Homi Jehangir Bhabha : Architect of Modern Science and Technology in India

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Abstract

After describing Bhabha’s early life at Bombay, now Mumbai, we discuss his research career at Cambridge, where he made many distinguished contributions to positron physics, cosmic rays and the meson theory. These include theory of positron-electron scattering (Bhabha scattering), Bhabha-Heitler theory of cosmic ray showers and prediction of heavier electrons (ie. muons). Later in his life, after 1945, Bhabha worked in India at Bangalore and Mumbai. In India Bhabha laid foundations of modern nuclear science and technology. He emerged as a successful institution builder founding Tata Institute of Fundamental Research at Mumbai and the Laboratories of Atomic Energy Establishment at Trombay, now renamed as Bhabha Atomic Research Center.
Introduction

Homi Jehangir Bhabha (1909-66) started his career as a theoretical physicist at Cambridge in the nineteen thirties and distinguished himself by his researches in the emerging areas of high energy physics and cosmic rays. Later he excelled as a builder of institutions in India devoted to modern science and technology. He founded the Tata Institute of Fundamental Research (TIFR) in 1945 at Bombay, a premier institution devoted to excellence and the pursuit of research in the frontier areas of science. He was the motive force behind the creation of the Atomic Energy Commission (AEC) by the Government of India in 1948 and became its first Chairman. When the Department of Atomic Energy (DAE) of the Government of India was set up in 1954, he was appointed as its Secretary. The AEC and DAE were responsible for establishing a chain of research laboratories, including the Atomic Energy Establishment at Trombay (later renamed Bhabha Atomic Research Center) and for commissioning India’s nuclear reactors for research and for the generation of power. These activities also led to the growth of electronics technology in the country and, somewhat later, to those related to space technology. Bhabha, more than any other person, was responsible for introducing and nurturing the growth of modern nuclear science and technology in India. He was a multifaceted personality equally at home in the world of arts.

1. EARLY LIFE

Homi Bhabha was born in 1909 at Bombay in an established Parsi family with a modern and nationalistic outlook. The Parsis are a small community, mostly settled around Bombay and in the nearby State of Gujarat, and have acted as a pace setter in the process of social change initiated by the impact of western civilization on India brought about by the colonial rule by Britain. His father, Jehangir H. Bhabha, had been educated at Oxford and studied law at Lincoln’s Inn. At New College at Oxford J.H. Bhabha was one of the founder members of an India group ‘Nav Ratan’ (nine jewels) which eventually transformed into the ‘Indian Majilis’. J.H. Bhabha was initially associated with the judicial service of the State of Mysore. He shifted to Bombay in 1908 after his engagement to Miss Mehram Pandey who came from the business family of the Petits and was a granddaughter of Sir Dinshaw Manekji Petit, first Indian baronet and a philanthropist. He joined the Bar at Bombay and was for a while Presidency Magistrate. Later, in 1915, he joined the firm of Tata Sons and was directly involved in their scheme of hydroelectric power generation. He was also a trustee of the J.N. Tata Trust and Lady Meherbai Tata Education Trust and other philanthropic schemes. As a young man, Homi Bhabha was exposed to discussions on large industrial projects involving hydroelectric power, steel and chemicals. Homi Bhabha’s grandfather, Dr. Hormusji J. Bhabha, CIE, had been Inspector-General of Education with the Education Service of the State of Mysore. Homi Bhabha had available to him the large library of books left behind by his grandfather. To this library had been added a large collection of books on art and recorded western music on gramophone discs by his father.

Homi Bhabha’s aunt Meherbai, the only sister of his father, was married to Sir Dorabji Tata. He used to go to his aunt’s place regularly for lunch during his school days at Cathedral
and John Connon High School at Bombay as the school was situated quite close to the home of the Tatas. The Lady Dorab Trust was later to play a significant role in Homi Bhabha’s life.³

Bhabha left for Cambridge to study engineering in 1927 and joined Gonville and Caius College. Sir Dorab Tata had also spent two years at the college and had donated 25,000 pounds to it in 1920.

2. Bhabha At Cambridge

The Cambridge of that period was an exciting place to be in for a physicist. It was there, in 1927, that Dirac had formulated the quantum theory of emission and absorption of electromagnetic radiation, i.e. quantum electrodynamics. He followed it next year with his celebrated Dirac equation for the electron, which provided a natural explanation for the spin and the magnetic moment of the electron and for the Sommerfeld formula of the energy levels of the hydrogen atom. The new feature of the Dirac equation corresponding to ‘negative energy electrons’ was brilliantly vindicated by the discovery of positrons in cosmic rays by C.D. Anderson in 1932. Bhabha was caught by this excitement and wrote to his father on 8 August, 1928 for permission to shift from engineering to physics. He wrote, ‘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 know I shall do great things here’.⁴ His father was willing to support a further stay of two years at Cambridge to let him pursue theoretical physics and get a mathematics tripos provided Bhabha first devoted himself to his engineering tripos and got a first class. In June 1930 he passed his mechanical tripos in the first class and was now free to devote himself to theoretical physics. It is amusing that, contrary to what Bhabha wrote to his father, he was to be a great success in managing large enterprises in science and technology and his engineering background was also to stand him in good stead. The bedrock of acceptability of his leadership was, however, provided by his achievements in physics. In the milieu of Cambridge he flowered into a fine physicist.

His earliest research interest was in quantum electrodynamics, especially with processes involving positrons. In 1935 he worked on ‘The scattering of positrons by electrons with exchange on Dirac’s theory of positrons’. This process in now known as Bhabha Scattering and was a confirmation of the view that negative energy electrons can indeed be interpreted as positrons. Bhabha and Heitler’s work in 1937 provided a natural explanation of the observed phenomenon of cosmic ray showers. A high energy electron traversing matter loses energy by producing hard quanta of radiation and these quanta again materialize into high energy electron-positron pairs. This conversion of energy into radiation and reconversion into secondary charged particle pairs takes place repeatedly, resulting in an ‘effective’ shower loss of energy by the high energy charged particles. Before their work it was suspected that this ‘effective’ shower loss of energy of the primary particle signifies a breakdown of quantum electrodynamics. Their work completely accounted for the properties of the ‘soft’ component of cosmic rays and thus showed that no failure of the standard theory was involved. The studies on the absorption of cosmic rays in lead had suggested that, apart from the ‘soft’ component, cosmic rays also had another component, the ‘penetrating component’.
A beautiful phenomenological analysis of the data on this component of cosmic rays led Bhabha to postulate the existence of new particles with positive and negative electronic charge and of mass of the order of a hundred times the mass of an electron. Bhabha thus predicted the existence of muons which were almost contemporaneously discovered experimentally by Anderson. Initially there was of course some confusion between muons and the particles, now called pions, postulated by Yukawa to account for nuclear forces. Bhabha was the first to suggest that these particles with mass intermediate between electrons and protons, ‘mesons’, must spontaneously decay and that Einstein time dilation formula can be experimentally tested by measuring the variation of the life times of these ‘mesons’ with their velocity in the laboratory frame. He, together with a select band of British scientists, N. Kemmer, H. Frohlich and W. Heitler, was among the earliest major workers on meson theory outside Yukawa’s group in Japan. In fact the word ‘meson’ was coined in a discussion between him, Kemmer and Pryce.\(^5\)

3. BHABHA IN INDIA

3.1. AT BANGALORE

In 1939 when Bhabha was in India on a holiday visit, the second world war broke out in Europe. As a result of uncertain war conditions prevailing there he could not go back to Cambridge and found himself stranded in India. He joined the Indian Institute of Science, in 1940, as Reader in the Physics Department in charge of the Cosmic Ray Research Unit set up by the Sir Dorabji Tata Trust for him. Incidentally the Trust had also provided a cyclotron to M.N. Saha around the same time. While at Bangalore he was elected Fellow of the Royal Society in 1941 and was also promoted to Professor the following year.

During the Bangalore period (1940-45) Bhabha initiated work on classical relativistic spinning point particle theory (Bhabha-Corben equations), and continued working on meson theory, leading to the first suggestion about the existence of nucleon isobars, and on cascade theory. He also initiated experimental work in the field of cosmic rays. Apart from scientific research work ‘he found his mission in life’\(^6\) during this period. He had been away from India and exposed to the scientific and cultural life of Europe for thirteen years, leaving India at the young age of seventeen to return at the age of twenty-nine. He was now exposed to India as a mature young man, and as a result of introspection and variety of experiences during this period, he began to identify himself more and more with India and its cultural heritage. He saw that there was much work to be done here if science and technology were to be harnessed for the development of the country. He saw his mission as bringing modern science and technology to India.

3.2. TATA INSTITUTE OF FUNDAMENTAL RESEARCH

On 12 March 1944 Bhabha wrote a formal letter proposing the setting up of an Institute of Fundamental Research in India to Sir Sorab Saklatvala, Chairman of the Sir Dorabji Tata Trust. In this he noted, ‘I had the idea that after the war I would accept a job in a good university in Europe or America, because universities like Cambridge or Princeton provide an atmosphere which no place in India provides at the moment. 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’. Before this formal letter there had been exploratory correspondence with J.R.D. Tata and with his encouragement and support the Sir Dorabji Tata Trust decided to support the scheme. The proposed institute, named Tata Institute of Fundamental Research, started functioning with Bhabha as its founder director in June 1945 at Bangalore. It was soon shifted to Bombay and was formally inaugurated in its temporary premises at Kenilworth (Peddar Road) on Wednesday, 19 December 1945. He had indicated in the same letter his initial choice of research areas for the institute, ‘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’. Bhabha worked on his theory of relativistic wave equations for elementary particles (Bhabha wave equations), cascade theory and stochastic processes, and on multiple meson production. His last research paper in theoretical physics was written in 1953. Later he became more and more involved with developing the atomic energy programme in India.

3.3. ATOMIC ENERGY

Already at the time of writing the letter to Sir Dorabji Tata Trust on 12 March 1944, Bhabha had visualized that the proposed institute devoted to basic research should play a role in developing high quality applied research and nuclear power programmes in India. As he wrote, ‘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 vigorous 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. ....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’. It has been remarked often that this letter suggesting peaceful nuclear applications was written more than a year before the world at large became aware of atomic energy unfortunately through its military application at Hiroshima and Nagasaki.

An Atomic Energy Committee was constituted by the Council of Scientific and Industrial Research in India towards the end of 1945 with Bhabha as the Chairman. Some of the other members were S.S. Bhatnagar, M.N. Saha and D.N. Wadia. The committee initiated some survey work on atomic minerals. On 26 April 1948 Bhabha submitted to the Prime Minister, Jawaharlal Nehru, a comprehensive ‘note on the organization of atomic research in India’ and
recommended the formation of the Atomic Energy Commission of India.\textsuperscript{7} The Commission was established in August 1948 with Bhabha as Chairman, and S.S. Bhatnagar and K.S. Krishnan as members. Its charter requested the Atomic Energy Commission. \textquoteleft(1) to take such steps as may be necessary from time to time to protect the interests of the country in connection with Atomic Energy by exercise of the powers conferred on the Government of India by the provisions of the Atomic Energy Act; (2) to survey the territories of the Indian Dominion for the location of useful minerals in connection with Atomic Energy; and (3) to promote research in their own laboratories and to subsidize such research in existing institutions and universities. Special steps will be taken to increase teaching and research facilities in nuclear physics in the Indian Universities\textquoteleft.

The initial trained manpower for atomic energy work came from the Tata Institute of Fundamental Research. The Physics Division of AEC was housed at TIFR in the early days. The early activities of the electronics and technical physics division of the Atomic Energy Establishment at Trombay (later renamed Bhabha Atomic Research Centre) were also started at TIFR. This electronics production unit at TIFR eventually developed into the Electronics Corporation of India Ltd. The control systems for Apsara, which was Asia\textquotesingle s first nuclear reactor, were also built at TIFR. As Bhabha mentioned in his speech at the inaugural function of the new building for TIFR at its present location on 15 January 1962, \textquoteleft'It is not an exaggeration to say this institute was the cradle of our atomic energy programme, and if the Atomic Energy Establishment at Trombay has been able to develop so fast, it is due to the assisted take-off which was given to it by the institute in the early stages of its development. It is equally true to say that the Institute could not have developed to its present size and importance but for the support it has received from the Government of India\textquoteleft.

By the middle of 1949 the Rare Minerals Survey Unit, later renamed Atomic Minerals Division, had been set up. The Indian Rare Earths Ltd. was started in 1950 to mine and process Kerala and Orissa beach sands. The Government of India created the Department of Atomic Energy in 1954 with Bhabha as its Secretary. It is to be remarked that this decision to create a department of atomic energy owes much to the vision and faith of Bhabha and Nehru as, at that time, use of atomic energy to generate electricity was not a proven technology even in the developed Western countries. The swimming pool type research reactor, Apsara, achieved criticality on 4 August 1956. The research laboratories of the Atomic Energy Establishment at Trombay were formally inaugurated by Prime Minister Nehru on 20 January 1957 and produced nuclear grade uranium metal in 1959. The reactor CIRUS and the research reactor ZERLINA became critical in 1960 and 1961 respectively. The plutonium plant was commissioned in 1964. The Power Projects Engineering Division was created to devote itself entirely to the Indian nuclear power programme.

Following the initiative of President Eisenhower of USA, it was decided by the United Nations in December 1954 to hold an international conference on developing the peaceful uses of atomic energy in Geneva in 1955. Bhabha presided over this first United Nations conference with grace and distinction. His presidential address on the contributions which nuclear energy could make to solve the world energy supply problems was masterly. He was, however, unduly optimistic about the prospects of the exploitation of energy from nuclear
fusion.

3.4. ELECTRONICS AND SPACE PROGRAMME

Apart from pioneering atomic energy in the country, Bhabha also played a crucial role in introducing space research and programme in India. Largely through his initiative, the Indian National Committee for Space Research was set up in 1962 under the chairmanship of Vikram Sarabhai. The first rocket launch was carried out from Thumba Equatorial Rocket Launching Station near Trivandrum on 21 November 1963. Bhabha also announced on that day the formation of a space science and technology centre. The Thumba facility was made available to the international community through the United Nations in December 1965. We have noted how the early work in electronics and instrumentation laid the foundations for later work at atomic energy laboratories and to the establishment of the Electronics Corporation of India. Bhabha gave a high priority to the development of electronics in India. He therefore accepted the Chairmanship of the Electronic Committee constituted by the Government of India. The Bhabha Committee report made recommendations concerning the future plans and development for the electronics industry in India.

Bhabha tragically died in an air crash on Mont Blanc on 24 January 1966. He was on his way to attend a meeting of the International Atomic Energy Agency at Vienna. Indian science and technology lost a very distinguished man of vision and drive at a crucial juncture of its post-independence development.

4. BHABHA AS A RENAISSANCE MAN

Bhabha was likened to ‘a man of renaissance’. He was a man of science and technology. He was a great administrator of science. He was equally at home in the world of arts. Bhabha grew up listening to his father’s and his aunt’s excellent collection of recorded western classical music. Later he developed a taste for classical Indian music and dance also. The choice of Vienna as the headquarters of the International Atomic Energy Agency was to a large extent decided by Bhabha’s desire to combine attendance at its meetings with an opportunity to attend the fine musical concerts there. He enjoyed sketching and painting and left behind a number of these. As M.F. Hussain noted, ‘Though a scientist by profession, he was an artist by nature .... . To a great extent Bombay is what it is today because of Bhabha. In the early fifties he conceived the idea of starting a collection of painting at TIFR .... and Bombay witnessed the birth of modern art’. He was also uniquely qualified to edit a special issue of the Indian art magazine Marg on the occasion of the five hundredth anniversary of Leonardo da Vinci, the original renaissance man. He designed the buildings of the Tata Institute of Fundamental Research with great care and attention to every minute detail. The glass windows had frames of a special new aluminium alloy to withstand sea breeze corrosion, and this alloy was manufactured for the first time in India at Bhabha’s initiative. The buildings are not only functional but also beautiful. As Helmut Bartsch, the architect, noted, ‘In this development the architect worked with a client rather than for a client. The client displayed unending interest and encouragement and constantly added intelligent suggestions and advice. The result, it is hoped, is a building which will not only
fulfil its function but should afford a great deal of enjoyment'. The siting of the Atomic Energy Establishment is such that the island of Elephanta, which contains beautiful seventh century cave temples, is directly visible. The same juxtaposition occurs between Kalpakkam reactor centre and the famed Mahabalipuram temples. He also had a keen sense of landscape and the Tata Institute of Fundamental Research and the Bhabha Atomic Research Centre are surrounded by beautiful trees and gardens.

5. Bhabha’s Writings

Bhabha brought to India nuclear science and technology and left behind him a legacy of large and successful scientific institutions, technological laboratories and power reactors. He contributed a great deal to inculcate the scientific temper in India through his activities. He, however, did all this by his example and by creating the needed infrastructure. He did not do so through writing about it. In the present selection we have tried to present some of his writings which are close to humanist concerns.

Bhabha’s research papers deal with high energy physics and cosmic rays. These are now available in a volume, Homi Jehangir Bhabha: Collected Scientific Papers. No collection of his other writings and speeches has been published so far. His major concern in these is with atomic energy in the context of the Indian situation. Most of these writings on atomic energy are also, by and large, of a technical nature, involving detailed consideration of feasibility and economics of atomic energy and full of graphs, tables and figures. International aspects of atomic energy are also examined. In their style Bhabha’s background as a theoretical physicist and as one given to precision, shows through. However, any selection from Bhabha’s writings cannot be representative without some of his papers on energy and atomic energy. We have chosen two of the non-technical ones. One of these is his presidential address at the International Conference on Peaceful Uses of Atomic Energy at Geneva in 1955. As Lord Penney says in his memoir on Bhabha, this ‘was a brilliant essay about energy and population, and described in simple direct style the changes in living conditions. The address is as vivid and true today as when it was written’. This article puts atomic energy in the perspective of human use of energy through its history. In the more specific context of developing countries he presents the case for atomic energy in his article ‘The Role of Atomic Energy in Asia’ written for the inaugural issue of Asian Atomic Newsletter brought out by the Philippines Atomic Energy Commission in 1964. We have chosen this presentation as it was one of his few general writings.

Bhabha’s broad views on science and technology and its place in the world is best brought out in a paper ‘The Role of Science and Technology in Producing an Integrated World’ which he prepared for the Centennial Conference on Science and Engineering Education at Massachusetts Institute of Technology in 1961. A lecture delivered at a meeting of the International Council of Scientific Unions ‘Science and the Problems of Development’ on 7 January 1966 provides an authoritative version of the philosophy which Bhabha followed in his activities as a builder of institutions towards the development of science and technology in India. It is as thought-provoking and relevant today as when it was delivered.

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4. Ibid. 3, p.85.

5. For more detailed account of his scientific work see B.V. Sreekantan, ‘H.J. Bhabha: His Contribution to Cosmic Ray Physics’; V. Singh, ‘H.J. Bhabha: His Contribution to Theoretical Physics’, in B.V. Sreekantan, Virendra Singh and B.M. Udgaonkar (eds.), *H.J. Bhabha: Collected Scientific Papers*, pp. xi-xxii,xxiii-xlvii.

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7. This note and some other documents relating to Bhabha’s work on atomic energy and his selected correspondence with Jawaharlal Nehru appear in a special issue, *Nuclear India*, vol. 26, no. 10(1989), compiled by M.V. Ramaniah.

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