going to be a leap in the dark, the chances of success being very uncertain and unpredictable. In the end he made the latter choice and fortunately for him he did not have to suffer any pangs of regret for this crucial decision. He was successful in building up a research institute of international standards and almost simultaneously on a larger and wider level he built up the Indian atomic energy programme, a comprehensive scientific-technological-industrial enterprise which has resulted in half a dozen indigenously built nuclear power plants and ultimately made possible the Pokharan-1998 explosions. His indelible mark on the entire domain of Indian S & T, beyond theoretical physics, mathematics, and atomic energy is clearly visible even to this day.

More than five decades have passed since the post-independence S & T build-up started in which Bhabha made a zestful contribution. The time is ripe now to take stock of the present situation, to find out what part of Bhabha's dreams we have achieved and what remains to be achieved, and where we have gone astray. A fresh look at the life of this great son of India at this juncture should prove to be both valuable and inspiring, because Bhabha's original vision contains many aspects which have not been realised and are still relevant.

1
CHILDHOOD AND EARLY EDUCATION

Homi Bhabha was born on 30 October 1909 in Mumbai (then Bombay) of Jehangir Hormusji Bhabha and Meherbai (nee Meherbai Framji Panday). It was a rich heritage from a highly cultured and accomplished Parsee family. The Parsees constitute a tiny Zoroastrian community in Western India, mainly concentrated in southern Gujarat coast, and in and around Mumbai. The peace-loving migrants from Persia had thoroughly assimilated themselves in the social fabric of Gujarat, and with the advent of the British Raj they took to commerce and industry establishing themselves in Mumbai. The Mumbai Parsees formed a highly Westernised entrepreneurial community.

Homi's father was a barrister from London with an M.A. from Oxford. He was a legal adviser to the house of Tatas and served on the board of directors of many Tata companies. And to top it all, he was a connoisseur of classical Western paintings and music, and had a deep interest in flowers, trees and gardens. Homi's paternal grandfather,

Dr. Colonel Hormusji J. Bhabha, had M.A. and D.Litt. degrees from England, and served as Inspector General of Education in the then princely state of Mysore in present-day Karnataka. He was decorated by the British with C.I.E. Mysore was one of the few progressive and modern princely states in British India and Colonel Bhabha had contributed to its development in good measure.

Homi's mother was a very beautiful lady with an impressive personality. She was the granddaughter of the famous philanthropist Sir Dinshaw Petit, First Baronet.

The Bhabhas also had close family relationship with the Tatas. Homi's paternal aunt, Meherbai, was the wife of Sir Dorab Tata, the elder son of Jamshed N. Tata, the founder of the Tata industrial empire.

Protected and Secure Childhood

In the rich and cultured family, Homi had a materially secure and emotionally well-protected childhood. As an infant, he used to have very little sleep. The worried parents consulted the family doctor, but his medicine failed to make the child sleep longer. Finally, a well-known European child specialist was consulted, and extensive and thorough tests were conducted. To the parents' relief, the doctor pronounced that the child was quite healthy and normal, but he slept less because his brain was super active. It was also discovered that the baby had a musical ear. Music would instantly pacify the crying child, and he would start listening to it intently. The result was that the parents and family members did everything they could to nurture his latent talents.

At the age of seven, Homi joined the Cathedral School and then proceeded to the John Connon High School in the Fort area. The schools were run on English lines and attended mainly by children of the Europeans in Mumbai, and those of Westernised Indian elite. The faculty, too, had some European members. Along with academic activities the school laid stress on sports, music and arts education. As a boy, Homi was somewhat aloof and a loner. He had many extracurricular interests, yet he easily managed to win many prizes for his academic performance.

Though he was attending probably the best and the most expensive school in Mumbai, his real schooling took place within the family itself, under the guidance and the watchful eyes of his parents and paternal aunt. The Bhabha family resided in a two-storey house on Little Gibbs Road on the Malabar Hill. It had a big private library. Homi's grandfather had collected over the years many valuable books on education, literature, and arts, as well as on scientific and technical subjects. Homi's father had added to it volumes of Illustrated Masters in classical Western painting, which he had collected during his studentship in the UK Later, books on flowers, trees, and gardens enriched the library. And when Homi's talent in science and mathematics became evident, related books found their way to this collection. In addition to this treasure at home, the rich library of Sir Dorab Tata was at his disposal. Lady Tata was the paternal aunt of Homi, and being childless treated him like a son. Esplanade House, the ancestral home of Tatas was just across the road from school and Homi used to take his lunch here, and he spent a good deal of time in the library as well. Being a voracious reader and having a quick grasp, he had made good progress in various subjects. Just two feats need to be mentioned here. Before the age of fifteen, he had gained a good understanding of Einstein's theory of

relativity, and in the domain of arts, he was familiar with the works of classical European painters, even of the second rank, and had become somewhat like an amateur art critic in his own right.

At home he took painting lessons from Jehangir Lalkaka, and at the age of seventeen his self-portrait won a prize in the exhibition of the Bombay Art Society.

His musical talent was nurtured by his maternal aunt Miss Cooma Panday, who had a valuable stock of records of classical Western music, including Beethoven, Mozart, Bach, Haydn, Schubert and others. With his younger brother Jamshed and another cousin, Homi would spend hours in concentrated silence, listening to the symphonies of the masters played on an old-style hand-wound gramophone. Though he himself did not play or compose, music had an important place in his life till the end. He tried his hands at instruments too. He took violin and piano lessons. (Lady Meherbai Tata was an accomplished piano-player.) But he could not pursue these hobbies further, as he got increasingly immersed in his studies.

Apart from his forays in artistic and scientific domains, mention must be made of another hobby that he got engaged in. It was playing with "meccano", the then rare engineering toy. Parts are assembled here to make small models of different machines. Homi used to spend hours in playing with the "meccano" and showed a marked preference for trying to build up models other than those shown in the accompanying booklet.

There are always a few individuals, however small in number, in any society with such multi-faceted talents in germinal form. But very often circumstances do not allow these germs to sprout. Bhabha was certainly fortunate enough to be born in a family, which could readily recognise these talents and also could afford to supply the necessary conditions for nurturing them. Bhabha was fortunate in another way, too. And that was much more significant from the point of view of his future career.

This was his growing up in the house of his aunt, Lady Tata. The Tatas had maintained good relations with the British rulers. But at the same time, they were on equally good terms with the national leadership of the independence movement. Mahatma Gandhi, Sardar Patel, Motilal Nehru and Jawaharlal Nehru, and other bigwigs of the National Congress used to visit the Tata house when in Mumbai. Tata and Bhabha families were even on friendly terms with the Nehru family. The outcome was that Homi in boyhood got the opportunity to see the national leadership from close quarters, and even to listen to their conversations and discussions. He had heard Gandhiji when the latter stayed with the Tatas at the time of the launch of the first Civil Disobedience Movement. Even for ordinary men and women such encounters prove to be enlightening. For a much more sensitive person it can be still more valuable. Sir John Cockcroft has specially mentioned another aspect of the influence of the Tatas on Bhabha's formative years. The Tatas have invested in basic industries like steel, heavy chemicals, and hydroelectric power projects, which form the foundations of wider spread industrialisation down the stream. Being privy to the discussions of such projects had an important effect on Bhabha, as per Sir John.[1] Later, as science builder and organiser in independent India, Bhabha showed a broad vision and the capacity to think and organise within wider national and international context, which is not common to all great scientists. The roots of this can be traced partly to his boyhood exposure.

Homi passed the Senior Cambridge Leaving examination in 1924 with distinction. The next step was, naturally, going to England for graduation at Cambridge. But that was not immediately possible, because he was only fifteen, and the minimum admission age for Cambridge was eighteen. So he spent the academic year 1925-26 at the Elphinstone College, doing F. Y. (Arts), and then 1926-27 at the Royal Institute of Science in the first year B.Sc. Class. The Director was Prof. G. R. Paranjape, the first Indian director of the institute. Prof. Tawade, who later became the Vice-Chancellor of Karnataka University, was one of his physics teachers. But these two years were only the waiting period before he could proceed to Cambridge.

In October 1927, having reached eighteen, he left for England.

2
MAKING OF A PHYSICIST— THE CAMBRIDGE YEARS

Gonville and Caius College, Cambridge

Homi Bhabha joined the Gonville and Caius College in 1927. He was not a stranger here. Sir Dorab was an alumnus earlier, and had given a donation to it. Bhabha's joining Cambridge was just a part of the Oxbridge tradition of the extended family for two generations. His mathematical abilities and creative play with the meccano had raised hopes in the minds of his father, and Sir Dorab that this boy was fit for heading the Jamshedpur steel works of the Tatas, and accordingly Homi had joined for the Mechanical Sciences Tripos in deference to their wishes.

But the times were not normal at Cambridge when Bhabha had arrived. A scientific revolution in physics was in full steam in Europe, and the Cavendish Laboratory in Cambridge was at the centre of this raging storm. It was two-pronged advance. On the theoretical front rapid developments were taking place in quantum mechanics after the breakthroughs achieved by Heisenberg, Schrödinger, and Dirac with Bohr, de Broglie, Pauli, and others just following closely behind. And, on the experimental front, under the dynamic leadership of Lord Rutherford, new discoveries in nuclear and atomic structure of matter were being made in rapid succession. This had created a highly charged atmosphere in Cambridge around the physics department, and especially the Cavendish Laboratory. Not only other disciplines, but, even other branches of study in physics were completely overshadowed and dwarfed. P. A. M. Dirac had later described this highly creative period as one in which "second rate minds were able to do first rate work." Rutherford, the experimentalist and Dirac, the theoretician were then the two tallest heroes in Cambridge among a galaxy of tall scientists. And during his very first year Bhabha had attended Dirac's lectures.

For a first-rate and ambitious mind like Bhabha's the aura and the ambience was irresistible. Within a year after joining the Gonville and Caius College, he dashed off an impassioned letter to his father. In this letter, dated 8 August 1928, he declared: "I seriously say to you that business or a job as an engineer is not the thing for me. It is totally foreign to my nature and radically opposed to my temperament and opinions. Physics is my line...I am burning with a desire to do physics...I have no desire to be a

"successful" man or the head of a big firm. There are other intelligent people who like that and let them do it...I, therefore, earnestly implore you to let me do physics."

This impassionate plea was not enough to convince father, who was quite familiar with the work and lifestyle of Indian academics because of his close association with the Indian Institute of Science, Bangalore, and probably did not have the faintest idea of the charged atmosphere in the domain of physics at Cambridge. The father expressed his doubts, and with more exchange of letters, father and son struck a deal. If Homi got a first class in engineering Tripos, father would finance his stay for two more years for him to do the Mathematics Tripos. And so was avoided any resentment and bitterness on both sides. Homi did his Mechanical Sciences Tripos with full vigour and concentration, obtained a first in 1930, and straight away joined for the Maths Tripos, which, too, he cleared with a first in 1932. And thereafter he plunged into research in physics.

Here it would be instructive to take a look at Bhabha's earlier record in India. As such, he was equally interested and proficient in both sciences and arts during his schooling period. He certainly had a mathematical bent of mind, and had studied the theory of relativity on his own at the early age of 15 or 16. But his interest in arts and music was equally deep and, moreover, was more highlighted. He took painting lessons and won prizes for his oils; he enjoyed and appreciated classical European painting and Western music. He also played violin and piano. All this was in the family tradition, and so appreciated by everybody concerned. But the mathematics-physics aptitude was perhaps exceptional in the family immersed in business and industry, and might have remained somewhat dormant, or not prominently projected or expressed. It was the exposure to the excitement in the Cavendish Laboratory that brought out this facet boldly to the forefront, and he resolved, then and there, to focus his genius in this field. He had been hovering at the junction, indecisive of which path to tread, and here in Cambridge the choice crystallised before him. To paraphrase his own words, one can say—there were many artists who liked to paint and they did it, but Bhabha's turning away was definitely beneficial to science in general, and to India in particular.

One must note here in passing that a similar choice confronted him more than a decade later, and he opted for institution-building and organising science, in preference to a purely scientific career. There are only a few multi-talented individuals, but even fewer with the foresight to make the right choice at the right historical junction.

Plunging into Research

1932 was the miracle year for the Cavendish Laboratory. James Chadwick had demonstrated with very delicate and intricate experiments the existence of the neutron, which was predicted theoretically earlier, but because of its lack of electric charge this particle within the nucleus with mass equal to the mass of the positive proton, was dodging the experimentalists for long. Cockcroft and Walton had produced transmutation of light elements by bombarding them with high-speed protons from an accelerator, thus taking the first step in realising the age-old alchemical dream of converting one element into another. Though it was not gold, ultimately their success would result into things worthier than gold. During the same year, P. M. S. Blackett and Occhialini obtained clear and beautiful photographs in a magnetic cloud chamber of electron-positron pairs and their showers produced by gamma-radiation. It was a revelation to the eye of what Nature

had till then kept hidden. The same year, Carl Anderson in the USA had proved the existence of positron (anti-particle of electron with same mass and equal but positive charge) in cosmic rays. Positrons were theoretically predicted by Dirac in 1930, so this too, was a morale-booster for Cambridge physicists. In this exciting and charged atmosphere, Bhabha's initiation into research took place. His performance in the Maths Tripos earned Bhabha the Rouse Ball Travelling Studentship. This made it possible for him to visit important research centres on continental Europe. He visited Bohr's institute at Copenhagen. It was the main hub of the theoretical developments with Bohr as the presiding deity and the driving force, just as the Cavendish Laboratory under Lord Rutherford was the centre of experimental developments. Copenhagen was like a holy place where aspiring and talented physicists made pilgrimage from all over the world to absorb some of the aura surrounding Bohr. And Bohr on his part was particularly fond of interacting with young minds. There were long discussion sessions that continued beyond the seminar room into the dining hall, overflowed into the garden walks around the institute extending on weekends into long treks in the countryside or skiing excursions. For young sensitive Homi it must have been as exhilarating as the presence of Rutherford and Dirac had proved back in Cambridge.

From Copenhagen he proceeded to Zurich to work with Wolfgang Pauli, another giant working on the forefront of the quantum revolution. Apart from his own original work, Pauli had the reputation of being a ruthless critic- and most physicists waited with bated breath to receive his comments on their work, and heaved a sigh of relief when Pauli nodded his acceptance. Bhabha wrote his first research paper in July 1933 under the guidance of Pauli. It was published in the *Zeitschrift fur physik* in October 1933. He was then 24. He also visited another leading figure, Kramers, in Utrecht. The same year he was selected for the Isaac Newton scholarship. In early 1934 he went to Italy to work at Enrico Fermi's Institute of Physics in Rome. Fermi was another leading figure and quite exceptional in being equally at ease with both experimental and theoretical physics. His 1925 theoretical work on the quantization of a perfect mono-atomic gas had led to the famous Fermi-Dirac statistics; around 1930-31 he had given a theory of Beta (electron) decay, and his experimental work on the bombardment of metals using neutrons was to lead to the identification of a new radioactive element in 1934, and in 1936 he was to discover that slow neutrons bombardment leads to nuclear reactions. He was to get the Nobel Prize for Physics for this in 1958, and later in the USA working on the Manhattan Project for the atom bomb he was to be the main spirit in producing the first controlled fission chain reaction on 2 December 1942. Bhabha's third research paper, which was started with Hulme in Cambridge, was completed here. That year he received his Ph.D. from Cambridge. His adviser was R. H. Fowler, the son-in-law of Rutherford. Incidentally, Fowler was also the adviser to S. Chandrasekhar.

Dr. Bhabha continued to be based in the Gonville and Caius College. In 1936 he was selected for the Senior Studentship of the Exhibition of 1851. This year he visited the Wills Physical Laboratory at Bristol and worked with a senior scientist, Walter Heitler, on the problem of cosmic ray showers, developing the now-famous Bhabha-Heitler cascade theory. The result was announced in July 1936 in a letter to the journal *Nature,* and the full article running into 27 pages was published in 1937 in the Proceedings of Royal Society. This work at the age of 27 earned Bhabha a permanent place in the textbooks on cosmic ray physics. Next he turned his attention to another aspect of cosmic

rays and worked on meson physics. This continued till June-July 1939. By then he had procured a Royal Society grant to work at Manchester in the laboratory of P. M. S. Blackett. But before taking up that assignment he returned to India on vacation.

Scientific Contributions in Cambridge

As mentioned earlier, the decade from 1925 witnessed revolutionary developments in modern physics centred around the structure of atom. The theory of quantum or wave mechanics was developing rapidly with breathtaking speed. With new instrumentation, more refined techniques and meticulous efforts on the part of the experimentalists, a flood of data was becoming available.

In this scenario the task of the theorist was subject to a two-fold division. Lord Penney in his biographical memoirs of Bhabha has put succinctly as follows: "...they either strive to advance basic theory which is very far from logical and mathematical completeness, or attempt to relate observed phenomena to predictions of the theory such as it was. Successes in the latter direction were of course the main justification for faith in the correctness of the theory."

Bhabha embarked on the latter course in his research. His conversion from engineering to physics in the very first year in Cambridge was induced by Dirac's lectures, and Dirac was a kind of role model for him. He had great faith in Dirac's theory and strove to apply his relativistic wave equation to explain the observed phenomena. He naturally chose to explore the then high-energy range. At that time, man-made accelerators were at a primitive level and really high energies were encountered only in cosmic rays. So, he turned his attention to cosmic ray physics and elementary particles, which was then a relatively neglected field, while many were busy with the theory of nucleus. Bhabha's first research paper, written at Zurich, when he was with Pauli, dealt with absorption of cosmic rays by matter. Cosmic rays are streams of very high-energy particles and gamma radiation incident on earth originating from the sun or even from outside the solar system. There are two components of cosmic rays observed on ground or in the atmosphere, classified as "soft" and "hard". The soft component is relatively less penetrating, consisting of electrons and photons, while the hard component is much more energetic and penetrating. Bhabha's earlier work dealt with the soft component, what can be described as positron theory. When a positron (e+) collides with an electron (e-), they annihilate each other and are converted into electromagnetic energy in the form of photons (packets or quanta of radiation). Bhabha developed a theory of this process. Then he turned to the reverse problem of electron-positron pair production in the collision of fast moving charged particles, when electromagnetic energy materialises into an electron and a positron. He also worked out the scattering of positrons by electrons. This is known as Bhabha scattering, and his results are now accepted as standard and routinely used to calibrate beams at large accelerators where positron or other anti-particle beams are produced. His 1936 collaboration with Heitler dealt with the problem of particle showers. It was observed that when a very fast, highly energetic electron interacts with matter, it loses energy by various processes during its passage. Cloud chamber photographs had revealed that a primary electron passing through a lead sheet produces a shower of particles. Earlier theoretical attempts, by Heitler with Hans Bethe, to calculate the loss of energy had not yielded answers tallying with the experimental observations. Bhabha and

Heitler now successfully solved the problem with their theory of cascade. The incident high-energy electron is scattered by a nucleus, which slows it down, effectively putting a brake on the speeding electron, while at the same time diverting it somewhat from its original direction of travel. The decrease in the kinetic energy of the electron appears as a radiation photon and it is termed as braking radiation (Bremsstrahlung). This high-energy photon later produces an electron-positron pair. The electron produces another braking radiation photon, and the positron, when it annihilates some other electron, gives rise to a pair of energetic photons, and so on, till the energies fall below a threshold. This cascading effect produces a shower of electrons, positrons and photons, which widens as it spreads downwards. In a plate of lead within a cloud chamber the whole shower is compressed and is contained within a small volume, because lead has a very high density. In nature, where the primary electron is incident on the upper atmosphere and the air has very low density compared to that of lead, the shower can reach to the ground extending over a large area. The Bhabha-Heitler model was successful to a large extend in explaining the experimental observations. Later in India, Bhabha was to do further refinements of this cascade theory.

This was the work related to the soft component of cosmic rays. But charged, ionising particles were also observed that could penetrate more than a metre of thickness in lead. This was the hard component. The theory predicted that no electron of any reasonable energy could penetrate more than 15 cm of lead, unless Dirac's theory broke down at very high energies. Bhabha was not prepared to concede this, and he concluded that the particles must be some heavy ones with mass about 100 times the electron mass. No such particles were actually known then, and it was a bold and original conjecture on his part. Two years earlier, in 1935, the Japanese physicist Hideki Yukawa in his theory of nuclear forces had postulated particles with mass lying between that of the electron and the much heavier (2,000 times) proton. But Bhabha was unaware of that and had put forward his conjecture independently. When his attention was drawn to Yukawa's work, he identified the U-particle (Yukawa particle) with the "heavy electron" in the hard component of cosmic rays. And he developed in 1938 a theory of nuclear forces based on these U-particles.

Meanwhile, the American experimentalist Carl Anderson, the discoverer of positron, had detected such a heavy particle and named it "mesotron". Bhabha wrote a letter to *Nature* in February 1939, arguing that since the Greek word for middle is meso, it would be more logical to call the new particle "meson". Bhabha's baptism of the new particle has been accepted. He also pointed out a possible feature of this new particle—a possible test of the time dilation phenomenon. Einstein's special theory of relativity had predicted that time slows down for a fast moving body. Of two identical clocks, if one starts moving relative to the other at rest, then, when a minute passes in the one at rest, the moving clock registers less than a minute. Of course, it is a rather weird phenomenon. For an observer on the moving clock, the clock at rest is moving in the opposite direction and its time undergoes dilation. For normal velocities we are used to, including supersonic aeroplanes, the effect is next to nil. It becomes noticeable only when the speed becomes comparable to that of light. This is the case with high-energy elementary particles. Bhabha argued that a meson at rest may disintegrate spontaneously, having a certain half-life (the period in which half the particles disintegrate). So the meson can be considered a "clock", and, therefore, it follows that the time of disintegration is longer (as

seen on ground) when the particle is moving. Since the meson in cosmic rays moves with very high speed, the time dilation effect is large enough to be measurable, and since has been experimentally confirmed.

All this indicates that Bhabha was working very efficiently at the cutting edge of the rapidly advancing research in Cambridge. As a theorist he very competently applied the relativistic Dirac equation to the problems in quantum electrodynamics. According to Lord Penney, among the successes of Dirac's theory, those achieved by Bhabha were most important.

There were many bright stars in the Cambridge firmament at that time, and Bhabha had effectively managed to shine with them. He had proved his mettle and showed that his callow rhetoric at the age of 19, expressed in the letter to his father, had solid substance behind it. The peer appreciation was reflected in his being invited to be a member of the Kapitsa Club. The Russian physicist Pyotr Kapitsa was the ace student of Lord Rutherford. Every Tuesday evening a group used to meet in Kapitsa's room to discuss the latest scientific developments. It was a private, informal gathering, strictly for chosen invitees. Any Tom, Dick and Harry could not attend it. It was rumoured that many revolutionary breakthroughs were first announced in these meetings, and then became known to the scientific community at large. Sir John Cockcroft has especially noted in his memoirs of Bhabha the lecture he gave before the Kapitsa Club on 1 February 1938.

An interesting episode highlights the esteem in which Bhabha was held by his seniors. James Chadwick, the discoverer of neutron in 1932 and the Nobel Prize winner in 1935, was at Liverpool, and wanted to hire an academically active theoretician for the post of a Reader in Theoretical Physics. He first thought of Heitler who was a lecturer in Bristol, but changed his mind as appointing a German would have created problems with some of the high-ups in the university. Turning to Cambridge he approached Bhabha at the Gonville and Caius College.

Bhabha saw Chadwick, who was very much pleased with him, but did not employ him. The reason— "Bhabha was too good. The post required some teaching to be done, and the quality of students was not the quality of students in Cambridge, and I thought that much of it would be drudgery to a man like Bhabha, who was a most exceptional man. He was a painter and a poet and had extremely wide interests...not merely interests but far more than that—and I did not feel that however much I like him it was fair."

The membership of the Kapitsa Club had wider importance beyond scientific work. He came into close and friendly contact with a group of chosen scientists, and the composition of the group was international. Within a few years, when he was to embark upon his efforts to create a centre of excellence of fundamental research, and to build the Indian atomic energy programme, this acquaintance with top scientists and the experience of the ambience of excellence was to prove a great asset to him as an institution builder and science organiser.

The World beyond Physics

Though physics was his first love, Bhabha's prolifically intense personality was multi-dimensional. Raman had later described him as a truly renaissance man. Even though he was working on the forefront of research, as he himself wrote to his younger brother, he

could not concentrate on his mathematical work beyond 4 or 5 hours a day; it was too exhausting. And he needed a break, and some diversion. After his mathematical physics, he had a lot of time on hand and talent too. It is a measure of his intensity of life that he did not fritter away the spare time just like that, but directed it towards his other talents which he had relegated to a secondary position, but had not abandoned, and most probably elevated them as a form of relaxation, or meditation in modem-day parlance.

Even in his undergraduate years, while doing tripos, he had engaged himself in extracurricular activities. He was a member of the rowing team, and took part in athletics. He also took to reading literature during this period, Shelley and Keats and Shakespeare being his favourites. These were, of course, new tastes acquired by him. His old passion for classical music was further refined in Britain and on his trips to the European continent where he attended many live concerts. He developed a lasting love for the city of Vienna. And he continued painting as an expression of his inner self. Many of his colleagues have commented about it, saying that he would have been an accomplished painter had he not turned a physicist. His paintings had found place in a London Exhibition. He had also managed to find time to paint the backdrop scenery for an opera and to design a cover in modern style for the college magazine.

Moreover, his creativity and energy outside physics was not confined to individualistic artistic expressions. It had a social dimension as well. This scion of an aristocratic family had also been deeply affected by the social upheaval that raged around him during the Great Depression, though personally he did not have to suffer any privations, nor even inconveniences. The rise of Hitler in Germany and the consequent persecution of Jews was an added shock. And that led him to join the Socialist Club. (It must be mentioned in passing that socialism was not totally alien to Tata family. Shapurji Sakalatvala, the nephew of Jamshedji Tata, had headed the Tata office in London and he was twice elected to the British Parliament—first time as an independent Labour MP and second time as a candidate of the Communist Party of Great Britain.) At that time J. D. Bernal, the noted crystallographer and another multi-faceted personally in Cambridge, had a deep influence on the scientific community there. Bernal was propagating very enthusiastically the doctrine of the social function of science (SFS). His contention was that science has deeply affected and changed society, but it is not an abstract, merely intellectual activity independent of the surrounding society. Science, too, like other activities, is rooted in society and moulded by society. To that extent the impact of science is dependent on the society and those who control the societal activities. History has demonstrated that science has been used mainly by the powers-that-be for their benefit, while the benefits that have percolated to the general public are more like by-products. With all the breakthroughs in science and technology in the Western world, it was simultaneously rocked by World War I, and then, the Great Depression. This was because society was governed by capitalist and imperialist forces whose main motive was private profit-making and colonial exploitation. While scientific knowledge was misused by the powers-that-be to these ends, it also affected science itself, not allowing its full potential to flower. Modern science has the potential, not only to solve the present problems of poverty and unemployment but, to bring in untold benefits to the entire humanity. To achieve this, scientific development must be consciously planned for the benefit of the entire society. This was the social function of science that Bernal was forcefully promoting in the thirties and was finally published in a volume of the same title in 1939.

A large number of scientists in Cambridge, as well as in other centres, were influenced by Bernalism, and Bhabha was among them.

The Bernalist influence, too, made *a* significant impact on his future career, and the role he played in the science and technology build-up in independent India.

In a sense the formative years in Cambridge made a great physicist out of him, and at the same time, had sown the seeds of an institution builder and science organiser who would mould the future of Indian S & T field.

3
TAKING ROOTS IN INDIA— THE I.I.Sc. INTERLUDE

Bhabha was on a vacation in India in 1939 when World War II broke out in Europe. Before leaving Cambridge he had procured a Royal Society grant to work at Manchester in the laboratory of P. M. S. Blackett. The outbreak of war put a stop to it. It was clear that even if he had taken the risk to reach England by some circuitous route, it would not have been possible to resume his work from the point where he had left it.

The situation had undergone a drastic change. All the normal research in the UK had almost come to a halt. Most of the scientists were either called for war duty directly, or had switched over to war-related research. The situation on the European continent was even worse. Already with the rise of Hitler to power in 1933, the exodus of Jewish scientists from Germany was under way. With the beginning of war its rate accelerated, and its scope spread over the rest of Europe. The worst consequence was that the international bonhomie among scientists, so characteristic for more than a decade, was suddenly annihilated. Not only visits to different centres became difficult, even free exchange of ideas and news through publications and by correspondence came to a stop. The war created walls of secrecy between scientists from different nationalities.

Keeping up with Research

Under the conditions Bhabha had just to wait and watch. He obviously tried to make the best of his enforced extended vacation. There was a lot of unfinished work he had on hand when he left Cambridge, and he could easily put it in a finished form from India. And there were a number of universities and institutes eager to invite him to lecture on his specialisation, cosmic ray physics.

In the first year, he divided time between Mumbai, his home town, and Bangalore, his second home town, where his family had a long-time, close association with the Indian Institute of Science. In the latter half of 1939 he delivered three lectures on Cosmic Radiation at the Bombay University, a summary of which was published in the November issue of the University journal. Two of his research papers were published in the Proceedings of the Indian Academy of Science, Bangalore. Both the papers were received in October 1939 and were communicated by C. V. Raman himself. One was titled “The Production of Bursts and the Spin of Meson.” This was a three-page paper with H. Carmichael and C. N. Chou as joint authors. The preface carries a note that this work was done in Cambridge in June and the delay in publication due to the outbreak of

war had prompted the short note. The detailed calculations and discussions were to be published elsewhere. The second paper was a classical theory of electrons and carries the address of Gonville and Caius College. Earlier that year a paper on classical theory of meson was published in the Proceedings of Royal Society, London and communicated by Dirac. It shows that after his work in quantum electrodynamics Bhabha had turned to classical theories of meson and electron at Cambridge itself. This work is described as more in the nature of a pure and mathematical theory than the earlier more phenomenological theory. This slight change of track must have made his enforced stay in India more bearable after losing the charmed ambience of Cambridge.

Another point that emerges from this is that Bhabha had established some rapport with C. V. Raman, who was then heading the Physics Department at I.I.Sc. Raman had earlier in 1933 come from Calcutta to Bangalore as the first Indian Director of I. I. Sc. Due to differences with and opposition from other faculty he was forced to step down in 1936, but had stayed on as Head of the Physics Department. In 1936 J. C. Ghose, the eminent chemist from Kolkata, was the Director. Raman, it appears, was somewhat keen on Bhabha joining I.I.Sc. He had ambitious plans for research at his department, particularly in nuclear physics and cosmic rays. Earlier he had succeeded in bringing Max Born, the teacher of Heisenberg and a collaborator in developing Matrix Mechanics, as a Professor to I.I.Sc. Born had to leave Germany after Hitler's rise to power, because his wife was Jewish. But Raman's move got embroiled in controversy, with the result that Born left for Edinburgh in the UK after a brief stay of about one and a half years, and Raman stepped down from the Directorship.

In 1940, the American physicist Robert Milliken, famous for measuring the charge of the electron very precisely, was in Bangalore with his younger colleagues, Neher and Pickering. They were on a global tour to measure the latitude variation of primary cosmic rays using flights of rubber balloons. Bangalore lies very close to the geomagnetic equator, and so the flights were launched from the Bangalore observatory. Other experimental flights in India were conducted from Agra and Peshawar. Milliken's visit impressed upon Raman with the possibility of research in this field. Besides, Vikram Sarabhai was then working with Raman on his Ph.D. thesis in cosmic rays. Sarabhai, ten years younger than Bhabha, was a Ph.D. student at Cambridge and was also stranded in India due to the war. He had obtained special permission from Cambridge University to continue his experimental work under Raman's general guidance. In this situation, the presence of Bhabha with his highly recognised theoretical work in cosmic ray showers and elementary particles, must have rekindled Raman's hopes of starting research in this emerging area at Bangalore. Though funding during the war period was harder to come by, Bhabha's close links with the Tatas was a strong ray of hope.

On the part of Bhabha, too, Bangalore was the most suitable choice under the circumstances, and he decided to settle there for the time being. His letter in *Nature* published in March 1940 on classical theory of dipoles carries the address as "at present at I.I.Sc." Another 23-page-long paper in the Proceedings of the Indian Academy of Sciences in April 1940 says— "at present at Dept. of Physics, I.I.Sc." He was looking for some arrangement to be worked out, and in the latter half of 1940 the Dorab Tata Trust sanctioned a special grant under which he was appointed as "Special Reader in Cosmic Ray Research Unit" at I.I.Sc.

Bhabha's work habits were rather peculiar. He stayed in the West End Hotel, a posh hotel, which had been his favourite during earlier visits to Bangalore. He used to work late in the night. So his day started rather late. He would come to the Institute in his big car in the afternoon and would stay till late evening working in a small room. His work had now become more mathematical and theoretical, less dependent on experimental data, which, in any case, was not readily available to him as it was in Cambridge. He had got in touch with a mathematician, B. S. Madhava Rao. Rao had worked with Born during the latter's brief stay in Bangalore, and was apparently the first to introduce in India the teaching of Group Theory, a new branch in modern algebra. Bhabha had heard about Rao from Born when he had visited Edinburgh in 1937. Once in Bangalore, he got in touch with Rao. On many evenings they had long discussions in Rao's home. Their collaboration resulted into a paper on "scattering of charged meson", completed in December 1940 and published in the Proceedings of Indian Academy of Sciences in 1940. This was Bhabha's first joint paper in India. Unfortunately the collaboration did not last longer. But one must note the remark made by Lord Penney in his Biographical Memoirs of F. R. S. that in his Bangalore period Bhabha displayed knowledge of and skill in methods of modern algebra to a degree unusual among theoretical physicists of the time.

In 1941 Bhabha was elected the Fellow of the Royal Society, London, Raman being one of the proposers of his nomination. Even today this is considered a signal honour among Indian scientists. In those days of British Raj it was obviously more so. At the young age of 32, it enhanced Bhabha's status to a considerable extent

At around the same time he was being considered for the Adam's Prize by the Cambridge University, and was invited to write a monograph on elementary particles. He wrote the thesis titled *The Theory of Elementary Particles and their Interaction, for* which the Adam's Prize was awarded in 1942. According to Prof. M. G. K. Menon, though Bhabha received many awards and honours in his life, his election to the Fellowship of the Royal Society and the award of Adam's Prize occupied a special place in his mind. In the same year he was promoted to a full Professorship in Cosmic Ray Research at the I.I.Sc.

By now, scientists from other centres were gravitating to Bangalore to work with him. D. Basu and S. K. Chakraborty were the first two to arrive. D. Basu was a colleague of Meghnad Saha at Calcutta (now Kolkata), and Saha had arranged for his prolonged stay at Bangalore. A joint paper on the theory of particles was published in 1942. With S. K. Chakrabarty Bhabha started working on the refinement of the cascade theory he had earlier pioneered with Heitler in the UK. A paper titled *Calculations on Cascade Theory with Collision Loss* was published in 1942. Two more joint papers on the theme appeared later on.

While on the research front he was thus getting settled, on the family front he received a great shock. Around the middle of 1942 Homi's father died. Homi's family, with his parents and younger brother Jamshed was extremely close-knit. The death was highly disturbing to the mother and her sons. It took Homi a few months again to concentrate on his research.

In 1943, he had a brilliant collaborator in young Harish Chandra. They worked for about a year or so, on the mathematical theory of point particles. This resulted into two

papers published in the Proceedings of the Royal Society in 1944 and 1946. Harish Chandra soon left for Cambridge; worked with Dirac; switched over from physics to pure mathematics. He later joined the Institute for Advanced Studies, Princeton, USA and achieved great fame as one of the leading mathematicians of the 20th century.

Meanwhile, Bhabha's work in Cosmic Ray Research Unit had taken an interesting turn. In his theoretical work he had already turned from phenomenology to more mathematical and pure theory. Partly this was due to the circumstances. The experimental data that was pouring in during his Cambridge years from the experimentalists working with cloud chambers and Geiger counters and new accelerators was no longer coming forth. Though mathematically minded, Bhabha was more of a physicist than a pure mathematician. His ultimate reference frame was Nature herself, the objective reality out there. However elegant and beautiful a theory may be, and however aesthetically satisfying the results he obtained by applying the theory to certain concrete problems pertaining to electrons, protons or mesons, their correctness would be judged only against observations. That was absolutely essential if one were to do serious science, as he had learnt from his hands-on experience in the UK and Europe. And since there were no facilities in India to conduct the kind of experiments he had depended on in Cambridge, he decided to take steps to fill up this lacuna, albeit on a modest scale. The trait of a builder and organiser that had regressed in Cambridge, when he switched over from engineering to physics, probably resurfaced in the changed circumstances in war-isolated India.

Bangalore, as we have seen, is in an advantageous position for cosmic ray experiments because of its proximity to the geomagnetic equator, its latitude being 3.3 degrees North. But even the basic equipment for the purpose was not available. So Bhabha decided to build the devices indigenously. Expertise in electronics and other instrumentation was required, and somehow he was able to bring the required staff together. A unique Geiger counter telescope and a quadruple coincidence G-M telescope were designed for studying the penetrating component of cosmic rays at high altitudes. The rubber balloons used by Milliken were not available to him. But he was resourceful and influential enough to overcome this barrier. At the time, the 84th Air Depot of US Air Force was stationed at Bangalore. They had high-flying planes. Bhabha managed to get permission for sending his telescopes up to heights of about 30,000 feet. On 26 and 28 December 1944, two flights were conducted and half-hour exposures at various altitudes from 5,000 to 30,000 feet were obtained. These were the first measurements of high-altitude intensity of mesons obtained at equatorial latitude. A few months later subsequent flights took place. The results were analysed and published, two papers appearing in 1945 and one in 1946. S. V. C Aiya, H. E. Hoteko, and R. C. Saxena were the other three authors of the joint papers. Bhabha also built at I I Sc. a 12-inch diameter circular cloud chamber, like the one Blackett had built at Manchester. In 1945 it was moved to Mumbai. The scattering characteristics of mesons in the penetrating component of cosmic rays were studied with this cloud chamber.

Trying one's hands at experiments while continuing with theoretical work would have been a good achievement for any good scientist. But Bhabha was at the same time deeply engaged in a few other areas, too.

Getting to Know the State of Indian Science

Bhabha's reputation had preceded his arrival in India, and as a result he got many invitations to deliver lectures on cosmic rays and elementary particles in universities and institutions spread all over the country. Like Raman in Bangalore, Saha in Kolkata was also keen on inviting Bhabha. In December 1940, he delivered a series of ten lectures on cosmic rays at Calcutta University; and in February 1941, he was invited to be the President of the Mathematics-Physics-Chemistry Section at the 11th Annual meet, held at Agra, of the National Academy of Sciences, India (NASI). The NASI was organised by and was under the influence of Saha, while the Indian Academy of Sciences (IAS) with headquarters at Bangalore was the domain of influence of Raman.

When Bhabha was elected F. R. S., London in 1941, he became a member of a select group of Indian scientists. He was the 8th Indian F. R. S. and the 5th living one. Raman, Saha, Birbal Sahni, and K. S. Krishnan were the other Fellows, and at that time they were all in their 40s and 50s. Naturally, Bhabha attracted a lot of attention and hopes. During the year he was invited to lecture at Madras (now Chennai), Allahabad, and Lucknow Universities. And, in January 1943, he was made the President of Physics Section at the 30th Indian Science Congress held in Kolkata. He was offered Professorial Chairs at Allahabad University and at the Indian Association of the Cultivation of Science, Kolkata where Raman had earlier accomplished his Nobel Prize-winning research. There was another offer from Mumbai somewhat later. The Inspector General of Education of the then Bombay Province invited Bhabha to join the Royal Institute of Science (his earlier Alma Mater). The Government was prepared to provide additional funding to upgrade the status of the RIS to an institute of higher research.

By now the war had continued for more than three years, and the end was not in sight. In India he was the most sought-after physicist and, with the many offers open to him, he was in the enviable position of being able to exercise his choice. One must give this factor its due weight age. During those war years, academic jobs were very scarce. Even posts of lecturers were not available in sufficient numbers, and many persons with foreign degrees, and even Ph.D.s were constrained to work as research assistants on rather low salaries. Bhabha's exceptional merit was responsible for Chairs being offered to him, and precisely for this reason, he was reluctant to jump after them.

Bhabha had visited most of the major universities and institutions in the country and had come into personal contact with the main players in Indian science. With his first-hand experience of the European centres on the advancing front of research, he must have had some definite ideas about the kind of environment he wanted. The option of going back to Cambridge or Princeton or some such centre in Europe or the USA after the war was always open to him. He was willing to stay in India, but on his own terms.

Bhabha was already holding a full-time Professorship at I.I.Sc and did not accept the invitations to Allahabad, Kolkata and Mumbai. About his rejection of the Allahabad offer, he wrote to Birbal Sahni that he was not interested in university politics or in bossing over others, but he would like no interference from others too. He wanted to do research in peace and with full independence. He had a long meeting with the Vice-Chancellor of Allahabad University, who agreed to all his conditions, but he did not find the atmosphere in the physics department to his liking, and so rejected the offer. The same must be, more or less, true of the other offers. He probably did not want to work

within the university structure, as it existed then. (Remember that even Chadwick had not hired him at the Liverpool University because it would not have been fair to him.) He wanted a centre for fundamental research, a new institution to start with a clean slate. That he could think about such a move, was due to his Tata legacy. It was within the realm of the possible.

A few words about the divisions in Indian science scenario at the time are in order here. As mentioned earlier, there were two academies functioning on the national level—the IAS and the NASI, dominated respectively by Raman and Saha. And there was one more body, the NISI (National Institute of Sciences, India) formed by the Indian Science Congress Association. Though most of the scientists were members of all the three bodies, the existence of three separate bodies naturally made it difficult to represent or project the case of Indian science united to the government of India or other authorities. There was some regional flavour, too, associated with the IAS and the NASI with two strong personalities dominating them. Bhabha, with some others, was for a unified academy for the entire country and with a more democratic constitution.

Things came to a head in the latter half of 1943 when the visit of Prof. A. V. Hill, the Secretary of the Royal Society, was scheduled to take place at the end of the year. Hill was invited by the Secretary of State, India to review the state of Indian science, and submit a report to the Government of India with recommendations for its development. There was a feeling in Britain that the science and technology potential in India was underutilised. Of course, by utilisation it was meant the utilisation for the British war effort. Prior to war the Government funding to S & T was paltry and mostly channelled to areas like the various surveys (geological, biological etc) that were more useful for the exploitation of Indian natural resources, rather than intellectual enlightenment and material prosperity of the Indian people themselves. However, the prospect of enhanced Government funding did create excitement within the camp of scientists, always starved of funds. Hill was to meet leading scientists, and to visit various universities to apprise himself of the problems facing them. He was to inaugurate the Indian Science Congress in Delhi in January 1949. As a representative of the Royal Society, Hill was received with great warmth and cordiality despite the strong anti-British feelings then prevalent in the wake of the Quit India movement. There was talk of some kind of Royal Charter being granted to a representative Indian academy of science, like the one the Royal Society, London had, provided certain constitutional points were taken care of. A unified academy representing the entire scientific community in India would have been in a better bargaining position when negotiating with the Government, and so Bhabha was in correspondence with other senior scientists to bring this about. But his efforts were fruitless.

There was another interesting sidelight to Hill's visit. At that time there were four Indian Fellows of the Royal Society namely Birbal Sahni (1936), K. S. Krishnan (1940), Homi Bhabha (1941), and S. S. Bhatnagar (1943), who had not undergone the Admission Ceremony for elected Fellows. Traditionally the new Fellows had to go to London and sign in a special volume made of parchment leaves, during a specially conducted admission ceremony. Over the three centuries, quite a few elected Fellows, who could not visit London, had not signed in the book, which had Newton as one of the earliest signatories. As a very special gesture, the Royal Society had decided to conduct the admission ceremony of the four Indians on Indian soil just before the inauguration of the

Indian Science Congress. A special parchment paper leaf was brought by Prof. Hill for the purpose. In the history of the Royal Society this was the first time that the ceremony was to be held outside the Society's premises in London. This exceptionally unique gesture was obviously for the diplomatic purpose of appeasement of the Indian scientific community. But this move, too, got entangled in disagreements, and in the end only Bhabha and Bhatnagar attended, Sahni and Krishnan abstained Bhabha was somewhat disillusioned by this lack of success of the scientific community to present a united front. But he was not disheartened. By that time he had decided to chart his independent course and had already taken some significant steps in that direction. But we would say more about that later. The important point was that he was not going to work within the university structure, nor was he getting aligned to any of the existing spheres of influence. He had got a good feel of the state of Indian science, its deficiencies and potentialities, and undercurrents too.

Discovering Indian Culture and History

While he continued with his research and spent time in coming to grips with the reality of Indian science, Bhabha accomplished another important feat. He acquainted himself with the wider Indian culture.

He had left India at the tender age of 18 and till then his upbringing was almost totally Western, both at home and in school, ("...fed on a diet of Beethoven, Chopin, Shakespeare, a culture entailing the use of knives and forks", as Prof. Bikash Sinha has described.) After that he spent 12 formative years in the UK and Europe. By now he was a mature scientist in his thirties. He had neither time nor opportunity to get familiar with the general Indian culture, history and ethos. He was unfamiliar with the ground realities in India with her wide and diversified socio-cultural spectrum. World War II and his own scientific achievements had now presented him with the opportunity to know his country of birth more closely with the mature understanding of the world that he had acquired in his European sojourn.

In Bangalore he became a member of a talented group, deeply interested in cultural matters. Vikram Sarabhai and Mrinalini were two young prominent members of the group. Mrinalini was an accomplished classical dancer from Kerala, and she was the sister of the famous-to-be Captain Laxmi of the Azad Hind Fauj. In this group Bhabha got acquainted with classical Indian music and dance.

In Europe he had become very knowledgeable with European architecture, painting and sculpture, both in the technical and the artistic sense. During his tours around the country, he grasped the opportunity to visit historical cultural sites like Ajantha, Ellora, Elephanta Island, Sanchi, Fatehpur Sikri, etc, which brought to his vision Indian architectural, sculptural and painting heritage. When in Delhi, he squeezed time during his busy schedule to visit Purana Quila, Lodhi Tombs and Hauz Khas to draw pencil sketches of the monuments.

For a gifted and quick-witted person like him, these exposures, however brief they might have been, were sufficient to anchor his Western and modern world-view in the rich cultural and historical heritage of India.

Committing Himself to Nation-building

Even more important for the future was his response to the rapidly changing national situation, on the verge of independence. In Bangalore, as well as in Mumbai, he moved in the intellectual circles with liberal, left-socialist leanings. During the reign of Com. Puran Chand Joshi, there was a liberal phase in the Communist Party of India, when a number of intellectuals, writers and artists had gathered around the party. Bhabha was one of them, associated with the front organisation "the Friends of the Soviet Union", For some time he was considered a sympathiser. He used to subscribe to the party paper, *People's War*. He had a Bernalist vision about the social function of science, and agreed with the Nehruvian vision of the modernisation of India by the use of S & T as tools for rapid development of our economically and socially backward nation. It must be stressed that a majority of scientists at that time, including Saha, shared these visions. Bhabha had the prescience to sense the impending period of fresh development in free India. And he had more definite and concrete plans in mind.

4

INSTITUTION BUILDING

The election as the Fellow of the Royal Society marked the peak of Bhabha's scientific career and the beginning of the other important phase in his life, that of an institution builder and administrator of science.

Having decided to stay back in India, his attention focused on establishing a centre of excellence in fundamental physics and pure mathematics in the country, on a par with the European centres he had been fortunate to visit. His ambition was to provide similar ambience and facilities to talented youngsters right in the country. This was not pure nostalgia for Europe. There was much deeper foresight as by now he was well aware of the tremendous importance future held for developments in nuclear science leading to a new source of energy. With independence looming on the horizon, the new institution was bound to make substantial contribution to the building up of a modern India.

Bhabha wanted to start with a clean slate, where he would have full freedom to implement his ideas without undue interference from others. And for help, he decided to turn to the Sir Dorab Tata Trust, which had been responsible for making his enforced stay in India tolerable and less frustrating, than it otherwise would have been, by funding his posts of Special Reader in 1940, and then of full Professor since 1942 at the I. I. Sc.

The informal and formal correspondence he carried out with the Trust, and some of the Trustees, deserves to be quoted at length for the light it throws on Bhabha's deep conception and comprehensive vision, not only about a research institute in fundamental physics and pure mathematics, but about the total development of Indian S & T field. A good deal of his success in and influence over the post-independence S & T development and institutionalisation can be traced to this vision and the vigour with which he pursued it

On 19 August 1943 he wrote an informal letter to J. R. D Tata, in which he stated that "...lack of proper conditions and intelligent financial support hamper the development of science in India at the pace which the talent in the country would warrant...It is one's

duty to stay in one's own country and build up schools comparable with those in other lands."

J.R.D.'s reply was encouraging: "...If you and/or some of your colleagues in the scientific world will put up concrete proposals backed by a sound case, I think there is a very good chance that the Sir Dorab Tata Trust...will respond. After all, the advancement of science is one of the fundamental objectives with which most of the Tata Trusts were founded, and they have already rendered useful service in the field. If they are then shown that they can give still more valuable help in a new way, I am quite sure that they will give it their most serious consideration. With J.R.D.'s positive reply, Bhabha earnestly set himself to work out a comprehensive scheme with a concrete, well-focused proposal. He seems to have explored many possible avenues for help for the new institute. At the national level, the Board of Scientific and Industrial Research (BSIR), established at the start of World War fl, was upgraded in 1942 to the Council of Scientific and Industrial Research (CSIR) under the stewardship of Sir S. S. Bhatnagar with whom Bhabha had a good rapport, and Bhabha was likely to have sounded Bhatnagar about possible help from CSIR. Since he had decided to set up the institute in Mumbai, the University of Bombay and the Government of Bombay Province were other planks of support, and he had already established contacts there.

And he was eagerly looking forward to the visit of Prof. Hill due in late 1943. The special gesture to conduct the signing-in ceremony for the four Indians recently elected Fellows of the Royal Society was certainly going to enhance Bhabha's prestige on the Indian scene. Taking advantage of this opportunity, Bhabha sought Hill's advice during two long meetings in Mumbai and Delhi, and received some valuable tips and insights into the functioning of research institutions in Britain.

With enough groundwork and thoughtful preparations, he wrote a formal letter, dated 12 March 1944, to Sir Sorab Sakalatvala, the Chairman of the Sir D. T. Trust. It was a proposal presented with a flourish and a comprehensiveness that he has to display time and again in future. It is worth quoting in detail. Bhabha wrote:

My Dear Sir Sorab,

The scheme I am submitting now is not one, which has been hastily conceived. It has been germinating in my mind for nearly two years, and I recently discussed it at length with Prof. A. V. Hill both at Delhi and Bombay. Prof. Hill, Senior Secretary of the R.S., apart from being an eminent scientist himself, is one who has a great and intimate knowledge of the organisation of science and scientific institutions in England, and the many valuable suggestions he made have been incorporated in the scheme as it stands now...I should like to make a few remarks to explain its background.

There is at the moment in India no big school of research in the fundamental problems of physics, both theoretical and experimental. There are, however, scattered all over India competent workers who are not doing as good work as they would do if brought together in one place under proper direction. It is absolutely in the interest of India to have a rigorous school of research in fundamental physics, for such a school forms the spearhead of research not only in less advanced branches of physics, but also in problems of immediate practical application in industry. If much of the applied research done in India today is disappointing or of very inferior quality it is entirely due to the absence of a sufficient number of outstanding pure research workers who would set the

standard of good research and act on the directing boards in an advisory capacity. (This was accomplished in Great Britain)... Moreover, when nuclear energy has been successfully applied for power production in, say, a couple of decades from now, India will not have to look abroad for its experts but will find them ready at hand. I do not think that one acquainted with scientific development in other countries would deny the need in India for such a school as I propose. The subjects on which research and advanced teaching would be done would be theoretical physics, especially on fundamental problems and with special reference to cosmic rays and nuclear physics; and experimental research on cosmic rays...For the location of the school I think Bombay would be the most suitable place in India...Once a lab like the one proposed is established in Bombay, it will be easier to collect further money for it in addition to what the Tata Trusts may give. I am confident that both the Government and the university would be prepared to give regular financial support.

I also hope that in time we shall receive liberal support from the Board of Scientific and Industrial Research whose avowed policy includes support for pure research.. .It would be in the interest of efficiency if BSIR decided to subsidise us to carry on the pure research, which is its intention to foster by paying us, say, 10% of the annual expenditure it contemplates on the projected National Physical Laboratory...Prof. Hill...repeatedly stressed the fact that all research has in the beginning to be built round a suitable man...The same principle has guided the financing of

research in Germany...The object has thus been expressed by the President (of Kaiser Wilhelm Society) Adolf V. Harnack, "The Society shall not first build and institute for research and then seek out the suitable man, but shall first pick up an outstanding man and then build an institute for him...

financial support from Government need not however, entail Government control...To quote Prof. Hill in his lecture to the Science Congress at Delhi—"Many of these independent scientific institutes in Great Britain nowadays are receiving substantial State support, but nearly always when this is done a buffer of some kind is interposed to prevent Government support from becoming Government control." (Hill's underlining).

I am convinced within five years we could make Bombay the centre of fundamental physical research in India...

I would like to add a few personal remarks. It was while I was on holiday in 1939 *that the war broke out and stopped my return to my job in Cambridge. For some time after that, I had the idea that after the war I would accept a job in a good university in Europe or America...But in the last two years I have come more and more to the view that provided proper appreciation and financial support are forthcoming, it is one's duty to stay in one's own country and build up schools comparable with those that other countries are fortunate in possessing...The scheme I am now submitting to you is but an embryo from which I hope to build up in the course of time a school of physics comparable with the best anywhere. If Tatas would decide to sponsor an institute such as I propose through their Trusts I am sure that they would be taking the initiative in a move, which will be supported soon from many directions and be of lasting benefit to India.*

With kind regards

Your sincerely

H. J. Bhabha

The Tatas responded promptly. On 14 April 1944, the Trustees of the Sir Dorab Tata Trust met to consider the proposal. Bhabha was a special invitee and joined the meeting in the latter half after his proposal was sanctioned in principle, and the discussion veered round to the modalities of implementation. The Trustees came to the decision that right from the start financial and administrative help should be sought from the Government of Bombay Province and the University of Bombay. Bhabha readily agreed to it.

With this successful accomplishment Bhabha had forged ahead of other senior scientists in the country, like C. V. Raman and M. N. Saha, who were also trying to establish their own institutes. He then plunged headlong into the business of setting up the institute.

As the aftermath of the Hill visit, a scientific delegation of leading Indian scientists was invited for a long, four-month tour of the UK, the USA and Canada scheduled from October 1944 till February 1945. S. S. Bhatnagar, M. N. Saha, J. C. Ghose, were among those who had accepted the invitation. But Bhabha opted out. He was no longer interested in the general survey of research institutes and universities in America and the UK which he was anyway quite familiar with. He had a specific and concrete task before him, and was in intense hurry to realise it.

There were a great many details to be worked out at the administrative and financial levels—finding a place to locate the institute in Mumbai, meeting persons in authority to realise their cooperation that he had visualised, transferring his office and equipment in the CRRU in I.I.Sc. from Bangalore to Mumbai, and, most important of all, to recruit suitable faculty. He particularly wanted a couple of senior researchers to give a head start to the new institute.

His very first and immediate step in the direction was to dash off a letter to his old Cambridge colleague, S. Chandrasekhar, who was then in the USA with the University of Chicago and was elected E R. S. earlier that year. In that letter dated 20 April 1944, he invited Chandrasekhar to join him as Professor. He wrote:

We hope to make the institute a centre of advanced research, especially of theoretical research in physics and mathematics in India. Your own line of research would certainly come within the scope of the scheme...The Professor's grade will be the same as that in the I. I. Sc., Bangalore, namely Rs. 1000-1250, though, of course, in special cases the starting salary may be anything above Rs. 1000...The leave and vacation rules will be more or less the same as in the Bombay University, enabling you to take 4 to 5 months' vacation a year which you may use for visiting foreign countries like USA and maintain contact there. I think you will hardly get more favourable conditions for carrying out your research anywhere and especially in India. For example, as you are aware, a Professor in an Indian university even under the most favourable and special conditions is over laden with routine work and in the Government research institutions one would be the victim of the usual red-tape with little understanding of the needs of scientific men.

He then proceeded further, echoing his view as he had stated in the letter to DTT:

I have recently come to the view that provided proper appreciation and financial support are forthcoming, it is the duty of people like us to stay in our own country and build up outstanding schools of research such as some other countries are fortunate enough to possess...It is our intention to bring together as many outstanding scientists as possible in physics and allied lines so as to build up in time an intellectual atmosphere approaching what we knew in places like Cambridge and Paris...[1]

This informal letter was followed by more exchanges. Chandrasekhar's initial response (letter dated 22 May 1944) was quite positive. Later he had some reservations and offered to come for a year, try things out and then decide on accepting a permanent position. By the start of 1946 he was given a formal offer. But somehow he chose to continue his stay at the University of Chicago.

Another senior appointment that materialised was of D. D. Kosambi as Reader in mathematics. A Harvard graduate, Kosambi was then with the department of mathematics in Fergusson College, Pune. A polymath, besides some research work in mathematics and statistics, he had gained considerable reputation as an Indologist, a Sanskrit scholar, and a Marxist intellectual. They had met in Bangalore and Bhabha had long discussions with Kosambi in Mumbai before he joined. The other member of the research staff was R. P. Thatte, who was earlier working with the *S.* P. College, Pune, teaching Radio Physics, as electronics was then known.

With Bhabha as Director, and Kosambi and Thatte as founding research faculty,, the new institute, named Tata Institute of Fundamental Research (TIFR) started functioning officially on 1 June 1945. The budget for the year 1945-46 was Rs. 80,000, comprising 45,000 from the DTT, and 25,000 from the Government of Bombay as recurring grant, and a grant of Rs. 10,000 coming from the Atmospheric Research Committee of CSIR, Government of India. Half the portion of a bungalow located on Pedder Road (presently Dr. Deshmukh Marg) in south Mumbai was rented for Rs. 200 per month. In fact, the bungalow, named Kenilworth, belonged to Bhabha's maternal aunt, Ms. Coomi Panday He was born here and his own office was located in the room of his birth.

With the help of Thatte, the equipment from CRRU, Bangalore was shifted to Kenilworth. Initially, the routine administrative work was being looked after by the D. T. Trust staff, sparing the time for Bhabha. Bhabha, while working on the development aspects, also busied himself in tidying up the work he had done at Bangalore. By December, the shifting of the lab was complete, and a few research papers had been published in his name bearing the address of the new institute—Tata Institute of Fundamental Research, Colaba, Bombay.

The Institute was formally inaugurated by Sir John Colville, Governor of Bombay Province, on 19 December 1945, and Bhabha proudly announced the work already at the credit of the Institute over the brief period of five months or so. This was typical Bhabha style, which would be seen often later.

Reviewing the state of elementary particles to date, Bhabha made a strong plea for fundamental research in physics and mathematics elaborating on its social and philosophical implication in the existing context:

Today we all know of the great importance of fundamental research and the recent release of atomic energy for practical purposes has brought forcibly before the public

how entirely new avenues can be opened up by fundamental research, namely, the study of nature for itself unhampered by any preconceived practical ends. The pursuit of science and its practical applications are no longer subsidiary social activities today. Science forms the basis of our whole social structure without which life, as we know it, would be inconceivable. As Marx said, 'Man's power of nature is at the root of history', and we have in our own time seen the history of our world shaped by those countries which have made the greatest scientific progress...The progress of science has also been of great philosophical importance in widening our mental horizon and showing the limitations of common sense ideas based upon the world immediately perceived by our senses...The study of cosmic radiation forms the main field of experimental research at this institute, though I hope and trust that in the near future experimental work will also extend to nuclear physics...To deal with this vastly increased range of human experience our philosophical and logical background has had to be widened and mathematics has provided the most powerful vehicle for the exact transcription of thought which cannot be expressed in words...I have touched on the philosophical aspects of science because ideas are some of the most important things in life, and men are prepared to suffer and die for them. Theoretical work, both the creation of new mathematics and the use of it in the description of nature, is to form an important part of the work of this institute...I am convinced that it is ultimately these exact theories, embodying in concentrated form our knowledge, which will form the basis of the mental discipline of the youth of future generations rather than the study of dead languages or limited or archaic forms of logic.

With such a flying and spirited start of TIFR, Bhabha busied himself with recruiting scientific workers. He had a two-pronged strategy. As an immediate measure he looked for help from the University of Bombay. Prof. Taylor from Wilson College, being interested in cosmic ray studies, offered voluntary collaboration. Father Rafael, the Spanish professor from St. Xavier's College, sent two of his younger colleagues, Vaze and Sahiar, to help with the assembling of the cloud chamber that had been brought from the CRRU, Bangalore. Later, the duo joined the Institute and assisted Thatte in indigenously constructing the G-M counters for radiation measurement.

In 1946 Bhabha spent nearly six months in Europe and the USA. The First Empire Scientific Conference was to be held in Britain, and Bhabha was *a* member of the Indian delegation. He arranged his own tour along with it and went around different research centres. First, he wanted to find out what was happening in fundamental research, particularly in atomic and nuclear science, now „ that some glimpses were percolating after the explosion of the bombs on Hiroshima and Nagasaki, and the end of the war. Though the secrecy regime was not over, Bhabha's close acquaintance and personal friendship with a number of key players in the Manhattan Project was sure to help him in getting guidance for the development of TIFR. Secondly, but no less importantly, he was on the lookout for promising Indians working abroad in various universities and research centres. He would enquire about their work and invite them to join his institute. And this was an open invitation. His success on this count was remarkable.

In late 1946, the CSIR sanctioned Rs. 40,000 for a high-energy accelerator. Ten appointments were made for the project. Bhabha wanted to purchase a Betatron from the American company General Electric. However, the deal could not be clinched as the US Government, in its attempt to maintain its supposed advantage over nuclear research, and its monopoly over atomic bomb, forbade accelerator export. (It is interesting to note that

around the same time Enrico Fermi at the Chicago University too, wanted to purchase the G. E. Betatron. But the company hiked the price, so Fermi cancelled the order and built the machine on his own.) However, the new young appointees with Indian degrees formed promising theoretical and experimental groups. R. R. Daniel, G. S. Gokhale, Alladi Ramakrishnan, B. V. Sreekantan are some of the names who did important work and have contributed to Indian science. Sreekantan later became the Director of the Institute.

Researchers from other universities and institutes also gravitated to TIFR, initially for short periods on leave and later joining as regular faculty. For example, D.Y. Phadake, a Ph.D. from Germany, working in a technical institute in Mumbai, Prof. Dharmatti from the R.I.S. Mumbai joined the TIFR and A. S. Rao came from the Benaras Hindu University.

Bhabha's persuasive tour of 1946 had also started bearing fruit. From the USA came two mathematicians, Pesi Masani and K. Chandrasekharan. The latter, who came from the Institute of Advanced Studies, Princeton, was instrumental in developing the School of Mathematics, which soon attained international status, and is now a leading centre on the world mathematical map. Drs. Raja Ramanna and B. V. Thosar joined the School of Physics after returning from the UK. Many other names, who have made substantial contributions to Indian science, joined the Institute in a steady stream, Ramanthan and M. S. Narasimhan (Maths), M. G. K. Menon, B.M. Udgaonkar and Virendra Singh (Physics); Govind Swarup (Radio astronomy); Obaid Siddiqi (Molecular Biology), just to mention a few names, form a very impressive list.

Still more impressive was the entry of Bernard Peters, a cosmic ray physicist, in 1950. A student of Oppenheimer, Peters was with the Rochester University. During the McCarthy inquisition period in the USA when intellectuals, scientists, and artists were persecuted for alleged un-American activities (which meant progressive thinking and sympathy for leftist ideology), Peters had become a victim. Though the Rochester University resisted Senator McCarthy's pressures, as did many other American universities, the general atmosphere of suspicion and vilification made it difficult for Peters to concentrate on work and he was on the lookout for a post outside the USA. He was introduced and recommended to Bhabha in 1948 in a Conference on Cosmic Rays in the UK, and Bhabha had invited him to India. In 1950 Peters came to TIFR to attend a conference on Cosmic Rays and Elementary Particles, and stayed on to work with the cosmic ray research group, initially on a two-year contract and then from 1952 to 1959 as Senior Professor. It was Bernard Peters and his group, which included M. G. K. Menon, which put India in the frontline on cosmic ray research in the world.

Thus within a decade TIFR had grown from a small embryo into a large dynamic and fastest growing research institute in the country. It started in June 1945 in a 6,000 square feet area with a budget of Rs. 80,000 and a skeletal staff. In 1946-47, the CSIR grant increased to 75,000 and its Director, S. S. Bhatnagar, became a member of the Governing Council. In 1948-49, the Ministry of Natural Resources and Scientific Research, Government of India gave a grant of one lakh. Naturally, with such expansion, the space at Kenilworth became insufficient, and a place measuring 35,000 square feet was rented from the Tatas and the Institute was shifted in September 1949 to the Old Yacht Club

near the Gateway of India, a beautiful place overlooking the Mumbai harbour, with the historical Elephanta Caves offering a panoramic vista across the creek.

Within four years the Institute had expanded into a space nearly six times larger. But Bhabha's vision and ambition was vaster still. He was on the lookout for a more suitable and larger space to build up the campus of TIFR as per his taste and aesthetic sense. That is an exciting story in itself to which we will turn at the end of this chapter.

In 1955, the Institute reached another milestone. A Tripartite Agreement between the Dorab Tata Trust, the Government of Bombay, and the Government of India was signed, making TIFR "the National Centre of Government of India for advanced study in nuclear science and mathematics." The support now came from the newly established Department of Atomic Energy (DAE) in Government of India. By now the grants were mostly from the Centre, and increased liberally. By 1966, the year Bhabha died, the budget had reached the figure of 1.5 crore.

In terms of both quantity and quality, TIFR can perhaps be rated as the fastest-growing research institute in post-independence India. Naturally, it attracted the best talent in the country, and the selection procedure was very rigorous and strictly merit-based, by and large free from considerations of caste and creed, and regionalism and provincialism, the bane of many institutions in our country. Even a large number of scientists trained abroad returned to join the Institute, and a remarkably large proportion was successfully retained. In itself it was a laudable success story, and compared to other research centres in the country it was no less than spectacular.

An important factor in nurturing excellence and retaining talent in the Institute was Bhabha's success in getting eminent foreign scientists to visit and stay in the Institute for various periods.

P. M. S. Blackett, the British Nobel laureate, was the first foreign scientist to give a lecture in the Institute as early as 1947. He was a frequent visitor and initiated the study of paleo-magnetism in the Institute. P. A. M. Dirac gave a course in Quantum Mechanics and Relativistic Field Theory in 1954. In 1960 Niels Bohr was in residence in the Institute for a short period. Laurent Schwartz, Hannes Alfen, Murray Gell-Mann, Felix Bloch, John Cockcrofit, J. D. Bernal, C. F. Powell are a few names among the large number of physicists who visited the Institute. Similarly, among mathematicians Carl Siegel, Andre Weil, Norbert Wiener, Harish Chandra, Paul Erdos are some of the well-known names. International conferences, symposia and workshops were held. On many occasions, when eminent scientists were visiting this part of the world, they were persuaded to visit Mumbai. This way the Institute became known in the advanced centres in physics and mathematics the world over. And the most beneficial thing was that the TIFR research workers had the chance to listen to and interact with these leaders of world science, and some even produced joint work. This was a very valuable opportunity made available to them right on Indian soil. Earlier such interaction was very rare for aspiring youngsters unless they migrated abroad.

It must be stressed that arranging visits and stay of foreign scientists was not easy in those days, Bhabha's personal reputation and acquaintances notwithstanding. It involved expenditure of foreign exchange, which was a real problem then. The other person who successfully used this strategy was P. C. Mahalanobis, who maintained a steady stream of

eminent foreign visitors to the Indian Statistical Institute in Kolkata. Mahalanobis' biographer, Ashok Rudra, has termed it the "strategy of brain irrigation."

As a result, TIFR scientists had better opportunities to visit advanced centres abroad, and better facilities, too, were made available to them. Once in five years, one-year sabbatical leave could be availed of. Working in TIFR was no longer like working in some isolated backwaters.

However, this was not a purely intrinsic, independent growth. There was an equally important external factor responsible for it. There was a much larger framework into which the Institute was embedded and networked, and which provided sustenance and boost for its growth, offering the much-needed niche in a resource-starved country. TIFR was the cradle of the Indian atomic energy programme in the beginning, and later benefited from it.

And the Indian Atomic Energy Programme was another vision of Bhabha, which we must now turn to. But before that let us go back to the exciting story of the new campus of TIFR.

The New Building—A Temple of Modern India

As mentioned earlier, Bhabha wanted to house the Institute on its own campus. For him the Institute did not consist merely of the research workers. The structure and the ambience formed as much an integral part of the Institute as the personnel working within it. Of course, the urgency of the task of starting fundamental research and to keep abreast of the rapidly advancing frontier was undeniable, and so he had not waited for any buildings to come up first, but had made his staff work even in old barracks and servants' quarters, when necessary. The work must go on, was his motto. But this was only a concession to and recognition of necessity. When the time was ripe, he would do it and that too without any compromise.

The creative and intellectually exciting and exhausting fundamental work he envisioned needed and deserved an equally inspiring and soothingly comfortable workplace. He had rejected a plot of land offered by the Government of Bombay as being too small. After thorough scouting, he selected a plot on the southern tip of Mumbai Island on the Arabian sea-front. (The OYC was located on the inland harbour creek.) There was one catch though, and what a catch it was! The land belonged to the Indian Navy. As the saying goes, the Railways and the Armed Services always acquire, and never surrender, land. But Bhabha proved to be more than a match. Despite the Defence Ministry's initial flat refusal, he persisted, and with the firm backing of the Prime Minister, and help from S. S. Bhatnagar and other well-wishers, he succeeded. The President of India, as the Head of the Armed Forces, leased the plot to TIFR in 1953. The story of the construction of the new buildings has acquired a legendary status, and reveals many interesting facets of Bhabha's many-sided personality.

Bhabha did everything in an impeccable style! As architects, he appointed the well-known American firm Holabird and Root of Chicago. They had experience of designing several laboratories, including one for the US Atomic Energy Commission. The eminent architect Helmuth Bartsch was to be the principal architect. As Executing Architects, the Indian firm of Master, Sathe and Bhuta was appointed. They had been the architects of

the recently completed complexes of the National Chemical Laboratory at Pune, and the National Physical Laboratory at Delhi. In addition, the veteran architect Kanvinde, who then was with the CSIR was associated for working out details. The most noteworthy aspect was Bhabha's own intense involvement in the process, right from the designing stage. Classical and modern European and Indian architecture had always been his special field of interest. Before turning to mathematical physics, he had acquired a Mechanical Science Tripos in Cambridge, and so he had a certain technical competence too, in addition to his strong aesthetic sensibilities in the field. His involvement can be aptly summed up by the statement Bartsch made later— "I have worked for many clients before. This was the first time I was working *with* the client."

In 1953 Bhabha had immediately shifted the Physics and Electronics Groups, working under Raja Ramanna and A. S. Rao respectively, to the old barracks existing on the new plot. The Cascade Generator too was housed there in a separate building. With the master plan of the new buildings completed, the formal Foundation Stone Laying Ceremony took place on 1 January 1954 at the hands of the Prime Minister, Jawaharlal Nehru, with great style and aplomb. A large number of dignitaries, some foreign scientists (including T. D. Lee, a Nobel laureate), as well as members from the world of arts were specially invited.

The planned outlay was Rs. 1.5 crore with a built-up space of 2, 56, 000 square feet. The buildings, with beautiful campus garden, were ultimately ready by the middle of 1961 with the final cost touching Rs. 4 crore. Though this sounds quite usual in our country, the reasons behind it were unusual. It was Bhabha's meticulousness and adamant refusal to make even the slightest compromise on quality or aesthetic and utility aspects that caused this inordinate delay, which even ruffled the patience of J. R. D. Tata, the Chairman of the Governing Council. At every stage Bhabha participated in the construction process, and he made his senior faculty as well to get involved. There was constant talk between the architects and scientists, and at the last stage the architects actually asked scientific workers to mark on the plans every piece of major equipment and even the furniture, so that the spaces, rooms and buildings could be very intimately correlated. There was also a lot of pioneering in the use of materials. The well-known story of the rust-free aluminium fittings is worth repeating.

During the construction Bhabha noticed that some of the window and door fittings had already developed rust due to the salty sea breeze. He immediately had all the fittings dismantled, rusted or otherwise, and ordered the use of a rustless Al alloy instead. At the time, no one in the country had the capability of extruding the special sections for the purpose. So the well-known Godrej and Boyce Company was asked to import a special heavy machine for the purpose, and make the fittings available. It caused delay then, but with the new capability being available in the country such fittings soon became quite common everywhere.

Yet, when the buildings were finally complete, the outcome was so breathtakingly pleasing that almost everybody forgot about the delay and the cost overrun. Moreover, the buildings have withstood the ravages of time and climate so nicely that for decades not even repainting was needed, leave aside other maintenance expenditure-It was truly one of Nehru's Temples of Modern India. The formal opening ceremony was held on 15 January 1962, again at the hands of the Prime Minister Jawaharlal Nehru. In his speech

Bhabha proudly elaborated on the symbiotic relationship between the Institute and the Atomic Energy Commission. Initially after its formation the AEC had naturally turned to the Institute for training its personnel and for carrying out its major projects; and in turn AEC had given substantial help to the Institute by providing funds for increasing its activities and for specialised equipment for nuclear research. The small electronics group at the Institute had developed and built the essential control systems and instruments for atomic research and it was the nucleus from which the Electronics Division at the Trombay establishment of AEC had grown, and the Institute had transferred 46 scientists to this establishment including stalwarts like A. S. Rao and Raja Ramanna. Bhabha declared proudly that the TIFR had been the cradle of the Indian Atomic Energy Programme.

5
INDIAN ATOMIC ENERGY PROGRAMME

The successful building up of TIFR as a centre of excellence in fundamental research in physics and mathematics was achievement enough for Bhabha to earn a permanent place in Indian science institutionalisation. But Bhabha displayed a vision still broader and spectacular, going beyond the limits of pure research into the realm of technological and industrial development. His dream was a modern, self-reliant India—highly industrialised and technologically advanced—leap-frogging over historical, cultural, and colonial handicaps directly into the second half of the 20th century, which the advanced countries represented. His solution was both simple and complex, like Lenin's after the Russian Revolution. Lenin had given the slogan— "Socialism equals electrical power." Bhabha too, wanted ample electrical power for Indian modernisation and industrialisation.

By 1939 the basic principles of the nuclear chain reaction were known, and during the war, though the work in nuclear science was a closely guarded secret, for a scientist of Bhabha's stature it was not difficult to guess what might have been transpiring behind the screen of secrecy. That was the reason for his confident statement in his letter to the Dorab Tata Trust in 1944 that when nuclear energy would be tapped within a decade or so, India would have her experts on hand. With the atomic bombs dropped on Hiroshima and Nagasaki in August 1945 the entire world was shockingly made aware of the power hidden within the nucleus of an atom, and the secret of Fermi's controlled chain reaction in an atomic pile, built on the grounds of the University of Chicago, became known to scientists. As if to expatiate for their sins, however unwittingly committed, the talk of harnessing nuclear energy for producing cheap and plentiful electrical power gained currency among scientists. Bhabha, with his thought already trained on the idea, naturally saw the opportunity of starting the Indian effort in this newly opened field.

In 1946, the process of granting India independence got under way. In September, the Viceroy appointed the Interim Government with Jawaharlal Nehru as the Vice Chairman. The CSIR had established an Atomic Research Committee. Though *$. S.* Bhatnagar, M. N. Saha, and many other senior scientists were members of the ARC, Bhabha's early conceptualisation of an indigenous atomic energy programme, and the springboard of

T1FR under his feet made him the most important and influential member of the ARC. In his individual capacity, he had held informal discussions with scientists in the UK, Canada, France, and Norway, during his 1946 tour, about possible help for Indian atomic energy development. During 1947, Bhabha also became member of two important scientific committees. First, the CSIR Review Committee, and secondly, the Scientific Manpower Committee, under the Chairmanship of Bhatnagar. It also offered him a fuller insight into the state of Indian science at the time of independence.

And, so it came about that when on 26 August 1947 (just 11 days after independence) the CSIR set up a "Board of Research on Atomic Energy", Bhabha was appointed its Chairman. It was an advisory body reporting to the Governing Body of the CSIR composed of 28 members including officials, scientists, and industrialists. Bhabha was not satisfied with the Board, its constitution and limitations. He had submitted to Nehru a report after his return from Europe and America, and emphatically stated that within the next couple of decades atomic energy would play an important part in the economy and industry of countries, and if India did not wish to fall even further behind the industrially advanced countries, it would be necessary to take more energetic measures to develop this branch of science, and appropriate larger sums for the purpose. Now after the second meeting of the Board of Research and Atomic Energy, held in Mumbai on 9 and 10 April, he wrote a note to the Prime Minister, dated 26 April 1948, on "The Organisation of Atomic Research in India."[1] It was a crucial note on which the PM acted promptly, accepting every major suggestion of Bhabha. To paraphrase Bhabha himself (from his earlier letter of the DTT), it was an embryo from which the atomic energy programme has grown to its present status.

At the outset, Bhabha made it clear that the quickest and most desirable way of developing atomic energy in India would be to come to an agreement with the Governments or atomic energy agencies of one or more countries. India needed to build an atomic pile to quick-start its own self-reliant atomic energy programme based on the plentifully available thorium. Thorium can be used as fuel only after it has been treated in an atomic pile, which needed uranium, which India did not have, and would have to get from abroad. He then put down two basic conditions that virtually dictated the organisational structure for Indian atomic energy research. First, absolute secrecy to be ensured with regard to any secret information given by a foreign A. E. agency; and secondly, some of the top people will have to do more than one job at the same time, given the paucity of scientifically and technically trained personnel. He recommended a very small and high-powered body composed of, say, three people with executive power, and answerable directly to the Prime Minister without any intervening link. The body was to be referred to as the Atomic Energy Commission (AEC). The AEC should have its own secretariat, independent of any other Ministry or Department of the Government. For coordination among the various Science and Technology related Departments and the AEC, Bhabha even proposed the composition of a three-member AEC, consisting only of scientists, namely: 1. Chairman, 2. Director of Scientific and Industrial Research as member-secretary, 3. one other eminent scientist ("Sir K. S. Krishnan, F.R.S. is suggested"). Bhabha even asked for allocation of a sum of Rupees one crore at once, to be spent over the next 3 to 5 years while mentioning his exploratory talks with the British, French, and Norwegian atomic energy agencies. He also recommended the setting up of a heavy water manufacturing plant.

The Prime Minister accepted Bhabha's note with all the major suggestions of Bhabha. On 10 August 1948 the Government of India passed the Atomic Energy Act, appointing the Atomic Energy Commission with Bhabha as the Chairman, S. S. Bhatnagar as Member-Secretary, and K. S. Krishnan, the Director, National Physical Laboratory, as the third member. There was no place for bureaucrats, and no other Ministries or Departments involved. Bhabha was answerable directly to the Prime Minister. It was a major triumph for Bhabha, empowering him to go ahead at full throttle to develop the atomic power programme he had in mind. No doubt, the rapport between him and the PM was uniquely responsible for it. Nehru had displayed full confidence in Bhabha. But there was also the obverse side to it. In the process he had stepped on too many toes, and not only among contending scientists. There must have been a lot of heartburns among the bureaucrats and the politicians of the day. Bhabha had to strain all his organising and intellectual resources, and employ all his diplomatic skills to survive in this world of high-power politics. And he had to deliver. Any failure would have attracted severe criticism from many quarters. That he could pull it through speaks volumes for his abilities, not only as a scientist, but as an organiser and administrator, and diplomat, too!

Comprehensive Atomic Energy Programme

Right from the start, Bhabha seems to have conceptualised a comprehensive programme for the development of atomic energy, extending over a wide spectrum. At one end was fundamental research in nuclear science and mathematics, aimed to make available sufficient manpower indigenously. At the other end was the countrywide prospecting and mining of mineral deposits, like uranium and thorium, needed for nuclear power technology. And a whole gamut of other activities lied in between, spanning applied sciences, engineering and designing, technological R&D, and industrial production of essential materials. The military application of atomic energy for nuclear weapons development, and the hotting up of the cold war made it clear that help from the advanced countries would be limited to restricted areas, and may be subject to stringent conditions.

Under these circumstances, it was a tightrope walk. Bhabha's success in getting the AE Act passed, whereby all these activities were combined under the single authority of the AEC with he himself having the unquestioned authority in the closed, protected system, proved to be of crucial advantage. Bhabha's long-term strategy was clear, and founded on the specific Indian situation, as he perceived it then. India had limited uranium deposits, but large known deposits of thorium in the form of monazite in the beach sands on the west coast. Thorium is not a fissionable material. It can be converted into nuclear fuel in stages.

Conventional nuclear reactors use uranium as fuel. Natural uranium has two principle isotopes, U-235 and U-238, out of which U-235 is just about 0.7 per cent. U-235 undergoes fission by capture of slow neutrons and U-238 by fast neutrons. When a uranium nucleus captures a neutron, it undergoes fission, releasing a large amount of energy, plus additional fast neutrons, which cause further fission thus leading to a chain reaction. In a power reactor, the chain reaction is controlled, by using *a* moderator to slow down the neutrons. So only U-235 undergoes fission, and U-238 remains largely unaffected. The two types of reactors then in use were using either enriched uranium

(higher percentage of U-235) with ordinary water as moderator, or natural uranium with heavy water as moderator. In the operation of these reactors, along with power generation, some of the U-238 is converted into plutonium-239 which does not occur in nature, but is fissile. By extracting, the U-239 from the used fuel of uranium reactors, a next generation plutonium reactor can be operated. In this reactor, if the Pu-239 fuel is mixed with U-238, along with power generation, more fuel is cooked up by conversion of U-238 to Pu-239. So this reactor was called plutonium breeder. This was the second stage on which the French were working seriously. Bhabha went one step further to envision a third stage.

Th-232, when bombarded with neutrons, is converted into another isotope of uranium, U-233, which is fissile. By using thorium along with U-238 in the second stage plutonium breeder, it was possible to cook not only more plutonium, but also U-233. When sufficient U-233 is accumulated, the third generation reactor using U-233 fuel can be operated. Fed with thorium, this U-233 breeder would produce power and cook up more U-233. Where thorium is not available the nuclear fission power cycle ends at the second stage. Once all the U-238 stock is over say in a couple of centuries, the plutonium breeders would come to a stop. But where thorium is available the third stage can continue fission power production till the thorium stocks last. With her plentiful supply of thorium, India would have assured power supply for a thousand years, even if no other technological invention came into being. This was the grand vision Bhabha had. Of course, it was still at theoretical level. No thorium reactors were in operation anywhere in the world. Bhabha's thinking was at the cutting edge of the new technology

Yet, it was this vision, in conjunction with the executive autonomy he had successfully achieved, which explains, in large measure, the early success of the Indian atomic energy programme.

The work of the AEC started almost from scratch. Exploration activities related to atomic minerals, like uranium and thorium bearing ores, were being organised by the Geological Survey of India. This was taken under the purview of the AEC. By 1950, detailed surveys began with vigour. A Government-owned company, Indian Rare Earths Limited, was formed, and by 1952, a production plant was started at Alwaye in Kerala for the processing of the monazite sands- Major uranium deposits were discovered near Jadaguda in Bihar. At the same time, research in nuclear power related subjects like chemistry, physics, engineering, biology, metallurgy, electronics control instrumentation etc, was started on a small scale. TIFR was the natural base for such research activities. When the Institute moved from Kenilworth to the Old Yacht Club, the original place was used for this purpose. With funding from the AEC, the TIFR staff helped in this research, and also trained the freshly recruited AEC personnel in nuclear science. As the work expanded rapidly, need was felt to consolidate the various laboratories under the AEC in a central research organisation.

Beyond the distant north-east suburb of Chembur, there was a sleepy fishing village Turbhe, called Trombay in its anglicised version, located on the inland creek north of Mumbai harbour. There was a large tract of sparsely populated land bordering on the creek to the east, and bounded by the Trombay Hills, highest in Mumbai, on the west. The 1200-hectare, crescent shaped tract, far away from the hurly-burly of metropolitan Mumbai, had large chunks of both hilly and marshy terrain. For Bhabha it was an ideal

location from both the security and the aesthetic points of view. This land was acquired for the proposed research establishment, and work on the thorium plant was immediately started in 1953.

In the same year, the small research groups in Kenilworth had spread out to other locations due to the expansions of their scale of operations. The metallurgy group moved out to the OYC; chemistry and spectroscopy groups moved to the premises of a defunct textile mill on Cadell Road (now Veer Savarkar Marg) on the west coast of Mumbai; and physics and electronics groups shifted to the old barracks in Colaba, where the new buildings of TIFR were to be constructed. Till about 1957, most of the technological R&D work took place under the umbrella of TIFR, and as the Trombay site developed, these activities moved over there. But the symbiotic relationship remained intact.

The Year of Triumph

The year 1954 turned out to be a very happy and significant year for Bhabha, and saw him scale the heights of glory and power. The year started on a pleasant note with the foundation stone laying ceremony of the new buildings of TIFR taking place on 1 January and Bhabha was awarded the Padmabhushan honour by the Government later in the month.

AEC was an advisory body, and by now its activities had so expanded that a separate Department in the Central Government became necessary to execute its rapidly developing programme. And so in August the Department of Atomic Energy (DAE) was established, directly under the Prime Minister, and Bhabha was appointed the Secretary to GOI, DAE. The Department had powers to fund, create, and operate all facilities for the Atomic Energy Programme, from mineral exploration to technological R&D. Immediately thereafter, the Trombay organisation was established under DAE, and named as the Atomic Energy Establishment, Trombay (AEET), and Bhabha was appointed the Director, AEET.

So, he now simultaneously held the three most important positions in the Indian AE Programme—Chairman, AEC; Secretary, DAE; and Director, AEET, while he continued to be the Director, TIFR. Hardly nine years since the foundation of TIFR and just seven years after Independence, he had become the most powerful man in Indian science.

More remarkable was the fact that he had managed to keep Mumbai as his base, where both TIFR and AEET were located. The new Government Department, DAE, had its main office in Mumbai, and only a liaison office in New Delhi, the seat of Central Government. It must have been felt as quite a revolutionary jolt by the rigid bureaucracy dominated by the ICS/IAS generalists. At one stroke, Bhabha had managed to keep himself aloof from the atmosphere of court intrigues while joining the Government service, and like a frontline general, had himself stationed where the action was. With so much power concentrated in his free hands, and a comprehensive vision in his ambitious mind, Bhabha marched forward very firmly and quickly, covering and consolidating new ground.

The small groups working in TIFR premises formed the nuclei of various research groups in AEET. But there was no structured organisation at the beginning. Within the broad overall policy, Bhabha gave maximum freedom to his staff members to “display

initiative in picking fruitful lines of work and in developing new ideas". The emphasis was on indigenous know-how for self-reliance in nuclear field. Initially there were only a few divisions, which differentiated as the establishment grew.

As the first step in power generation, it was decided to build a 1 MW swimming pool type reactor at Trombay. It was to be a light water-enriched uranium reactor, on the lines of one at Harwell in the UK. Sir John Cockcroft, the Director of the Harwell AE Establishment, was a friend of Bhabha from his Cambridge days, and Bhabha had persuaded him to help the Indian effort by supplying the uranium fuel rods. An agreement was signed in October 1955 between the UKAEC and the DAE. Except the fuel, the rest of the reactor was to be designed and built totally indigenously. The electronic control system was built under the leadership of A. S. Rao, while the TIFR workshop fabricated the necessary equipment. The assembling was started in 1955 and within a year it was commissioned. It attained criticality on 4 August 1956. It was the first nuclear reactor in Asia. It has been used for a variety of experimental studies in neutron physics, radiation chemistry and biology, for production of radioisotopes for agricultural research and for training of personnel for bigger and more complicated reactors.

During the last phase of commissioning, some fifty scientists and engineers were working round the clock for a week, and Bhabha himself was present on the spot for the last 48 hours. The successful completion of the swimming pool reactor generated a lot of self-confidence among the AEET scientists and engineers, and at the same time, raised the prestige of and the respect for Bhabha among his supporters and opponents. By this time a number of other projects were in operation or on the anvil in AEET. The thorium plant had become functional in 1955. A Uranium Metal Plant and a Fuel Fabrication Plant were being planned. And while the work on the 1 MW swimming pool reactor was on, Bhabha was trying to build a bigger experimental reactor. Initially he had a reactor of a British type in mind, but in 1955 a generous offer came from the Canadian Government, under the Colombo Plan, for the NRX type 40 MW reactor. This offer was accepted and preparatory work had begun in 1956.

Thus, by the end of 1956 a good deal of activity was going on the AEET campus. It was nearly two and a half years since its establishment. But, in the style typical of Bhabha, the formal inauguration function was held only on 20 January 1957 at the hands of the Prime Minister.

On the occasion Nehru named the swimming pool reactor, already in operation for nearly five months, Apsara.

The Canadian-Indian Reactor Project

As mentioned above, by 1956 preparatory work on the Canadian offer for a 40 MW NRX type reactor had begun. There were three basic types of reactors then in operation: 1. light water-enriched uranium type, 2. heavy water-natural uranium type, and 3. graphite moderated type. Bhabha had zeroed in on the heavy water type earlier, as is clear from the fact that he had recommended setting up of heavy water manufacturing plant in his note "On organisation of atomic research in India" way back in April 1948. For

Indian situation, using enriched uranium as fuel or graphite as moderator would have made self-reliance more difficult.

The Canadian atomic power programme was developed by W. B. Lewis, based on heavy water; and development of commercial electric power generation in thermal plants using heat generated by a nuclear reactor was considered to be a major contribution of Canada to energy resource technology. The NRX type reactor, operating at Chalk River in Canada, was a research reactor preceding the CANDU type commercial reactor. Lewis was also a friend of Bhabha from his Cambridge days, and Bhabha had some consultative discussions with him during their earlier meetings. An agreement was signed between the two Governments. Scientists from the DAE and the Atomic Energy of Canada Ltd were to jointly build this high neutron flux research reactor. Half the cost was to be borne by India and the other half by Canada under the Colombo Plan. The heavy water needed was to be supplied by the US AEC.

The construction started in 1956, and took about four years for completion. More than 1,000 engineers and skilled artisans worked on the project, including 30 Canadians. On-site training was given to the workers, and Indian engineers gained valuable experience from their Canadian counterparts. The erection was completed at the beginning of 1960, and operational testing took a few months. The initial fuel was to be supplied by Canada under the agreement. But the Uranium Metal Plant, producing nuclear grade uranium, and the Fuel Element Fabrication Plant, started around 1957 were already operational by mid-1959. And, so half the initial charge used in the CIR came from Trombay's own production. The reactor attained criticality first on 10 July 1960. Later the CIR was given a weightier name—CIRUS, an acronym for Canada-India Reactor Utility Service. Cirus is still operational.

With Apsara and Cirus functional with assistance from UK, Canada, and the USA, Bhabha wanted to construct a 100 per cent Indian reactor. Zerlina, a zero-energy research reactor for lattice investigation and study of different fuel assemblies was undertaken. It was designed to have a variable core permitting a variety of experiments. Zerlina was successfully built and attained criticality on 14 January 1961. This totally indigenous reactor was made possible because, apart from the experience the DAE scientists and engineers had acquired from the construction of Apsara and Cirus, Bhabha now had fresh indigenous talent available in house.

The Training School

The DAE required personnel specialised in various science subjects like physics, chemistry, biology, and engineering subjects like electrical, mechanical, electronics, chemical engineering, metallurgy etc and then these were to work in the highly inter-disciplinary field of nuclear power generation and allied technological R&D. Everybody needed to have some grasp of the overall field and more intensive knowledge in his specialisation. The number of subject specialists required was rather small. So, instead of being dependent only on on-job training, Bhabha decided to route selected recruits through the Training School, which imparted intensive in-house training of one-year duration, before assigning them to various divisions functioning in the AEET or elsewhere.

The Training School was started in 1957. A Training School Committee was formed with Dr. Raja Ramanna, Head of Nuclear Physics Division, as its Chairman, and other Division Heads and senior scientists as members. The Committee was to decide the policy and the syllabus contents, from time to time, as per the requirements. Dr. K. K. Damodaran, a Ph.D. in nuclear science from London, who had returned from the UK to join AEET in August 1956, was appointed the Head of Training School Division. There was no written test. (That started much later when the number of applications became very large.) A few thousand graduates from all over the country, with consistently good academic record were invited for interviews. The interview panel consisted of senior scientists, and even Division Heads used to be present in the early years. Candidates were interviewed thoroughly and intensively. About 150 trainees were selected, between 20 and 30 or so from each specialisation. The teaching faculty consisted mainly of scientists from AEET, TIFR, and the Indian Institute of Technology, Bombay. During the early period stalwarts like H. N. Sethna, Raja Ramanna, Yash Pal, M. G. K. Menon, B. M. Udgaonkar, R. R. Daniel gave courses in the School. At the end of the year a graduation ceremony was conducted, prizes were given to toppers (now called Homi Bhabha Awards), and they were absorbed in various Divisions as per the needs of the establishment and the performance of the candidates. Gradually the Training School graduates have become the mainstay of the DAE establishment, as the older generation retired. Dr. Anil Kakodkar is the first product of the School who became Director, BARC (as AEET has been renamed) in 1996, and then Chairman, AEC in 2000, in a way fulfilling Bhabha's prophecy that India would not have to look abroad to man her science programmes. (The same thing happened in TIFR when Prof. B. V. Sreekantan became Director after M. G. K. Menon, who was UK educated.)

In addition, the Training School also exemplifies the way Bhabha nurtured and made mature his staff for the role they had to play at the national and international levels. It must be stressed again that, as in TIFR, the selection procedure was strictly merit-based, without any regional or provincial bias. Bhabha allowed no quarters for political influence either. The trainees came from all over India, and not necessarily from the urban elite. Naturally, though the salary grades they would get after passing were comparable to the IAS cadre, the class composition was different for these academics. And so they had to be groomed in mannerisms too, suitable for the task of facing the international community, and travel and training in foreign countries that Bhabha visualised for this cadre.

One Col. Ottley was the Administrative Officer of the Training School, and Mr. Allardice (an ex-ICS officer) was the Controlling Officer in AEET, and these two Westerners would look after this department. There has been some criticism of Bhabha being westernised, and of having imposed Western mores. There may be some justification in it. At the personal level it would be unjustified to criticise Bhabha for his family upbringing, while at the larger social level, in the light of what has transpired in the country since then, faulting Bhabha may be wrong. It was part of the travails of modernisation, which was certainly necessary. In any case, we must see these things in their proper context. Just an example. In the Students' Hostel there was the following "dress code" for dinner—trousers and shirt; and strictly no banians and pyjamas or lungis! Of course, once a month Bhabha would visit the Hostel for dinner, and then, in his presence, a tie was a must. But one still meets old people who proudly describe how

the opportunity of foreign travel and exposure to foreigners instilled confidence in them vis-à-vis Western scientists.

Consolidation

In 1958, the Lok Sabha passed a resoultion proposed by Bhabha, as Secretary to GOI, defining the constitution of the Indian AEC, and vesting in AEC full executive and financial powers of the Government of India. The salient features were:

1. The AEC shall consist of full-time and part-time members, the total not less than 3 and no exceeding 7,

2. The Secretary in the DAE shall be the ex-officio Chairman of AEC,

3. Another full-time member of AEC shall be Member for Finance and Administration, who shall also be the ex-officio Secretary to GOI in DAE in financial matters.

4. The Director of AEET shall be the third ex-officio full-time member in charge of R&D.

Further, the AEC was given the responsibility for formulating the policy of DAE, for preparing the budget for the DAE and getting it approved by the Government, and for implementation of the Government policy in all matters concerning atomic energy.

Thus Bhabha significantly consolidated his already considerable powers, as well as autonomy, within the Government. Rapid development of atomic energy made the 1948 Act inadequate, and therefore new legislation was introduced in 1962. The Atomic Energy Act 1962 included some extra powers and responsibilities, under the changed circumstances, regarding radiation protection, power generation and its distribution, etc.

Steps towards Power Generation

By now Bhabha was under pressure to deliver commercial power. The Planning Commission had sanctioned an atomic power station to be erected at Tarapur in Maharashtra. In 1963 a Bilateral Agreement was signed with the General Electric Company of the USA. It was to be a turnkey project, two 200 MW reactors of enriched uranium—light water

6

THE SCIENTIST-DIPLOMAT

In setting up a centre of excellence in pure research, and organising the national atomic energy programme, Bhabha rendered valuable service to the development of Indian science. But in the process he had to display qualities and talents in addition to being a first-rate scientist. He proved himself to be a good organiser and leader of young scientists, and a man who could influence the political leadership of the country. He also had to play the role of a diplomat on the international scene, acting like India's scientific ambassador in the advanced countries.

As already noted, while scouting for young Indian talent working in the USA and Europe, he had, at the same time, managed to contact leading scientists in those countries. While collecting information on Indian students working in their laboratories, to be invited to join the TIFR, was easy, discussing developments in atomic energy and the likely help India could expect from those countries was a delicate matter, because by now most of nuclear research was veiled in secrecy Though Bhabha was on friendly terms with many of these scientists, they were now dealing with State secrets of their countries, many probably working on military programmes of weapons development, or industrial programmes of commercial atomic power development. Under these circumstances diplomatic skills were needed and Bhabha had to assume the role of an unofficial ambassador of the Indian State too. As it seems, he played the role with both the finesse and the aplomb characteristic of him.

Lord Penney, the ex-Chairman, UK Atomic Energy Authority, has said, "Bhabha used to come to England often. He went to all countries, he had friends everywhere. He became in England the man we always asked about scientific matters in India."

In 1948, in his note to Nehru, on organisation of atomic research in India, Bhabha had said that agreements with the Governments or the atomic energy agencies of one or more countries were desirable. The first break in this direction he achieved was the agreement with France. The Franco-Indian atomic agreement was signed in 1951, which covered a wide range of subjects and, in particular, proposed joint study of a natural uranium reactor moderated by beryllium oxide. Dr. Bertrand Goldschmidt, Director, External Relations and Programmes, AEC, France, who had taken part in the negotiations in 1950-51, visited India for a month, and became a friend and admirer of both Bhabha and India. A number of scientists from TIFR and AEC visited France for training and experience in this new and revolutionary domain of S&T. Dr. Goldschmidt has rather nostalgically recorded later that when the AEC started in France, "We were very isolated due to obvious political reasons and also due to the prevailing Anglo-American policy of atomic secrecy. Homi Bhabha was the first leader of a foreign atomic energy organisation to propose collaboration with France."

The next success Bhabha achieved was with the UK resulting into the Apsara swimming pool reactor. Sir John Cockcroft, Director, Atomic Energy Establishment at Harwell, was a friend of Bhabha from his Cambridge days. An agreement was signed with the UK for the supply of fabricated enriched uranium in 1955, and in September the same year, an Indian team attended the first International Course in Reactor Science and Technology at Harwell. Around the same time, Bhabha was also looking forward to acquiring a larger high flux research reactor. The UK could supply one of the types already under operation at Harwell. But Bhabha opted for the heavy water reactor of Canadian design. Negotiations with W. B. Lewis in Geneva in 1955, led to 40 scientists and engineers being sent to Canada for about a year's training in reactor construction and operation. The final result was C1RUS, for which heavy water was obtained from the US AEC.

The rather quick decisions and implementation of these projects, which involved inter-governmental negotiations, and the favourable terms Bhabha was able to extract, speak for his negotiating skills, as well as his self-confidence. This was more sharply demonstrated during the negotiations for the Tarapur project during 1962-63, regarding

the form of controls and safeguards, a really complex matter. The most contentious issue related to safeguards on equipment The Indian position was that no safeguards on equipment should apply, and only those on special materials supplied by the USA or produced in the reactor were justifiable. But the Americans were adamant. The issue was finally resolved in a manner in which the policy positions of both India and the USA remained unaltered, according to Dr. M. R. Srinivasan, former Chairman, AEC. He further says that Bhabha's achievement in the Tarapur negotiation would have been a feather in the cap of a seasoned professional diplomat.

From the other side, Joseph Wiesner, who was then Special Assistant for S&T to President Kennedy, and took part in the Tarapur negotiations, has made the following interesting remarks: "We often disagreed, not so much on basic objectives or fundamental principles as on methods, interpretations, and orientations. We argued endlessly during the period—about the form of controls to be placed on the power reactor, which the US was planning to help India build at Tarapur. I was enthusiastic about the American proposal to allow the IAEA, of which Bhabha was a Director, to be the supervising agent. Bhabha supported the Indian proposal for a bilateral arrangement similar to the ones the US then had with many countries, particularly in Europe. We argued the issue for many months in Washington, in Geneva, in Delhi and Bombay. I could not understand why India, a nation with an often-articulated commitment to the international control of atomic forces, would not accept the unique leadership role that the situation offered. Homi could not accept what appeared to be a second-class position for India, despite his solid commitments to international control of nuclear materials." Wiesner has also added that Bhabha shared Nehru's "dreams, fears, ambitions and viewpoints, including many that were not always understood or appreciated in the US-neutralism, for example—and was often regarded as anti-American when he was indeed, only being pro-Indian".

Though these were important feats Bhabha achieved for India in the international arena, his most important achievement, which shot him into international limelight, was at the first Geneva Conference on Peaceful Uses of Atomic Energy, over which he presided in 1955.

This is an exciting story and illustrates quite vividly the supreme confidence Bhabha exuded, to some irritation and some amusement to others; and how he strove to break the walls of secrecy surrounding nuclear science and sought to make the knowledge of this technology available to all the countries to help solve their problems of development. In retrospect, Bhabha might be accused of naivety and over-.optimism. But that charge could stick to many others as well.

First Geneva Conference on Peaceful Uses of Atomic Energy 8-20 August 1955

Knowledge once given cannot be taken back—Bhabha

The Manhattan Project for the atom bomb during World War II was carried out on the US soil, far away from the actual theatre of war. Britain, Canada, and France were part of it, and the USSR, though the war ally, was kept in the dark. Along with the US, British, French, and Canadian scientists, a large number of scientists from other parts of Europe, who had fled from Hitler, were also engaged on the project. And an overwhelming

proportion of the huge cost of $2 billions (200 crores) was borne by the USA. During the project, the single largest S&T project till date, a lot of new science and technology was developed. It was clear to all concerned that once the war was over, with or without the bomb or its use, the new technology of power generation would play a vital role in the economy of the post-war world. As it happened, the bomb was successfully made and used for ending the war on the Eastern Japanese front. And thus atomic energy became a double-edged weapon, both for political and economic hegemony.

The initial lead and, of course, the unprecedented vast investment, led the USA to the policy of atomic secrecy. Even during the Manhattan Project the USA was reluctant to share, even with the UK, information not directly related to the bomb, and it had generated some friction among the allies working on it. After the war the US stand hardened. With the result that France, the UK, and Canada started their own atomic research programmes. The scared USSR launched her programme on a war footing. In 1949 the Soviet atom bomb was exploded, in 1952 Britain tested her bomb, and in 1953 the Soviet hydrogen bomb test was carried out. It also became clear that the USA would not be able to hold on to her monopoly even in power generation technology of atomic reactors. The USSR, the UK, France, as well as Canada had small-scale power reactors operating on their soil. The UK, Canada, and France had even shown readiness to supply the new technology to others. By continuing the ban on transferring atomic technology the USA stood to lose in the emerging market for atomic power generation.

This necessitated a change of policy, and so in 1954 President Eisenhower declared his new policy of "Atom of Peace". The USA was ready to share the new technology for power generation and peaceful applications. At the same time, it was equally necessary to take care that the spread of this technology would not be misused for making atomic weapons and for other military applications. This entailed some kind of international controls and restrictions, which nations must agree to. The United Nations was the suitable forum available for the purpose. And so the US Secretary of State, John Foster Dulles, proposed a resolution to the UN, which was unanimously adopted by the UN General Assembly on 4 December 1954. It was proposed to establish an international atomic energy agency, and as the first step towards that goal, to hold an international technical conference of Governments of member States. A Scientific Advisory Committee (SAC) under the Chairmanship of the UN Secretary-General, was established consisting of representatives of seven States, namely the USA, the USSR, the UK, France, Canada, India and Brazil. (China at that time was not admitted to the UN)

Bhabha naturally became the Indian representative on the SAC. He had left Mumbai for Bangalore to spend his Christmas holidays. When he arrived at Bangalore airport, a call from Delhi was waiting for him, and he was informed about the proposed conference and told that the Prime Minister wanted him to represent India in the SAC. He shortened his vacation and after due preparations, arrived in New York in the middle of January 1955.

Dag Hammarskjold was the UN Secretary-General. The seven member committee helping him to organise the proposed conference had John Cockcroft (UK), B. Goldschmidt (France), and W. B. Lewis (Canada)—all old acquaintances of Bhabha. Prof. Isidor Rabi (USA), Academician Skobeltzin (USSR) and Dr. Ribeiro (Brazil) were the other members. This was the first time that scientists from the Soviet block and the

Western block were going to come face to face on such a sensitive matter. The heat of the cold war was still on. Obviously the task of deciding the rules of procedure and the topical agenda, choosing the various executive bodies and officials was not expected to be easy. Bhabha seems to have played a mediatory role between the opposite camps. As per Laura Fermi, who acted as the historian of the US AEC at the Conference, the members of the Advisory Committee were divided at first on who should fill the role of the President of the Conference. Many names were suggested, and there was considerable debate. In the end, all members agreed on Homi Bhabha, who had been suggested by the French representative, Bertrand Goldschmidt.

The Conference was to be held at Geneva in Switzerland from 8 to 20 August. There were hardly six months for the preparations. But Bhabha went about his task in a self-assured manner. He never had any diffidence or inferiority complex in the presence of other bigwigs. Later almost everybody agreed that the success of the First Geneva Conference was to a great extent due to Bhabha's competent and skilfui leadership.

The Conference was a big event. There were about 1,400 delegates from 73 nations and 7 specialised agencies of the UN. About as many observers and 900 media persons attended this biggest-ever scientific conference in the Palais des Nations in Geneva. And, more than 1,000 scientific and technical papers were submitted.

On the opening day, Bhabha delivered the Presidential Address, excellently fitting the grand occasion, and its significance for the global community.

He declared that the purpose of the Conference was to discuss peaceful uses of atomic energy, and to *exchange scientific and technical knowledge* connected with it. Knowledge, he emphasised, is the most important possession of man. "It is accumulated knowledge of centuries which differentiates modern man from his ancestor in the dawn of civilisation. It is this knowledge, and not any notable change in his physical or mental equipment, which has enabled him to build the civilisation of today," he declared, and then launched into global historical description of the evolution of mankind in civilisational terms, his focus being the availability and use of energy.

Bhabha divided the history of mankind into three epochs, each marked by a change in the energy pattern of society. The first and the longest epoch, covering almost the entire period of 250,000 years of man's existence on earth, was characterised by the use of muscle power, whether human or animal. The second epoch started barely 200 years ago, marked by widespread use of chemical energy, by burning fossil fuels, like coal and oil. This had led to the industrial revolution and the present pattern of industrialised society. And the third epoch was marked "by the discovery of atomic energy and dawn of atomic age, which we are just entering."

Bhabha related energy supply to the development of civilisation—"restricted supply of energy puts limitations on the development of civilisation". In societies, carried on the muscle power of slaves or of a particular class in society, the fruits of civilisation could only be enjoyed by a few. With the Industrial Revolution the masses in highly developed countries were enjoying a much better standard of life. But large areas of the world were still underdeveloped. Rolling out figures of available energy resources and rates of energy consumption, he declared that if the entire population of the world were to consume energy per capita at the same rate as in the USA, the world's known resources of fossil fuels would be exhausted in less than a century. If the light of our civilisation

was not to be extinguished, atomic energy source has to be developed. "For the full industrialisation of the underdeveloped areas, for the continuation of our civilisation and its further development, atomic energy is not merely an aid, it is an absolute necessity," he told the assembled audience. And further on he said, "Atomic weapons He outside the scope of this conference, but we cannot entirely separate the applications of peace from the applications of war. The rise of an atomic power industry in many parts of the world, the development of which is necessitated by the growing demand for power, will put into the hands of many nations quantities of fissile material, from which the making of atomic bombs will be but a relatively easy step. A widespread atomic power industry in the world will necessitate an international society in which the major powers have agreed to maintain peace." He then quoted a few lines from the Russell-Einstein Manifesto, warning the world against nuclear war and appealing for peace. In his closing remarks he said, "This Conference has already broken down many barriers, and we have come to know of the remarkable advances in atomic energy, achieved in several countries of which we were totally ignorant hitherto. If so much has been achieved through the individual and isolated efforts of a few countries, how much more could be achieved by the combined effort of all.. .We have the unique opportunity of giving our knowledge to others for the common good. I hope this Conference will play its part in helping the progress of mankind towards the ever-widening dawn of the atomic age, with the promise of a life, fuller and happier than anything we can visualise today."

Bhabha's Historic "Indiscretion"

On the face of it, Bhabha's presidential address was an excellent but typical, opening speech quite suitable for such international gatherings. Yet, there was more to it. His phrases like "knowledge should be freely available and shared", "It is unreal to believe that security can be ensured by secrecy", were not merely empty rhetoric. The opening speech contained two unexpected statements.

The first was: "It is a matter of regret that there are several areas of the world not directly represented at this Conference, whose populations constitute *a* quarter of total world population." It was a factual statement referring to China, which was not yet admitted to the UN. Many Western representatives resented this, as political questions were not supposed to be referred to in this scientific conference. But Bhabha's remark was not played up by any delegate and was quietly ignored. But it can be said that Bhabha might have had the Prime Minister's consent for making such a reference, as Nehru, as the leader of non-aligned movement, was a protagonist of China's admission to the UN.

Bhabha's other statement, however, was like a bull in a China shop causing a great commotion, and this might have been his own move. He said, closing his address:

The historical period we are just entering in which atomic energy released by fission process will supply some of the power requirements of the world, may well be regarded one day as the primitive period of the atomic age. It is well known that atomic energy can be obtained by a fusion process, as in the hydrogen bomb, and there is no basic scientific knowledge in our possession today to show that it is impossible for us to obtain the energy from the fusion process in a controlled manner...I venture to predict that a method

will be found for liberating fusion energy in a controlled manner within next two decades.

Fusion was not on the Conference agenda and was not mentioned in any paper submitted to the Conference. In fact, fusion was a top-secret matter, and the USA, the UK, and the USSR were seriously engaged in controlled fusion research. Bhabha upset the applecart on the very first day of the Conference. Certainly he must have had some inkling of the research going on, and was not happy with the secrecy being maintained about it. He struck a blow for openness.

There were two interesting consequences. Both the USA and the UK, on the one hand, reluctantly admitted doing fusion research, and on the other, stressed that, fission reactors had a long innings to play.

Cockcroft held a press conference, and said that fusion power may be generated "within a generation". Admiral Strauss, Chairman, US AEC, in his press conference, disclosed that the USA had been working for considerable time on controlled thermonuclear reactions. Bhabha himself met the press and held his ground, but also said that there would always be place for fission power even in a world of fusion power. In the aftermath, Admiral Strauss held a press conference in Washington on 3 October 1955 and disclosed the US AEC's major research effort at Princeton University and at AEC's laboratories at Los Alamos and at California, the project named "Sherwood". The other consequence was to create apprehension in the minds of representatives of business and industry, assembled at Geneva. With fusion research proceeding secretly, and a number of fission power reactors in operation or under construction in the USA, the UK, the USSR, France and Canada, it was time for commercial exploitation of fission reactors. In fact, it was the main motive behind the US proposal of "Atom for Peace", which had led to the Geneva Conference. Industry in the UK and the USA was interested in selling reactors and power stations to other nations, and was investing enormous amounts in uranium mines and other aspects of atomic power plants. In informal meetings outside the Conference Hall, representatives of industry discussed reactor sales with people from underdeveloped countries. Naturally, the industry was worried by Bhabha's forecast that fission may soon become the primitive period of atomic age. They had to be assured that uranium was going to be good business for quite some time to come.

Cockcroft in his lecture on 19 August even mocked at Bhabha, saying—"although we are working seriously on this problem in Britain, my vision is not good enough for that. I am not as bold as Dr. Bhabha, our President. I am sure that he would not mind my saying that the experimental physicist must inevitably have a greater appreciation of problems and difficulties than a theoretical physicist". However, Otto Frisch, who was working on fusion in the UK, has recalled in his memoirs that Bhabha's prediction at the time appeared to him as somewhat pessimistic. Some comments were even favourable to Bhabha. The British physicist P. M. S. Blackett called the incident "Operation tin-opener", and a statement of the British Association of Scientific Workers pointed out—"The fact that the matter was discussed even unofficially was due to the initiative of the President of the Conference, H. J. Bhabha of India...had the Chair been occupied by a less forceful character, the Conference might have concluded with the world still ignorant even of the possibility of taming the hydrogen bomb reaction."

The outcome was that in the Second Geneva Conference held in 1958, fusion was part of the agenda, and Bhabha chaired that session. But the Americans never really did pardon Bhabha for such a transgression. He was rated anti-American, as Wiesner has recalled.

Eventually the atomic energy programme the world over got bogged down in various technical difficulties. Controlled fusion is still a distant dream, and even fission reactors are shut down in many countries for economic, environmental, and safety reasons. Bhabha himself climbed down from his high slogan of "power too cheap to meter", to say in 1964, in the Third Geneva Conference, that though not too cheap, there was no alternative to atomic power, and coined the epigram—"No power is expensive as no power". But in 1955 the situation did look very optimistic, and Bhabha's blow for an open system, where every nation should have access to the latest technology, must be judged in that light.

International Atomic Energy Agency (IAEA)

The Geneva Conference on Peaceful Uses of Atomic Energy was a sort of preparatory general meet to establish an international agency under the auspices of the UN to supervise the control and safeguards regime that would be necessary, if nuclear reactors were to be used across the world for power generation.

A Preparatory Conference of twelve nations was held in Washington in 1956 to negotiate the statutes of the International Atomic Energy Agency (IAEA), and later that year a Plenary Conference in New York, discussed the issue of controls and safeguards. Bhabha was intimately associated with this body from its inception till his death. He played a decisive role in shaping the statutes of IAEA, and then in drafting the initial programme for it. The location of IAEA was also a contentious issue. It had to be a place on which the major powers had to agree, particularly the USA and the USSR. In the end Vienna in Austria was chosen, and it has been mentioned by many participants that Bhabha had a major influence in tipping the scale towards Vienna for obvious political reasons, and also because he himself adored Vienna as the capital of European music with its opera and the concerts.

Bhabha was a member of the Board of Governors of IAEA. Dr. Sivgard Eklund was chosen as the Director-General. The Director-General appointed a Scientific Advisory Committee of seven, which consisted of the same members who were on the UN SAC earlier. Bhabha also led India's delegations to the sessions of General Conference, which was the annual gathering of all the Agency's member States.

In all these capacities—as Director of IAEA; Member, SAC; and leader, Indian delegation—Bhabha was a strong protagonist of the developing countries, particularly Indian view on nuclear development. In particular, he assertively took an independent line vis-à-vis the nuclear weapons powers regarding the issue of "safeguards". He insisted that safeguards should be applied not only to the newcomers to atomic energy, but to the major powers as well. His persistence bore fruit and IAEA safeguards systems were being applied to some major nuclear power stations in the USA, the UK, and other countries. He also argued that safeguards be kept to a minimum, major safeguards should be applied to the chemical plutonium separation plants (where Pu is separated from used

reactor fuel and can be diverted to making of bombs), rather than to the reactors. Though the nuclear powers probably never felt comfortable with Bhabha's stance, he was widely appreciated and respected among other nations. It was on his way to Vienna, via Geneva, to attend the SAC meeting scheduled on 25 January 1966 that Bhabha met with his death in a plane crash on Mont Blanc, the highest peak in the Alps.

Nuclear Disarmament

Closely connected with the work of the IAEA was the issue of non-proliferation of nuclear weapons and nuclear disarmament. Of course, everybody unanimously agreed that a future nuclear war would be a disaster for the entire mankind. The practical questions were: How to stop development of nuclear weapons of more and more destructive power? How to prevent more nations from acquiring nuclear weapons? What to do with the existing weapons stock?

At that time there were four nuclear weapons States— the USA, the USSR, the UK, and France. (China entered the nuclear club in 1964.) The nuclear States took a narrow view of non-proliferation: just no more additions to the membership of the club. The freeze on the development of more powerful weapons, and reducing or, at least, not increasing the existing stock of weapons by the nuclear weapons States themselves, was a separate issue, they thought.

Bhabha naturally did not like this—a second-rate status for the non-nuclear States, which would compromise their sovereignty. He articulated his views in these fora quite eloquently. In a sense, he was the architect of the Indian policy on nuclear disarmament and proliferation in those early days. The declared policy of the Government of India was not to develop nuclear weapons, and to use atomic energy only for peaceful purposes. Bhabha set this within the larger international framework.

He was totally committed to the position that atomic energy for power generation was essential to the continuation of our civilisation. And he had stated in his President's Report to the UN (12 October 1955) and on other occasions, that even if widespread use of atomic energy for peaceful purposes forced us with political and military problems, we had no option but to solve those problems. Further, the remarkably parallel work, done in secrecy in several countries till 1955, made one thing clear: it was unreal to believe that security could be ensured by secrecy, or the ability to develop atomic reactors and weapons was the monopoly of any single nation or a group of nations. A 300 MW power station would produce enough plutonium for production of between 20 and 35 atomic bombs a year, depending on their size. And, therefore, atomic bombs were within the capacity of a number of countries in half a decade or a decade. Disarmament was, therefore, the only way, and he even talked about a UN security force, strong enough to maintain peace in a relatively disarmed world.

But Bhabha stressed that nuclear disarmament cannot be separated entirely from general disarmament. Even if we could achieve total nuclear disarmament, we would just be back to the pre-World War II situation, which did lead to the disastrous war. So, it was in the interest of everyone to see progress towards general disarmament, as soon as possible. Anyway, for countries like India, it was not possible to change the positions, or

even the attitudes of the major powers, and eventually even India had her Pokharan-I in 1974 and Pokharan-II in 1998.

But regarding the Pokharan-I implosion, it must be noted that Bhabha himself had made preparation in this regard. He was for peaceful nuclear explosions for the Ploughshare Programme, that is, for making plutonium devices for civil engineering purposes like making storage cavities, for water diversion, irrigation and flood control, for constructing canals or harbours, or blasting passages through mountains for highways or railways. In fact, a US researcher had submitted a paper on this aspect to the Third Geneva Conference in 1964, which Bhabha had quoted. But later developments made such applications not feasible.

7
CONTRIBUTIONS TO OTHER AREAS OF NATIONAL SCIENCE

A person of great stature always exerts influence, which transcends his own field of specialisation. And so it was with Bhabha. With his boundless energy, comprehensive vision, and influence in the corridors of power, he made contributions to wider areas of Indian science, beyond fundamental research in physics and mathematics, and the atomic energy programme. Some of these were quite pioneering efforts and deserve special mention.

Indian Space Research Programme

Bhabha's younger friend from the Bangalore days, Vikram Sarabhai had followed in his footsteps and founded his own institute in 1947 at Ahmedabad—the Physical Research Laboratory (PRL). Compared to TIFR it was a smaller effort, devoted to atmospheric and geomagnetic research. It was getting some grants through the CSIR.

After the first man-made Russian satellite, Sputnik, was launched in 1957, Sarabhai became interested in space research and its potential applications. He visualised that the use of satellite communications for broadcasting educational programmes to the vast rural hinterland, as also the use of remote sensing technology from space could prove a great help in addressing many of the problems before our country. Sarabhai was not so much interested in space science and exploration of space per se, but in using space technology for solving problems on the ground. A believer in leapfrogging principle, he said that India need not follow the historical path, followed by the advanced countries, step by step, but must leapfrog from the backward level we were on directly to the most modern level, skipping the intermediate steps.

This was a vision Bhabha readily took to heart. He decided to encourage and support Sarabhai. A space research division was established under DAE in 1961 with Sarabhai in charge. The PRL became an autonomous institution, like the TIFR, jointly administered by the DAE, the Government of Gujarat, and the Ahmedabad Education Society (AES) formed by Sarabhai. Bhabha gave full freedom to Sarabhai in matters of space research, and with the DAE's financial backing, the Indian space programme had an energetic start.

In 1962, the Indian National Committee for Space Research (INCOSPAR) was established with Sarabhai as its Chairman. In 1963, the Thumba Equatorial Rocket Launching Station near Thiruvananthapuram in Kerala at a location of 8 degree north was established with help from the UN, and in December 1965, it was recognised as the first International Sounding Rocket Launching Facility by the UN for use of other countries.

After Bhabha's death in 1966, Sarabhai took over as the Chairman, AEC, and looked after both the space research and the atomic energy programme. In August 1969, the Indian Space Research Organisation (ISRO) was established with its headquarters at PRL, and the Thumba station and other space research units were entrusted by the DAE to ISRO. After Sarabhai's untimely death in 1971, the expanding space research programme resulted in the establishment of the Space Commission and a separate Department of Space (DoS) at the Centre in 1972. India has since successfully launched her own rockets and satellites, and the space programme now forms a major and important component of Indian S&T efforts.

And it was Bhabha, who in the initial period, acted as a catalyst to nurture and boost the space research.

Electronics

In TIFR Bhabha had long back, set up the Electronics Group, which developed the electronics equipment needed for cosmic ray studies, and other experiments. The Electronics Division at AEET (presently BARC) grew out of this TIFR nucleus, and the necessary equipment and control systems for the reactors were built in-house. However, the electronics industry in the country was not much developed.

The war with China in 1962 exposed Indian weaknesses, among other things, in the field of electronics. Bhabha was quick to recognise the appalling dependence of the country on foreign sources in this field, which is vital not only to defence, but also to national development. As Chairman, AEC, he made a recommendation to the Government of India to set up an Electronics Committee "to survey the needs of the country in electronics components and equipment, and to recommend measures for the planned development of electronics, so that the country as a whole may become self-sufficient in this field in the shortest possible time, and in the most economical manner." In August 1963 the Government appointed the Electronics Committee with Bhabha as Chairman. Vikram Sarabhai, A. S. Rao and Bhagvantam were three other members of the Committee, and a large number of representatives from user ministries, K&D organisations, and industry assisted it in its work.

The Bhabha Committee took a comprehensive survey of the field. The existing industry was at a primitive level, and electronics was considered mainly a matter of concern to the entertainment sector. Bhabha put forth the proper perspective in which electronics needed to be seen in the modern world, as an essential component of a technologically advanced society, recounting that this industry, which was hardly two decades old, was already the fifth largest one in the USA, and was bound to become increasingly important. He also laid great emphasis on the crucial role the electronics computers were destined to play in the near future in all fields, from pure research to industry, and many other areas.

The use of computers would become inevitable in railways and communications, missile guidance and meteorology and even in such a complex field as national planning," he wrote, and further proclaimed that "computers were giving rise to a new world view and a new scientific culture in society.

The Committee laid down the blueprint for a ten-year development of the electronics industry in India. Over a brief period of two years, 21 reports were submitted, and the final report was completed in December 1965. It was estimated that electronic equipment worth around Rs. 1,600 crore would be needed in the next ten years in India, but the necessary investment was only around Rs. 170 crore, with an annual income generation of around Rs. 300 crore.

The Report emphasised the high employment potential of the industry: the capital investment per skilled worker would be around Rs. 5,000, compared with Rs. 150,000 in the steel industry, in ten years nearly 4 lakh persons would get employment, most of whom would be skilled workers, engineers and scientists. Moreover, women had more opportunities here, because of the traditional skills they possessed, than in other industries involving heavy labour.

The Report enjoined the Government to take a firm policy decision to allow the growth of this industry on the scale recommended by the Committee and to implement it rigorously. At all levels, from policy formulation to management and actual production, important executive positions should be in the hands of scientists and technologists, and avoidance of unnecessary bureaucratic delays was essential.

Unfortunately Bhabha could not actually submit the Report to the Government, because of his tragic death in January 1966. Sarabhai, who stepped into his shoes, delivered it. Sarabhai has said that the Electronics Committee Report was "one of Bhabha's most memorable contributions".

Eventually, the Electronics Corporation of India Limited (ECIL) was established at Hyderabad under the leadership of A. S. Rao; the Electronics Commission and later, the Department of Electronics (DoE) was established at the Centre. However, bureaucratisation could not be avoided, and although a good deal of progress did take place, it was not at the rate Bhabha had visualised.

Pure and Applied Science Research

Bhabha used the strong and wide DAE umbrella to provide sheltered niches for pure, as well as applied research in diverse areas, not limiting himself strictly to atomic energy related development. The TIER was brought under DAE immediately after the Department was established. It may appear natural, as it was a unique case, TIFR being the cradle of Indian atomic energy programme. But Bhabha had a wider view encompassing a much wider area of S&T, and he, in his magnanimous or imperious style, (depending on which side one belongs) did not care much about conventional jurisdictional authority, or territorial boundaries within the domain of Indian science.

There were two principles he followed. One: if there is an able and competent researcher, capable of building a group, give him strong backing and full autonomy in his sphere. Two: if he found that some existing institution was languishing due to lack of

sufficient support or otherwise, and taking it under the DAE umbrella would improve its performance, he would go ahead with it—call it takeover or merger or whatever.

Let us see some interesting examples of this.

In TIFR itself Bhabha supported two important subjects, once he came across suitable persons, namely, Molecular Biology and Radio Astronomy. This *was* in the early 1960s by which time the Institute had already grown to an international status in fundamental physics and pure mathematics.

Molecular Biology and Prof. Obaid Siddiqi

Way back in 1944, while he was planning to establish TIFR, Prof. Hill had written to Bhabha that biological research was neglected in India, and it should be taken up under the proposed institute. But at that time Bhabha did not mention biology in his proposal, restricting only to physics and mathematics. Probably, he did not wish to spread his efforts too thinly. By I960, he was full of confidence.

In 1962, at a seminar in Cambridge, Bhabha met Leo Szilard, the great Hungarian physicist and a migrant to the USA, who had played a prominent role during the Manhattan Project of atomic bomb. Szilard pointed Bhabha's attention to the Indian molecular biologist, Obaid Siddiqi, who was then closely associated with him in the Pennsylvania University. Siddiqi himself has stated, "...I do not know what Szilard told Bhabha, but within a week, I got a letter requesting me to join TIFR. It did not have a biology unit in 1961, so Bhabha asked me to first get whatever equipment I needed."[1]

Obaid Siddiqi, born in 1932, was a young man of 30. With an M.Sc. in biology from the Aligarh Muslim University, he had gone to Scotland, and thence to Pennsylvania University in the USA. The new molecular biology division was to be a part of the School of Physics in TIFR. There was some initial opposition from the Faculty to venture into such a new area, totally unrelated to the type of work that was going on there. But Bhabha had made up his mind. He asked every Faculty member to contribute 10% of his budget to provide the starting funds for Siddiqi's facility.

Siddiqi fully justified Bhabha's trust. TIFR molecular biology group has attained international status, and Siddiqi himself achieved many honours, including FRS and Padmauhushan in 1984.

Radio Astronomy and Prof. Govind Swarup

In September 1961, four Indian radio astronomers (those who study the skies using the radio waves, and not the visible light, coming from the stars and galaxies) working abroad jointly addressed identical letters to Prof. D. S. Kothari, Chairman, University Grants Commission; Dr. Hussain Zaheer, Director-General, CSIR; and Dr Bhabha, Chairman, AEC. They had a proposal for the formation of a radio astronomy group in India. Copies were also sent to some international experts in the field, requesting them to send their comments on and assessment of the proposal for the consideration of these Indian organisations. While the UGC and the CSIR were taking their own time to look into this proposal, Bhabha moved quickly. As Bhabha was away in Geneva, the proposal was forwarded to him, and he called the foursome to meet him in Washington DC, in

November. They had a lively meeting and after satisfying himself about their abilities, Bhabha decided to repose his trust in them. Two more months and Govind Swarup received a telegram from Bhabha, dated 20 January 1962: "We have decided to establish a radio astronomy group. STOP. Letter follows with offer."

In April 1963, Swarup joined TIFR, and stayed on to achieve impressive progress in this newly developing branch in the ancient science of astronomy, resulting into the big radio telescopes near Udagamandalam (Ooty) and Pune.

Govind Swarup (b. *1929),* who was a student of K. S. Krishnan at the National Physical Laboratory, Delhi in the early 1950s, was sent to Sydney, Australia to study radio physics under the Colombo Plan Fellowship Programme in 1955. From there he had proceeded to Stanford University in the USA for a PhD in radio astronomy.

After he joining TIFR, he submitted within months, a proposal to erect a large cylindrical radio telescope near equator, somewhere in south India, for studying quasars and other radio sources, with four to five times the collecting area of the Jodrell Bank radio telescope in the UK, one of the largest in operation in the world at that time. It was to be built totally indigenously. Bhabha gave his full backing to Govind Swarup.

A site near Ooty on a hill slope (11 degree north latitude) was finalised in January 1965. The Tamil Nadu Government allotted the site without any delay, the Tata Consulting Engineers helped in the structural designing and mechanical fabrication of the components, and by February 1970 the 530 m by 30 m large cylindrical telescope became operational. That was after Bhabha's death. But just a few days before that, on 6 January 1966, Bhabha had proposed the Ooty radio telescope as a centre for inter-university work.

Meanwhile, during 1968 to 1970, Swarup had successfully accomplished the indigenous fabrication of dish antennas for the satellite earth station at Arvi near Pune. Later in the 1980s, he proposed the construction of a Giant Meter-wave Radio Telescope (GMRT) at Narayangaon near Pune. This, one of the largest radio telescopes in the world, with 30 dish antennas spread over an area of 25 km, has become operational in the late 1990s. Swarup was elected FRS in 1991, and has won many national and international awards.

Autonomous Institutions under DAE

As already mentioned, TIFR in 1955 and PRL in 1961 became autonomous institutes under the DAE umbrella. But there were other cases too—the SINP, Kolkata, and the Tata Memorial Centre, Mumbai.

The Saha Institute of Nuclear Physics (SINP): Meghand Saha was the first person in the country to start the study of nuclear physics in 1938 in the Physics Department of the University Science College in Kolkata, where he was the Palit Professor. He wanted to have a cyclotron in the university, and sent his student, B. D. Nagchaudhury, to Berkeley, California to work under Ernest Lawrence, the inventor of cyclotron. The construction of the Kolkata cyclotron was started in 1941, but got delayed inordinately due to the wartime difficulties. After the war ended with the use of the atomic bombs, he realised

that the subject had developed to such an extent, that a university department was inadequate to do justice to it, and a separate institute was called for.

Thus, in 1948, the foundation was laid for the Institute of Physics (INP was renamed Saha INP after his death), and on 11 January 1950 the opening ceremony took place at the hands of Irene Curie, the daughter of Marie Curie and herself a Nobel Prize winner. In 1951, it became an autonomous institute, with its own constitution and governing body, within the University of Kolkata, and the finance came mostly from the Central Government. It became an all-India institute, but the scale of operation was still small due to funding limitations. In 1954, Bhabha had a meeting with Saha, and the Institute was offered Rs. 50 lakh for the duration of the Second 5-Year Plan through DAE, many times larger than what was available till then.[3] Though Bhabha and Saha were not seeing eye to eye for quite some time, Saha being a vocal critic of the atomic energy programme as it was being implemented by Bhabha, the personal differences were kept aside when the future of the Institute was concerned. Saha accepted the offer, and INP became an autonomous institute under the DAE umbrella. Rid of the earlier financial constraints, it grew rapidly. Now it has a new large campus in the Salt Lake area, next to the Variable Energy Cyclotron Centre of BARC in Kolkata, and has acquired international reputation like the TIFR

The Tata Memorial Centre: Somewhat different in context, but similar in spirit, is the story of the Tata Memorial Centre, a cancer hospital with a research centre, under DAE. The Tata Memorial Hospital for treatment of cancer patients was a pioneering project in the country undertaken by the Dorab Tata Trust. Established in 1941, well before TIFR, it was run by the DTT on its own till 1949, when the Bombay Government started giving an annual grant of Rs. 1 lakh. But cancer treatment is a costly affair, and in the absence of such facilities elsewhere, patients from all over the country came to this hospital. As it became difficult to manage, in 1957 it was handed over to the Government of India with the Ministry of Health taking charge.

The hospital by then had a group of devoted surgeons and doctors whose reputation had spread all over the country. The Ministry of Health, which had the responsibility of all aspects of national health, could not allot enough resources for the specialised hospital, and it experienced a period of decline. Some of the doctors then met Bhabha and pointed out that the US AEC was running a number of cancer research centres and hospitals in the USA, as the radiation therapy used in cancer treatment needed isotopes etc which came under the jurisdiction of the AEC, and they requested Bhabha that Tata Memorial Hospital be saved by taking it under the wings of DAE. Bhabha immediately saw the Prime Minister, got his approval and since 1963 the TMH came under DAE. In his capacity as the Chairman, AEC, Bhabha served on the Government Board of the hospital.

In 1966, the TMH and the Indian Cancer Research Centre were merged and named the Tata Memorial Centre with the Chairman, AEC as the ex-officio Chairman of its Covering Council.

The precedence established by Bhabha, mostly by the mere force of his influence in overriding the usual bureaucratic hurdles, has become a legacy of DAE. The pre-eminent position of the DAE has been used to provide space where good work, not directly related

to atomic energy programme, can be carried out with the benefit of the excellent conditions and ambience available in the normal DAE institutes. Later the Institute of Mathematical Sciences (MATSCI) in Chennai, when it ran into trouble, was taken under DAE. The Institute of Physics, Bhubaneswar, Orissa, and the Harish Chandra Institute, Allahabad, also come under it

In TIFR itself, the Homi Bhabha Centre for Science Education (HBCSE) was established to improve science education at school level. The National Board of Higher Mathematics (NBHM), established to improve the mathematics education at the university level, also operates under the DAE, and among many other achievements it has enabled India to enter the Mathematics Olympiad scene with notable success.

"Nurturing excellence wherever you find it" was the motto of Bhabha, and he did not hesitate to throw his weight around to achieve it, imperiously ignoring the protests of many who thought that he was encroaching upon their territory. One thing is certain that compared to many other institutions these have maintained a higher standard of excellence.

While on the subject, it is interesting to note that when the AEET campus was being developed, Bhabha also had plans to convert the Trombay Hills into a National Botanical Garden, and some steps were also taken. However, after his death, the project was eventually dropped.

8
SCIENCE AND TECHNOLOGY ADMINISTRATOR

Bhabha himself was a great scientist and a very capable and inspiring leader of scientists. We have also noted his skills of diplomacy, as well as his clout and influence in the corridors of power. But all these qualities would still not have sufficed for him to achieve the kind of success he did. There was another decisive factor—his strong views about S & T friendly administration and his insistent, even adamant, attempts to get them implemented. Bhabha displayed two salient features in his attitude towards administration: one, a strong anti-bureaucratic bend against red tape, and two, a strong urge to empower scientists and technologists in the administrative set-up of S&T institutions. He tried to bring about a new administrative culture, at least in the S&T domain under his authority.

As Secretary to the Government of India, Bhabha himself was in the seat of a top bureaucrat, and as the Chairman, AEC, he even enjoyed the status of a Cabinet Minister at the Centre. But he never had much love for the functioning of the ICS/IAS bureaucracy, a legacy of the Colonial Government, structured for administering a subject people, rather than supervising and executing the development process of these people.

Critics of Bhabha have often resorted to mentioning his family connection with the house of Tatas. This may give a facetious impression that his anti-bureaucratic was hinged upon a bias for corporate, private sector as against the public sector. But this would be unjust to Bhabha. He was very well aware, and had said so explicitly, that in a country like India, modernisation and particularly establishment of modern S & T infrastructure had to be accomplished in a planned manner with Government support. He was not against public sector per se, but against the bureaucratic red tapism that usually

permeated the Government administration. Even while proposing the establishment of TIFR, way back in 1944, he had written that Government support would be needed, but "Government support without Government control" was what he aimed at.

This brings us to the positive side of his criticism of bureaucracy. In the domain of S & T, he wanted to put scientists and technologists in the forefront of decision-making, from policy formulation to execution and management of the projects.

In his last major speech, delivered in January 1966 at the meeting of the International Council of Scientific Unions held in Mumbai, he had succinctly stated his viewpoint. The speech entitled "Science and the Problems of Development"', was concluded with following remarks.

It is thought by many that we are reasonably advanced in administration, but backward in S & T. This statement is misleading. We have fortunately inherited extremely competent administrative service capable of dealing with all the types of administration, which had to be dealt with before independence, in what was intended to be a static and underdeveloped economy. Consequently, experience of the type of administration needed for industry and for S & T has been lacking.

The type of administration required for the growth of S & T is quite different from the type of administration required for the operation of industrial enterprises, and both of these are again quite different from the type of administration required for such matters as the preservation of law and order, administration of justice, finance and so on. It is my personal view, which is shared by many eminent foreign scientists, that the general absence of the proper administrative set-up for science is a bigger obstacle to the rapid growth of S & T than the paucity of scientists and technologists, because a majority of scientists and technologists we have, are made less effective through the lack of the right type of administrative support. The administration of scientific R&D is an even more subtle matter than the administration of industrial enterprises, and I am convinced that it cannot be done on the basis of borrowed knowledge. It must necessarily be done, as in the technologically advanced countries, by scientists and technologists themselves.

In his own domain Bhabha did this with notable success. Even on the Governing Council of TIFR, there were representatives of Central and State Governments, but Bhabha with the force of his personality, saw to it that the scientists and technologists always had the upper hand and the bureaucrats' role was limited to help implement the decisions taken, within the Government framework. In TIFR, the Faculty, which consisted of professors and senior scientists, took decisions after free discussions. In AEET, there were the Trombay Council and Trombay Scientific Committee, consisting of Division Heads and senior scientists, which decided upon the course of action, after collective deliberations. Obviously, Bhabha being a dominant and towering personality, his views often prevailed (and he used to be right most of the times), but he was not comfortable with mere yes-men, and wanted everybody to discuss every proposal threadbare, listened to others, and sometimes did yield his position, when convinced by others.

A noteworthy characteristic of his was that once a decision was taken and specific responsibility allotted to a person, Bhabha would not interfere in the matter, but would give full freedom and extend his full support to the person. Another characteristic of his functioning was that he never started with a rigid organisational structure, even at the

AEET in the initial period. Starting with a loose, open-ended organisational entity, placed within a broad policy framework, he allowed it to grow without too many constraints. In T1FR there were no fixed numbers of research posts. If a worthy person were available, a post would be created for him even at the professor level. If someone did excellent work, he would be promoted without looking at his or others' seniority ranking. As a corollary, some non-performers had to stagnate, and, of course, appointments were made for fixed terms only. Though AEET was a different game, even there he used the same organic principle, what he himself called, "growing science".

It must, however, be acknowledged that Bhabha could accomplish feats within the DAE, because he was able to convince Nehru, who lent both his personal prestige and the Prime Minister's authority to Bhabha.

As an administrator, Bhabha was a protective boss and a successful fund-raiser, and he did not hesitate to bulldoze his way through any unnecessary bureaucratic obstacle. This was largely responsible for the initial comparatively rapid growth of the atomic energy programme. In the process whether any other field of S & T suffered or not, is a debatable issue. But it can certainly be asserted that the usual rigidity of bureaucratic functioning would have bogged down the rather complex and comprehensive atomic energy programme before it could encounter technical and political difficulties, as happened with many other institutions and projects in our country

This was also responsible for Bhabha's success in not only recruiting good talent, but, more importantly, in retaining it. Many of the scientists and technologists would have otherwise migrated to more congenial places abroad.

Bhabha was clearly able to maintain an ambience and working conditions, which provided challenging problems and means to pursue them, as also enough freedom and comforts and opportunities for further progress.

Precedence plays a very important role in Government functioning. Many of the precedents established by Bhabha have changed the face of S & T administration in the country, and we now have a large number of senior scientists and technologists working for the State, not merely in advisory capacity, but in executive positions, like Secretaries to the Government. So much so that sometimes we hear critics berating the scientific bureaucracy!

It was not that Bhabha confined his attention only to the aspects of administration related to scientific and technological matters. He was equally concerned with ordinary and routine matters, where the well-being of his staff and the maintenance of the facilities were involved. And he was meticulous about still mundane details like typing by the office staff, referring to people as "Shri" and not "Mr", or instructing authors of scientific papers about how to refer to the Trombay Establishment while writing their address. There are a number of notes, memoranda, and standing orders, which throw light on the interesting facets of his personality and functioning.

Let us quote from a note to the Prime Minister he wrote while the Apsara reactor commissioning was in its final stage, and scientists were working round-the-clock for days on.

The Note, dated 31 July 1956, says:

Our scientists have worked exceedingly hard and long. Everything should be done to relieve the physical strain. I have, therefore, ordered

a. Two cars at their disposal on a 24-hour basis to take them to and from their residence at any time they consider best—

b. Lunch and dinner supplied by an appropriate restaurant be provided to them at Trombay in the reactor building.

Both (a) and (b) are not permitted by Government regulations, and I, therefore, wish to have the Prime Minister's approval for the action taken.

Jawaharlal Nehru, of course, obliged.

Another gem is the standing order issued by him (dated 23 February 1961), when the new campus of TIFR was being occupied...

...the new buildings are now nearing completion and will be in full operation in next few months...no pains have been spared in providing as good conditions of work and amenities for comfort and general well-being as are found anywhere today...Each member of the staff should have a sense of personal pride in these buildings and it is his duty to take personal interest in their proper maintenance...

...normal and elementary good manners with regard to use of buildings and fixtures and furniture must be observed— misbehaviour should be reported to the super visor... All Faculty Members and senior Administrative staff have the responsibility...

...Move about and talk quietly so as not to disturb others, especially in public areas like lounge, canteen and reading room—doors be closed deliberately and quietly...strictest norms of cleanliness throughout the buildings especially in the lavatories and marks from dirty hands should not be left on walls...Disciplinary action will be taken against those who persist in misusing lavatories.

When the AEET campus came up, similar orders, about housekeeping and other matters were issued, with one senior staff member in each laboratory or building, given special responsibility. Even in a matter as simple as the annual increment for the employees, Bhabha introduced innovative change. Increment dates were decoupled from the exact date on which the employee joined the establishment, and increments were given in either February or August for all. This must have simplified the work of the Accounts Department a lot, but it is not difficult to imagine the consternation it must have caused among the orthodox accountant. Elsewhere, if an employee had joined on the 6th or 9th day of a month, advancing his date of increment to the first day of the month has been *a* recent change.

Bhabha also made many other facilities available to his staff not so common for those days. In a metropolis like Mumbai, residential accommodation near the workplace and special transport were certainly envious perquisites, and good medical care, too. The tradition has continued after his death and the DAE employees can be rated among the most privileged workforce in this regard.

Bhabha was an aristocrat in his personal life, and often arrogant towards others who had to deal with him. But to his staff he was a caring, benevolent aristocrat. There are

also stories about his going out of his way to help employees, who were in difficulties and needed special care.

9
THE ARTIST, PATRON AND CONNOISSEUR PAR EXCELLENCE

Since I cannot increase the content of life by increasing its duration, I will increase it by increasing its intensity... Art, music, poetry, and everything else that I do have this one purpose—increasing the intensity of my consciousness and life.

—Homi Bhabha (1934).

C. P. Snow has famously written about the great divide in modern society, between the world of science and the world of liberal arts. There is a nostalgic harking back to the European Renaissance period with Leonardo da Vinci as an icon for the future complete man. Yet there are always exceptions to the general rule, and even the 211th century has thrown up many great geniuses with the Renaissance personality. Bhabha was certainly one of them.

Bhabha was a man of both the worlds in a double sense. A man of science and that of arts, he also spanned Western and Eastern civilisations. A man steeped in wide culture, he was at home with paintings and music, appreciated literature, architecture and landscaping, loved flowers, trees and gardens. A scientist of great calibre, the arts were for him "what made life worth living".

As an Artist Himself

Bhabha himself did a large number of paintings, drawings and sketches, which were praiseworthy by professional standards.

Since childhood, he was exposed to a range of illustrated books on European masters in the family library with the collections of his father and grandfather. By the age of 15, he had become familiar with the world's art masterpieces. He took lessons in painting from Shri Jehangir Lalkaka, and did oil paintings in the British academic style. In the Annual Exhibitions of the Bombay Art Society, he had won many prizes in the artists-under-18 groups.

His stay in Cambridge and the extended visits to European centres of scientific research, while making a first-grade physicist out of him, also afforded ample opportunities to develop the painter in him. He visited the art galleries and museums of Europe and its impact was strong. In the words of his younger brother Jamshed Bhabha:

Seeing the originals of Impressionist and post-impressionist masters stimulated him to change his drawing and painting from the dull academic style learnt in Bombay to a more vigorous individual style.

This was a very creative period not only for Bhabha, the scientist, but also for Bhabha, the artist. The rigorous mathematical physics he was engaged in at that time, he could not

pursue with concentration beyond five hours a day. So the remaining time he would devote to artistic pursuits, as a kind of relaxation and recharging of batteries. He painted a number of oil canvases, including compositions with human figure, often inspired from musical themes. He also did "abstracts", and painted scenery for the Amateur Dramatic Club.

He designed an artistic and symbolic new cover for the college magazine, and Sir John Cockcroft has noted that this was too radical a design even for the students of the college. And he was active in portrait studies, and drawings and sketches of gardens and monuments and sculptures while he moved around Europe.

Oil painting is time consuming, and most of Bhabha's output belongs to drawings, especially after he returned to India and immersed himself in research and organisational work. But throughout this period he continued to sketch and draw as he toured around India.

His paintings found place in exhibitions in London, including the Commonwealth Painting Exhibition in 1964. A portfolio of his drawings, with introduction by the noted art critic, Karl Khandalavala, was published by the MARG Publications, shortly before his death. And M. F. Husain has stated that Bhabha's sketches were first-rate, his fine lines reminiscent of Leonardo da Vinci. This is high praise, indeed!

Presently a number of sketches and drawings by Bhabha adorn the 14th floor special dining room of the new Hostel-cum-Guest House building in BARC.

A Connoisseur Par Excellence

Though Bhabha's interests spanned over a wide range, he was not a dilettante. He appreciated and understood the arts both aesthetically and technically. Let us have a quick look at some of these interests.

Music: Bhabha was perhaps born with an ear for music. His parents had noticed early that switching on music had an instant effect of calming down the crying baby- From an early age, he developed a deep love of music, listening to the gramophone records of Western classical music in the collection of his maternal aunt, Ms. Cooma Panday (who owned the bungalow, Kenilworth, the birthplace of both Bhabha and TIFR). By the time he was 16, he was familiar with many of the major symphonies, concerts, and chamber music of Beethoven, Mozart, Bach, Haydn, and Schubert; as also popular classical European music by Chopin, Wagner, Tchaikovsky and others.

As for Indian music, even during his Cambridge days, he used to listen to records of classical music. But it was in the 1940s, when working at Bangalore, that his knowledge of Indian music widened and deepened, and he began enjoying A. Ramanuj Iyengar, Subbalakshmi, Semmangudi and many others.

The place of music in his life can best be described in the words of his younger brother, Jamshed Bhabha: "What religion, with its forms of ritual and prayer, is to so many, music was to him. In time of stress, it gave him solace and strength, and all time, music was a source of immense stimulus and inspiration to him."

But though a matter of intimate personal experience, Bhabha also appreciated music in a wider historical perspective. The following comments of his, made as early as 1934, are illuminating:

Mozart came at the end of an epoch, Beethoven at the beginning of another. It is Beethoven's birth after the French Revolution that explains the new force in his music and the new spirit of faith in human progress. In Mozart's time, the inequities that were so strong, had always existed and, in the mentality of those times, might have gone on always existing. In Beethoven's time, the French Revolution had shown that inequalities of opportunity and class could be overcome and that the oppressed classes could be raised to a higher position. This eliminated the helplessness of the spiritual atmosphere before the French Revolution. This is one main reason for the great power of the music of Beethoven and his heroic themes.

Literature: Though perhaps the least important among his interests, for whatever reasons, it speaks volumes for Bhabha's boundless energy that during the Cambridge days, so full of theoretical physics and painting and music, he still managed to find time to read Shakespeare, Shelley, Keats and T. S. Eliot, a creditable pastime achievement in itself for any average person.

Architectural Monuments: The books in the family library had acquainted Bhabha with the monuments of European architecture. His European sojourn during the Cambridge days made it possible for him to visit these sites, and look them over with the cultivated eye, both of the artist and of the engineer. And he lingered around making sketches in his notebook.

Though not a subject of his study even for the Mechanical Sciences Tripos, he could speak with authority on architecture. R. B. J. Patel, a noted architect, who worked on the construction of AEET, had once accompanied Bhabha on a tour of Europe, and has reminisced that it was "a trip that was as much a tour conducted by him of the architecture of Versailles, of the 'Gothic' and the 'Baroque', as of reactors and laboratories."

After the return to India, during his travels across the country for scientific lectures, meetings and other organisational work, he turned his attention to Indian architecture. He visited Elephanta and Ajantha caves, Verul (Ellora) and Sanchi, Fatehpur Sikri and old Delhi cities, and made sketches.

Rudi von Leyden, a Jew who had migrated to India after Hitler's rise to power in Germany, was a noted art critic. In his reminiscences after Bhabha's death, he has written that "Bhabha was deeply conscious of the beauties of the cities of Delhi, and whenever he could steal an hour, would relax at Hauz Khas, or in sight of one of the Lodi Tombs, or in front of the magnificent facade of Shershah's mosque of Purana Kila."

Cecil Powell, the British Nobel laureate in physics, had, during one of his visits to India, seen the temples at Belur and Halebid. When Powell met Bhabha later, Bhabha explained to him that these temples represented an extremely late stage in the development of architectural style in India; that just as the art and architecture in the early history of Egypt and in the early dynasties, were characterised by great simplicity and

naturalism, so was the case in India; but that in India the earliest remains had almost all disappeared, so that we see a kind of immensely elaborate rococo, and nothing of India's real classical style. Perhaps, like the relics of Mohenjodaro and Harappa, some of them would one day be unearthed, hoped Powell.

R. Von Leyden has recounted another incident, which shows what place architecture had in Bhabha's vision of modern India. Once Bhabha and Leyden were standing together on the ramparts of Purana Kila and Bhabha spoke, in great anger, of the rape of the beautiful city of Delhi by sterile PWD architects, by the tastelessncss of the bu-reaucrats and politicians, by the avarice of land speculators, and by the complete lack of culture in the city, where a half ruined chhattri at the end of a broken-down wall had more significance than all the post-1947 "Bhawans" put together. Leyden has emphasised that what Bhabha regretted most was the loss of tremendous and challenging opportunities after independence to create worthy modern Indian architecture."

Trees and gardens: Bhabha's love for trees and gardens is better known, with some legendary incidents of his valiant efforts to save trees from the axe.

His initiation into this field, too, took place in the family library and with frequent family trips to Bangalore, the garden city of India and, as in other areas of interests, he cultivated it into a comprehensive viewpoint, with aesthetic, artistic, technical, environmental and historical elements fused together seamlessly.

He visited gardens wherever he went and made sketches and took photographs. The French and the English gardens of 18th century and the Mughal Gardens in India were his favourite. And he was also well versed in the Italian, Japanese and Persian gardens.

For him landscaping was not a luxury, and he held that the garden was an essential component of site development in any establishment He considered landscaping, the choice of plant material and its positioning a matter of artistic composition. Bhabha was particularly fond of the Palace Gardens of Versailles in France, where the beauty of Nature was tamed and controlled by the skilful hands of the French artists.

Bhabha had a passionate love for trees. In the words of S. D. Vaidya, Superintendent, Parks and Gardens (and later Head, Landscape Architecture Section), AEET: "His sensitive mind perceived the trees as living sculptures, giving a character of their own to the place where they stood ungrudgingly for generations". Naturally, he could not stand cutting down trees as an inevitable fallout of development. The chief architect of the modern Indian S & T build-up that he was, he went out of his way to save trees, even going to the extent of changing plans. In AEET the road alignment was changed to save a 100-year-old mango tree. In the new TIFR campus a rain tree stood on the way of the approach road. It was not possible to change the road alignment, so the tree was transplanted elsewhere on the campus. There were also a number of full-grown peepul, banyan and Barringtonia trees where the new buildings were to come up. Each one was transplanted on the campus with success. It involved large expenditure, but for Bhabha it was not an avoidable one. He even went to the extent of saving trees which were to be cut down during road-widening activity of the municipal corporation, and were auctioned to timber contractors. The AEC Chairman would not hesitate to intervene with the local municipal authorities to save a tree. This attitude, to some extent, did percolate

elsewhere. For example, the ITT campus at Powai Hills in Mumbai, did have a large tree transplanted. According to Vaidya, Bhabha started the era of transplanting big trees in our country.

Gardens and trees, and naturally flowers follow! Suffice it to say that it was Bhabha who pioneered rose cultivation in Mumbai. Vaidya has written, "It was believed impossible to grow roses in Mumbai. But with Bhabha's initiative, AEET started to grow roses and in 1960, there were as many as 750 named varieties growing successfully in the Rose Garden."

No wonder Bhabha played a prominent role in the "Citizens' Committee for Beautiful Bombay."

A Patron of Art and Artists

Himself a painter of considerable talent, and a formidable connoisseur with wide and deep culture, Bhabha, in addition, played an important role as a patron of art in modern India.

As a young artist, he was familiar with the Mumbai art world before leaving for Cambridge. With the establishment of TIFR, Mumbai again became his base and he once more got involved with the artists. By now he was a famous scientist and naturally, his presence and appreciation were encouraging. But Bhabha went a step further, and bought paintings.

Shri Kekoo Gandhy, who later established the famous Chemould Gallery, owned a frame shop, where the paintings were framed for exhibition. According to him, Bhabha often used to come from Kenilworth, where TIFR was located, to visit his shop in the afternoons, to look at the paintings brought there for framing. In particular, there was a kind of unwritten agreement between them that before any exhibition of paintings, Bhabha would be called a day before, and he would talk to the artists about their paintings. He would have the paintings held up before him for a long time and would examine them minutely and suggest the type of frame for the painting he had selected to buy. Gandhi has remarked that "Bhabha's selection was not impulsive, but a kind of team work." He bought paintings not only for his own collection, but also for the Institute.

Most of the paintings he bought were from the new generation artists, who represented the emerging trends in India, and not from those in the British academic or traditional Indian styles. In a way, he was encouraging and patronising the contemporary Indian art. When the Institute was located in the Old Yacht Club, there was a fairly large collection of paintings, which adorned the walls in the offices and the corridors and along the stairs. Many visiting scientists have made special reference to this collection. As the Institute moved onto the new campus, the collection expanded. Larger paintings, as well as sculptures in wood and metal were added. Bhabha had acquired a bust of Einstein sculpted by the famous London based artist, Epstein, as also a couple of Rajasthan temple pillars in stone.

J. J. Bhabha has said, "My brother had been successful in getting the then Prime Minister Nehru, to sanction as much as 1% of the TIFR budget for buying art." Lord Penney, in his article in the Biographical Memoirs of the Fellows of Royal Society, has specially quoted von Leyden: "Bhabha collected for the Institute one of the finest and

most representative collections of contemporary Indian art. The paintings and sculptures bought by him not only adorn the gardens, the vestibules and the corridors, but also the individual study chambers and the seminar rooms." One finds here V. S. Gaitonde and S. H. Raza, jamini Roy and Badri Narayan, N. S. Bendre and Palsikar, F. N. Souza and K. H. Ara, B. Prabha and H. A. Gade, and K. K. Hebbar and M. F. Husain among others.

It goes without saying that the expenditure involved attracted criticism from outsiders, and objections from Government auditors. But Bhabha had a strong conviction that the cerebral activity of the scientist had to find its counterpoint in the activity of the senses in art, and this would enhance his creativity.

Bhabha also lent his presence to various activities that were afoot at that time. Independence had brought in fresh winds of change. In 1948, an All-India Art Conference was held in the Asiatic Society, Mumbai with a view to establishing an all-India body to promote fine arts in the country. Many eminent artists, including Svetoslav Roerich, participated and Bhabha was among them. Somewhat deeper was his involvement with the activities of the Progressive Artists' Group in Mumbai.

The Progressive Artists' Group (PAG) was formed under the initiative of the painter, Francis Newton Souza, in 1947. Souza was then under the influence of the Progressive Writers' Association, a group of left-oriented, young generation talented writers, which included Krishna Chandra, Mulk Raj Anand, K. A. Abbas among them. The founding members of the PAG were F. N. Souza, S. H. Raza, K. H. Ara, M. F. Husain, H. A. Gade (all painters), and S. K. Bakre (a sculptor who later turned to painting). V. S. Gaitonde joined the group later. Others, like Tayab Mehta, Krishna Khanna, Akbar Padamsi, were close associates, and many others sympathised with the principles of the group.

The word "progressive" did imply, in Souza's original conception, a certain leftism: "To bring about a closer understanding and contact between different sections of the artists' community and the people", etc. But the link was rather tenuous. Most of the artists involved were innocent of any ideology, and were deeply concerned with their own art form. They were dissatisfied with and rejected both the British academic style and the traditional Indian style, and wanted to evolve their own contemporary Indian style. As Souza later wrote in 1949, "We have studied the various schools of painting and sculpture to arrive at a vigorous synthesis." In this sense the PAG represented a new rising trend in Indian art, and Bhabha fully appreciated this. The PAG operated from a small room in the Artists' Aid Centre (later renamed, Artists' Centre) on Rampart Road in South Mumbai. Group discussions and lectures were held here. Mulk Raj Anand and von Leyden were among the speakers. Gade, who was the Secretary of PAG in later years, remembers Bhabha having delivered an important lecture, presenting a broad view of the art of painting.[1]" Bhabha unfailingly attended these meetings, accompanied by his mother. The first exhibition of the PAG was held in 1949. However, the group dispersed within 3 to 4 years, as Souza and Bakre left for the UK, and Raza migrated to Paris, although each one continued to develop as an artist. In 1954, PAG was officially closed.

But while it lasted, Bhabha was a regular visitor. He would drop in from the nearby OYC, where TIFR had shifted, to see the paintings, and was accompanied by his colleagues. The mathematician, K. Chandrasekharan, himself started painting as a result.

Gaitonde was Bhabha's most favourite painter; Ara was a close friend, who for some time gave painting lessons to the children of the employees of the Institute. Gade has

mentioned that Bhabha bought paintings at the price quoted by the artist, which in those days ranged from Rs. 200 to Rs 400 at the most. Another fond memory of Gade is of the opening ceremony of the new TIFR buildings.. .Artists were specially invited, seated in front, and later introduced to Prime Minister Nehru by Bhabha with comments on their work.

M. F. Husain had a special relationship with Bhabha. His first exhibition at Chemould Gallery was inaugurated by Bhabha, and in 1961, Bhabha executed a fine pencil portrait of him. "I sat for him for an hour or so in his house," Husain has recalled with pride." And for the new TIFR building, Husain did a 40 feet by 10 feet mural, which adorns the wall just outside the entrance to the library.

The mural had a very special place in the artistic adornment of the Institute Bhabha had in mind- For the purpose he had invited about 10 artists from all over India to submit paintings of a fixed size (350 cm by 30 cm or so). No subject was prescribed, and each one was paid a fee. One of the paintings was to be selected for doing the mural. All the artists submitted their paintings and these are displayed in the corridors of the Institute.

For the mural Bhabha zeroed in on Husain's *Bharatabhagyabidhata* and Hebbar's *Civilisation. Bharatabhagyabidhata* is in Rajasthani style—bright colours, a Garhi, men and women, and horses, camels and elephants in procession. *Civilisation* has a theme depicting the evolution of man from the primitive stage, when he was scared of the elements, to the modern one, when he has become the master of the elements. Both these paintings are presently displayed opposite each other in the fifth floor corridor. Bhabha is said to have deliberated for long over them before choosing Husain.

Husain worked on the mural in the Institute itself. He was allotted a separate room where he painted four separate pieces on canvas, which were then glued together on the wall. As good quality material was not available in India at that time, the canvas and all other material were specially imported. The artist was paid about Rs.15, 000, a princely sum for that period. ("Now it would be worth 2 crores," said Husain.) Bhabha would often drop in with colleagues and chat over tea. Husain has said jocularly: "I enjoyed that stay among the scientists—the lunches, the conversations etc. In fact, I stretched time, and took one-and-a-half years for the work which otherwise I would have done in one-and-a-half months."

According to Husain, Bhabha was the first corporate patron of contemporary Indian art. At that time, though they already had good work behind them, the "Society" (that is, the art critics and rich patrons; the establishment) did not recognise contemporary Indian artists. In the beginning "Rabindranath Tagore and Bhabha were the only ones to recognise the significance of contemporary Indian art".

And now let us return to AEET once again.

An Artist Working on a 3-d Canvas

The AEET was dedicated to Bhabha, and renamed the Bhabha Atomic Research Centre (BARC) by Prime Minister Indira Gandhi on 12 January 1967. Today, it stands, as the largest scientific establishment in the country, celebrating the memory of Bhabha, the most important architect of post-independence Indian S & T build-up. But, for Bhabha himself, the AEET site presented itself as a vast 3-d canvas to be sculpted into a

masterpiece, representing a scientific monument of modern India—one, not merely ordered by imperial fiat, but one, in the execution of which he participated intensely.

Bhabha was known to be very meticulous about the selection of scenic sites for his establishments, as is evident from the TIFR, the Ooty Radio telescope and the Kalpakkam Atomic Power Station and Research Centre sites. Yet the AEET site was something special still.

Literally a virgin tract, the 1,200 hectare plot had a most beautiful location—a high crescent-shaped hill on the west, its extremes almost reaching the creek waters, sheltered the plot from the hustle and bustle of the Mumbai metropolis (and that is true even today nearly half a century later). The waters of the Mumbai harbour in the Thane creek on the east, with thick mangroves along the waterfront, provided a quiet buffer. And the famous Elephanta Island, with its Trimurti caves, in full view across the waters, is a reminder of the ancient glory of India. Bhabha wanted his establishment to be a modern-day equivalent of Elephanta, counterbalancing and complementing the modern with the ancient. It was to be a modern S & T centre, and architectural monument with beautiful gardens on the background of a thickly wooded hill—the Scientific-Industrial Versailles of modern India.

To comprehend what Bhabha had in mind, it is best to quote him from a note he wrote to the Prime Minister: "Architects for AEE", dated 18 June 1956. Informing Nehru that the main site was virgin with no buildings, that it would have 23 large and small buildings for laboratories, library, administration, workshops, etc, he wrote that the estimated cost was between Rs. 2 and 3 crore and the sum of 3 crore had been provided for the purpose in the second 5-Year Plan of the Department. Then he spelt out his vision:

"These unique circumstances present an opportunity for developing an architectural project which is not only functional and efficient, but of architectural significance, reflecting the development of the age we live in. There is indeed an obligation on the Department to do the best it can and to see that the opportunity is not missed."[1]-

He then informed the Prime Minister about the proposal from Department that five architectural firms be invited to prepare the site plan with suggestions for the general architectural concept which would run through the entire architecture. It was proposed to pay Rs. 3,000 honorarium to each firm and a Rs. 10,000 prize for the winner. Then came the complaint, which Nehru had become familiar with—"The Minister of Finance has turned down the proposal (without seen by its Secretary)". And he commented that this explained "Why architecture, one of the glories of Indian civilisation in the past, has now sunk into complete insignificance." And then came the punch line. Bhabha wrote that since immediate action was needed he was putting the proposal before the Prime Minister for approval. Once approved, "the papers will be sent back to the Finance Ministry for ex-post factor sanction".

Bhabha worked closely with the architects at all stages, from planning and designing through the construction to the execution of finishing details, putting his heart into it. Not only architecture, even landscaping and layout of gardens and the afforestation of the Trombay hills received equally intense attention from him. Legendary stories are known about his total involvement in this monumental endeavour.

R. B. J. Patel, one of the architects, has written, “It was just his tremendous and contagious enthusiasm in all fields of endeavour which made each one feel—the scientist, or the engineer or the horticulturist—that his was the subject of Bhabha’s special interest.”

As regards architecture, Patel notes:

In more ways than one, Trombay was his “brain-child”— his architectural laboratory where those of us who worked with him had the unique opportunity of full-scale experimentation with materials, textures and building-grammar... The Master-planning and Layout Development of the Research Site, a venture which occupied his sustained interest and attention throughout the last ten years, from the conceptual stages to the very end, was not mere broad-lined exercise to which he limited himself. He took the plunge into all of the many faceted problems, even in site engineering, that continually arose, and pursued each sometimes in the minutes details—The immensity of the scale on which one had to think in terms of Trombay, strangely enough proved to be his “forte”, in the masterly handling of vast spaces he excelled. His extensive travels abroad and in India were pilgrimages through the places, temples and gardens on which the master architects of the past had left their mark—and these were also his sources of inspiration and of considerable data collection—obtaining his approval on any aspect of a scheme or its detail was a major task. He would not settle for just the safe and the logical. Modular Lab at Trombay, was the only single building (besides the TIFR) to which he gave his special care and attention, In its innumerable design details that had to go through his surveillance, every season had its major architectural hurdle to cross before he would be convinced and gave his final consent. For example, I remember 1964, as “the year of the Concrete Facia”, or 1965 as “the year of the Jalli”. It all added up to a mental and emotional climate that stimulated—may be in which many a mind and heart even felt dedicated.’

Similar was the case with gardens in the spaces between the various _ laboratory buildings and on the hill slopes, and the plants and trees that covered the hills. According to S. D. Vaidya, top priority was given to the afforestation programme—planting over 15 lakh trees to cover all the barren portions of the hill, completed on a task force basis, even before the erection of the main laboratories. He was criticised for giving priority to aesthetics but replied that trees take their own time to grow, whereas laboratory construction can be accelerated artificially. In this industrial Versailles of Trombay, he wanted gardens like Versailles Gardens but with typical tropical plant material. Thus arose the Bougainville Garden (lush green mantle of tropical plants and bright cheerful colours of temperate flowering plants), the Rose Garden and the Mogra Garden. Horticultural experts were engaged to decide upon the right plant at the right spot.

During the construction period, he would often drive up the hill and from a vantage point (“The Bhabha Point”) would take a bird’s eye-view of the entire complex that was taking shape between the hill and the creek. He died before the completion of his dream of Trombay, which in the words of R. B. J. Patel, seemed “a cruel and meaningless fate for him”.

10
EPILOGUE

When you have a deep truth, then the opposite of a deep truth may again be—deep truth.

—Niels Bohr

Bhabha has left behind a rich legacy for Indian science. The wide network of various research institutes and laboratories and industrial complexes are the tangible monuments to his memory. But still more important is the large number of personnel in different branches of S & T that the country possesses. These trained scientists are confident of their abilities in the international area, and assertive in their role in the national development programmes— in policy formulation and implementation. The important and sometimes decisive role that top scientists have come to play at the national Government level represents in a way, the intangible legacy of Bhabha.

Opinions may differ about the appropriateness of the direction Indian S & T has taken, but the achievements of India in fields like space technology and nuclear energy, leading to indigenous development of rockets and satellites, and a number of nuclear power stations and the Pokharan-II explosions, firmly belong to Bhabha's legacy. Also, the important contributions of Indians in the fields of pure mathematics, radio astronomy, and molecular biology owe a great deal to his foresight and support.

Bhabha was an excellent facilitator and coordinating manager, a protective administrator, and a dashing fund-raiser. But as a teacher, who led others to greatness through his personal teaching, he was not quite comparable to other great scientists, as has been noted by E. C. G. Sudarshan. Though half a dozen pupils did get their doctorates under his guidance, he was not the legendary "Professor" like Rutherford or Bohr. Nearer home, our own C. V. Raman, and the Acharyas, J. C. Bose and P. C. Ray, exerted more influence as teachers.

As regards Bhabha's own work in fundamental physics, it would be appropriate to quote Sudarshan again. He has said:

Amongst people of our own times, Bhabha's work on Cascade Theory is on a par with Meghnad Saha's work on ionisation equilibrium. The only ones that surpassed it were Satyendranath Bose's discovery of Bose-Einstein statistics and C. V. Raman's of the Raman Effect. Yet it is a sad commentary that the momentum of Bhabha's discovery did not inspire comparable work in India—significant work on the frontiers. Whatever research excellence in theoretical particle physics has developed in India had to be kindled from other sources...There was no close group of brilliant young colleagues and pupils who made up a critical mass to sustain his spirit. This dilemma faces many of our best scientists even today.

It is to Bhabha's credit that instead of migrating abroad, he migrated to the field of S & T institutionalisation within the country.

Though notably successful in his own domain, his larger grand dream about fundamental research has remained unrealised. For him, fundamental research was the launching pad for self-reliant development and national prosperity for independent India. It was to be the foundation on which the edifice of applied research and technological development was to be erected. This has not materialised. Self-sustained development of applied and technological research, appropriate for Indian needs and reality, has not taken off.

Even in fundamental research, the few pockets of excellence existing in the country have not been very successful in influencing the quality of research and teaching in the wider academic world of Indian universities.

The debate about specialised research institutes versus the universities is quite old. It has been said that the growth of specialised research institutions under the AHC, the CSIR and the DRDO after independence was accompanied by serious deterioration of science in the universities, which lacked adequate resources, lamentable in comparison with these specialised institutes. Bhabha did talk of "growing science", "growing one's own people together" with the absorption of those returning from studies in universities abroad in the AEC institutions. He meant thereby that the AEC was not depleting the universities by siphoning off their talent. But the fact remains that given the limited resources marked for S & T, the large proportion that got channelised to these institutes deprived the university system of its normal proportionate quota of funds and fresh talent for research. This was further compounded by the rapid expansion of the university system, both in terms of the number of universities and the enrolment of students. This was the larger dilemma of an underdeveloped and poor country trying to catch up with the modern developed world. It was as much a necessity to raise the general level of education in society, as it was to make concerted efforts, in a few fields of specialisation, and nurture excellence. Bhabha, as the most influential scientist-leader of the specialised research, naturally attracted criticism from those who lamented the deterioration of the universities. But surely there were many other complex factors responsible for that, and the blame cannot be laid mainly at Bhabha's door. Certainly the TIFR was expensive, but to the extent it did develop into a centre of excellence, the expenditure has proved to be a wise investment: in the long run. B. D. Nagchaudhury has noted that "the concentration of power in the three organisations—the CSIR Labs, the Defence science labs, and the Atomic Energy labs—in the matter of scientific activity has resulted in the building up of the three scientific empires. It was causing the universities and other centres of academic science, which are the sources at which scientists are trained and grow to maturity, to languish. The situation has been further aggravated by the lack of scientific communication in our country between the scientists in these three groups. Bhabha often expressed his unhappiness at this state of affairs and was lately quite concerned about trying to do something about bringing the universities closer to the science research of Government Labs."

Given the breadth of his vision and the strength of the hold he had on Indian S & T policy making, it is tempting to surmise that Bhabha himself might have addressed this problem of imbalanced or lopsided development in due course. But his premature death makes such a speculation meaningless.

Bhabha was often criticised for his arrogance and haughtiness. But that is not an uncommon trait. Raman was arrogant, many others too. C. F. Powell has said, "Without a certain ruthless arrogance he would never have achieved what he did, and he did much." S. Chandrasekhar too has made illuminating remarks on the subject. Admitting that during his visit to India in 1961 he came across criticism of Bhabha from various quarters, he said: "I turned around and asked them, 'Why don't you be a little tolerant? After all, he has built this institute. And so far as I know this is the only institute where admissions are made on the basis of merit without the considerations of region or caste or creed. If he has certain weaknesses, why don't you overlook them?'... My own view is that Bhabha did an enormous amount of good for Indian science, even though he had his weaknesses...like exaggerated forms of personal prestige." Nagchaudhury has also made special mention that Bhabha was "singularly free from any sectarian bias or traditional inhibitions."

Much has also been made of Bhabha's close relationship with the Prime Minister. It is said that he succeeded because of his influence with Nehru. To do justice to Bhabha, this assertion also needs to be viewed within die larger context.

Modern science and the associated technology have become an integral part of the mainstream administration of society. Scientific R&D is no longer confined to either the purely academic domain or the purely commercial domain. And it has also become expensive. So State participation has become inevitable. Even in a country like the USA, with a strong private corporate sector, State funding is an essential factor in the R&D domain, even in the universities. In a poor, underdeveloped country like India, Government support has no alternative, and the problems of resource allocation have been far more difficult, and some sort of power struggle is unavoidable.

In those transitional early years, when new structures were being developed, Jawaharlal Nehru as an individual played a unique role. It must be remembered that regarding the development of S & T, even Meghnad Saha had banked upon Nehru in the days just prior to independence. And Nehru's backing was available to a number of others as well. Bhabha was no doubt more successful than others. But beyond that it is not fair to read too much into it.

In fact, patronage of S & T was in the air and the ascendancy of scientists to positions of power was a general phenomenon around the world. If Bhabha appears to have monopolised the domain of physical sciences in India, one may even say that given the size of the country, it was regrettable that India did not have a few more Bhabhas with a few more institutes like TIFR taking roots independently in the early period.

Appendix I

Bhabha: A Chronology

1901, Oct 20	born in Mumbai (then Bombay)
1924	passed Senior Cambridge leaving examination studied in Elphinstone College and Royal Institute of Science (since underage for Cambridge University)
1927, October	joined Gonville and Caius College, Cambridge, England

1930	graduated in Mechanical Science Tripos; B.A. (Cantab)
1932	Mathematics Tripos with a first, Rouse Ball Travelling Studentship in Maths, Cambridge Visited Copenhagen and Zurich
1933	Isaac Newton Scholarship
1934	Ph.D., Cambridge
1936	Senior Studentship of the Exhibition of 1851 Bhabha-Heitler Theory—letter in Nature in July
1937	Bhabha-Heitler Cascade Theory of Cosmic Ray Showers—27 page article in Proceedings of Royal Society
1939	stranded in India as World War II begins
1940	Special Reader in Cosmic Ray Physics, I. I. Sc. Bangalore
1941	elected F.R.S. London
1942	Adam's Prize, Cambridge University Full Professor, Cosmic Ray Research Unit, I. I. Sc. Bangalore
1943	Sectional President, Physics, 30th Indian Science Congress Kolkata.
1944. March *12*	Letter to the Sir Dorabji Tata Trust
1945 June 1	Foundation of TIFR; Director, T1FR
1946	Member, Atomic Research Committee, CSIR
1947 August 26	Chairman, Board of Research on Atomic Energy
1948 August 10	Chairman of the newly established AEC, India; Hopkins Prize of the Cambridge Philosophical Society
1951	General President, 38th Indian Science Congress, Bangalore
1954	Padmabhushan; Secretary to GOI, DAE; Founding Director, AEE
1955	President, First International Conference on Peaceful Uses of Atomic Energy
1956 August	Apsara swimming pool reactor critical
1957	Training School established at AEET; President, National Institute of Sciences, India (NISI)
1959	elected Honorary Fellow of the American Academy of Arts and Sciences
1960	CIRUS reactor critical
1961	ZERLINA reactor critical; space research started under DAE
1962 January 15	New building of TIFR inaugurated
1963	appointed Chairman, Electronics Committee; Tarapur Atomic Power Station agreement with the USA signed; elected a foreign associate of the National Academy of Sciences of the USA
1960-63	President, International Union of Pure and Applied Physics
1964	Tarapur construction started

1965 Plutonium Plant at Trombay inaugurated; Electronics Committee Report finalised.

1966 Jan24 Death over Mont Blanc, Alps in the crash of Air India's plane Kanchanjunga.

Appendix II

Bhabha's Research Papers and Speeches

Bhabha had published 64 research papers over a period of more than two decades from 1933 to 1954. There are about 40 speeches and articles by him on the subject of atomic energy and S&T development and policy.

His scientific papers are published by TIFR in a single volume: *Homi Jehangir Bhabha—Collected Scientific Papers,* Editors—B. V. Sreekantan, Virendra Singh, and B. M. Udganokar; pp LXXIX + 1023, 1985. It contains three introductory articles by the editors, which offer comprehensive reviews of Bhabha's work: "His contributions to cosmic ray physics" by Prof. Sreekantan, "His contributions to theoretical physics" by Prof. Singh, and "Homi Bhabha on growing science" by Prof. Udganokar. This collection also includes reprints of two memorial lectures delivered by Sir John Cockcroft and Prof. M. G. K. Menon at the Royal Institution of Great Britain, London in 1967, and the article by Lord Penney in the Biographical Memoirs of Fellows of Royal Society, London, vol. 13, 1967. A partial list of Bhabha's writings and speeches on Atomic Energy and S&T is also appended.

Three important speeches delivered by him are:

1. Presidential Address—First International Conference on Peaceful Uses of Atomic Energy, Geneva, 1955 (in *Homi Bhabha—Father of Nuclear Science in India* by R. P. Kulkarni and V. Sarma, pp. 59-73, Popular Prakashan, 1969)

2. "Role of Atomic Power in India and itS immediate possibilities"—paper read at the First Geneva Conference, {in Journal of Scientific and Industrial Research, vol. 14-A, pp. 561-568, 1955)

3. "Science and Problems of Development"—Speech delivered at the International Council of Scientific Unions' Conference, January 1966 (in "Science Policy Studies"—Eds. A. Rahman and K. D. Sharma; pp. 275-291, Somaiya Publications, 1974)

Appendix III

In Commemoration of Bhabha

Bhabha's memory has been kept alive in various ways.

In a rare gesture, the Ministry of Communications released a special commemorative stamp on his birthday in October 1996.

In January 1967, the Atomic Energy Establishment, Trombay (AEET) was renamed the Bhabha Atomic Research Centre (BARC) by Prime Minister Indira Gandhi. The

auditorium, under construction in Bhabha's time in the TIFR, was inaugurated by the Prime Minister in 1968 and named the Bhabha Auditorium. It has become a prime venue for prestigious programmes in Mumbai.

The road in Navy Nagar in South Mumbai leading to TIFR is named Homi Bhabha Road.

In the field of education, the Homi Bhabha Centre for Science Education (HBCSE) established under TIFR is very actively involved in improvement of science education in municipal schools in Mumbai and rural schools in the hinterland of Maharashtra and other States. Its recent involvement in the Science Olympiad movement in the country has attracted the attention of talented elite students. Bhabha's name is, thus, widely familiar to students.

In the world of arts, there is the Homi Bhabha Arts Reference Library, located at the Jehangir Art Gallery premises. It contains books from Bhabha's own collection.

And in the world of scholarship, the Homi Bhabha Fellowship Council was established on the first death anniversary of Bhabha, and on his 19th death anniversary the Homi Bhabha Fellowship programme was launched in perpetuity by the Tata-Ford Joint Trust.

References

1. Science Reporter, CSIR, October 1996, Commemorative volume— tributes from eminent scientists and colleagues from India and abroad.

2. Homi Jehangir Bhabha by Lord Penney, Biographical Memoirs of Fellows of Royal Society, London, 1967.

3. Homi Jehangir Bhabha by Sir John Cockcroft and Prof. M. G. K. Menon, The Royal Institution of Great Britain, 1967

4. Homi Bhabha Father of Nuclear Science in India by R. P. Kulkarni and V. Sarma, Popular Prakashan, Mumbai, 1969

5. Science in India by Ward Morehouse, Popular Prakashan, Mumbai, 1971

6. Science Policy Studies: Eds. A. Rahman and K. D. Sharma, Somaiya Publications, 1974

7. Building Scientific Institutions in India: Saha and Bhabha by R. S. Anderson, Montreal, 1975

8. Nuclear India, DAE Publication, (a) February-March 1996, (b) January 1967. (c) October 1989

9. The Heartbeat of a Trust—Fifty Years of the Sir Dorabji Tata Trust by R. M. Lala, Tata-McGraw Hill Publication, 1984

10. Homi Bhabha (in Marathi) by Chintamani Deshmukh, Granthali, Mumbai, January 1994.

11. Bhabha and His Magnificent Obsessions by G.Venkataraman, University Press (India) Ltd., 1994

12. Homi Bhabha As Artist (A selection of his paintings, drawings and sketches) Edited by Jamshed Bhabha, Marg Publication, November 1968.

Appendix IV

Letters, Memos and Office Orders

Cosmic Ray Research Unit

Indian Institute of Science

Bangalore, India

11th February, 1944

My Dear Sahni,

Thank you for your kind letter of the 4th January. You may be right in thinking that the present moment is inopportune and some of us may be wrong in thinking otherwise. But I feel that things are happening and more are likely to happen in the next few years, and it is the duty of those who have no personal advantage to gain from this matter to see that as far as possible things take a shape which will ultimately be beneficial to India. It is only for this reason that I have taken any interest in this matter at all, for as you know I grudge any organisational activity which takes me away from my research. I am now working on an important piece of research in connection with my book, and but for this I should certainly have come to Lucknow to see you. Although you have decided to stand aloof for the time being, I am sure I will have your good wishes in any endeavour I make to see that things go into the right channels as far as possible in the unfortunate times we live in. If after some time you feel that our efforts have not been in vain and we have accomplished something of benefit to the cause of science in India, then I hope you will decide to give us your collaboration, and you will receive a warm welcome. When I visit north India again I shall take the opportunity of visiting you in Lucknow, but I do not know now when that will be.

With kindest regards to you and Mrs. Sahni.

Yours sincerely,

P.S. Please remember me to Mr. Haldar of the Arts School.

Prof. B. Sahni, F.R.S.,

Dean of the Faculty of Science,

Lucknow University, LUCKNOW.

Ref : DAE/I/16-A/2149

Standing Order

June 15, 1958.

Whenever a Selection Committee is proposed, the grade of each member should be put in brackets after his name, in the case of departmental staff.

(Thus:- A. Blunderer (C)

In the case of outsiders, their designation should be given.

Sd. H. J. Bhabha

copd : cgv: 30.6.56

DEPARTMENT OF ATOMIC ENERGY

Ref: Adm. 7(18)/56 February 7, 1957

Memorandum

I notice that, in scientific papers sent for publications, the Atomic Energy Establishment is often described as "Atomic Energy Establishment, Bombay, India". In future, it shall be described as "Atomic Energy Establishment, Trombay, Bombay, India". This instruction is issued, as in due course, the Establishment should come to be known in Atomic Energy circles briefly as "Trombay", just as the British centre is known as "Harwell", and the French one as "Saclay". It may then be possible to drop "Bombay" altogether.

copd: cgv 18.6.65

Sd. H. J. Bhabha.

DEPARTMENT OF ATOMIC ENERGY

Ref: DAE/I/16 A(ii)/2254

Apollo Pier Road, Bombay 1. July 6, 1958.

I notice that, of late, people are referred to as 'Mr.' in papers of the Trombay Establishment, such as, Minutes of the Technical Advisory Committee, selection committees, etc. There is a Government direction, which says that 'Shri' should be used, and I see no reason to seek a departure from this direction. Even the London Times refers to well-known Frenchmen as 'M'. and not 'Mr.'. 'Mr.' may of course be used in foreign correspondence. For the plural we might adopt the abbreviation 'Ss.' in the place of 'Sarvashri'.

copd: cgv: 30,6.66

Sd. H. J. Bhabha 6.7.58

ATOMIC ENERGY ESTABLISHMENT TROMBAY

Sale of Flowers

The following arrangements have been made for the sale of flowers from the Trombay Establishment.

1. The Superintendent, Parks & Gardens, will issue a notice from time to time indicating the types of flowers which are available for sale with the prices.

2. The flowers will be available with the Security Officer at (a) South gate, Trombay, and (b) the Old Yacht Club.

3. Any Head of a Division wishing to purchase flowers of a particular type on a particular day will inform the office of the Superintendent, Parks and Gardens, at Trombay (Telephone No. 521401-Ext. 257) before 3 p.m. of the same day of the type of flowers he wishes to purchase and the quantity. He will also indicate from which of the two places mentioned above he will pick up the flowers. The flowers will be charged to him whether picked up or not.

4. The flowers to the extent available will be ready for collection from 4.30 p.m. at the South Gate, Trombay, and from 7.30 p.m. at the Old Yacht Club on the same day or at any time in the following day. Any additional flowers which are available beyond those ordered by the Heads of Divisions will be available for purchase by any member of the Trombay Establishment, the Tata Institute of Fundamental Research, Indian Rare Earths Ltd. or the Department of Atomic Energy at either of the places mentioned in paragraph 2 above.

Sd. H. J. Bhabha

Director 18.1.64

Cpd: rsp : 7.7.66.

ATOMIC ENERGY ESTABLISHMENT TROMBAY

February 17, 1964. Standing Order D 3-1964

Visitors' books in an Establishment like the Trombay Establishment are intended solely to keep a record of the signatures of those who visit it, in particular the distinguished visitors. There is no room in such a visitors' book for a 'remark' column and any such visitors' book should be changed immediately, the old ones being, of course, retained for the signature they contain. The visitors' book should be attractive to look at, made of good paper, well bound and properly chosen.

cpd : rsp: 8.7. '66.

Sd. H. J. Bhabha Director 17.2. 1964

End