Vikram Sarabhai, the Scientist

U R Rao

U R Rao, currently Chairman of PRL Governing Council, started his career as a cosmic ray scientist under Vikram Sarabhai and continued his research in USA as a prime experimenter on Pioneer and Explorer Series of Spacecrafts. On his return, he started the satellite program in India resulting in the launch of over 18 satellites including Aryabhata, INSAT and IRS satellites. As Chairman of the Indian Space Program during 1984-1994, he accelerated rocket technology development, resulting in the successful launching of ASLV and PSLV rockets. He was also responsible for promotion of space technology application for communication, meteorological forecasting and management of natural resources.

Formative Years

Vikram Sarabhai, born on the evening of August 12, 1919 to a wealthy industrial family, had the best of education in science, mathematics and liberal arts from the most competent teachers arranged by his parents. Blessed at the age of seven by Gurudev Rabindranath Tagore, who had predicted that this bright boy would one day become a great celebrity, Sarabhai had developed an intense love for science from his childhood days. His interest in science became an obsession as it took an active shape in 1940, when he returned to India after graduation from Cambridge University on the outbreak of World War II. He joined the Indian Institute of Science, Bangalore to carry out research on 'Time variations of cosmic rays' on the advice of C V Raman. Encouraged by the institute atmosphere created by C V Raman and Homi Bhaba, who were working on theories of mesons and cosmic ray showers, Sarabhai built an experimental set-up with Geiger Muller counters to carry out systematic continuous measurements of cosmic ray intensity at Bangalore and later at Apharwat (about 4 km above sea level) in the Kashmir Himalayas. His first scientific paper 'Time distribution of cosmic rays' was published in the *Proceedings of the Indian Academy of Sciences* in 1942, barely two years after he started his research. He went back to Cambridge University in 1945 to continue his investigations on cosmic rays and photo fission and returned to India in 1947 after receiving his PhD degree from Cambridge for his thesis on 'Cosmic ray investigations in tropical latitudes'.

Soon after his return in 1947, Sarabhai set about the task of establishing the Physical Research Laboratory (PRL) and the Ahmedabad Textile Industry Research Association (ATIRA) at Ahmedabad. Sarabhai had conceived the idea of PRL in 1943 itself, when he was hardly 24 years old, during his extensive interactions and discussions with K R Ramanathan, an eminent atmospheric scientist and Director of Poona Meteorological Observatory. With Ramanathan as the founder director of PRL and a small group of young research students like me, Sarabhai built up PRL into an outstanding institution dedicated to fundamental research in cosmic rays, aeronomy and space sciences. ATIRA, the first of the many institutions he built during the next two decades, was conceived as a think tank for the development of textile industry under his guidance.

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PRL started functioning immediately, in two small rooms in the nearby M G College of Science pending the construction of its own building and facilities on a neighbouring plot of land provided by the Ahmedabad Education Society. After collecting enough funds, Sarabhai requested C V Raman to lay the foundation stone of the PRL building in 1952, which was done in the presence of Homi Bhaba, S S Bhatnagar and many other luminaries in the field of science. All the research activities in M G Science College were shifted to the new PRL campus in 1954, after it was declared open by none other than Jawaharlal Nehru.

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It was at this time, the existence of a continuous outflow of ionized particles from the Sun into the interplanetary space was proposed by Parker of Chicago University, even though suspected a few years earlier by Biermann from the comet tail observations. The discovery of solar wind or the stream of ionized particles continuously oozing out of the Sun with supersonic velocities varying from 300-2000 km/sec by Mariner II and their effect on the Earth's magnetic field by Snyder and this author clearly established Parker's idea. The interplanetary space, which was once, considered a vacuum became the most interesting laboratory filled with solar plasma and magnetic field irregularities. *In situ* observations of the solar wind and magnetic field fluctuations in the interplanetary space using space probes had also confirmed the presence of a boundary called magnetosphere at about 60,000 kms away from the Earth along the Sun-ward direction, due to the pressure exerted by the Earth's own magnetic field, confining the Earth within a magnetic cavity called magnetosphere. The solar wind flows round the magnetosphere to form a long tear shaped tail along the dark side of the Earth. While within the magnetosphere the Earth's magnetic field exerts dominant influence, outside the magnetosphere it is the solar wind plasma and the interplanetary magnetic field, which modulate the cosmic ray particles. The modulation of cosmic ray intensity due to the influence of the radially blowing solar wind carrying with it the frozen magnetic field, manifests itself as minute diurnal and semi-diurnal to 27 day, 11 year and 22 year cycle of variations in addition to the sporadic large decreases named after Forbush and violent increases due to the emission of particles during intense flares on the Sun. Variations in the intensity of cosmic rays in space and time thus became the most important probes to study and understand the fascinating dynamics of the interplanetary space between the Sun and the Earth.

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Detection of the minute diurnal and semi-diurnal (24 hour and 12 hour periodicity) changes using ground based cosmic ray measurements required a thorough understanding of the changes introduced by pressure and temperature variations in the atmosphere, which were of the same order of magnitude and sometimes even larger than the effect they were trying to study. As Sarabhai used to say, it was like listening to music in a noisy atmosphere, which though difficult to discern, was highly rewarding as it provided the clue to what was happening in space. The measurements carried out by Sarabhai and this author using east and west pointing telescopes inclined at 45° to the zenith, both being equally subjected to the influence of atmosphere, unambiguously established the presence of diurnal and semi-diurnal variations in cosmic rays. To relate these variations in cosmic rays to the electromagnetic conditions in space, and to the exact direction in space these rays come from, it was necessary to understand and correct for the bending of these rays in the Earth's magnetic field. Extensive and painstaking calculations carried out by this author at the Massachusetts Institute of Technology, USA (MIT) in association with McCracken, finally resulted in understanding the diurnal and

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semi-diurnal variations of cosmic rays as due to the azimuthal streaming of these particles caused by the corotating solar wind with frozen in magnetic field.

Sarabhai along with his students carried out extensive studies of the day to day changes of cosmic ray intensity, which provided the instantaneous snap shot of the highly varying electromagnetic state of the interplanetary space. Recognising the importance of the changing magnetic field irregularities on the Sun and their effect on the interplanetary space, Sarabhai decided to collaborate with MIT in setting up a giant meson monitor at Chacaltaya, Bolivia at a height of about 5340 meters above sea level to study very short period variations of 1-30 cycles per hour in the cosmic ray intensity. With these observations he and his group were able to establish a complete correspondence in spectral changes in interplanetary space, magnetosphere and in cosmic rays measured on Earth.

Sarabhai very quickly recognised that the solar winds emanating from different regions of the Sun will have different velocities, taking the cue from the highly varying intensity of green coronal line emissions, which originate in different regions of excitation in the solar corona. He worked out the implications of the non-uniform solar wind particularly as the fast plasma overtakes the preceding solar plasma creating shock transitions and turbulent conditions. The effect of such shock transitions on cosmic ray intensity, some of which often last for several months, led him to propose a new mechanism for explaining 27 day recurrent effects and the so-called large Forbush decreases of cosmic ray intensity observed in space and on the ground.

In the last few years Sarabhai's interest shifted to the study of fluctuations in the geomagnetic field and their origin. Using the data from the precise measurements of the horizontal component of the geomagnetic field (*H*) from several low latitude observatories across the world, he and his group studied, in great detail, the diurnal changes in *H*, which usually reaches a maximum value around noon and a minimum during the night.

These studies led them to correctly interpret that a considerable part of the changes in H is due to the changes in the current system at the magnetopause and in the magneto-tail, induced by the changes in the interplanetary solar wind plasma.

The extraordinary pace of research carried out by Sarabhai and his colleagues established PRL as an outstanding research institution attracting increasing support from CSIR and the Department of Atomic Energy (DAE). The school of cosmic ray scientists set up by him, undoubtedly one of the best in the world, achieved international recognition. PRL nurtured by Sarabhai along with Ramanathan whose scientific interests in aeronomy, radio astronomy, meteorology and atmospheric physics complemented Sarabhai's own interests, became an unique institution for carrying out space science research. He was elected as the Secretary of the internationally instituted Subcommittee on Cosmic Ray Intensity Variations (SCRIV) and also as a member of the cosmic ray commission of the International Union of Pure and Applied Physics (IUPAP).

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From the studies carried out at PRL and elsewhere it became clear that practically in every part of the universe, except on the surface of the Earth, hydromagnetics clearly dominated the physical phenomena. These developments naturally led Sarabhai to propose the inclusion of systematic worldwide study of cosmic ray variations with standard equipment as a part of the International Geophysical Year (IGY) study, which was enthusiastically accepted. The importance of carrying out space observations in all wavelengths from infrared, optical, ultraviolet, radio waves to X-rays and gamma rays, unhindered by the Earth's atmosphere was already well-established. Worldwide observations of cosmic ray variations and their significance in unravelling the electromagnetic state of the interplanetary space, clearly established the need to have concurrent observations of particles, radiation and magnetic field, both in space and time, to understand interplanetary dynamics. As direct *in situ* measurements in space became accessible, with the advent of the satellites and deep space probes after the coming of the space age

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in 1957, Sarabhai's interest naturally led him to initiate a dynamic space programme in India and in this process making the Physical Research Laboratory the cradle of the Indian Space Programme.

Multifaceted Personality

While Sarabhai with his deep and abiding interest in pure science made it the central theme of his life, his inborn multifaceted character found its expression in extending the benefits of science to all aspects of socio-economic development. He excelled as an Institute builder and was involved in nurturing over 30 institutions, covering both public and private sectors. Without compromising on his love for basic sciences, he took on additional responsibilities, working against time, as if he was aware of the short time he had in which he had to compulsively achieve his goals. He had a shining vision, in which we as his students and young colleagues fully shared – a vision for enabling India to leap frog into the future through the adoption of appropriate technologies. In his own words "A positive approach out of our predicament lies in finding solutions where the particular disadvantage of developing nations, which is that they have little to build on, is made an asset rather than a liability. It is necessary for them to develop competence in advanced technologies and to deploy them for the solution of their own particular problems, not for prestige, but based on sound technical and economic evaluation involving commitment of real resources".

In 1962, COSPAR had pointed out that "The equatorial region has special scientific interest for meteorology and aeronomy. In particular, the magnetic equator is highly significant in the investigation of the Earth's magnetic field and the ionosphere". Considering that the magnetic equator passes over South India and the equatorial electro-jet phenomena, confined to a narrow region over the magnetic equator, has tremendous influence on the dynamics of the equatorial ionosphere, Sarabhai decided to establish The Equatorial Rocket Launching Station (TERLS) at

Thumba, near Thiruvananthapuram for carrying out aeronomy and astronomy experiments. Convinced of the need to develop indigeneous competence in space technology, the immense practical benefits of which in the fields of communication, education and management of natural resources were already clear, Sarabhai established the Space Science and Technology Centre in Thumba to begin work on rocket technology. In his speech delivered at the dedication ceremony of TERLS in 1968, Sarabhai elaborated his vision as follows: "We do not have the fantasy of competing with the economically advanced nations in the explorations of the moon or the planets or manned space flight. But we are convinced that if we are to play a meaningful role nationally, and in the community of nations, we must be second to none in the application of advanced technologies to the real problems of man and society, which we find in our country". His vision on the development of space technology and its extensive application for the betterment of society continues to be the guiding light of our space programme even today.

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Sarabhai's scientific contribution cannot be judged only by the quantum of scientific research papers he wrote – rather by the impact of his ideas and the enormous influence he had in shaping not only his students but also institutions, programmes and thoughts with which he was associated. The dynamism and purposefulness he infused, contagious enthusiasm and inspiration he transmitted and the deep concern and love for people he showed made a strong impact on his close colleagues and the institutions he built. Bruno Russi, the celebrated scientist from MIT with whom Sarabhai collaborated, very aptly summed up Sarabhai's contribution to science at the special session of the cosmic ray conference held at Denver in 1972 as "I believe that the stature of Vikram Sarabhai as a scientist depends not so much on any specific achievement as on the unique character of his scientific personality. For him scientific research was an act of love towards nature. He had an almost uncanny capability to absorb and store in his mind a vast amount of experimental and theoretical data. Having done that and guided by what I am tempted to call an artistic intuition, he would then proceed to arrange these data into a self-consistent picture bringing out hidden regularities and relationships; a picture which, through the years, would progressively evolve and become more precise. This is why his death dealt such a hard blow not only to the personal feelings of his fellow scientists, but to science itself".

The country as well as the world has seen many a greater scientist, or an administrator, industrialist or a social reformer, manager or a skillful diplomat. Vikram Sarabhai's unique stature lies in brilliantly combining all these roles in himself.. He was able to combine his intense desire to establish new institutions and innovative traditions with an excellent sense of economics and managerial skill. Above all, he was a very warm and charming person, always smiling and never losing his poise, even in the face of most adverse situations.

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With his mother Saraldevi and Sir C V Raman at the foundation stone laying ceremony of the Community Science Centre, Ahmedabd, 1968.