

Remembering Dr. Homi Jehangir Bhabha, F. R. S

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Dr. Bhabha in deep thought

Dr. Homi Jehangir Bhabha enriched India in its post Independence days for more than 2 decades with his pioneering scientific ideas and brilliant administration leading to the building of two most prominent institutions in India, the Tata Institute of Fundamental Research (TIFR) and the Atomic Energy Commission (AEC), the two institutions that stand as leading pinnacles in science, the crowning achievements of human endeavor. Remember that these were built soon after the Independence when we have had minimum facilities in the universities and colleges to even hold classes. Note also the emphasis on Fundamental Research, one that Dr. Bhabha placed on the character of research.

Dr. Bhabha left us more than 4 decades ago, yet we remember him very clearly as if we have had been with him all this time. This is manifestly so, because by his virtuous philanthropy and clear actions he changed the scene of Indian science, and also changed all of us in this process. To achieve his philosophy, a highly successful scientist that he was, he sacrificed his personal scientific career to spend most of his time to grow India. We have today a million reasons to remember him for his contributions. More importantly, we owe him an immense debt of gratitude for what he did to India's science, technology and education. In the field of science, he changed an underdeveloped country into a very developed country by his actions within a period of about 25 years. This task could have been accomplished only by a very original and creative scientist, a truly great Indian scientist amongst the handful of the greatest Indian scientists who enriched the corridors of India; the like of whom we may not have for next several centuries.

I feel greatly honored to have been asked to write for the Physics News and also to give the Bhabha Commemorative lecture. I feel like a small man standing at the foot of a mountain, who has been asked to describe the loftiness of the mountain. Howsoever inadequate I feel now, in a brief moment of haste, I did accept these tasks. I would therefore like to take this opportunity to thank Drs. Arun Grover and Dipan Ghosh to have had the confidence in me to execute these tasks.

A great deal has been written about the extraordinary life and brilliant scientific career of Dr. Bhabha, and about his great accomplishments in growing, science, technology and education in India. Dr. G. Venkataraman has written a detailed and lively account of Dr. Bhabha's research and his contributions to India; also about his passionate love in art, music and architecture, and last but not the least about Dr. Bhabha the artist. I would also like to refer to important articles written earlier by Drs. M. G. K. Menon and B. V. Sreekantan.

I will touch on the highlights of Dr. Bhabha's career in my own perspective, touching upon my reminiscences relating to the personal approach of Dr. Bhabha in his day to day life; how he looked at science, both in context to science as necessary for raising the human spirit, and science which must be cultivated at the highest level in India for a balanced intellectual and social existence. In my presentation, I would also selectively discuss some of my close interactions with him, which created an indelible impact on my thinking.

My remarks will deal with four points:

1. Dr. H. J. Bhabha the scientist
2. The philosophy and passion of Dr. Bhabha
3. My reminiscences of personal interactions with Dr. Bhabha
4. Concluding remarks

1. Bhabha the scientist

At the age of 18, Dr. Bhabha left for England to pursue higher studies at Cambridge. His parents had sent him for higher studies to Cambridge, knowing that he was brilliant and that if trained in engineering he could build a great career in Tata Industries. Dr. Bhabha however managed to convince his parents that he was interested in physics, and physics only. He told his parents: *"I am burning with a desire to physics. It is my only ambition. I have no desire to be a "successful" man or the head of a big firm."* He finished Mechanical Tripos and Mathematical Tripos; the latter because of his deep interests in physics.

After finishing Mathematical Tripos Dr. Bhabha worked for short periods with Wolfgang Pauli at Zurich and with Enrico Fermi at Rome. In 1934 he was awarded the Isaac Newton Studentship which enabled him complete his Ph. D under Dr. R. H. Fowler, who was also the Ph. D thesis advisor for Dr. Chandrasekhar. After his Ph. D he continued his research until 1939 during which time, he developed on several issues relating to cosmic ray phenomena and the interactions of electrons, protons and photons at high energies, in context to issues in the fields of quantum mechanics and relativity. *These advances were made by him in the 30's when little was known about the nature of high energy interactions. Cosmic rays were then the principal source for revealing information in this field. Sea level cosmic ray data revealed that the secondary cosmic radiation consisted of two components: the soft and the penetrating components. The former, the soft component was easily absorbed in a few centimeters of lead, and even multiplied at first in passing through thin layers of lead. The penetrating component passed through the atmosphere and even to greater depths.*

By 1932, the only known fundamental particles were electrons, positrons, photons, neutrons, protons and alpha-particles. During 1933 and in the subsequent years, Dr. Bhabha, some in collaboration with Heitler, published several papers dealing with the production of soft electron-positron showers in the atmosphere. The papers by Dr. Bhabha elegantly resolved the problem of development and absorption of soft component in the atmosphere, in accord with the experimental data provided by Bruno Rossi.

In 1937, Dr. Bhabha published another classic paper on the penetrating component of the cosmic radiation in the Proc. of the Royal Society stating that the experimental cosmic ray data would find a natural explanation if the secondary cosmic radiation in the atmosphere consisted of charged particles of mass intermediate between electron and proton, setting the mass around 100 electron masses. This was an original deduction, also challenging some theorists at that time who suggested that at higher energies, there occurred a breakdown of the quantum mechanical theory! Dr. Bhabha's prediction was soon corroborated by the discovery of Neddermeyer and Anderson, and Street and Stevenson who found particles of mass ~ 200 electron masses in their cloud chamber experiments. These particles were then given the name "meson".

Subsequently Dr. Bhabha predicted in a paper in Nature in 1938 that the meson would be unstable and would probably decay into an electron and neutrino. The decay of meson helped resolving the anomalous absorption of the penetrating component in the atmosphere.

I have briefly discussed some of the outstanding discoveries made by Dr. Bhabha in just a few years of research in England.

Dr. Bhabha came to India for a brief holiday in 1939. Since he could not get back to England because of the war, he joined the Physics Department of the Indian Institute of Science, at that time headed by Sir C. V. Raman. He then started his research work working with some students. "He also started experimental studies of the secondary component of cosmic radiation at several altitudes between 5000 and 30,000 feet. The high altitude studies were made using a B-29 bomber aircraft belonging to the US Air Force, making them the first studies made at equatorial latitudes. Dr. Bhabha also constructed a 12" cloud chamber identical to the one operating in Manchester".

Finally, at Bangalore, he nucleated the Tata Institute of Fundamental Research (TIFR) in June 1945 in the campus of the Indian Institute of Science.

2. The philosophy and passion of Dr. Bhabha

Dr. Bhabha's principal philosophy was that the large scale development of science in India was the main ingredient needed to achieve technological advancement. He was convinced that the task of fast developing a country was the problem of establishing modern science in it, and building its economy on modern science and technology.

In his address to the Assembly of Council of Scientific Unions on Jan. 4, 1966, Dr. Bhabha commented on Science and Development in India during the past 20 years: "It is interesting to note that practically all the ancient civilizations of the world, Persia, Egypt, India, and China- were in countries which are today underdeveloped. ... "What the developed countries have and the underdeveloped lack is modern science and an economy based on modern technology. The problem of developing the underdeveloped counties is therefore the problem of establishing modern science in them and transforming their economy to one based on modern science and technology. "

Considering that the technological surge in the European countries began more than a thousand years ago, compared to less than 70 years ago in India, we have indeed made rapid progress. In my opinion the setting up of the 2 institutions TIFR and the AEC was the primary trigger that brought confidence to the masses and the scientists themselves.

Dr. Bhabha was always clear and confident about his ideas, and he executed them with dedication and the fullest energy, a conviction that is evident (see figure below) in his actions which he embarked upon with a rapid-fire sequence.

Dr. Bhabha had already nucleated the Tata Institute of Fundamental Research (TIFR) in June 1945 in the Indian Institute of Science (IISc) at Bangalore. The TIFR was translocated later on to

Bombay, and quickly gained international recognition in the fields of cosmic ray physics, theoretical physics and mathematics. The TIFR also served as a cradle to the highly successful program of Atomic Energy in India. Following his philosophy, he spent a larger part of his time to grow science in India and he put his efforts to grow confidence in the Indian scientific community, with the view that it could perform at the highest level in spite of the fact that the average income per person in India was a small fraction of that in developed countries. In the TIFR, his passion was to create an electric atmosphere where individuals, students, scientists, technical persons and even the administration personnel were obliged to do their best. He provided very rich atmosphere for work. The TIFR building was always considered a unique structure- some called it the Bhabha's Taj Mahal. I must hasten to state that it was *not* built based on any ideas of exuberant/ unrestrained expenditure of money; it was built with a purpose as stated above.



Dr. Bhabha, a visionary

Central to setting up these organizations lay three main themes in the Homi Bhabha's philosophy for spurring growth of science and technology in India: (i) growing a large group of trained scientists in the field of nuclear physics so that when atomic energy became a reality, India had the trained scientists at hand to avail of this energy source for power production, (ii) spreading sophisticated technology in the fields of electronics, high vacuum techniques and nuclear physics to colleges, institutes and industry, and finally, (iii) implanting and sharing highly trained scientists in universities as teachers. *The first two ideas met with great success whereas the third idea met only lukewarm reception, but had this not be the case the universities would not have been in the position that they are in today.*

The scientific programs at the Tata Institute of Fundamental Research

Dr. Bhabha was of course deeply interested in cosmic ray physics which was in those days the only natural way to provide information on the nature of high energy interactions, and thereby the structure of the nucleus. At the TIFR that he translocated later on to Mumbai, Dr. Bhabha decided to grow several areas of research at the TIFR, prominent among which were: Cosmic Ray

physics, Theoretical Physics and pure Mathematics. This was a master stroke as time would show the great advantage of having related/mixed scientific disciplines in one institute. The TIFR besides serving as a cradle to the highly successful program of Atomic Energy in India, *gained international recognition in the fields of, cosmic ray physics, theoretical physics and mathematics.*



Dr. Bhabha explaining some aspects of cosmic ray research



Dr. Bhabha releasing a cosmic ray payload.

Besides the reasons given above for giving high priority to cosmic ray research, there was another important reason also for which Dr. Bhabha had a very sound basis. The primary cosmic ray spectra extends to the lowest energies, few MeV: it also extends to energies beyond 10^{14} MeV. The differential spectrum follows a power law with a slope of (-2.5). At the Earth, the cosmic ray spectra is modulated by the Earth's magnetic field restricting particles below a certain energy which is a function of the geomagnetic latitude. Consequently, considering the slope of the spectrum, and the fact that at low latitudes, the incident cosmic rays would be dominated by high energy particles. Dr. Bhabha realized that it would be ideal to work with the cosmic ray beam in India to study the basic structure of nuclear matter and the nature of elementary particles. His conclusion was borne out by successive studies carried out at the TIFR, which made important discoveries in the field of high energy physics and elementary particles, and put India on the map of fundamental research in the fields of cosmic ray physics, high energy physics and elementary particles.

3. My reminiscences of personal interactions with Dr. Bhabha

I learnt about many facets of Dr. Bhabha's approach to life in several meetings with him. I will give some examples here. Interactions with Dr. Bhabha, remote or direct, infused me with energy and excitement to do fundamental and creative science that would be befitting the great country in which we live. Every meeting with him changed me, and inculcated in me a new view of science, and how a scientist should think. Even today I often think of my exciting encounters with Dr. Bhabha which gave me concrete ideas as to how I should choose my research and grow avenues for creative research in India. In fact as all know, that was his own obsession: to do outstanding fundamental research himself, and to make it easy for the rest of the country to do by providing world class facilities to do research.

On an occasion, I had an appointment with a doctor to remove one of my cysts. I was stopped by a direct message from Dr. Bhabha that I should cancel the doctor's appointment and instead go to the Tata Memorial Hospital where he had arranged an appointment with a doctor. A similar event happened another time. I was very surprised how Dr. Bhabha knew about my doctors' appointments, and more importantly, I wondered why he cared what I was doing?

I would like to narrate to you an incident which made a deep impression on me. Here I would reveal the names of the persons in this story, since they were the embodiment of very high standards and principles.

One day as we were interviewing potential graduate students, we got a letter from Dr. Bhabha saying that he has received a letter from Mrs. Indira Gandhi asking him to look over the suitability of her Secretary's son for joining TIFR as a Research Student. She explained that the candidate has not been keeping good health and that is the reason he did not do well in his recent examination. Dr. Bhabha asked the interviewing committee to check on the student's intelligence and understanding of science. I may add here that my co-committee member was Prof. Yash Pal. In any case we interviewed the candidate and found him to be inadequate to do research at the TIFR. We communicated our finding to Dr. Bhabha. Let me tell you that the committee was concerned, and also not concerned, because we did our job. We never heard from Dr. Bhabha, and the case was closed.

A lesson we learnt from this is that all persons, besides doing whatever they do, have to have the highest principles, a lesson which came very handy to me when I became the Director, PRL. I was approached at numerous occasions to hire persons in PRL. With Dr. Bhabha's example, my simple approach was to tell the person making the recommendation: "Thank you for bringing to my notice such and such case. I will arrange to have the person interviewed at PRL, and if he/she is found suitable, we will invite him/her to join PRL".



Figure shows Dr. Bhabha showing an elementary particle event to Nikita Khrushchev

During 1958-1960, I was visiting the Scripps Institution of Oceanography (SIO). During my stay I wrote several papers and discovered the cosmic ray produced isotope, ^{32}Si . I was offered Faculty position by the SIO Director, Roger Revelle. Towards mid-1960, Dr. Bhabha had come to La Jolla since there was big celebration at the General Dynamics in which Niels Bohr, Robert Wilson, Freeman Dyson and other dignitaries were also present. Dr. Bhabha had then learnt that the SIO Director had offered me a Faculty position. Dr. Bhabha arranged to have a meeting with me at La Jolla, and after some general discussions told me: "Come back soon". I of course had refused the Faculty position offered to me, and was happy to inform him that I would return within a month.

Back home, I was very lucky to have gone to a few meetings where Dr. Bhabha was discussing plans of growing TIFR, and I also had the opportunity to walk with him when he was taking rounds of the TIFR building. These meetings gave me the clear impression that whatever Dr. Bhabha did, was executed with total-insight and an immaculate eye for details. Many examples can be given.

He always kept an overall view on the functioning of TIFR, ensuring that it functioned as a graceful and efficient system, including its beautiful and aesthetic buildings and gardens. He greatly valued the well being of its scientists. He made it compulsory that senior scientists should be regularly checked for overall health very often. When TIFR scientists went abroad for the first time, he would help them learn the ways of the West by sending them to a lady expert in the Western culture.

He also expressed his desire that when TIFR scientists go to meetings, they should not go in multiples, since in case the plane crashed, it would be a big loss to TIFR. *Ironically and very sadly, we lost him in a plane crash!*

I learnt that Dr. Bhabha did not believe in micro-management. He selected able persons to lead in different areas of science. With his acute perception and ability he knew whom to assign the task. Having done so, he proceeded to build the TIFR and the Atomic Energy agency in a holistic manner, to grow these to be the best in the world. To this end he also strived to build stronger Indian schools, colleges and industry. He was very clear in his mind that the development of these facilities only within the TIFR and the AEC would not be useful!

For Dr. Bhabha's ideas to be implemented, he needed able assistance from scientists. As I stated earlier, with his acute perception and ability he selected able persons to lead in different areas of science, and left the execution of the task to them. Thus he was a builder, one who grew self-working lofty institutions; he was not a micro-manager. Let me illustrate Dr. Bhabha's way of functioning in management by an example.

Dr. Bhabha was planning a meeting at the AEC in which distinguished scientists such as Cockroft, Blackett and others were invited. The time was short, and Dr. Bhabha wanted that by the time of the meeting, the plutonium plant should also be operational. I happen to be present at the time when Dr. Bhabha told Dr. H. N. Sethna what he was planning to do. Having said this, he just went away, leaving Dr. Sethna to get on with the task; a beautiful example of his style of management. During one of his rounds of the TIFR premises, I once walked with him and a senior Faculty member. Dr. Bhabha visited the buildings and also the toilets; on the latter he explained to us what was not executed properly.

Since Independence, there have been many examples of leaders in science. Many scientists followed the practice of micromanagement. Without being specific on names, I hesitate to conclude that real examples demonstrated that micromanagement in science is a very dangerous practice in science because it does not let individuals show their best.

Once at a dinner at his house with Prof. P. M. S. Blackett, he asked me about name of a person who could take the responsibility of taking on a task. I gave him a name and added that this person did not have much work on his shoulders. Dr. Bhabha was in a hurry and he was just waiting to hear a name from me, but then he dropped everything and said I want to tell you something you do not understand. *Never give an important task to one who has nothing to do. Give it to a busy person; he will find time to do it.*

On another occasion, I walked with him going through the accommodations built for the TIFR scientists next to the TIFR premises. Dr. Bhabha visited a flat in the housing to see how scientists organize their homes. He found that a scientist had a study table on one corner in the living room. On seeing it he immediately commented that the study table was placed incorrectly. So here is a puzzle for you.

There is a window in front of you. And there are two walls on either side. You are required to put a table against one of the walls. Which wall you will put the table against; the wall on the right or the left of the window? The answer is very scientific, and depends on whether you are right- or left-handed.

4. Concluding remarks

In the very recent past there lived a person amongst many of us here, who in all moments of time available to him, thought of science on ideas which revealed the structure of matter, its grand form and beauty, and last but not the least, how he could make India which had just then become free from foreign control, a powerful country which derived its strength from the knowledge of science.

This person passionately took on the task on himself to transform Indian science, taking it to great heights in the realm of physical sciences, so that Indian science was at par with science in the world. *Whatever he aspired to do, he succeeded in it.* The great transformation he executed is visible everywhere in India today; it was accomplished by him in a very short period of time, between 1939 and 1965.

Several of you here in this gathering had the opportunity to see him and learn about his thoughts. There was no person like him; he was a person who realized most of his dreams, but was unfortunately taken away from his country very early in his life!

Of course, you know whom we are talking about. This is the story of Dr. Bhabha, a highly successful scientist who sacrificed his personal scientific career to spend most of his time to grow science and technology in India. He spent a disproportionately large amount of his time building and growing first class scientific institutions and the culture of science, completely neglecting his personal research. History of India after independence clearly bears witness to the fact that those who truly succeeded in growing the culture of science were great scientists themselves, a necessary condition, because only a great scientist really knows what the culture of science is. In the pre-Independence days of India we had several great scientists, *but history also tells us that brilliant scientists generally continue to spend most of their time on their science.*

Dr. Bhabha loved the beauty inherent in science, the beauty of simple mathematical equations and he loved beautiful people. These thoughts, combined with his ideas to diffuse science in all of India kept him very busy, and motivated. Our ex-Prime Minister Indira Gandhi once said:” *When Homi visited them that it was like a fresh breeze flowed through the window.*”

I wonder how many of us realize what we had and what we lost. There was no one like him; a great scientist who wanted to raise India to great heights. I wonder how many of us even those who were active in TIFR and in the Atomic Energy Commission ever realized what a great privilege it was to live in the era of Homi Bhabha, and serve in the TIFR, or in the AEC.



A visionary and a great scientist.

How lucky were we to have such a distinguished scientist amongst us, who was not only a great scientist, but one who transformed India and told us that we could do any thing we wished to do, to perform at the highest level in science compared to any one else in the world. This of course has an underlying concept, namely that Indians did not generally have the same confidence as the foreigners. One of the reasons for this is of course the fact that in pre-Independence India, the British spent very little money to do basic research. Here I would like to hasten to mention that even in the pre-Independence days we had great scientists who carried out very fundamental research which lies at the heart of the foundations of physics, for example, Bose and Saha.

And now I am coming to the concluding part of my talk.

Did you know that “Bhabha” is a lunar impact crater that is located in the southern part of the Moon's far side:

“It is nearly attached to the southeast rim of the larger crater Bose, and the outer rampart of that crater has produced a slight inward bulge along the northwest face of Bhabha. This is a relatively

fresh crater with a nicely terraced inner wall. This terracing is most notable along the southeastern half of the crater, and nearly disappears along the north-northwest rim where the inner wall is at its minimum extent. The rim and inner wall have not been significantly eroded, and there are no craterlets of note along the rim. The interior floor has a formation of central peaks that forms a semi-circle with the concave interior open to the north. The remainder of the floor is relatively level, with a single small craterlet in the northern part."

JRD Tata recognized the talent and leadership of Homi Bhabha, and gave him complete support to build the TIFR and the Atomic Energy program. J. R. D. Tata held Bhabha in very high esteem. In his own words, as he once commented: "Bhabha was one of those who made me believe that some men in human history are born with the stamp of predestination on them which leads to accomplishments beyond human capability". On his part, during his lifetime, within about 2 decades of setting up of the TIFR, Homi Bhabha demonstrated the great merit as well as national relevance of his ideas and ambitions.

If Dr. Homi Bhabha had not perished in the air-crash, we would have quite a different India today. With the tremendous success he already had in a decade of his efforts, and the respect with which scientists and politicians held him, he would have solved a large number of problems which we face today.

We all have to learn from the life of Dr. Homi Jehangir Bhabha, namely that a single scientist can contribute so much to the *growth and shining of a big country*. Most of the readers of Physics News are scientists, and there are even a larger number of scientists in our country. *Why can't we follow the example of Dr. Bhabha in our own personal way, and contribute to the growth and shining of our country, either by doing science at the highest level, or by further raising Indian science, technology and the level of education in India to the highest level.*