

VIKRAM SARABHAI

THE LEGEND UNVEILED



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Preface

There are scientists who burn mid night oil in lab, immerse themselves in experiments and uncover some extraordinary reasoning behind natural phenomena, other kind of scientists are research managers who through networking and coordination come up with solution to a problem society is facing and there are rare scientists who built organisations of international repute serving the motherland through Science and Technology. Dr Vikram Sarabhai was such a rare scientist who built organisations which have given distinguished position to India on a global scientific map.

His versatile personality and diverse experience from being a researcher, academician, industrialist, policy maker and nation builder had made him believed that only efficient managers can uplift public and private enterprises for the betterment of the society. He believed in 'man making' and devoted his entire life in building institutions for creating Men-Leaders for New India.

I am very happy that Vijnana Bharati is publishing 'Vikram Sarabhai- a Legend Unveiled" a biography of Dr Vikram Sarabhai in a very lucid way. This book is indeed like a pure crystal form of Dr. Sarabhai's mind and is timeless in its relevance and unequalled in its value. I followed Dr Sarabhai

as a social worker, I can't agree more with Dr. Sarabhai's idea of nation building by man making.

The book very convincingly presents Dr. Varabhai's dream and message that the contemporary problems of the society can be solved through application of Science and Technology. India poised to become a Super Power while its Space Program initiated by Dr Sarabhai has already proved its metal globally. I see this book as a light house that will direct the young minds to dream and aspire high to serve the motherland through application of Science.

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निदेशक/Director



Foreword

I am very happy and proud that 'VijnanaBharati', the largest science movement in our country is publishing the book 'Vikram Sarabhai: the Legend Unveiled' probably the first of its kind for school children of our country. Reiterating Dr Kalam, who rightly pointed out "Educationists should build the capacities of the spirits of inquiry, creativity, entrepreneurial and moral leadership among students and become their role model". This book taking up this quote as their mission has crystallized the very essence of Dr Sarabhai's life and thereby has indirectly unveiled the history of Indian space programme. The book successfully has brought out the evolution and the gradual expansion of space research as we see it today. Space technology made gratifying contributions to the various facets of development of our nation including television, weather broadcasting, satellite communications for developing and identifying earth's resources, agriculture, meteorology and disaster warning. If we could only dream of moon or mars long time ago and now make it into a reality, it is through this great visionary's effort and conviction that India is no way behind other developed nations as early as six decades back.

As we ponder through the pages of the book, it has like a story taken us through the various facets of Dr Sarabhai's life from childhood to his training in Cambridge and then his association with stalwarts like Dr. CV Raman and Dr Homi Bhabha which helped him shape his career forward. The various hurdles and bottle necks he had to face in building up this organization are gracefully depicted in this book which would in turn inspire the younger generation for posterity. The book is magnificently capped by a chapter on the various accomplishments of ISRO which was kick-started by Dr Sarabhai and is still continuing. The various illustrations and quotes in this book are apt and definitely would incite any imaginative mind to adopt this book and thereby science into their soul.

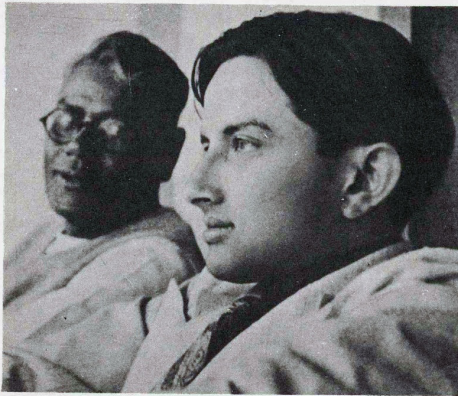
India needs at the moment more and more scientists with a keen aptitude and attitude with disciplined minds like Dr Sarabhai. I am certain this book will throw the doors open to all the

Introduction

Not many of us, even those rooted in Science day in and out remembers one of the great legends of all times our motherland had ever seen-Sri Vikram Ambalal Sarabhai-As is often said, some are born with a silver spoon, but not many of them utilizes those golden moments which comes as opportunities through their ancestral strength to the best of their ability. But Sarabhai did it ! As an eminent scientist exclaimed once, *“Sarabhai died when only 52, removing one of the obstacles to India’s ill-calculated and premature nuclear explosion of 1974.”* If Indians have profuse reverence towards science and scientific fraternity, it is through the lives of eminent scientists like Vikram Sarabhai. Like Dr.Homi Bhabha, Vikram Sarabhai was born into a wealthy family, but he was a rare combination of extreme passion towards science topped with an equal and sustained love for other fields like dance, theatre, music, art etc to state a few making him a versatile figure probably unmatched by any other scientific brain our country ever witnessed.

Vikram Sarabhai ran the Atomic Energy Commission (AEC) and Indian Space Research Organisation (ISRO) together, but his greatest success was in preventing these establishments from becoming typical government scientific institutions

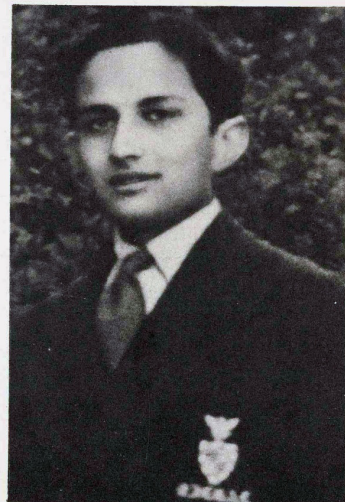
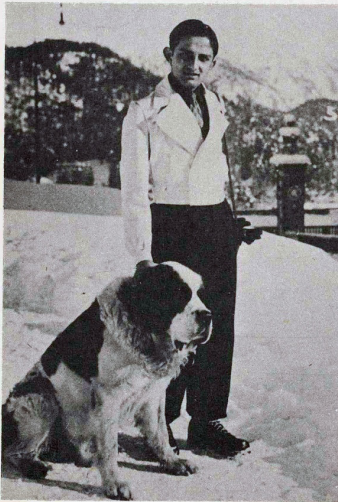
during his reign. India's first rocket launch makes us feel that globalisation had already gone very far by 1963 with the French supplying us a RADAR, the Russians a computer, and the Americans the training necessary for us to take our nation to further heights which is a dream these days when it was just a man's extreme passion and effort making it possible way back in 1960s. It seems strange that an eminent, born-wealthy scientist was chosen to hold the mantle of the country's two



As a student at the
Indian Institute of Sciences,
Bangalore, 1942.

As a student at St. John's
College, Cambridge, U.K.

As a student in U.K.

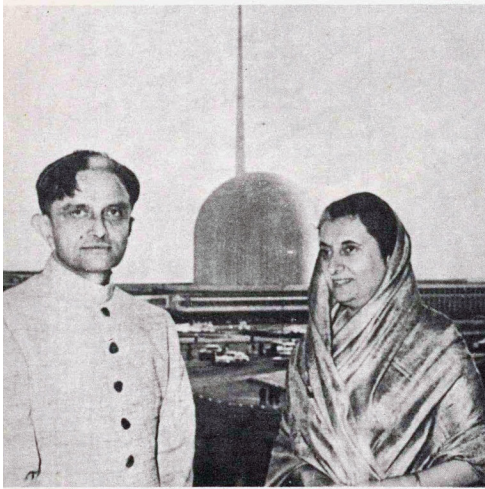


premier scientific establishments just because he proved all his strength by himself which no one could even dream of those days. Sarabhai even in those days belonged to a rare genre and class of scientists who were far more concerned of society than science.

Dr. Vikram Sarabhai was a multi-faceted personality, an outstanding scientist, deeply committed to the development of the country by the application of modern technology. He was a visionary and a dreamer and often used to say *"I have a dream, a fantasy may be, that we can leap-frog our way to development"*.

In fact, Dr. Sarabhai had myriad of dreams. One of his best known dreams was a Space Program for the country, which is already a reality now. Also, was the launch of a National Satellite System for bringing about entertainment and education of high quality to every door of Indian villages, thus leading to qualitative improvement in the richness of rural India. Today, the common man cannot imagine a day without the television (TV), weather broadcasts or the numerous telephone systems, dotted all over the country.

It all started with entrusting the study of the subject of Space Research to the Department of Atomic Energy (DAE) under Dr. Homi Jehangir Bhabha in 1961. In the following year, the Indian National Committee on Space Research (INCOSPAR) was set up with Dr. Vikram Sarabhai as the Chairman. Dr. Sarabhai utilized the opportunity for organizing Space Research in India. The Thumba Equatorial Rocket Launching Station (TERLS) was established at Thumba, a sleepy fishing village near Thiruvananthapuram. On November 21, 1963 the first rocket was launched from Thumba, under the stewardship of Dr. Sarabhai thus sowing the seed of space related activities in India. The activities have been steadily growing in proportion, ever since that time.



As Chairman, Indian National Committee for Space Research, speaking at the Thumba Equatorial Rocket Launching Station, Trivandrum, on the occasion of its dedication to the UN by the Prime Minister Indira Gandhi, 1968.

As Chairman, Atomic Energy Commission, with the Prime Minister Indira Gandhi, at the Bhabha Atomic Research Centre, Bombay, 1967.

For over two decades (1970-1993), tourists ensured they visit Trivandrum on a Wednesday! They could then count on a rocket launch from TERLS in the evening twilight. The rocket was M-100 from the Soviet Union (now Russia), one of the most reliable sounding rockets in the world. These launches were the combined efforts of ISRO and Hydro-Metereological Services (HMS) of the Soviet Union then. Even today, close to

the museum near VSSC in Thiruvananthapuram open for public, every third Wednesday large number of tourists witnesses the rocket launch by mid afternoon.

Apart from an ambitious space program involving satellite technology for developing and identifying earth's resources, communication, agriculture, meteorology and disaster warning, Dr. Sarabhai envisioned a bold electronics Industry and a large agro-industrial complex served by nuclear power stations. He had a firm conviction for a strong, self sufficient and self reliant India. He often paused to remind, *'We do not wish to acquire black boxes from abroad but to grow a national capability'*. All these traits, no doubt earned him the sobriquet, *"Father of Indian Space Program"*.

Attempt to look at the many-splendored personality of Dr. Sarabhai, with relevance to ISRO, all what our country attained in all its glory through this great visionary has been detailed in this book followed by a summary of what ISRO has achieved following the demise of Vikram Sarabhai, but definitely kick-started and envisaged by this great visionary. Finally, some scientific milestones in the life of Dr. Sarabhai are listed in a chronological order ending with the naming of a crater on the moon after him.

One can go on describing his profile for pages together. He was truly versatile with eagerness and wisdom glued together; his multifaceted talents were outstanding which no one else could emulate then or later. His vision or rather a fantasy as he often used to say *"was to leap-frog India ahead of time through science and technology into the next century in par with other developed nations, but this he wanted for the betterment of society"*. Through his never ending dreams, he built a Space Research Organization and a National Satellite Launching Station(NSLS). Today television systems, computers, national and international news, various entertainments, weather broadcast and land

phones to mobile phones became a reality which all started as dreams of this great visionary which did not allow him to sleep for days and months and years together till it ultimately became a reality.

Vikram's Family and Childhood

Vikram's parents were Sri Ambalal and Smt Sarladevi Sarabhai. The Sarabhai family, known for its modern and enlightened outlook those days stood apart from others. Their refined attitude, culture, education, willingness to accept all that is worthy of trying even if afresh brought to them a wide circle of friends from all walks of life from India and abroad. This



A luminary amongst scientists, his passing away left his people orphaned and stunned. Of work he was never tired and often put in 18 to 20 hours a day. "Stretch your working hours" he told his students.

Reference: Vikram A Sarabhai" – by Mrinalini Sarabhai -



At the age of 7.
Rabindranath Tagore was something of a phrenologist too. When young Vikram was presented to him, he intently looked at his physiognomy and expression, and the shape of his head, and quietly remarked to the parents that in future he would become a celebrity.

was fostered by their warm hospitality and pleasant demeanor which made their home a living space for days together for many important people during Vikram's childhood. The foremost amongst them was none other than Gandhiji who frequently visited their home by name 'Retreat'. This thereby attracted other political leaders, freedom fighters, social workers and many other distinguished and eminent personalities.

Rabindranath Tagore, J. Krishnamoorthy, Motilal Nehru, Jawaharlal Nehru, Maulana Azad, Sarojini Naidu, Srinivasa Sastri, C.F.Andrews and C.V Raman were some of them. Therefore, Vikram had the rare chance of seeing them and imbibing from them knowingly and unknowingly many good qualities which might have influenced his personality when he became a productive individual later.

His parents preferred a very simple life despite the fact they could afford any sort of luxury and pomp at that stage of life. They were always keen on punctuality and hard work, aspiring their children to grow better from what they provided after long hours of thought. They wanted their children to come up in life as exemplary human beings, productive to their motherland and at the same time living a life well anchored in honesty and sincerity.

On a routine evening in the city of Ahmadabad, on August 12, 1919, a boy was born to Ambalal Sarabhai and

Sarladevi Sarabhai in their home 'Retreat'. His brothers and sisters crowded around the new comer without knowing that their baby brother is going to make history etched in golden letters in their own country and even abroad. They celebrated his birthday with all happiness like in any household. He was named Vikram Ambalal Sarabhai.

Schooling those days for children from middle class and upper middle class or above families was either in government schools or private schools. But Vikram never attended any such schools. Like his brothers and sisters he studied up to the secondary stage in the private family schools which their parents provided for them after a long thought. This was unlike any other stream of education prevalent at that time. They after a long research introduced the 'Montessori system' for the first time in India. At this juncture, one should have an overview of the Montessori system of education. Montessori education is a distinct educational approach developed by an Italian physician and educator Maria Montessori. Montessori developed many of her ideas while working with mentally challenged children. Her first school, *La casa dei bambini*, was opened to working class children in the slum neighborhood of San Lorenzo in Rome. Her approach was characterized by an emphasis on independence, freedom within limits, and respect for a child's natural psychological, physical, and social development. Montessori education is fundamentally a model of human development, and an educational approach based on that model. The model has two basic principles. First, children and developing adults engage in psychological self-construction by means of interaction with their environment. Second, children have an innate path of psychological development. Montessori education involves free activity within a 'prepared environment', meaning an educational environment tailored to basic human characteristics, to the specific characteristics of children at different ages, and to the individual personalities

of each child. This independence in cultivating and developing one's innate talents would have probably paved the way for baby Vikram to head him in the path which his mind took him.

"Not in books have I read, nor in dreams have I dreamed of parents so devoted to their children and to their education" wrote Miss Williams, a young woman, who came from United Kingdom to teach the Sarabhai children at the Retreat. Sarla Sarabhai was called by Maria Montessori herself as the 'Ideal Montessori Mother'. Of the dozen or more teachers, there were many with PhDs, three were graduates from European countries and those from India were all respected teachers of great repute. The curriculum included Gujarati, Sanskrit, Hindi, English, Bengali. History, Geography, Mathematics, Physics, Chemistry, Drawing, Painting, Dancing, Music, Poetry, Handicrafts and Sculpture. There were also training sessions in various sports like badminton, tennis, riding, archery and yoga. Musical classes also were prominently included. Children were also trained to manage aviary, kitchen and even the cow sheds and also to manage cash and even receive and take care of guests.

The decision of his parents not to send Vikram and his rest seven siblings to any formal schools prevalent at that time where each student is given equal opportunity to study the same material not catering to their needs was far from what was expected to the other contemporary Gujarati families at that time. They started the schooling in their own home Retreat after searching and finding teachers with the same attitude and inclination to Montessori system. Such teachers mentioned earlier were then trained to adapt to it completely and the school started functioning in a small way to create awareness in the masses thereafter through years to come.

While concentrating on their studies, the Sarabhai couple never forgot to engage their children in playful activities and they frequented several hill stations like Mussorie, Simla,

Shillong, Kashmir, Ooty, Ceylon, Mount Abu and Matheran and other destinations in India during their holidays every year. This in turn helped them to see the various facets of India, diverse in culture and different in all ways. This family thus remains even today as an example and role model of a couple who strived hard after doing research by themselves as to the best upbringing methods of their children when such practices were even unheard of in India.

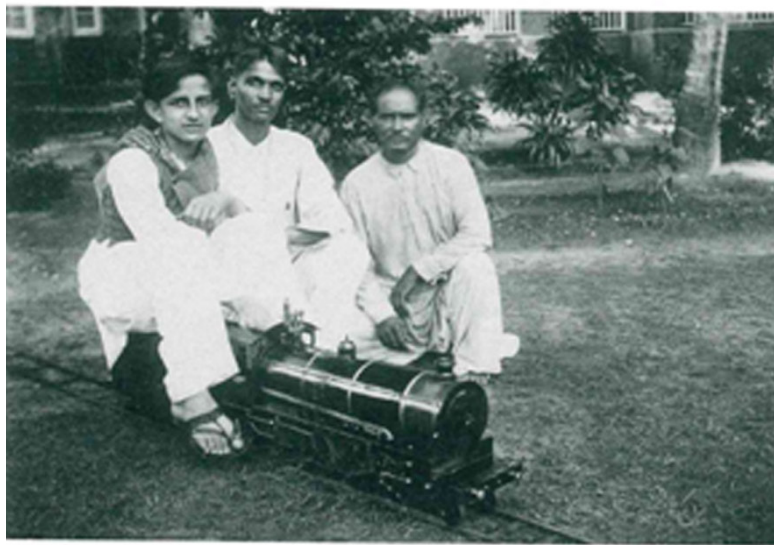
The Sarabhais were Jains and were ritualistic as far as their traditions were concerned, whereas they imbibed Western traits which were considered necessary in the ideal upbringing of their eight children. They were strict vegetarians and Vikram had exclaimed several times that he will remain a vegetarian 'out of choice', especially since he was a staunch follower of Gandhiji and believed in ahimsa and non-violence since early childhood. It was ironically said about Sarabhai household that even the dogs were vegans by choice and only milk was fed to ants on a daily basis.

There are only sketchy remarks on Vikram's childhood, his desires, his hobbies, his aspirations etc, To cite a few, was his nature to remain truthful and he did things with conviction right from the age of 6 or 7. To cite a few, on their trip to Simla with his family, he developed a desire to receive letters stamped in an envelope in his own name. Since there was no one to send letters to him, he started doing so regularly and each day in Simla when he started getting letters addressed in his name, his dad became suspicious and questioned him. He with all sincerity looking into the eyes of his father said, he himself posted them after gathering a bunch of envelopes from his father's secretary because of the simple fact that he loved receiving them. Such honest and unshaken qualities were part of his personality ever since he was very young.

His father at the age of 6 or 7 used to get him toy trains with rails, engines, stations and signals. He would play with them



Ambalal and Sarla with Vikram and Gita



Vikram with the toy engine he made

the whole day, would dismantle them and re-assemble them forgetting all other routine chores. He used to even sleep with them after playing the whole day. At the age of 6 or 7 he could ride a bicycle too well. He performed such weird tricks on it like pedaling at high speed, taking his hands and feet off the cycle and pulled up his legs crossed on the handle bars. Likewise, he had a small boat in their garden pond. With little boys and girls on it he would act smart by making the boat take unusual turns and twists often creating panic to others and onlookers.

At school, he was so versatile that he could comprehend many things at the same time which reflected in his future life as well. His memory was sharp, he was very attentive and he could comprehend even the very difficult tasks with so much precision within no time. There were umpteen languages to be learnt-Gujarati, their mother tongue to Sanskrit, Hindi, English and Bengali. Vikram became proficient in not only languages but also history, geography, sculpture, physics, chemistry, drawing, painting, music, dancing, botany, biology and horticulture. His innate likeness was always for mathematics and science and he gave much attention to it both. In addition to these science subjects, equal or more importance was attached by his parents to provide them all the essence of art and literature. The artists and dance teachers were recommended by Rabindranath Tagore who was a frequent visitor to their household those days. As per his desire such teachers were hired from the best of the lot from Bengal, Andhra and Manipur.

In 1920, while Tagore visited the Sarabhais and went on to stay for a month as their guest in Shillong, he happened to notice Vikram so closely. Tagore commented on the behavior and more so on the appearance of the boy as one with a large forehead and remarked to Sarla that "*this boy will achieve great things*". Other than Gandhiji, Motilal and Jawaharlal Nehru, Indira Gandhi and Tagore, other luminaries like



The Sarabhais with Rabindranath Tagore, 1920

*Uttarayan
Santiniketan, Bengal
November 1, 1935.*

It is with great pleasure that I recommend the application for admission of Mr. Vikram Sarabhai to the authorities of the Cambridge University. He is a young man with keen interest in Science and I am sure, a course of study at Cambridge will be of immense value to him. I know him personally and his people. He comes of a wealthy and cultured family in the Bombay Presidency and he has a brother and a sister studying at Oxford at the moment. In my judgment, he is a fit and proper person for admission to the University.

Rabindranath Tagore

Tagore's letter recommending Vikram's application for admission to Cambridge

Jagdish Chandra Bose, Jadunath Sarkar, C.V. Raman, Rukmini Arundale, J. Krishnamoorthy, Prithviraj Kapoor, Dadasaheb Mavlenkar, Madan Mohan Malaviya, Sardar Patel, Maulana Azad, Sarojini Naidu, C.F. Andrews, Muhammed Ali Jinnah and

Dr S.Radhakrishnan had been to Retreat several times as guests of Vikram's family. This in future life proved invaluable to him. Gandhiji was in turn brought home by the Sarabhai couple in 1918 to be treated for a serious illness.

The family needless to say thus got actively involved in the freedom movement. Although Ambalal was the foremost textile business tycoon in Gujarat, the family preferred to wear khadar. The whole Sarabhai family including Vikram at the age of his tender 10 years went to actively participate in the Dandi March, they all marched to the sea and made salt with Gandhiji.

What amused the small boy the maximum was the workshop which was built in the school, a landmark in the history of any Indian school at that time. In the company of his elder brother, Vikram spent hours with the various tools in it. He started making small things, and then started repairing minor things. This in retrospect was the hands of the great future scientist India was awaiting 2 or 3 decades later.

Thus the parents who themselves were great visionaries paved the way for an all -round growth of each child of the household where Vikram was born into. Unlike present days, the examinations took a back stage; the first examination ever came into picture only at the matriculation stage when the child was allowed to be an external candidate at the government R.C. High School in their home-town.

So, in brief, in the Retreat School, Vikram's foundation was laid with all zeal and strength for his future intellectual career. He covered all the languages, mathematics and arts. His study habits were unique in that he used to indulge in hard and sustained work, he would delve into the length and breadth of each subject with so much enthusiasm, so unbecoming of a child of his age. But all the time his primary interest was in pure science.

The Retreat School as cited earlier modeled on Montessorian principles, where the highest function of the teacher was to inculcate the interest and enthusiasm, not a ritualistic teaching as is well known. Vikram then went on to give the Intermediate examination at the Bombay University and then proceeded to Cambridge, United Kingdom for his higher studies. His teacher Sri J.S. Badami quotes(December 1935), *“Vikram has a very inquisitive mind, often asks questions for explaining which I have to go far and wide out of the prescribed course. This is very good and he should be encouraged to discuss details”*. And in appreciation to this great teacher Vikram’s mother Sarladevi replied once *“I am glad you are encouraging him even within the limited time at your disposal”*. This again shows the keen interest a mother was taking in the upbringing of her children. The same teacher also observed once in November 1936,*“He has worked hard during his holidays and is now far ahead of his college work, his progress has been very satisfactory”*. This teacher, Sri J.S. Badami later went on to become the General Manager of Vikram’s industrial initiative” Swastik Oil Mills Limited”. This may be the tribute of a disciple to his great teacher in his retired days for the painstaking mastering he displayed to shape Vikram’s career.

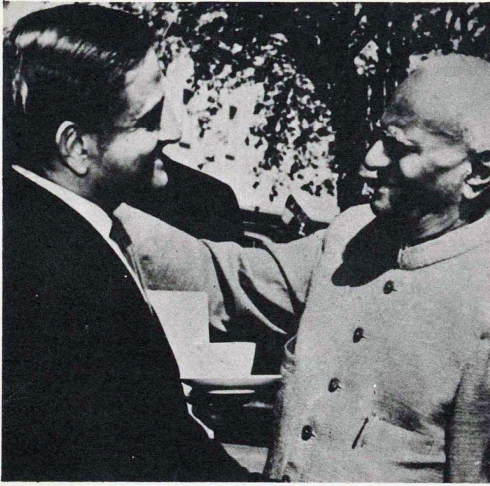
Vikram's Education and His Persona

It was customary those days in upper class Indian families to send their children to London for higher studies. After completing his basic education at the Retreat and clearing his matriculation through the R.C.High School, Vikram joined the Gujarat College. Gujarat College was the first college in the state built by the British in 1887.He spent two years there after his matriculation. He cleared the intermediate examination with very high marks in Physics and Chemistry. J.S.Badami who had taught him at the Retreat was one of his teachers at this College. Vikram also enjoyed Sanskrit poetry, he was very fond of Kalidasa and especially his works Meghadootam and Vikramorvasiyam. He was then given a letter of recommendation to go for higher studies by none other than Rabindranatha Tagore. In 1937, Vikram and his brother together sailed for London. Vikram was at Cambridge from 1937-1940. Indira Gandhi was also at England the same period, but she was at Oxford University. While Vikram stayed tuned to his passion i.e."Science', Indira had a politically inclined life even those days.

It was not one of the best times to be in Cambridge when Vikram reached there. The Cavendish and Mond laboratories declined in their glory unlike in early 1930s when Chadwick discovered the neutron, Walton and Cockroft caused light elements to transmute by bombarding them with high speed protons and Patrick Maynard Stuart Blackett and Giuseppe Occhialini demonstrated electron-positron pairs .Also the brilliant New Zealander Ernest Rutherford died a few months after Vikram arrived. Scared of Hitler, all Jewish scientists were fleeing Europe. Many reached America which was then going to emerge as the centre for science over ruling Europe. In September 1939 when war finally broke out, Ambalal wanted both his sons to return at the earliest to India. Vikram finally returned and had by then completed his undergraduate studies in physics and mathematics. He also obtained permission to continue his post graduate work back in India under the Nobel laureate Sir C.V.Raman. Thus in 1940, with a tripas in natural sciences, Vikram returned to India and joined the Indian institute of Science (IISc) in Bangalore.



With Sir C.V. Raman, the Nobel Laureate, who was Vikram Sarabhai's guide, at the Indian Institute of Sciences, Bangalore from 1940 to 1945.



With the President, V.V. Giri.

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



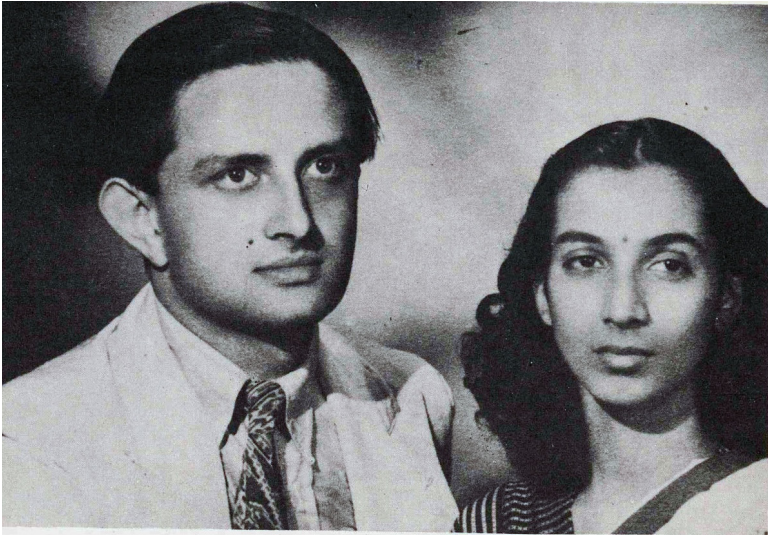
IISc was the dream come true of a Bombay industrialist Jamsetji Tata. Started as a centre for applied sciences with chemistry and electrical engineering .In 1940, physics was added to it and was headed by C.V.Raman who had won the Nobel for “Raman effect” in 1930 for investigations on the scattering of light particles. Raman knew the Sarabhais well and therefore it was not very tough for Vikram to transform

himself as his student. Vikram started his work on Cosmic rays, the penetrating radiations coming from outer space, best suggested by C.T.R. Wilson, best known as the inventor of the cloud chamber in 1911. When Vikram submitted his PhD thesis on "Cosmic Ray investigations in Tropical Latitudes", Cambridge went on to hire an external examiner for him. It was Robert Millikan, an American scientist and Nobel winner of the year 1923 who coined the term "Cosmic Rays". In 1937, he visited India to acquire data for his world survey of cosmic ray intensity, during which time he visited C.V. Raman. Even in the PhD thesis Vikram had noted that cosmic ray studies are to be conducted in South India near the magnetic equator which was unheard of at that time and which made history later in Space Research.

Under C.V. Raman, Vikram picked up an apparatus by name Geiger Counter. His early experiments itself led to his prestigious first paper "The Time Distribution of Cosmic rays". This he presented to the Indian Academy of Sciences in 1942. While at IISc, Bangalore his life took a different turn when he came across a scientific giant who had established by then as the founder of India's Atomic Energy Program by name Homi Jehangir Bhabha. He had graduated from Cambridge 10 years before Vikram. He had won several prestigious awards and fellowships by then, including the Issac Newton studentship award. He had worked with stalwarts in the field while in Europe such as Enrico Fermi and Wolfgang Pauli. He also authored two coveted papers on 'Positron Physics' and the 'Cascade theory of Cosmic Showers'. He joined as a reader in IISc, Bangalore when the war broke out. Bhabha too who was interested in Cosmic Rays in no time got attracted to Vikram and his charm or vice versa.

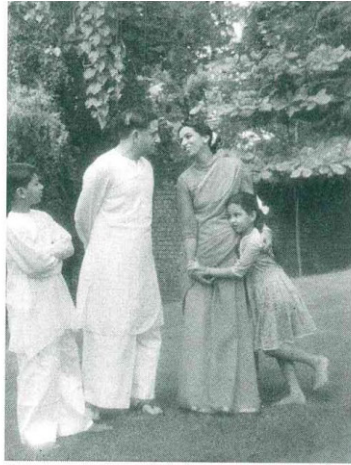
While in IISc, Vikram was not staying in the hostel, he preferred to stay in a house at Malleswaram by name

'Premalaya'. Vikram in his leisure time used to wander the road to the Vedanta College run by the Ramakrishna Mission. Vikram by then earned a good name and Bruno Rossi, a pioneer in X-ray Astronomy and Space Plasma Physics made Vikram a frequent visitor to his lab at Massachusetts Institute of Technology (MIT). Although Vikram never attained the stature of Bhabha as a prolific scientist in his early career life, but his

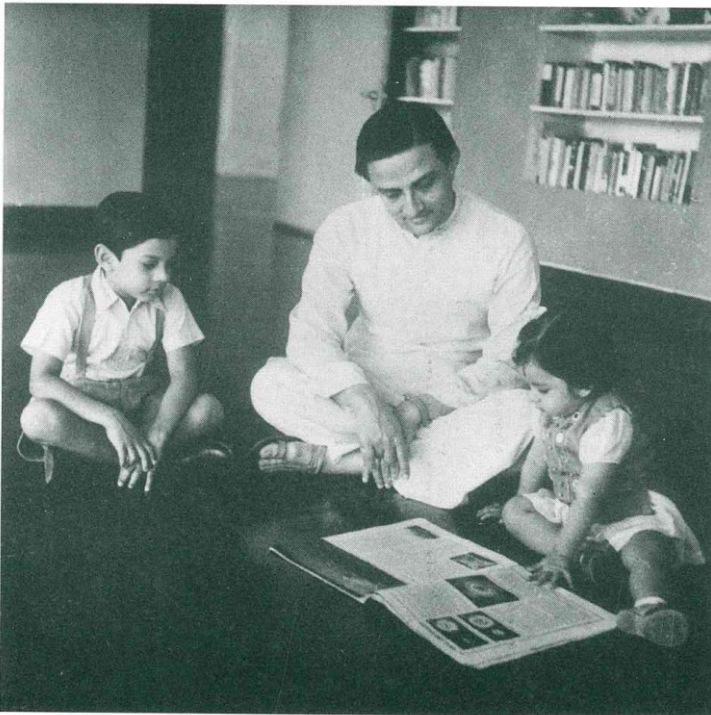


With his wife Mrinalini.

Mrinalini and Vikram Sarabhai
at their wedding, 1942.



Vikram and Mrinalini with the children



Vikram with his children: In Mrinalini's absence he was an attentive single parent (Courtesy: D. Pillay, *South Indian Cinema: Movies From India*)

organizing skills were exemplary and had been in the mantle of many organizations, so many of them that it became others a weary dream to follow.

In those days driven by a passion for South Indian music and art forms, he frequented such occasions of theatre and kacheris in Bangalore. M.S.Subhalakshmi the acclaimed musician and Ram Gopal, a proficient Bharatanatyam exponent thus became close to him. It is at Ram Gopal's place he met his future wife Mrinalini Swaminathan. Her elder sister, Captain Dr.Lakshmi Sehgal of Subhash Chandra Bose's Indian National Army was known to many as a distinguished freedom fighter. But Mrinalini was married to dance alone till she met the enterprising and dedicated Vikram.She was a graduate from Tagore's Shantiniketan in BharatAnatyam. In August 1942, the two of them married.

In 1943, Vikram set out to Kashmir to measure cosmic rays at a high altitude. Vikram by now on the suggestion of Bhabha developed a direct method of measuring the intensity of the slow mesons with the Gieger counter. Slow mesons are particles created by collision of primary radiation with atoms in the upper part of the earth's atmosphere and are found only in the vicinity where they are formed. Vikram noticed variations in intensity of the cosmic rays depending on the different times of the day. Thus he shifted his research to 'time variations of cosmic rays'.

In 1945, when the war ended, Vikram with his wife started their second stint to Cambridge to complete his doctorate. His oral examination was in Manchester where the Nobel laureate Blackett, a distinguished scientist in Nuclear Physics and Cosmic Radiation awarded Vikram his PhD degree. Vikram returned back to India in 1947.

Vikram met the famous Bharatanatyam exponent of Kerala origin, Mrinalini Sarabhai at Bangalore during his stint at the



With mentors and friends: from left to right, S.S. Bhatnagar, Homi Bhabha and C.V. Raman



A strong faith in international collaboration: Vikram with P.M.S. Blackett (front row, right), C.F. Powell (second row, left) and Homi Bhabha

IISc after his return from Cambridge as was mentioned earlier. Although, both of them were not keen on getting confined to wed locks at the early stage of their friendship since both were engrossed in two different fields with no similarity whatsoever, soon they decided to marry. After marriage they had two children, Kartikeya Sarabhai and Mallika Sarabhai.

Vikram's confidence poured through words many a times that India can make marvelous achievements by helping individuals "leap-frog" across a generation of technology. This phrase he often used in his life- "leap-frogging" - which in all its sense means India could tackle anything, build anything, solve anything through technology and science. He believed that people must be trained professionally in all sectors of society to build up their organizations through a constant process of evolution. Obsolete technologies were to be replaced by newer ones modified to tailor to the needs of one's own country. For this he believed acquiring if necessary the skills innate to other foreign lands rather than wait for them to flourish in its own way in a slow pace in our motherland. A technology as he believed which was one or two decades old could never satisfy the needs of a country, he considered them obsolete in all ways. He refused to command, instead he enriched people by inciting their inquisitiveness by probing and making them think better and understand their limitations and the drawbacks of the set up in which they are working. This prompted them to seek help in any country outside India, learn themselves to get to the level of what is expected of them and then come back and re-instate what is lacking in their organization. He believed that no time should be wasted, what is new and advanced in developed nations are to be borrowed and made a part of our betterment. The technological advancements which were already in vogue according to him need not be replicated or duplicated for want of time, but it should be made part of our skills and we should try to improvise further on them. This visionary in his future

life proved that time is not be wasted but good qualities and discoveries of any nation can become part of ours too in due course of time which can change the face of India. This was all the brain of great Vikram and his special qualities of making a better nation with no ego whatsoever coming in the way of marching towards prosperity.

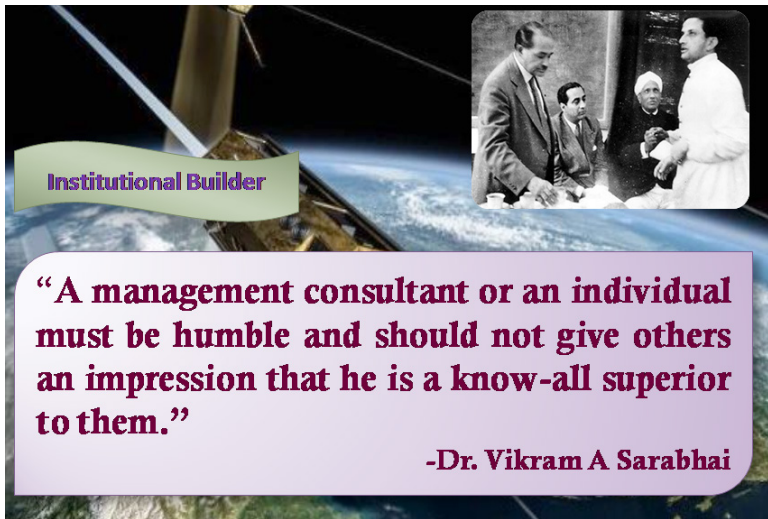
Vikram and Gandhiji

Other than the fact that they both hailed from Gujarat and Gandhiji was a frequent visitor to his home in his childhood days, even as a boy Vikram firmly followed the principles of Bapu. He allowed them to sink into his persona which in future life too, he held very strong even when he was struck with the most miserable moments in his life. Vikram was an absolute and staunch believer of truthfulness and expected the same from everyone. This brutal frankness admixed with extreme gentleness and tenderness was so strikingly remarkable and so far not experienced by anyone which made him a universally acceptable person par excellence. For him a day comprising 24 hours was never enough except for the 4-5 hours he had for himself, he did things with so much of haste in all spheres he was working at that moment, perhaps knowing that he has limited time left to complete his tasks before he departed this world at the pinnacle of his career at a tender age of 52. But until his last breath, he believed that nobody was the boss, nobody needs to be bossed. Vikram believed in the equality of all human beings and strongly believed in collective responsibility anchored in ahimsa and truthfulness, a quality so innate amongst Bapu's followers.

Vikram's Early Organisational Activities

Not only in science and technology, Vikram through his versatility made a great impact in many other fields which is briefly touched upon in this chapter. Only very few can become the Jack of all trades and at the same time master it as well. Vikram's life exemplified that multitasking is possible through hard work, sincerity and all the more effective time management. His colleagues and friends found it difficult to cope up with him since he worked round the clock, did not know how to waste time, switched within no time from one field to an entirely different field. For example from Space Research to textile industry to oil mills he could take himself and his mighty brain at the same time and he slept not more than 4 hours at night.

Vikram had a restless mind seeking new ways, new institutional arrangements, new combination of skills and completeness to deal with many problems in which he was involved and interested in. For instance, with Dr. M.S Swaminathan, at that time(1971),the Director of Indian Agricultural Research Institute(IARI) and Indian Council of Agricultural Research(ICAR), he planned a nuclear centre for



agriculture, a joint venture which would bring together the competence of nuclear scientists and agricultural scientists and the resources and support of the ICAR and the DAE. This is detailed in a later chapter.

Another joint venture he started was between All India Radio and ESCES (Experimental Satellite Communication Earth Station) to evaluate effectiveness of television as an instrument for mass communication to implement measures for increasing food production. The new institutional structures provided new boundaries and challenged existing assumptions and traditional definition of problems. Before embarking on Space Research and Nuclear Energy, let us see what all Vikram got committed to in his early days.

Swastik Oil Mills Limited

Taking the example of his illustrious father, wherever possible, Vikram preferred a scientific analysis of the problems facing any industry, be it manufacturing of goods, selling or

buying etc. For example in the oil seeds market, he went on to calculate the market prices of ground nut and castor seeds. These were graphically plotted and subjected to statistical analysis to get the final results. Such accurate methods were unheard of in those days. Thus application of research methodology to study and analyze the marketing activities of Swastik, with the help of computers (at a time when such means of assistance were practically unknown in India), yielded important data and eventually contributed towards making and sustenance of a strong organization. He also took keen interest in solving the problems between management and employees by employing human relation techniques which he experimented and proved useful through another organization which he pioneered, the Ahmedabad Textile Industry's Research Association (ATIRA). This was a shining example of how one organization can benefit from the qualities emanated through another one, even if both are quite different in their policies and structural framework. Only an astute administrator can undertake such credential moves for the betterment of the society.

His democratic outlook was reflected in all spheres of the company. He believed in the delegation of powers to each and every member of the company. There were weekly and monthly meetings to discuss the issues with all the staff involved. Each member of the association was given a chance to actively participate in these meetings and express their thoughts and bring forth constructive criticisms. This gave all of them a feeling of togetherness and prevented them from carrying home the feeling 'the employer and the employee'. At these meetings, Vikram even insisted that the chief executive or whosoever is the key person involved should take the lead and he being the Chairman of the company too, still took a back stage like all other members. This far sightedness and over simplicity and generosity were something which the country would emulate later in many other firms.

Democratic technocrat



“The social impact of innovative man has hit society like an avalanche. Scientific advances and technological innovations along with their social and political implications have suddenly overtaken the pace of human life cycle and produced a crisis of obsolescence”

–Dr. Vikram A. Sarabhai

He advanced his firm by delegating his subordinates and staff to attend foreign visits, markets, textile factories and other laboratories to help them learn and then adapt these technologies and if needed to collaborate with them in our motherland. This even today remains a model for all other employers to follow since such a magnanimous attitude with the nobility at heart for others to grow and contribute to his own company was something which was unheard of those days.

Ahmedabad Textile Industry Research Association (ATIRA)

In the late 1940s, there was a gentleman by name Kasturbhai Lalbhai who went on to become one of the close confidants of Vikram later. Padmanabh Joshi is credited with writing his PhD thesis on “*Vikram Sarabhai: A Study on Innovative Leadership and Institution Building*”, from Gujarat University in 1986. According to Joshi, Vikram was in fact availing the

benefits from the business partnership of Kasturbhai Lalbahi. He always kept many influential men at his hand. K.R.Ramnathan, an established scientific person, S.S.Bhatnagar ,Council of Scientific and Industrial Research (CSIR) Director General and K.S.Krishnan ,Director of the National Physical Laboratory were such people with whom Vikram created a lasting rapport.

On April 10, Jawaharlal Nehru, the then Prime Minister of India, opened the new laboratory building at the Navrangpura, Ahmedabad named Ahmedabad Textile Industry's Research Association, popularly known as ATIRA, the foundation stone of which was laid in November 1950 by Sardar Vallabhai Patel, Deputy Prime Minister of India. ATIRA is modeled on the same lines as the research associations in Great Britain, and this constitutes the first enterprise of its kind in which industry and the Government of India have co-operated in the field of research. The laboratories were on the Gujarat University campus and consisted of a multi-storied central block, covering an area of 100,000 sq.ft, which accommodated the library, offices and laboratories of the various research divisions, the administrative offices, the stores and precision workshop, and the services in a basement. The block is connected at one end to a single-story building which housed the pilot mill. The pilot mill is equipped with complete machinery for spinning, weaving and chemical processing with facilities for experimenting under a variety of conditions. Recognizing the increasing importance of industrial psychology and the science of management, the Association decided from the outset to include these in its organization. As a result psychologists and management experts formed the key persons to effectively run ATIRA, a concept new to India. It was also felt that during its early years the association should commence its work with the utilization of existing scientific knowledge and apply this for the immediate benefits of the industry. Emphasis was deliberately placed on operational research aimed at standardization and rationalization of existing

processes and work methods, and on applied research designed to introduce developments of practical use to the industry. This was done with the view of fostering scientific consciousness among those who work in the industry and creating confidence in the practical utility of applying the scientific method to the problems of industry.

Operational and applied research is generally carried out in the mills in collaboration with the technical staff of the mills. At all stages of the experiment, critical evaluation is continuously done in frequent conferences among the staff of the Association and in discussions with mill management and technicians. After the successful completion of experimental studies in two or three mills, the results were published in the form of research notes even in those days. When circumstances require that the Association should be engaged in routine services, separate units are created for this purpose. In this way the Association operates routine physical and chemical testing laboratories and provides servicing and supervision of quality control, training-within-industry programs and other management techniques to industry. The Association has divisions dealing with Physics, Chemistry, Statistics, Psychology, Liaison, Technology, Library and Documentation and Administration.

A project was conducted during 1950-51 in collaboration with Prof. Gardner Murphy, The United Nations Educational, Scientific and Cultural Organization (UNESCO) consultant to the Government of India, in order to study the labor-management tension within the textile industry. As a result of this study, the need for supervisory training was emphasized and training-within-industry programs were started in 1953 to fulfill this need with the technical assistance of the International Labour organization.

Even with the completion of the first five years of the Association during Vikram's time, the need for a properly

balanced research program covering both fundamental and applied problems has been increasingly felt. Such a program, where fundamental and applied research would complement one another and constantly provide new ideas, was entirely new to this country which Vikram initiated. One Ms kamla Chowdhry, a young woman from Punjab and an industrial psychologist helped Vikram sort out issues at ATIRA through her various counseling sessions and timely interference. She was a good friend of Mrinalini.

Vikram voluntarily relinquished the directorship in 1956 of ATIRA but was still active in its public activities. Along with the national laboratories of India, ATIRA is playing a significant part in tackling the great and important problems which face India today.

Sarabhai Chemicals

In addition to ATIRA, in 1950 he took another assignment on his shoulders as the Chair of the family's Baroda based pharmaceuticals 'Sarabhai Chemicals'. Vikram travelled once a week to Baroda to visit this firm in those times when there was no road connecting Ahmedabad and Baroda. He would travel by train and mostly his students from Physical Research laboratory (PRL) accompanied him and they worked all the while during travel. The pharmaceutical industry was not well rooted in India when Sarabhai Chemicals started. India did not have the technical expertise or managerial skills to tackle such ventures. Kasturbhai Lalbhai, Vikram's close friend by then, a textile industrialist with immense wealth and rich connections to people of all classes then joined hands with the American Lederle Labs. The Sarabhais opted assistance and collaboration from the New York based E.R.Squibb and sons. In 1951, K.J.Divatia, a US trained Chemist came and joined Sarabhai

Chemicals and became a full time employee later there. Those days when the pharmaceutical names which were known to people were Ranbaxy, Cipla, Cadila, Glaxo and Pfizer, Vikram launched a professionally managed Sarabhai Chemicals which is still a reputed firm in all its glory.

In 1956, Vikram entered into a collaboration with J.R. Geigy for making pharmaceuticals and dyes. Geigy were also the makers of the whitening agent 'Tinopol', which caused waves of profit in the market. Sarabhai Chemicals also put up collaborations with E. Merck of Darmstadt, Germany and started manufacturing Vitamin C. Vikram produced drugs in bulk like Penicillin and Streptomycin by then with his US counterpart Squibb.

At the same time, Vikram would travel every summer as visiting professor to MIT, Boston. Most days including Sundays, Vikram would be in PRL by 7AM in the morning. On Mondays, late morning he would then meet up with staff in ATIRA. On other days, around noon he would go to the Calico building where he supervised Sarabhai Chemicals and entertained visitors. In the evening he would take a brief break or at other times for a while, say 20-30 minutes in the afternoon or any time he would take a nap and come out of his sleep as fresh as ever much to the surprise of his colleagues.

When all these organizational activities flourished, he had all the time to dedicate to 'Darpana', his wife Mrinalini's dance academy in Ahmedabad. Mrinalini by then had become an international figure and was travelling world-over thus entrusting Vikram his time on parenting Kartikeya and Mallika. By this time, Vikram and his family moved out of Retreat to a place on the banks of Sabarmati their new home by name 'Chidambaram'.

Indian Institute of Management, Ahmedabad (IIM-A)

Vikram always believed that management techniques could be used for the betterment of the society. One of his often cherished project, the Indian Institute of Management came into being in Ahmedabad (IIM-A). The former Director of IIM-A, Jahar Saha and another of Vikram's colleague there, one Mr M.R.Kurup also confirmed this view that the lack of efficient managers brought a downfall of many public and private enterprises. This was at a time when in India the concept of professional management techniques were practically unheard of.

In 1956, in association with Kasturbhai Lalbhai, Vikram started the Ahmedabad Management Association (AMA) to conduct research and provide training to employees of companies. This was later transformed into the prestigious IIM-A in 1962. Vikram went on to succeed further in IIM-A by taking help and collaborations from the prestigious Harvard University. In 1936, Henry Ford had set up an independent, non-profit, non-governmental organization called the 'Ford foundation'. Ford mooted the setting up of two management institutes in India when Vikram was already in the process of starting the same in his motherland. Vikram remained unperturbed and with his long term allies Kasturbhai Lalbhai and Jivraj Mehta (the later Chief Minister of Gujarat) had by then established IIM-A. Till the final building was ready, IIM-A was housed in a Shahibaug Bungalow. Kamla Chowdhry, a family friend who helped him in ATIRA was the Senior Professor in IIM-A. She later went to Harvard as instructed by Vikram to do an advanced management program. Thus Harvard Business School became an established partner of IIM-A. Ravi Mathai took over from Vikram later as director of IIM-A when Vikram was engrossed in Space Research and later assumed Bhabha's Atomic energy Commission (AEC).

Involvement In International Geophysical Year (IGY)

The IGY, started in July 1957 was eagerly awaited by scientific community .This came up as an evidence of the growing interest in the possibility of using satellites for scientific exploration. It initiated an international multicentric effort to study the earth's atmosphere and oceans which eventually help one to explore space better. Vikram by now had been a common name in international fraternity with many great scientists like Bruno Rossi, James Van Allen (known by his discovery 'Van Allen Belts', the two belts of radiation surrounding the earth),Bertraand Goldshmidt, founder of France's Atomic Energy Commission, Sydney Chapman, PMS Blackett, Victe Neher, Philip Morrison, Donald A.Glaser, Linus Pauling, Y.Sekido, Maurice M.Shapiro and Joliot-Curie couple by then had visited the Retreat and PRL in those days.

The Birth of the Space Age in India

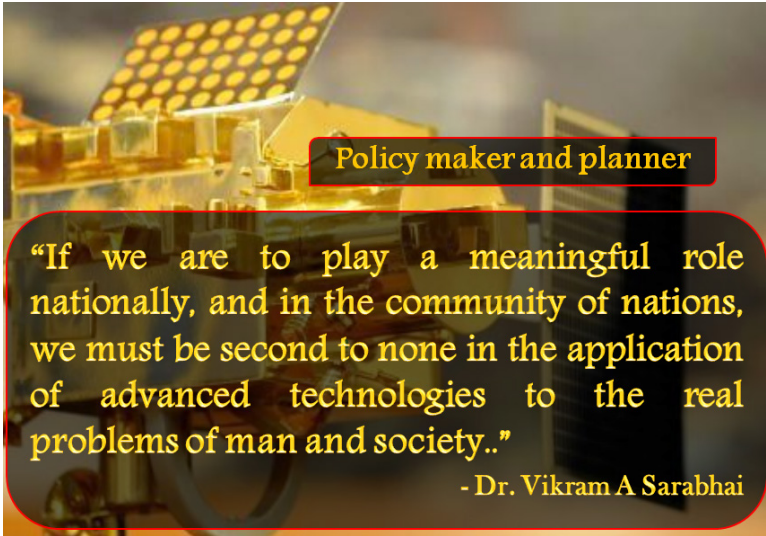
Vikram's contributions as "*Father of Space Program*" of India gels with the birth of the Space Age in India as well. One cannot split both of them since one lead to another and created history. A group of about 20 people came together in 1660 to launch the Royal Society in England who were seriously interested in science. Nearly three centuries later in India, two people with high end education became seriously interested pursuing science and technology as a tool for national development. They were united by a common thread of interest in Cosmic Rays. These two giants were Homi Jehangir Bhaba and Vikram A. Sarabhai. Dr.M.G.K Menon who recently passed away on 22 November 2016 (he was a physicist and policy maker who had a prominent role in the development of science and technology in India over four decades. One of his most important contributions was nurturing the TIFR, Mumbai, which his mentor Bhabha founded in 1945) compares these two visionaries and gives a beautiful summary as follows "*In many respects the lives of Vikram Sarabhai and Homi Bhabha were remarkably similar. Both died young-*



. Homi Bhabha (right) and Vikram Sarabhai in discussion. Bhabha was a mentor to Sarabhai.

Bhabha at 56 and Sarabhai at 52. Each was in the prime of life and one could have expected a decade or more of significant and decisive contribution from them. Each passed way from our midst suddenly, leaving a void difficult to fill. Each of them belonged to well-to-do and well-known families. Each could have chosen commerce or industry for a career but decided otherwise and devoted themselves to scientific research. Whilst the early inspiration for Homi Bhabha and for Vikram Sarabhai was pure science, each became aware, with the passage of time, of the power of science and technology as an instrument for social and economic change. And without giving up their basic love and interest in fundamental research, they looked for opportunities where science and technology could play a decisive role for the betterment of their fellow beings. Homi Bhabha put India in the nuclear map of the world. Vikram Sarabhai did it in the field of space”.

Post independence (after 1947), Jawaharlal Nehru at his capability as Prime Minister of India had shared a common ideology with Sarabhai and Bhabha. Nehru declared, “*Science alone can solve the problems of hunger and poverty, insanitation and*



illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by starving people”.

The modern space age was born on October 4, 1957 when the Union of Soviet Socialist Republics (USSR) launched Sputnik-1 into the orbit around the earth. An aluminium sphere, 58 cm in diameter, with four spring-loaded antenna trailing, it weighed approximately 84 kg. This milestone sent shockwaves in United States Of America (USA) while the USSR celebrated the launch as a victory. Between these two bitter enemies, the USA and USSR lay non-aligned countries such as India, which received the news of Sputnik-1 with reverence and dismay.

The International Council of Scientific Unions (ICSU), now known as the International Council for Science (ICS), responded to the launch of Sputnik-1 by creating a Committee on Space Research in 1958, popularly known as COSPAR. In 1962, COSPAR drew attention to major gaps in the world coverage of sounding rocket launching sites. It pointed out: *‘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.' This was as earlier mentioned Vikaram's observations in his PhD thesis a decade back .It therefore urged that a sounding rocket launching facility on the magnetic equator be established as soon as possible, as a first step in creating and using international sounding rocket facilities under United Nations sponsorship.

In August 1961, the government of India entrusted the responsibility of looking after Space Research to the DAE with Bhabha as the Secretary. The next year, i.e. in 1962, Bhabha created in DAE an Indian counterpart of COSPAR, called the Indian National Committee on Space Research (INCOSPAR) under the chairmanship of Vikram Sarabhai who had returned from Cambridge after his PhD in his second stint. And the rest is history!

Early Ventures on Space

One of the first initiatives of INCOSPAR was to organize a six-day seminar in Space Science at the Physical Research Laboratory (PRL), Ahmedabad a brain child of Vikram. Bhabha inaugurated the seminar on January 28, 1963 and emphasized the need for India to invest in the field of space. Let us reminisce his words, *"if we do not do so now, we will have to depend later on buying know-how from other countries at a much greater cost. In Space Research, we are today at the stage of where we were in atomic energy work over ten years ago. But science has developed considerably in India during these ten years, and in the DAE we have the largest scientific organization in the country. I, therefore, expect that within a few years, our present modest beginning will grow appreciably and Indian scientists will be making important contribution in the field of Space Research. At a time, when there are so many urgent demands*

on our limited resources, some people may well ask whether it is appropriate that we should spend some of them, even if in a modest way, on Space Research. I am convinced that the answer to this is "YES". Science and technology provide the very basis upon which the future of the country rests; and it is not possible for us to develop the best that our scientists are capable of, and to attract our best and most able people to scientific work, unless one can also provide them the opportunities of making discoveries in the fields of scientific endeavor, which has the most active and exciting today. The second reason for going into Space Research is that there are many areas in which it is likely to yield results of great practical interest and importance in the near future, and we would again be falling behind the advanced countries in practical technology if we were not to look ahead and prepare ourselves to take advantage of these new developments also". These words with such great foresight was proved a reality later by Vikram and Space Research is still marching to greater heights in our country whereby one can definitely with conviction and pride say that at least in Space Research "*Make in India*" dream of the present government headed by Sri Narendra Modi is proved true in all its meaning. India is now a role model for even the powerful nations to follow with awe and inspiration.

Homi Bhabha, the great scientist also started Nuclear Research in India as early as 1944, well before even the USA could test its first atomic bomb and within 16 months of the discovery of the Chain Reaction by the great Physicist, Enrico Fermi. During the same period, Lakshmi N Menon who was the Parliamentary Secretary in the Ministry of External Affairs answered questions in parliament in relation to bringing up the Rocket Launching Station in Thumba, Kerala. This parliamentary event occurred on January 21, 1963, a week prior to Bhabha's inaugural address at the Space Sciences Seminar. The rocket launching station was officially born thereafter as the Thumba Equatorial Rocket Launching Station (TERLS). Lakshmi Menon's statement before the parliament had three technical terms- 'magnetic equator', 'ionosphere' and 'sounding rockets'.

Magnetic Equator

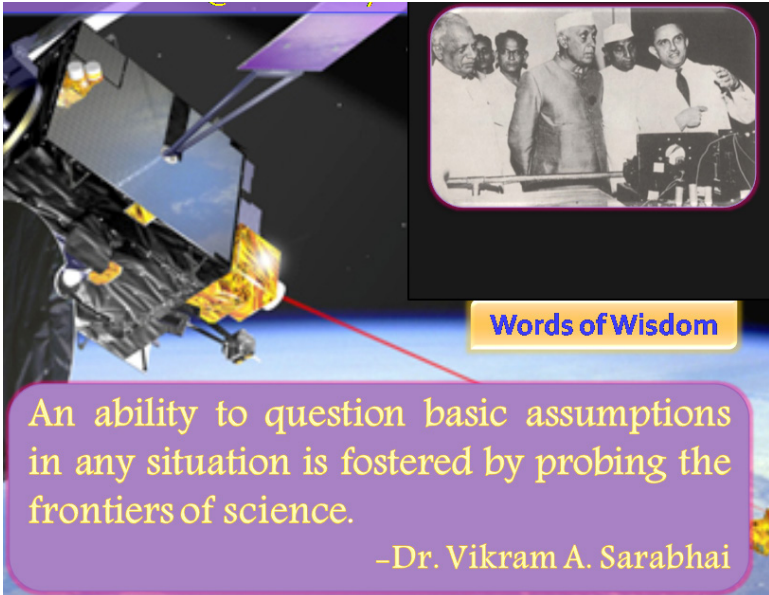
We all know that a compass needle generally points North, irrespective of whether the compass is in the Northern or Southern hemisphere. A compass needle is nothing but a tiny magnet which is so mounted that it can swing freely in a horizontal plane. But if the same needle is so mounted that it can swing freely in a vertical plane, then its behavior is different in the Northern and Southern hemisphere. In general, in the Northern hemisphere, the North pole of the compass dips down below the horizontal. By what angle it dips down depends on the latitude. The greater the latitude, the greater the 'dip angle'. For example, at the location 80.9°N 250.1°E , the North Pole points vertically down. In the Southern hemisphere, it is the south-seeking pole that points vertically down.

Between these two extremes, there must necessarily be a region where the compass needle remains strictly horizontal i.e. neither of the ends dipping down- the 'dip angle' being zero. A line joining all points in the earth where the dip angle is zero is called the "magnetic equator" or "dip equator". In technical terms, on the magnetic equator, the geomagnetic field is strictly horizontal. Directly above the magnetic equator, centered at an altitude of about 105 km in the upper atmosphere, is an electric current system called the "equatorial electro-jet (EEJ)". The EEJ current occupies a diffuse volume with a horizontal width of about 600 km and a vertical height of about 10 km. Yet, considering the global dimension of our atmosphere, the EEJ can be described as a narrow belt of current flowing from the East towards West. The height at which the EEJ flows is beyond the reach of balloons and is too low for a direct interaction with satellites. Direct sounding of the EEJ is, therefore best done by firing instrumented rockets ('Sounding Rockets') into the region for in-situ measurements. Thus a rocket launching station situated close to the magnetic equator is ideally suited

for the purpose. That is why TERLS is located at Thumba, Thiruvanthapuram, Kerala.

The Ionosphere

The gaseous envelope of the earth in which we lives is called 'atmosphere'. At the ground level, nearly 99% of the atmosphere comprises oxygen and nitrogen molecules and the remaining 1% is made up of inert gases such as Argon, Helium and other trace gases. As we go higher, the atmosphere becomes more and more tenuous. Thus, at ground level, there are 2.7×10^{19} air molecules in 1cc. This number decreases to about 10^7 at an altitude of 500 km, a drastic reduction by a factor of more than one trillion (10^{12}). At a height of 1000 km, the number (density) becomes a mere 1000 particles/cc. Also, at greater heights, the atmosphere has more helium than nitrogen or oxygen.



Words of Wisdom

An ability to question basic assumptions in any situation is fostered by probing the frontiers of science.

-Dr. Vikram A. Sarabhai

From 60 km and above, some of the gas particles get ionized. Normally, atoms are electrically neutral in that there is an equal number of electrons (which carry negative charge) and protons (positive charge). Thus, when an electron is removed, the atom is left with an excess positive charge and is called a positive ion. This process is known as 'Ionization'. The separated electron and the positive ion tend to attract each other. To keep them apart, energy is required. Thus, energy is required not only to ionize the gas, but also to keep it in the ionized state (plasma). The region where the ionization occurs in sufficient quantities to affect propagation of radio waves is called the 'Ionosphere'. Starting from around 60 km, the ionosphere extends to some hundreds of km. The EEJ is part of the ionosphere.

The Evolution of Indian Space Research

Indian Space Program

Now let us see how the Indian Space Program took its shape finally. The existing Space Research in India with its entire modern outlook can be traced to the laudable activities of scientist S.K.Mitra who conducted a series of experiments leading to the sounding of the ionosphere by application of ground based radio methods in 1920, in Kolkata. Later, prolific Indian scientists like C.V. Raman and Meghnad Saha laid down scientific principles applicable to Space Sciences. But it was after 1945 that organized Space Research took its final form in India. Vikram Sarabhai, known till then as the founder of PRL at Ahmedabad and Homi Bhabha, who had a major role in the establishment of the TIFR, Bombay are the two visionaries who are remembered for spear heading organized Space Research in India. Initial experiments in space sciences included the study of cosmic radiation, high altitude and airborne testing of instruments, studies of the upper atmosphere and deep



Some builders of modern India. Homi J Bhabha (glass in one hand with the other on the table), showing Jawaharlal Nehru (extreme left), the first Prime Minister of independent India, the model of the TIFR (Tata Institute of Fundamental Research) building. To Nehru's left is SS Bhatnagar, the first Director General of CSIR Laboratories. To Bhabha's left is Morarji Desai who became the Prime Minister in 1977. Between Bhabha and Desai, in the background, is MC Chagla, the eminent jurist and diplomat.

underground experimentation at the Kolar mines, one of the deepest mines in the world. Studies were then carried out at research laboratories, universities and independent locations.

Government support became available by 1950 when the DAE was founded with Homi Bhabha as Secretary. The DAE provided funding for Space Research throughout India. Tests on the earth's magnetic field studied in India since the establishment of the Observatory at Colaba, Bombay in 1826 and the various aspects of meteorology which were unveiled continued to yield valuable information. In 1954, Uttar Pradesh State Observatory was established at the foot hills of the Himalayas. A little later, the Rangpur Observatory was set up in 1957 at Osmania University, Hyderabad. All of them enjoyed the technical support and scientific co-operation of the USA Space Research. In 1957, the USSR successfully launched the Sputnik-1 and opened up possibilities for the rest of the world to conduct a space launch. Thereafter, the INCOSPAR was founded in 1962 with Vikram Sarabhai as its Chairman as detailed earlier.

In the early 1960s, close ties with the Soviet Union enabled Indian Space Research through Indian Space Research

Organization, (ISRO), which is an off shoot of INCOSPAR, chaired by Vikram Sarabhai to develop the Indian Space Program. It also helped in advancing nuclear power in India even after the first nuclear test explosion by India on May 18, 1974 at Pokhran, Rajasthan. The untimely demise of Homi Bhabha in an air crash on January 24, 1966 caused a drop in the above momentum for a while. Following this unfortunate incident, Sarabhai was sent to assume Bhabha's place as the Chairman of AEC and Secretary of DAE. The 1960s also saw the founding of the Space Science and Technology Centre (SSTC), Experimental Satellite Communication Earth Station (ESCES, 1967), the Sriharikota base (Sriharikota High Altitude Range, SHAR, now renamed as Satish Dhawan Space Centre (SDSC) and the Indian Satellite System Project (ISSP).

The ISRO in its modern form was created by Vikram Sarabhai in 1969. This organization then took control of all space activities in our country. Very aptly thereafter, Vikram Sarabhai has been honored as the *"Father of Indian Space Program"*. In his own words, *"There are some who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the moon or the planets or manned space-flights. 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"*.

Dr. Abdul Kalam later meaningfully added to it *"Many individuals with myopic vision questioned the relevance of space activities in a newly independent nation, which was finding it difficult to feed its population. Their vision was clear that if Indians were to play meaningful role in the community of nations, they must be second to none in the application of advanced technologies in their real-life problems. They had no intention of using it as a means to display our might"*.

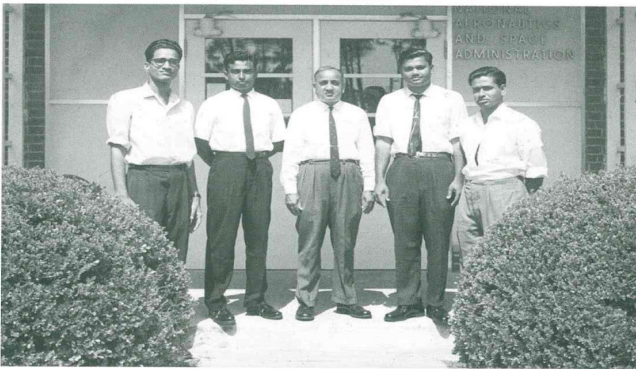
Amongst the most important practical applications of Space Research are those related to meteorology, to communications and to Geodesy (Geodesy is the branch of mathematics dealing with the shape and area of the earth or large portions of it). Orbiting meteorological satellites transmit cloud pictures covering an area of about a million sq km of the earth's surface. These are received by meteorological stations in different parts of the world including the Automatic Picture Transmission (APT) receiving station at the Meteorological Centre, Bombay. The information enables meteorologists to extend weather analysis to areas of sparse observations over land and sea. Operationally, they are useful for the issue of cyclone and storm warnings, for aircraft flight briefings and in aiding navigation of ships. Satellite's cloud pictures have revealed the existence of two belts of cloud maxima in the equatorial zone of the Indian Ocean even in July, separated by a region of minimum cloudiness at the equator. The meteorological Sounding Rocket Program conducted from Thumba has provided very interesting information on the pattern of winds near the equator. This observation has important consequences to our understanding of the Indian Southwest Monsoon.

From among the several bright young men who had come together for the space program, Vikram sent a small group to National Aeronautics and Space Administration, Washington, D.C.(NASA) to their Goddard Space Flight Centre and the Wallops Island facility for training. The French Space Agency, the Centre National d'etudes Spatiales (CNES), supplied the RADAR, the Russians a computer by name 'Minsk' and the Americans offered the necessary training.

Moreover, the scientific results would have a direct bearing on a better understanding of meteorology of great practical significance to the Indian economy. Amongst the laboratories related to the DAE the one which largely supported the mission



The St Mary Magdalene church in Thumba. The Indian space programme was literally born in this church; its origins can be traced to the 16th century.



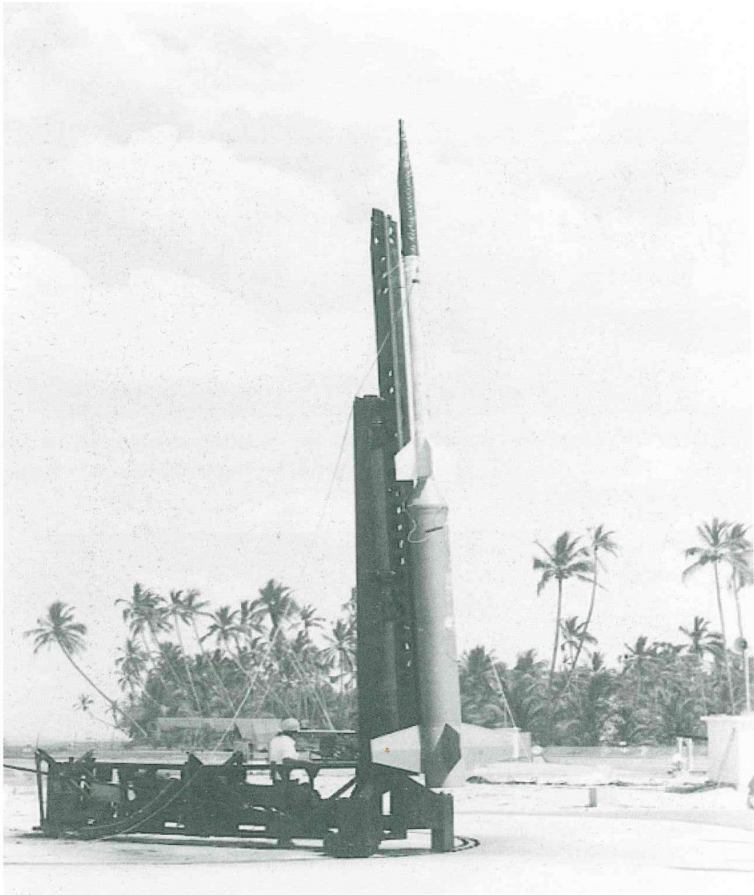
As early as 1962, Sarabhai had sent some young engineers to NASA for training. This 'Class of '62' comprised (from left): R Aravamudan, APJ Abdul Kalam, HGS Murthy, B Ramakrishna Rao and D Easwaradas. Missing from this photograph of the 'Class' are PP Kale and AS Prakasa Rao.

was the PRL, the brain child of Vikram which conducted basic research in the fields of aeronomy, cosmic rays, interplanetary space and solar activity. TIFR was the cradle of India's Atomic Energy Program.

In 1948, Nehru included the Atomic Energy Act before the Constituent Assembly and by 10 August 1948, the AEC was set up with a three-member Committee. In 1954, Bhabha was made the Secretary of the newly formed DAE. Moreover, though the administrative charge being carried over by an autonomous laboratory (TIFR), which at the same time was closely related to the DAE, there was overall co-ordination by the government giving the flexibility of an academic type of institution to it.

Let us now take a deeper look at the way Space Program evolved from the existing Atomic Energy Program. The Sounding Rocket Program was initiated by collaboration agreements with NASA of USA, CNES of France and Hydrometeorological Services of USSR. At the same time, for an ongoing program with Sounding Rockets, an agreement was made for the local manufacture, under license of Centaure Rockets. This responsibility for fabricating the rockets has been entrusted to the Bhabha Atomic Research Centre (BARC) at Trombay which was nothing but DAE renamed in the name of its founder Bhabha later. But the activity was transferred the next year to a new establishment in BARC itself by the side of a rocket propellant plant that has been set up. In 1966, the AEC approved the establishment of Space Science and Technology Centre (SSTC) with the major task of developing expertise in aerospace engineering, sounding rockets of superior performance and a modest satellite launcher. The Centre is also concerned with ground based experiments supporting Space Research and scientific payload construction. The centre was set up on Veli Hill, by the side of TERLS. A large group of engineers has been assembled at the SSTC to work in different disciplines of space technology involving propellant engineering, propulsion, structural engineering, aerodynamics, materials, control and guidance, technical physics, electronics, system engineering and test and evaluation. The first Rohini rockets, RH-75, was successfully flight tested there since November 1967.

Two other projects of the DAE of particular relevance to Space Research were the TIFR which was started in Bombay and then had one more establishment in Hyderabad; a brief mention of it has been made in the earlier chapters. This Institute has carried out, since 1959, more than 100 major flights with plastic balloons from Hyderabad. The balloons fabricated at the TIFR are capable of flying payloads up to 250 kg. The large balloons



The two-stage American sounding rocket, Nike–Apache. Its launch on 1 November 1963 marked the birth of the Thumba Equatorial Rocket Launching Station (TERLS) near Trivandrum. It thus also marked the birth of the Indian space programme.

can reach ceiling altitudes close to 5 gm/cm² and float at that altitude for about 8 hours. The other is a large cylindrical radio telescope in the Nilgiris, which will provide facilities to scientists from universities to undertake advanced research.

The Nike Apache was a two-stage sounding rocket used by NASA to loft instruments into the upper atmosphere. The Nike Apache was launched 636 times between 1961 and 1978. It was a popular rocket due to its low cost (US\$6000) and ability to be fired from many locales. The Nike Apache was used to carry a variety of payloads to study a wide range of topics including radio astronomy, meteorology, aeronomy, atmospheric conditions, plasma physics, and solar physics. NASA flew them from Brazil, Canada, India, Norway, Pakistan, Spain, Suriname, Sweden and USA. The maximum payload weight was 80 lb (36 kg) and the maximum altitude about 125 miles (200 km). Nike Apache was the first rocket launched by India from the TERLS in 1963.

The Success Story of ISRO Continues

Vikram Sarabhai thus launched ISRO with all its initial hiccups and later the organization moved up in its own steady pace devising new launch vehicles periodically and regularly. During the first phase (1960-1970s), India successfully developed a Sounding Rockets Program, and by the 1980s, research had yielded the Satellite Launch Vehicle-3 (SLV-3) and the more advanced Augmented Satellite Launch Vehicle (ASLV), complete with operational supporting infrastructure. ISRO further developed Polar Satellite Launch Vehicle (PSLV) and Geosynchronous Satellite Launch Vehicle (GSLV) technologies.

We will have a brief overview of these various launch vehicles in this Chapter. This will give the reader a chance to see how the first firm step of a visionary like Vikram Sarabhai paved the way for a historical organization like ISRO to come up in a country with limited resources. This chapter is a standing testimony and tribute to that great legend-Vikram Ambalal Sarabhai.

Satellite Launch Vehicle (SLV)

The Satellite Launch Vehicle known by its abbreviation SLV or SLV-3 was a 4-stage solid fuel light launcher. It was intended to reach a height of 500 km and carry a pay load of 40kg. Its first launch took place in 1979 with 2 more in each of the subsequent years, and the final launch in 1983. Two of its four test flights were successful. It is now decommissioned. SLV was the dream of Vikram who had a clear picture in mind of how to take it ahead even before its work was started by the ISRO 7-8 years after the untimely demise of Vikram. And this launch vehicle kick started a series of more refined ones which followed them in the later years.

Augmented Satellite Launch Vehicle (ASLV)

The Augmented Satellite Launch Vehicle (ASLV) was a 5-stage solid propellant rocket with the capability of placing a 150 kg satellite. This project was started by the ISRO during the early 1980s to develop technologies needed for a payload to be placed into a geostationary transfer orbit (GTO). Its design was based on SLV. The first launch test was held in 1987, and after that 3 others followed in 1988, 1992 and 1994, out of which only two were successful before it was decommissioned.

Polar Satellite Launch Vehicle (PSLV)

The Polar Satellite Launch Vehicle (PSLV) which is still active is an expendable launch system developed to allow India to launch its Indian Remote Sensing (IRS) satellites into sun synchronous orbits, a service until the advent of the PSLV was commercially available only from Russia. PSLV can also launch small satellites at GTO. The reliability of PSLV is now



The Augmented Satellite Launch Vehicle (ASLV) lifts off from Sriharikota. Through thorough analysis of the failures of the first two launches of ASLV, ISRO learnt the nuances of launch vehicle technology. The success of ASLV is a watershed in ISRO's march towards mastery over launch vehicle technology.

well established with launching of more than 30 space crafts into a variety of orbits. In April 2008, it successfully launched 10 satellites simultaneously, thus breaking the world record thus far set by Russia.

Geosynchronous Satellite Launch Vehicle (GSLV)

The Geosynchronous Satellite Launch Vehicle (GSLV) which is still active is an expendable launch system developed to enable India to launch its Indian National Satellite Systems (INSAT) type satellites into GTO and to make India less



16. A stunning view of the GSLV on the pad, as the sun paints the sky red!

dependent on foreign rockets. At present, it is ISRO's heaviest satellite launch vehicle and is capable of putting a total payload of up to 5 tons to low earth orbit. The last GSLV launch was on September 2, 2007 which successfully placed INSAT-4CR in the GTO.

Geosynchronous Satellite Launch Vehicle Mark- III (GSLV III)

The Geosynchronous Satellite Launch Vehicle Mark-III (GSLV III) is a launch vehicle intended to launch heavy satellites into GTO. It allows India to become less dependent on foreign rockets for heavy lifting.

ISRO and Its Various Other Sub-Centres

ISRO head quarters is located in Antariksh Bhavan in Bangalore.

Research Facilities Associated with ISRO

1. Physical Research Laboratory, Ahmedabad (elaborated in this chapter later)
2. Semi-Conductor Laboratory-Chandigarh-It conducts research and development in the field of semi-conductor technology, micro-electro mechanical systems and process technologies relating to semi-conductor processing
3. National Atmospheric Research Laboratory(NARL)-Tirupathi-It conducts fundamental and applied research in Atmospheric and Space sciences

4. Raman Research Institute (RRI)-Bangalore-It carries out research in selected areas of physics, such as Astrophysics and Astronomy
5. Space Applications Centre (SAC)- Ahmedabad- It deals with the practical aspects of space technology .Among the fields of research at the SAC are Geodesy, satellite based telecommunications, surveying, remote sensing,metereology, environment monitoring etc. The SAC additionally operates the Delhi Earth Station.
6. Liquid Propulsion Systems Centre(LPSC)-Bangalore, Thiruvananthapuram and Mahendragiri- it handles testing and implementation of liquid propulsion control packages and helps develop engines for launch vehicles and satellites. The testing is largely conducted at Mahendragiri.
7. ISRO Satellite Centre-Bangalore-One of the main satellite technology bases of ISRO. It serves as a venue for implementing indigenous aircrafts in India. The satellites Aryabhata, Bhaskara, APPLE, IRS-IA and INSAT series were constructed at this site.
8. Satish Dhawan Space Centre (SDSC)- Sriharikota, Andhra Pradesh-With multiple sub-sites the Sriharikota island facility acts as a launching site for Indian Satellites. It is also the main launch base for India's Sounding Rockets. It also houses the India's largest Solid Propellant Space Booster Plant (SPROB) and the Static Test and Evaluation Complex (STEX)
9. Vikram Sarabhai Space Centre(VSSC)-Thumba, Thiruvananthapuram, Kerala-this is the largest ISRO base and is also the main technical centre and the venue of the development of the SLV-3,ASLV,PSLV and GSLV series. The base supports India's TERLS and the Rohini Sounding Rocket Program.



Test firing of a solid booster. [Creative Commons](#)

10. Thumba Equatorial Rocket Launching Station(TERLS)-It is used to launch sounding rockets.
11. Indian Deep Space Network (IDSN)-Bangalore-This centre processes, archives and distributes the spacecraft health data and payload data in real time. It can track and monitor satellites up to very large distances, even beyond the moon.
12. National Remote Sensing Centre (NRSC)-Hyderabad-NRSC applies remote sensing to manage natural resources and study aerial surveying. It has training facilities in Balanagar,Shadnagar and Dehradun .
13. ISRO Telemetry, Tracking and Command Network (ISTRAC)-Bangalore. It has tracking stations throughout the country and all over the world in Port Louis (Mauritius), Bearslake(Russia),Biak(Indonesia) and Brunei.
14. Master Control Facility (MCF)-Hassan(Karnataka) and Bhopal(Madhya Pradesh)-Geostationary Satellite Orbit raising, payload testing and in-orbit operations are performed at this facility.MCF has Earth Stations and Satellite Control Centres for controlling satellites.
15. Indian Institute of Space Science and Technology(IIST)-Thiruvananthapuram-It offers undergraduate and graduate courses in Avionics and Aerospace Engineering.
16. Indian Institute of Astrophysics(IIA)-Bangalore-it conducts research in Astronomy, Astrophysics and related physics.
17. Development and Educational Communication Unit (DECU)-Ahmedabad-It conducts education, research and training mainly in conjunction with the INSAT program. The main activities carried out are the GRAMSAT (GRAMSAT program is an initiative to provide communication networks at the state level connecting the state capital to districts and blocks. The networks provide computer connectivity, data broadcasting, TV broadcasting facilities

having applications like e-governance, National Resource Information System (NRIS), development information, tele-conferencing, disaster management, telemedicine and distance education. The networks are operational in Gujarat, Karnataka, Madhya Pradesh, Orissa and Rajasthan. It is under implementation for North-Eastern region) and EduSat (EduSat is the flagship project of the Department of Science and Technology (India) which aims at providing education to the masses by using a satellite-based transmission system projects. It is also under the DECU).

18. Antrix Corporation-Bangalore-It is the commercial wing of ISRO. This marketing agency under the Indian government controls marketing of ISRO's hardware, manpower and software.

Other Facilities Include

1. Balsore Rocket Launching Station (BRLS)-Orissa
2. INSAT Master Control Facility (IMCF)-Bhopal
3. ISRO Inertial Systems Unit (IISU)-Thiruvananthapuram
4. Indian Regional Navigational Satellite System (IRNSS)
5. Aerospace Command of India (ACI)
6. Indian National Committee for Space Research (INCOSPAR)
7. Inter University Centre for Astronomy and Astrophysics (IUCAA)
8. Indian Department of Space (IDS)
9. Indian Space Science Data Centre (ISSDC)
10. Spacecraft Control Centre (SCC)
11. Regional Remote Sensing Service Centres (RRSSC)

Physical Research Laboratory (PRL)

It is a National Research Institute for Space and Allied Sciences, supported mainly by Department of Space and Allied Sciences, Government of India. It has ongoing research programs in Astronomy and Astrophysics, Atmospheric Sciences and Aeronomy, Earth Sciences, Solar System studies and Theoretical Physics. It manages the Udaipur Solar Observatory and is located in Ahmedabad.

Known as the '*Cradle of Space Sciences*' in India, the PRL was founded on November 11, 1947 by Vikram Sarabhai. In February 1952, the foundation stone of the new laboratory building was laid by C.V. Raman in the presence of Homi Bhabha. The main building was inaugurated in April 1954 by Jawaharlal Nehru. PRL had a modest beginning at Vikram's residence Retreat with research on cosmic rays and upper atmosphere. Dr. Kalpathi Ramakrishna Ramanathan (K.R. Ramnathan) was the first Director of the Institute who was initially at the Pune Observatory where he was the Deputy Director General. He then after retirement from the Indian Meteorological Department arrived at PRL to assume the Chair as the Director and Professor of Atmospheric Physics. The Institute was formally established at the M.G. Science Institute, Ahmedabad with support from the Karmkshetra Educational Foundation and the Ahmedabad Education Society. Praful Bhaskar, R.G. Rastogi, E.V. Chitnis, U.R. Rao, R.P. Kane, Satya Prakash, U.D. Desai, B.H.V. Raman Murthy and J.V. Dave all joined hands in PRL to work with Ramnathan and Vikram. Research areas were expanded later to include Theoretical Physics and Radio Physics with grants from the AEC. Today PRL is actively involved in research, related to five major fields of science. It is also active in the PLANEX planetary science and exploration program. PRL offers national awards to scientists who have made outstanding contributions to science and technology. The awards presented are Hari Om

Ashram Prerit Senior Scientist Award, Hari Om Ashram Prerit Vikram Sarabhai Research Award and PRL award.

Scientific Milestones (Research) of PRL

- 1950s - Cosmic Rays; Atmospheric Sciences
- 1960s - Theoretical Physics; Radiophysics
- 1970s - Earth and Planetary Sciences; Infra-red Astronomy
- 1980s - Particle Physics; Solar Physics
- 1990s - Laser Physics; Quantum Optics Non-linear Dynamics; Computational Physics; Astroparticle Physics; Cosmology
- 2000s - Quantum Information Solar X-ray Astronomy (SOXS); Submillimetre Astronomy ; Planetary Exploration

Indian National Satellite System (INSAT)

INSAT is a series of multipurpose geo-stationary satellites launched by ISRO to take care of telecommunication, broadcasting, meteorology and search and rescue needs of India. Commissioned in 1983, INSAT is the largest domestic communication system in the Asia Pacific region. It is a joint venture of the Department of Space, Department of Telecommunications, India Meteorological Department, All India Radio and Doordarshan. The INSAT system was commissioned with the launch of INSAT-IB in August 1983. (INSAT-IA, first satellite launched in April 1982 could not fulfill the mission). INSAT enabled the rapid expansion of Indian television and radio broadcasting telecommunication and meteorological sectors. It enabled rapid expansion of TV

and modern telecommunication facilities to even the remote areas and off-shore islands. Thus in no time INSAT became the largest domestic communication satellite system in the Asia-Pacific region. Some of the INSATs also carry instruments for meteorological observation. KALPANA-1 is an exclusive meteorological satellite launched by PSLV in September 2002. The satellites are monitored and controlled by MCF in Hassan and Bhopal.

Indian Remote Sensing Satellite (IRS)

Indian Remote Sensing Satellite (IRS) is a series of earth observation satellites, built, launched and maintained by ISRO. Following the successful launch of Bhaskara-1 and 2 in 1979 and 1981 respectively, India started the IRS program to support the national economy in the fields of agriculture, water resources, forestry, urban planning, flood risk zone mapping, ecology, geology, marine fisheries and coastal management. IRS is the largest constellation of Remote Sensing Satellites for civilian use in operation today in the world.

Chandrayaan-1

Chandrayaan-1 (Moon-traveller or Moon-vehicle) was India's first unmanned lunar probe. It was launched by ISRO on October 22, 2008 from SDSC, SHAR, Nellore, Andhra Pradesh. The idea of undertaking an Indian scientific mission to moon was initially mooted in a meeting of the Indian Academy of Sciences in 1999 that was followed by discussions in the Astronautical Society of India in 2000. Based on the recommendations made by the members of these forums, a National Lunar Mission Task Force was constituted by the ISRO. Leading Indian scientists and technologists participated in the deliberations of the Task

Development perspective



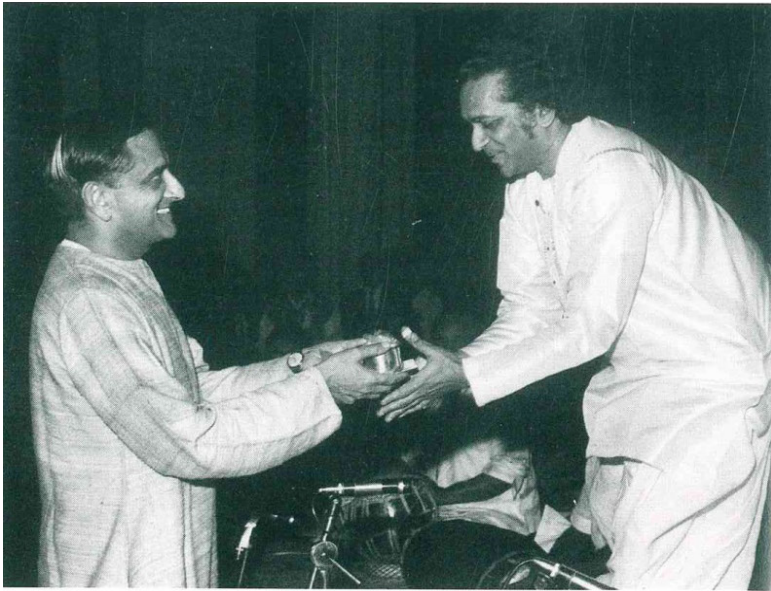
“Should one concentrate on providing the benefits first to urban communities and progressively go to rural areas?... It is that we should consciously reach the most difficult and least developed areas of country and, because they are in this state, we should reach them in a hurry.”

–Vikram A. Sarabhai

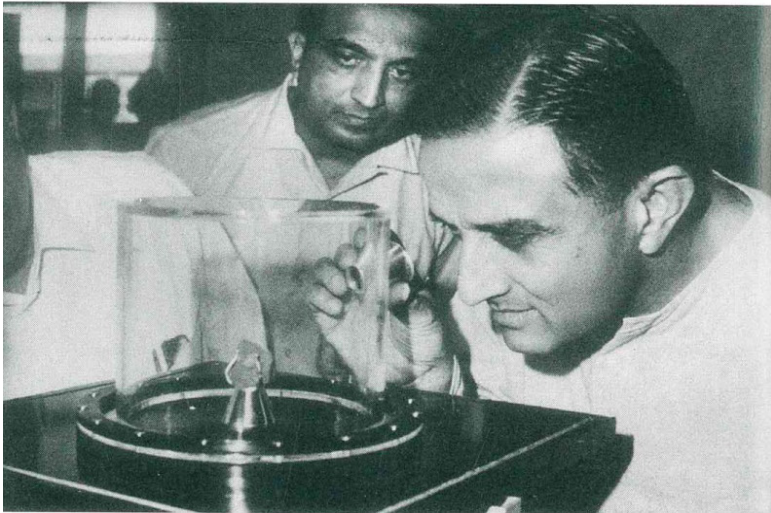
Force that provided an assessment on the feasibility of an Indian mission to the moon as well as dealt on the focus of such a mission and its possible configuration.

After detailed discussions, it was unanimously recommended that India should undertake the mission to moon, particularly in view of the renewed international interest in moon with several exciting missions planned for the new millennium. In addition, such a mission could provide the needed thrust to basic science and engineering research in the country including new challenges to ISRO to go beyond the Geostationary Orbit. Further, such a project could also help bringing in young talents to the arena of fundamental research. The academia would also find participation in such a project intellectually rewarding. Subsequently, Government of India approved ISRO's proposal for the first Indian moon mission, called Chandrayaan-1 in November 2003.

The Chandrayaan-1 mission performed high-resolution remote sensing of the moon in visible, near infrared, low energy X-rays and high-energy X-ray regions. One of the objectives



'First the education of the senses': Vikram with Pandit Ravi Shankar



Vikram and Praful Bhavsar examining a sample of a moon rock

was to prepare a three-dimensional atlas (with high spatial and altitude resolution) of both near and far side of the moon. It aimed at conducting chemical and mineralogical mapping of the entire lunar surface for distribution of mineral and chemical elements such as Magnesium, Aluminium, Silicon, Calcium, Iron and Titanium as well as high atomic number elements such as Radon, Uranium and Thorium with high spatial resolution.

Various mission planning and management objectives were also met. The mission goal of harnessing the science payloads, lunar craft and the launch vehicle with suitable ground support systems including Deep Space Network stations were realized, which were helpful for future explorations like the 'Mars Orbiter Mission'. Mission goals like spacecraft integration and testing, launching and achieving lunar polar orbit of about 100 km, in-orbit operation of experiments, communication/ telecommand, telemetry data reception, quick look data and archival for scientific utilization by scientists were also met.

The vehicle was successfully inserted into lunar orbit on November 8, 2008. On November 14, 2008, the moon impact probe separated from the Chandrayaan orbiter and struck the south pole, making India the fourth country to place its flag on the moon. Other than the various missions for which Chandrayaan was launched and became successful, water was discovered on the moon. This was confirmed on September 24, 2009 when Science Magazine reported that NASA's Moon Mineralogy Mapper (M3), an imaging spectrometer on Chandrayaan-1 has detected water on the moon. Chandrayaan-1 has thus proved that moon produces its own water. A scientific instrument on Chandrayaan-1 the Sub KeV Atom Reflecting Analyzer or SARA made this discovery possible. The moon absorbs charged particles emitted by the sun, which then interact with oxygen on the surface of the moon to produce water. Chandrayaan-1 also discovered large caves on the surface of the moon that can act

as human shelter on moon. Earlier, a Japanese aircraft Kaguya had also discovered a cave on moon.

The American Institute of Aeronautics and Astronautics (AIAA) selected ISRO's Chandrayaan-1 mission as one of the recipients of its annual AIAA SPACE 2009 award, a prestigious award which recognizes key contribution to space science and technology. Sri Mylswamy Annadurai, the Project Director of Chandrayaan-1 and his team in ISRO won the award for Accommodation and Tests of the highest International Lunar Payload ever (from 20 countries consisting of India, the European Space Agency representing 17 European countries, NASA and Bulgaria). He is currently the Director, ISRO Satellite Centre (ISAC), Bangalore and is the Project Director of Chandrayaan-2 and Mars Orbiter Mission.



An image of the lunar surface captured by the Lunar Reconnaissance Orbiter (LRO) from Chandrayaan-1

Mars Orbiter Mission (Mangalyaan)

India's first mission to Mars, the Mars Orbiter Mission, or Mangalyaan, reached the planet on 24 September 2014

completing its 300-day journey. While ISRO has been researching for a Mars mission for many years, the project was only approved by the government in August 2012. It was launched on 5 November 2013 from the SDSC, SHAR, Sriharikota, Andhra Pradesh. After travelling 670 million Km, Mangalyaan is now set to study the surface features, morphology, mineralogy and Martian atmosphere to better understand the climate, geology, origin, evolution and sustainability of life on the planet. It is the most cost effective of all the missions sent to the planet by any other country. India became the only country to orbit Mars in the first attempt.

Chandrayaan-2

Even before the launch of the Chandrayaan-1 mission, ISRO was already making plans for the follow-up Chandrayaan-2 mission. In September 2008 itself, the Chandrayaan-2 mission was approved by the government for a cost of Rs 425 crore. The budget does not include the cost of the GSLV launch vehicle, or the lander. The mission is an important step in India's plans for planetary exploration, a program known as Planetary Science and Exploration (PLANEX).

Present ISRO Chairman Sri A.S Kiran Kumar revealed to reporters the timing of the Chandrayaan-2 mission during an event that announced details of the South Asia Satellite, Prime Minister Narendra Modi's pet project and India's gift to neighboring countries. When asked about the Chandrayaan-2 mission, Kumar said, *"We are targeting first quarter of 2018 for the India's second mission to the moon which is more advanced than the first. There are three components of the mission, an orbiter, a lander and a rover"*. The rocket ISRO is planning to use for Chandrayaan-2 is a GSLV MKII, and will take off from the space agency's launch facility at the SHAR in the first few months of 2018.

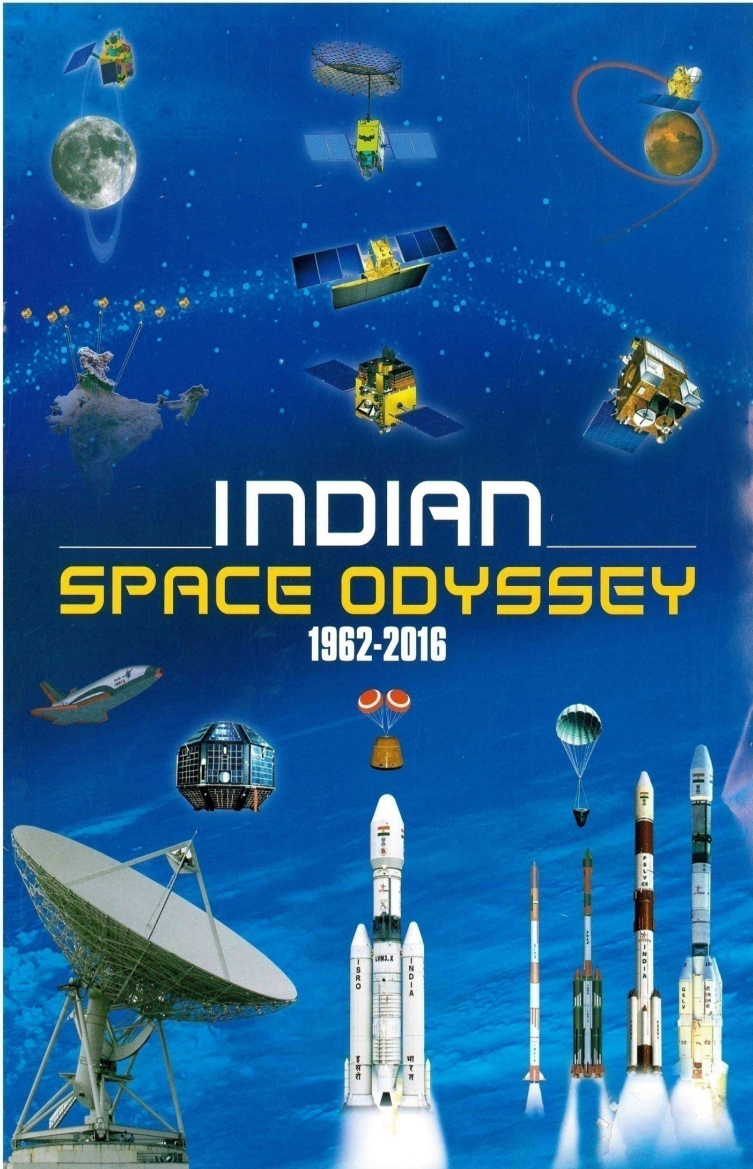


A panoramic view of the GSLV being transported to the launch pad.

The orbiter will be deployed at an altitude of 100 km above the surface of the moon. The lander will then separate from the orbiter, and execute a soft landing on the surface of the moon, unlike the previous mission which crash landed near the lunar south pole. ISRO is in the process of testing the actuators and sensors for the soft landing. A rover will then explore the surface. In 2007, ISRO signed an agreement with Russia, to get technical support for the Chandrayaan-2 mission. According to the agreement, the Chandrayaan-2 mission was supposed to be a joint project between ISRO, and the Russian space agency, ROSCOSMOS. As part of the agreement, Russia would provide the lander and rover parts of the mission, while India would be responsible for the orbiter. The mission was originally planned for 2015.

In 2011, the Phobos-Grunt, a Russian sample return mission to one of the two moons of Mars failed. The Phobos-Grunt Spacecraft was launched along with the Yinghuo-1, meant to be the first Chinese Spacecraft to go to Mars. The mission

failed, and the two spacecrafts ended up in the Pacific Ocean. Russia began a review of the mission, and the future of the Chandrayaan-2 mission depended on that review.



1962

Vikram Sarabhai,
the visionary behind the
Indian Space Programme



1963



First sounding rocket launched
from TERLS November 21, 1963



Prime Minister Jawaharlal Nehru visiting
Physical Research Laboratory, Ahmedabad



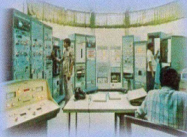
Indian National Committee for Space Research
(INCOSPAR) formed by the Department
of Atomic Energy and work on establishing
Thumba Equatorial Rocket Launching Station
(TERLS) started

1965



Space Science & Technology Centre
(SSTC) established in Thumba

1967



Experimental Satellite Communication
Earth Station set up at Ahmedabad

1968



Prime Minister Indira Gandhi, dedicating
TERLS to U.N. February 2, 1968

1969



Formation of Indian Space Research
Organisation (ISRO) August 15, 1969



New SSTC campus at Veli, Thiruvananthapuram

1971



SHAR Centre, Srihankota operationalised
October 1971, renamed as
Satish Dhawan Space Centre in October 2003

1972

Department of Space (DOS) established,
ISRO brought under DOS June 1, 1972



Prof. Satish Dhawan takes over as Secretary,
DOS & Chairman, ISRO October 1972



Space Applications Centre (SAC)
established at Ahmedabad

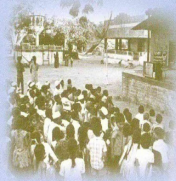
1972



ISRO Satellite Centre (ISAC)
established at Bangalore

1975

ISRO becomes Government Organisation
(April 1, 1975)



Satellite Instructional Television Experiment (SITE)
(1975-1976) using ATS-6 Satellite of USA



First Indian Satellite,
ARYABHATA,
launched on April 19, 1975

1977

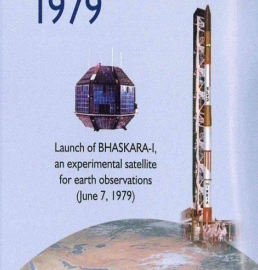
Satellite Telecommunication
Experiments Project (STEP)
(1977-1979) carried out using
Franco-German Symphonie
Satellite



1979



Launch of BHASKARA-I,
an experimental satellite
for earth observations
(June 7, 1979)



First experimental launch of SLV-3 (August 10, 1979)
The satellite did not reach orbit

1980



Liquid Propulsion Systems Centre (LPSC) started in Bangalore

Second experimental launch of SLV-3, Rohini RS-1 satellite placed in orbit (July 18, 1980)



1981



First developmental launch of SLV-3, RS-D1 placed in orbit (May 31, 1981)



Launch of APPLE, an experimental geo-stationary communication satellite (June 19, 1981)



Launch of BHASKARA-II (November 20, 1981)

1982



Master Control Facility (MCF) established at Hassan

Launch of INSAT-1A (April 10, 1982)



1983



Second developmental launch of SLV-3, RS-D2 placed in orbit (April 17, 1983)



Imagery from RS-D2



INSAT system commissioned with the launch of INSAT-1B (August 30, 1983)

1984

Prof. U.R. Rao takes over as Secretary, DOS & Chairman, ISRO (September 30, 1984)



Indo-Soviet joint manned spaceflight



INSAT system for Telecom, Television & Meteorology

1987

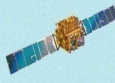


Stretched Rohini Satellite Series-I (SROSS-I) Satellite



First developmental launch of ASLV with SROSS-I satellite on board (March 24, 1987)
The satellite did not reach orbit

1988



Imagery from IRS-1A



Establishment of IRS system with the launch of Indian Remote Sensing Satellite, IRS-1A (March 17, 1988)



Second developmental launch of ASLV with SROSS-2 on board (July 13, 1988)
The satellite did not reach orbit



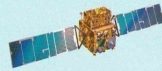
Launch of INSAT-1C (July 22, 1988)

1990



Launch of INSAT-1D (June 12, 1990)

1991



Launch of second operational Remote Sensing Satellite, IRS-B (August 29, 1991)

1992



SROSS-C Satellite



First successful launch of ASLV, SROSS-C placed in orbit (May 20, 1992)



Launch of INSAT-2A, the first satellite of the indigenously built second generation INSAT series (July 10, 1992)

1993



First developmental launch of PSLV with IRS-1E on board (September 20, 1993).
The satellite did not reach orbit



Launch of INSAT-2B (July 23, 1993)

Indian Space Research Organisation

1994



Dr. K. Kasturirangan takes over as Secretary, DOS & Chairman, ISRO (March 31, 1994)



Successful launch of PSLV-IRS-P2 placed in orbit (October 15, 1994)

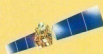


Fourth developmental launch of ASLV SROSS-C2 placed in orbit (May 4, 1994)

1995



Launch of INSAT-2C, the third satellite in INSAT-2 series (December 7, 1995)



Launch of Indian Remote Sensing Satellite, IRS-1C (December 28, 1995)



1996



Third developmental launch of PSLV-IRS-P3 placed in orbit (March 21, 1996)



1997



Launch of INSAT-2D, the fourth satellite in INSAT-2 series (June 4, 1997)

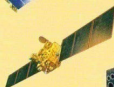


First operational launch of PSLV-IRS-ID placed in orbit (September 29, 1997)

1999



Launch of INSAT-2E (April 3, 1999)

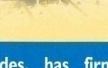


KITSAT-3 - Korean



DLR-TUBSAT - Germany

Launch of IRS-P4 (OCEANSAT) along with Two Satellites from abroad by PSLV-C2 (May 26, 1999)



2000

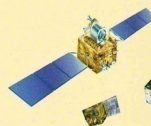


Launch of INSAT-3B, the first satellite in the third generation INSAT-3 series (March 22, 2000)

2001



Successful flight test of Geo-synchronous Satellite Launch Vehicle (GSLV), Experimental satellite GSAT-1 placed in orbit (April 18, 2001)



Launch of PSLV-C3, India's TES along with Belgian PROBA and German BIRD, placed in orbit (October 22, 2001)

2002



Launch of INSAT-3C (January 24, 2002)



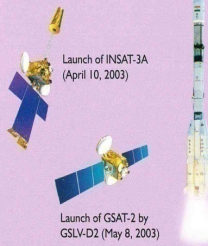
Launch of KALPANA-1 on board PSLV-C4 (September 12, 2002)



Space technology, in the last four decades, has firmly established its capability for socio-economic development in the country. With its unique capability to provide a synoptic view of the earth, it has unleashed a vast potential for applications in

...searching the realm of space

2003



Launch of INSAT-3A (April 10, 2003)

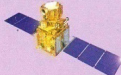
Launch of GSAT-2 by GSVL-D2 (May 8, 2003)



Mr G Madhavan Nair takes over as Secretary, DOS and Chairman, ISRO (September 1, 2003)



Launch of INSAT-3E (September 28, 2003)



Launch of RESOURCESAT-1 by PSLV-C5 (October 17, 2003)

2004



Launch of EDUSAT by GSVL-F01 (September 20, 2004)

2005



CARTOSAT-1



HAMSAT

Commissioning of Second Launch Pad and launch of CARTOSAT-1 & HAMSAT by PSLV-C6 (May 5, 2005)



Launch of INSAT-4A by Ariane 5 (Dec 22, 2005)

2006



INSAT-4C

Second operational flight of GSVL with the INSAT-4C on board (July 10, 2006). The satellite did not reach orbit.

2007



Launch of CARTOSAT-2 along with SRE-1 and two Satellites from abroad by PSLV-C7 (January 10, 2007)



LAPAN-TUBSAT INDONESIA



PEHUENSAT-1 ARGENTINA



Successful recovery of SRE-1 (January 22, 2007)

2007

Launch of INSAT-4B by Ariane-5 (March 12, 2007)



Launch of AGILE, Italian astronomical satellite by PSLV-C8 (April 23, 2007)



Indigenous Cryogenic Stage tested successfully (August 4, 2007)



Launch of INSAT-4CR by GSVL-F04 (September 2, 2007)

2008



Launch of TECSAR by PSLV-C10 (January 21, 2008)



IMS-1



CAN-X2 Canada



CUTE-1.7 Japan



CARTOSAT-2A



DELFI-C3 The Netherlands



AAUSAT-II Denmark



COMPASS-I Germany



SEEDS Japan



RUBIN-8 Germany

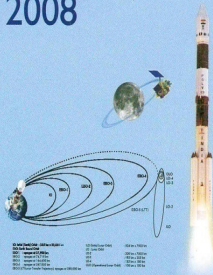


NLS-5 Canada

Launch of Cartosat-2A and IMS-1 along with eight Nano Satellites from abroad by PSLV-C9 (April 28, 2008)

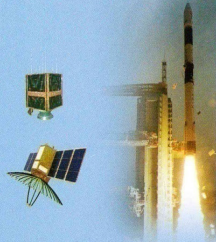
telecommunications, television broadcasting including education, meteorology and natural resources monitoring and management. India was among the first few countries to realise the potential of space technology for national development.

2008

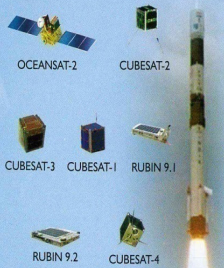


Launch of CHANDRAYAAN-1 by PSLV-C1
(October 22, 2008)

2009



Launch of RISAT-2 and ANUSAT by PSLV-C2
(April 20, 2009)



Launch of Oceansat-2 along with Six Nano Satellites from abroad by PSLV-C14 (September 23, 2009)



Dr K Radhakrishnan takes over as Secretary, DOS and Chairman, ISRO (October 31, 2009)

2010



Successful static testing of GSLV Mk III Launch Vehicle's S200 Solid Propellant Booster Rocket Stage (January 24, 2010)



Successful Static Testing of GSLV Mk III Launch Vehicle's L1 I10 Liquid Core Stage (September 8, 2010)

Launch of GSAT-4 by GSLV-D3 (April 15, 2010)
The satellite did not reach orbit

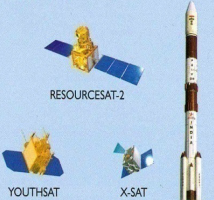


Launch of CARTOSAT-2B and STUDSAT along with three satellites from abroad by PSLV-C15 (July 12, 2010)

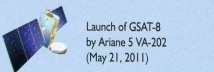


Launch of GSAT-5P by GSLV-F06 (December 25, 2010)
The satellite did not reach orbit

2011



Launch of RESOURCESAT-2, YOUTHSAT and X-SAT by PSLV-C16 (April 20, 2011)

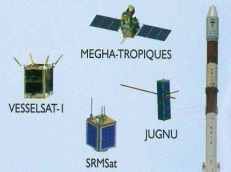


Launch of GSAT-8 by Ariane 5 VA-202 (May 21, 2011)

2011



Launch of GSAT-12 by PSLV-C17 (July 15, 2011)

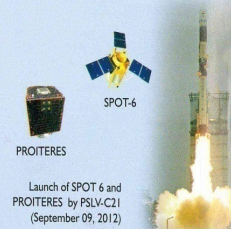


Launch of MEGHA-TROPIQUES, SRMSat, JUGNU and VESSELSAT-1 by PSLV-C18 (October 12, 2011)

2012



Launch of RISAT-1 by PSLV-C19 (April 26, 2012)



Launch of SPOT 6 and PROITERES by PSLV-C21 (September 09, 2012)

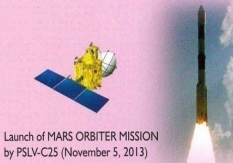


Launch of GSAT-10 by Ariane 5 VA-209 (September 29, 2012)

2013



Launch of SARAL, SAPPHIRE, NEOSAT, NLS 8.1, NLS 8.2, NLS 8.3 and STRaND-1 by PSLV-C20 (February 25, 2013)



2014



2014



Launch of SPOT-7, AISAT, NLS 7.1, NLS 7.2 and VELOX-1 by PSLV-C23 (June 30, 2014)



Launch of IRNSS-1C by PSLV-C26 (November 10, 2014)



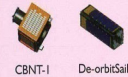
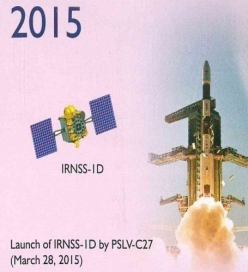
The first experimental flight of LVM3, the LVM3-X/CARE mission lifted off from Sriharikota on December 18, 2014 and successfully tested the atmospheric phase of flight. Crew module Atmospheric Reentry Experiment was also carried out in this flight. The module reentered, deployed its parachutes as planned and splashed down in the Bay of Bengal.

2015

A S Kiran Kumar takes over as Secretary, Department of Space, Chairman, Space Commission and Chairman, ISRO



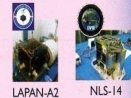
2015



Launch of DMC3-1, DMC3-2, DMC3-3, CBNT-1 and De-orbitSail by PSLV-C28 (July 10, 2015)



Launch of GSAT-6 by GSLV-D6 with indigenous cryogenic upper stage (August 27, 2015)



Launch of ASTROSAT, LAPAN-A2, NLS-14 and 4 LEMUR Satellites by PSLV-C30 (September 28, 2015)

2015

Launch of GSAT-15
by Ariane-5 VA-227
(November 11, 2015)



Launch of TeLEOS-1,
VELOX-CI, VELOX-II,
ATHENOXAT-1,
KENT RIDGE-1,
GALASSIA by PSLV-C29
(Dec 16, 2015)



2016

Launch of IRNSS-1E by
PSLV-C31 (Jan 20, 2016)



Launch of IRNSS-1F
by PSLV-C32
(March 10, 2016)



Launch of IRNSS-1G
by PSLV-C33
(April 28, 2016)



2016



RLV-TD

Launch of RLV-TD by HS9
Solid Rocket Booster
(May 23, 2016)



CARTOSAT-2
Series Satellite



SATHYABAMASAT



SWAYAM



LAPAN-A3



BIROS



M3MSat



SKYSat
GEN2-1



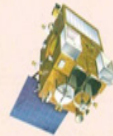
GHGSat-D



DOVE Satellites
(Twelve)

Launch of Cartosat-2 Series Satellite, Sathyabamasat,
Swayam, Lapan-A3, Biros, M3MSat, SkySat Gen2-1,
GHGSat-D & Dove Satellites (Twelve) by PSLV-C34
(June 22, 2016)

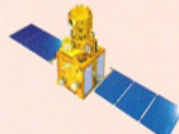
FUTURE...



INSAT-3DR



GSAT-18



RESOURCESAT-2A



GSAT-11



CHANDRAYAAN-2



ADITYA

July 2016



Rocket launches take place at VSSC once a month and are used for atmospheric research. (Courtesy VSSC, Thiruvananthapuram)

Successful Launches of ISRO in 2017

Title	Date
India's GSAT-17 communication satellite launched successfully	Jun, 29, 2017
PSLV-C38 successfully launched 31 satellites in a single flight	Jun, 23, 2017
First developmental flight of India's GSLV Mk III successfully launched-GSAT19 Satellite-the heaviest launched from Indian soil- to a geosynchronous transfer orbit	Jun, 05, 2017
GSLV successfully launched South Asia Satellite	May, 05, 2017
PSLV-C37 successfully launched 104 satellites in a single flight	Feb, 15, 2017

Vikram Assuming Homi Bhabha's Chair

Vasant Gowariker, a Chemical Engineer in London received a call from Vikram who had by then launched the Nike Apache from South India and had rose to fame internationally as an accomplished Space Researcher. Following the launch of Nike Apache Rocket in 1963, the French company 'Sud Aviation' offered a contract to produce their 'Centaure Sounding Rockets' and a small team from TERLS travelled to France to get trained in solid propulsion and hardware fabrication. The Indian government by then had given a clean chit to Vikram to go ahead for a Space Science Technology Centre (SSTC) to manufacture a series of indigenous Sounding Rockets. The series was named 'Rohini'. A later series was named 'Menaka'. It is said that the idea of naming rockets after Apsaras was Mrinalini's choice similar to the American style of naming rockets after Greek Gods. These early rockets were rigged out of ready-made Aluminum tubes with fins and a nozzle, tied to a rope to be retrieved as it explodes. People would shoot them and run for shelter behind coconut trees. Abdul Kalam by then nick named 'busy bee' by his colleagues was given the task of finding a substitute for expensive American fibre glass

nose-cones. Some other team members were made to develop indigenous pay loads.

In February 1968, Prime Minister Indira Gandhi was invited to the site of the Nike Apache launch and to dedicate



Vikram wanted to use television as a medium of development: here he is seen with Prime Minister Indira Gandhi at the *Krishi Darshan* Programme, New Delhi, 1967



With Prime Minister Indira Gandhi at CIRUS, 1967

the officially designated TERLS to the UN. After the ceremony, Vikram met with his senior colleagues and announced that the time was ripe for a feasibility study on developing a Satellite Launch Vehicle. The space programmers had not even managed to send a 2-stage rocket at that time. And people were surprised Vikram talking about a launch vehicle that could shoot upwards in a number of stages and also about releasing satellites which became a reality as was proclaimed by Vikram many years after his demise (See Chapter 7).

In early 1968, Vikram went on to unfold a plan to develop a Rocket Assisted Take Off (RATO), system for military aircraft to be used on the short runways in the Himalayas. Kalam and Captain V.S Narayanan were at the same time pulled in to join the newly formed Missile Panel in the Defense Ministry which had nothing to do with Vikram. With the evolving Space Program, Vikram became busier than ever, but as his character demands he now ventured into two small scale projects in the mid 1960s, the Nehru Foundation and the Community Science Centre. Since the early 1960s, Vikram wanted to explore concepts of development, the idea which he obtained from Prof.C.A.Doxiadis, the Greek Architect and founder of 'Ekistics' (it is the science of human settlement). Vikram thus started a foundation which he named after Nehru on a piece of land he owned at the outskirts of Ahmedabad using the honorarium which he received through the Bhatnagar Award in 1962. One of the early projects undertaken by the Nehru Foundation was a Group for the Improvement of Science Education (GISE). Raja Ramanna, a fellow physicist was on the panel of GISE to discuss science curriculum with Vikram. In 1965, Arnold Frutkin, Deputy Director of the NASA introduced Vikram to Axel Horn, a designer of educational programs. By September 1965, Horn visited Ahmedabad and conceptualized the functioning of the Community Science Centre. Though Vikram was not directly involved in the running of these two institutions, his presence was crucial in all their meetings.

In January 1966, when Lal Bahadur Sasthri, who had taken over after Nehru as Prime Minister, died of a heart attack in Tashkent, Indira Gandhi had to take the place immediately. Soon the news came of an untimely demise of Homi Bhabha. He died when Air India Flight 101 crashed near Mont Blanc on 24 January 1966. No one knew at that time that this untimely loss would later alter the course of Vikram's life. Indira Gandhi, who was a very close friend and well wisher of Vikram asked him to take the mantle of AEC in the place of Bhabha. Government regulations did not permit Vikram's involvement in various private organizations where he was playing pivotal roles before he assumed Babha's Chair at AEC. On June 1 1966, Vikram bid an emotional farewell to all his ongoing enterprising organizations and took over the mantle of Bhabha. By the time Bhabha died, the AEC at Trombay had expanded into the country's largest scientific enterprise with almost 8000 employees. From describing itself as the provider of cheap energy, the AEC also was instrumental in taking up the mission of safeguarding India's security.

Vikram's association with AEC even predated Bhabha's death. Vikram was already in the board of the AEC members by then. By this time, Homi N. Sethna, a Chemical Engineer, graduated at the University of Michigan, who was working at the Imperial Chemical Industries in London, joined the AEC. In 1949 following Bhabha's demise, Sethna convinced several others that he was the rightful successor to Bhabha. Vikram faced several altercations from Sethna, but as his personality demands, Vikram shrugged it all with extreme politeness.

When Vikram became the Chair of AEC, he took and saw matters differently from the other AEC technologists and scientists. Rather than asking how the nuclear explosive capability could help India, he always asked what material benefit it would do for India. When Vikram was confronted

in various press conferences, after he assumed the chair with questions like “ *What about the Atomic Bomb ?* ” “ *How long will it take us to make it?* ” etc., Vikram responded in length but in simple terms. “ *Paper tigers (Paper tiger is the English translation of a Chinese phrase referring to something that appears threatening but is actually harmless) do not provide security. If you want to rely on the atom bomb for safe guarding our country’s security, it is not achieved by exploding a bomb. It means a total defense system, a means of delivery, long range missiles, RADARS, high state electronics, metallurgic and industrial base. I would like to emphasize that security can be endangered not only from outside but also from within. If you do not maintain the rate of progress of the economic development of the nation, we should think of an internal as well as external threat. So the real problem relates to the utilization of natural resources for productive and social welfare against the burden of defense expenditure which a country can hardly bear at any particular time* ”. This was a stark contrast and blow to the existing thought processes of Bhabha and his team until then. Vikram did not reject atomic weapons, but was vehemently opposed to an aggressive military outlook without the necessary infrastructure to back this mighty step in India. He strongly believed with all conviction to develop a metallurgical and electronics base and said that it cannot be done without a good agricultural base. This great visionary was in favor of consolidating the country’s internal security first.

Almost immediately after assuming charge of AEC, Vikram made arrangements for many senior scientists and engineers of the AEC, to visit USA, USSR and France to learn the latest trends in reactors, high energy physics, applications of radioisotopes and radiation biology. In September 1966, he himself as a team with Brahm Prakash (Prakash was a metallurgist known for his work with nuclear materials in India. In 1950, Prakash took up the Headship of the Department of Metallurgy at the IISc, Bangalore.. In 1972 he joined as the first Director of the VSSC in Thiruvananthapuram) and Sethna with

few other scientists went on to learn the Advanced Reactor Technology in USA. On January 12 1967, at a ceremony held wherein the AEC at Trombay was renamed BARC after its late founder, Vikram was all praise for Bhabha ,remembering him a *'creative administrator'*, a *'dynamic leader'* ,a *'tireless worker'* and all the more *'a pioneer in promoting international cooperation in the peaceful uses of the atom'*.

Words of Wisdom

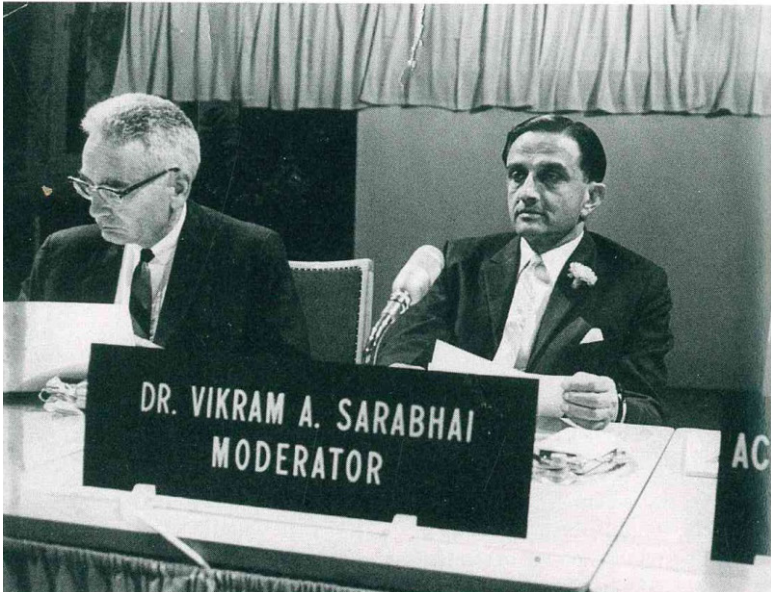
“A leader, if one chooses to identify one, has to be a cultivator rather than a manufacturer. ...One wants permissive individuals who do not have a compelling need to reassure themselves that they are leaders through issuing instructions to others rather they set an example through their own creativity...”

- Dr. Vikram A. Sarabhai

Soon after assuming the chairmanship at AEC, Vikram also started a very methodical study on the 'Cost and Significance of Asynchronous Satellites' to link together distant rural communities to the varied population of India using a powerful mass communication system using television. In 1967, a National Study Group with members such as U.R.Rao and Kiran Karnik who joined the AEC, conducted a Rural Development Television Program in collaboration with All India Radio, the Indian Agricultural Research Institute and the Delhi Administration. This milestone venture called 'Krishi Darshan', involved reaching out to eighty villages around Delhi through community television sets. A hybrid system involving direct broadcasts to several areas and five rebroadcast stations for the densely



As President, International Atomic Energy Agency Conference, Vienna, 1970



populated regions encompassing five lakh villages covered by an amount of Rs.160 crore came into existence.

He also initiated a study at the DAE, to explore the 'Implications of Low-cost Power to Agriculture'. The Agro Industrial Complex proposed by Vikram and augmented by the Green Revolution spear headed by M.S Swaminathan had the potential to strengthen India which saw a new beginning in this domain. Vikram firmly believed that this would in turn boost the Energy Program and moreover would give a new dimension to it.

The close of 1969 saw Vikram working so hard for the timely inauguration of the country's Nuclear Power Station, a project envisaged by Bhabha in Tarapur, Swayam, Maharashtra. In 1970, Vikram presided over the fourteenth General Conference of the International Atomic Energy Agency (IAEA) in Vienna. Although there were external pressures from within the government to seek nuclear weapons from outside the country, Vikram was dead against it. He wanted his country to be self-reliant and productive and claimed that we have all facilities and brains for it. On May 17 1970, Vikram announced that India would not seek nuclear weapons but still would retain the option of conducting nuclear explosions for peaceful purposes. A week later, he released " Atomic Energy and Space Research : A Profile for the decade 1970-1980", a ten-year plan for Atomic Energy and Space in India. During this period Neil Armstrong, the first man on the Moon, came to Bombay to visit Vikram and observe his various activities.

As was expected of Vikram to multi task, he with his sister-in-law Lakshmi Sehgal, who practiced Medicine in Kanpur, tried to find an answer to the 'population explosion' in India. Vikram's suggestion of 'male sterilization' at this juncture caused much furore. By 1971, Vikram had successfully completed 5 years in office at AEC. But Indira Gandhi, who was once a strong



With American astronaut Neil Armstrong at the Tata Institute of Fundamental Research, Mumbai



Vikram with Dr Kurt Waldheim, President of the first United Nations Conference on the Exploration and Peaceful Uses of Outer Space (1968) and later Secretary General of the United Nations, and his wife

allay of Vikram and his family was not in very good terms with Vikram by then due to various reasons. She in turn asked Vikram to choose between Space Research and Atomic research, which was a heart breaking decision for Vikram to make. These discussions were going on when Vikram in December 1971 travelled to Bombay to spent time with Mrinalini and Mallika .Kartikeya, his son and family had by then gone back to USA. Vikram’s mother Sarla wanted his son to have a break from his hectic schedule which Vikram finally agreed upon.



Former Prime Minister, Atal Bihari Vajpayee at ISRO's space port with the PSLV on the pad in the background. Some prominent political personalities in this picture include: C Rangarajan (Governor of Andhra Pradesh), Chandrababu Naidu (Chief Minister of AP) and Brajesh Mishra (National Security Advisor). Some senior ISRO personalities include: K Kasturirangan, S Vasantha, N Vedachalam, S Ramakrishnan, S Srinivasan and R Nagappa.

Vikram's Last Days

In 1971, around Christmas eve the same year, Vikram travelled to Ahmedabad from Bombay. He visited his mother, Sarla. His sister Geeta recalled later that after his dad's demise he was even more cautious and meticulous in taking care of his beloved mother. Sarla used to chide him for working so long hours. He used to share his retirement plans to her mostly than to anyone, that post retirement his wish was to sit by the side of an aquarium at the Community Science Centre and teach science to children. 'Science, Science, Science', this percolated in his heart, mind and soul at all times. One cannot detach Vikram from Science whatever he was working at. The link was mightier than the mightiest tie anyone could imagine. Only such a person can envisage an organization like ISRO in his life time.

On Sunday, December 26, 1970 he returned to Bombay from Ahmedabad, thoroughly exhausted. But he decided to make his routine trip to Thumba, Trivandrum, Kerala. Kartikeya had left for USA by then having procured a job, but Mrinalini and Mallika were in Bombay. After three of them had a lunch at a sea side restaurant overlooking the Bombay harbor, he received a cabinet paper from Delhi regarding a meeting he had to attend at SITE. So Mr Warriar, his private secretary,

booked an early morning flight to Delhi and Ramanna too travelled with him.

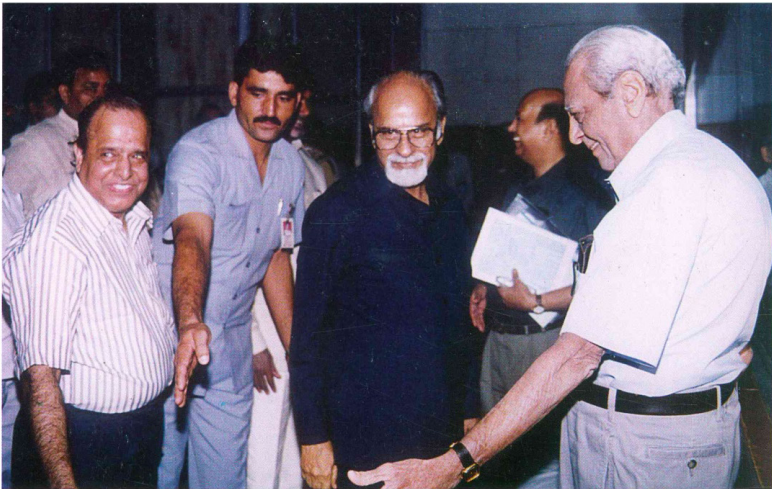
Since his health was a major concern to all his friends and family members by then due to long hours of strenuous work, he was taken for a check-up a week prior to this travel to one Dr R.J.Vakil. He was given a clean chit that he was fit and had no ailments after a complete examination. While on his flight to Delhi, on December 27, 1971, Ramanna recalls Vikram talking about his swings in blood pressure and his eagerness to learn yoga to combat it. This was surprising a note to come from a modern man who richly owned pharmaceutical firms manufacturing allopathic drugs.

Vikram returned the same day from Delhi and left for Thumba the next day morning. Mallika pleaded with him not to go since the New Year was fast approaching and she was all set to celebrate it in Ahmedabad with all family. Vikram promised to be there on time after his work in Thumba. The next two days, 28 and 29 December, 1971 he spent in Thumba immersed nose deep in all hectic work which was pending for his arrival. The whole of 29 December he spent working except for the lunch he had with R.D. John and H. G. S. Murthy, the head of TERLS. Afternoon, he met the Chemicals group. U. R. Rao later commented on the disappointment which Vikram shared in a single statement about the not so rapid pace of growth of the chemicals group, he just murmured "*we have to build the chemicals group*".

A meeting with the following people then happened the same day i.e. 29 December, 1970. Gowarikar, Suresh Thakur, Y.Janardhan Rao, A.E.Muthunayagam, E.V.Chitnis and M.K.Mukherjee. These meetings and discussions kept him occupied till dinner time. Even after dinner, all these dignitaries assembled in Vikram's room, which was the Kovalam Guest House (Halcyon Castle).The place was beautiful with the sea

waves lashing at the building and the gentle breeze causing a serene atmosphere. Vikram was bubbling with enthusiasm and no sign of ill health was noted. After the gathering dispersed at around 10 o'clock, Gowarikar went inside to have a personal conversation with him, he found Vikram lying on the floor with his hands crossed under his head. Without disturbing his sleep, Gowarikar left the place, although he mentioned this weird incident to his wife back home.

Vikram had promised to pick up Thakur on his way to airport to travel to Ahmedabad together. By 10.30 PM, Abdul Kalam called him from Delhi where he had attended a meeting of the missile panel. Vikram heard Kalam. Vikram instructed Kalam to wait at the Trivandrum airport the next day morning so that he could confer on the SLV-3 before he embarked his journey to Bombay. As dawn broke off, Nadesha Panicker, a room boy rang the bell of his room on the top floor. The door was locked from inside. He was assisted by the cleaning woman Santhamma since despite knocking; Vikram was not opening



Former Prime Minister, IK Gujral with three former Chairmen of ISRO: Satish Dhawan (right), UR Rao (with papers in hand) and K Kasturirangan (left).

the door. Through the side balcony outside, they saw a lean figure sleeping under the mosquito net. Soon Warriar arrived. They broke the door open and saw Vikram lying still with book open on his chest, his face fresh with a faint smile still lingering on it as if he is sleeping. No post mortem was done and still the cause of death remains an enigma to all, that too at the age of 52, when he had at least two more decades to go far and wide.

At 10.30 AM, Mallika lighted the pyre of her renowned father in Kartikeya's absence. Vikram's ashes were scattered in the Indian Ocean at Thumba where he spent a major part of his illustrious career. In 1974, a moon crater was named after Vikram. The International Astronomical Union at Sydney, Australia decided that crater 'BESSEL', in the Sea of Serenity would be named as Sarabhai Crater. Also, Padmavibhushan was posthumously conferred to this great soul whose contributions to our country was so versatile and unparalleled although one only know of him as the *'Father of the Space Program in India'*.

Vikram's Achievements: A "Leap-Frogging" Cascade

- 1919-12 August, born to Sarabhais in Ahmedabad
- 1937- Completed the intermediate examination from Gujarat College, Ahmedabad and joined St John's College, Cambridge, UK.
- 1940- Obtained tripos in Physics and Mathematics from Cambridge and returned to India; joined IISc, Bangalore and continued his post graduate research in Cosmic Rays as Prof C.V. Raman's student
- 1942- First scientific research paper published, in Proceedings of Indian Academy of Sciences, A. Vol. 15, p. 89; married Bharatanatyam exponent Mrinalini Swaminathan
- 1945- Returned to Cambridge to work for a PhD in Cosmic Ray Physics
- 1947- Awarded the PhD and returned to India; started ATIRA and PRL at Ahmedabad

- 1950- Took over the management of Sarabhai Chemicals, Baroda
- 1955- Established Suhrid Geigy Limited, Baroda
- 1957- Took over the management of Swastik Oil Mills Limited. Bombay; founded the Ahmedabad Management Association
- 1958- Established Sarabhai Merck Limited, Baroda (now called Sarabhai M.Chemicals)
- 1960- Took over the management of Standard Pharmaceuticals, Calcutta; established the Sarabhai Research Centre (SRC), Baroda and the Operations Research Group (ORG), Baroda
- 1961- Established Synbiotics Limited, Sarabhai Engineering Group and Sarabhai Glasses, Baroda
- 1962- Awarded the prestigious S.S. Bhatnagar Award for his scientific research in physics; appointed as Chairman of INCOSPAR; founded the IIM-A; selected as President, Physics Section, Indian Science Congress, Cuttack
- 1963- Established the TERLS, Thiruvananthapuram; member 'Electronics Committee'
- 1964- Convenor, Pugwash Conference, Udaipur
- 1965- Established SSTC, Thiruvananthapuram now known as VSSC; appointed as Member of AEC, Government of India; assumed Directorship of the PRL, Ahmedabad
- 1966- Appointed Chairman, AEC, Government of India; Secretary, DAE, Government of India; Chairman, Electronics Committee, Government of India; founded the Nehru Foundation for Development and the Community Service Centre; Member, International Council of Scientific Union; Awarded Padma Bhushan.

- 1967- Established Experimental Satellite Communications Earth Station (ESCES), Ahmedabad; set up Uranium Corporation of India Ltd, Jaduguda, Bihar; Established Electronics Corporation of India Ltd (ECIL), Hyderabad
- 1962-67 Chairman, COSPAR Consultative Group on Potentially Harmful Effects of Space Experiments
- 1968- Scientific Chairman of the UN Conference on the Exploration and the Peaceful Uses of Outer Space, Vienna
- 1969- constituted ISRO; became Chairman, ISRO; signed SITE agreement with NASA, USA
- 1970- President, 14th General Conference, International Atomic Energy Agency (IAEA), Vienna; presented a profile for the decade 1970-80 for the Atomic Energy and Space Research Program for India
- 1970-71 President, Indian Geophysical Union
- 1971- Scientific Chairman, 4th UN Conference on the Peaceful Uses of Atomic Energy; passed away at 52 years of age on 30 December, at Kovalam Guest House (Halcyon Castle), Thiruvananthapuram, India
- 1972- Awarded Padma Vibhushan posthumously
- 1974- A moon crater was named after Dr Vikram Sarabhai. The International Astronomical Union at Sydney, Australia decided that Crater BESSEL in the Sea of Serenity will be known as the 'Sarabhai Crater'

Memberships

1. Fellow, Cambridge Philosophical Society
2. Fellow, Institute of Advanced Studies,MIT
3. Fellow, Physical Society,London
4. Member, American Physical Society
5. Member, American Geophysical Union
6. Member, National Planning Council of the Planning Commission
7. Member, Central Advisory Board of Education
8. Secretary, International Institute Sub-Committee on Cosmic Ray Intensity Variations
9. Member, Cosmic Ray Commission of the International Union of Pure and Applied Physics
10. Member, International Council of Scientific Union
11. Member, Pugwash Committee
12. Founder and co-ordinator,Indian Pugwash Committee
13. Fellow, Indian Academy of Science
14. Fellow, Indian National Science Academy
15. Senior Visiting Professor,MIT
16. Member, the Inter-Union Commission of Solar Terrestrial Physics of the International Council of Scientific Union
17. President, Indian Rocket Society

Glossary

AEC	Atomic Energy Commission
AMA	Ahmedabad Management Association
AMA	Ahmedabad Mill-owners Association
ATIRA	Ahmedabad Textile Industry's Research Association
ASLV	Augmented Satellite Launch Vehicle
BARC	Bhabha Atomic Research Centre
CNES	Centre National d'Etudes Spatiales, France
COSPAR	Committee for Space Research
CSIR	Council of Scientific and Industrial Research
DAE	Department of Atomic Energy
DRDO	Defence Research and Development Organization
ECIL	Electronics Corporation of India Limited
GISE	Group for the Improvement of Science Education
GSLV	Geosynchronous Satellite Launch Vehicle
IAEA	International Atomic Energy Agency
ICAR	Indian Council of Agricultural Research
IISc	Indian Institute of Science
IIM-	A Indian Institute of Management, Ahmedabad
IGY	International Geophysical Year
INCOSPAR	Indian National Committee for Space Organization

INSAT	Indian National Satellite System
IRS	Indian Remote Sensing Satellites
ISRO	Indian Space Research Organisation
ISTRAC ISRO	Telemetry, Tracking and Command Network
MIT	Massachusetts Institute of Technology
NASA	National Aeronautics and Space Administration
NPL	National Physical Laboratory
NPTY	Non-Proliferation Treaty
NRSC	National Remote Sensing Centre
ORG	Operations Research Group
PRL	Physical Research Laboratory
PSLV	Polar Satellite Launch Vehicle
RATO	Rocket-Assisted Take-Off
SITE	Satellite Instructional Television Experiment
SLV	Satellite Launch Vehicle
SNEPP	Study of Nuclear Explosions for Peaceful Purposes
SSTC	Space Science and Technology Centre
TERLS	Thumba Equatorial Rocket Launching Station
TIFR	Tata Institute of Fundamental research
VSSC	Vikram Sarabhai Space Centre

**Photographs from
the life of Vikram Sarabhai**

(Courtesy- Vikram Sarabhai Space Center Library,
Thiruvananthapuram, Kerala, India)

**Vikram Sarabhai:
Words of Wisdom**

(Courtesy- Vikram Sarabhai Space Center Library,
Thiruvananthapuram, Kerala, India)