

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

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His versatile personality and diverse experience from being a researcher, academician, industrialist, policy maker

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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 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

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."

, QGLDQV KDYH SURIXVH UHYHUHQFH WRZD I
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
ORYH IRU RWKHU ÀHOGV OLNH GDQFH WKH
IHZ PDLNQQ KLP D YHUVDWLOH ÀJXUH SURE
RWKHU VFLHQWLÀF EUDLQ RXU FRXQWU\ HY

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.



S U H P L H U V F L H Q W L À F H V W D E O L V K P H Q W V M X

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.

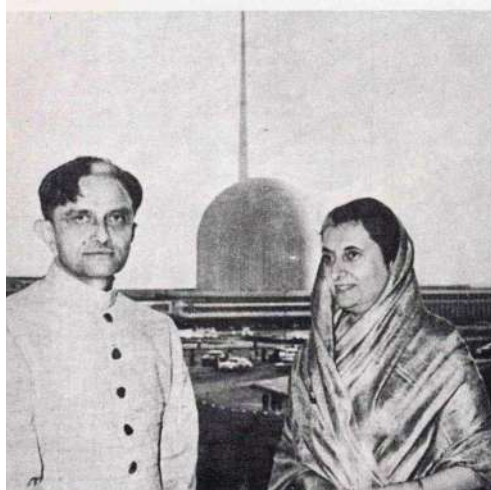
Dr. Vikram Sarabhai was a multi-faceted personality, an outstanding scientist, deeply committed to the development of the country by the application of modern technology. He was a visionary and a dreamer and often used to say “I have a dream, a fantasy may be, that we can leap-frog our way to development”.

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

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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 K D G D À U P F R Q Y L F W L R Q I R U D V W U R Q J V H India. He often paused to remind, 'We do not wish to acquire black boxes from abroad but to grow a national capability'. 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 I R O O R Z L Q J W K H G H P L V H R I 9 L N U D P 6 D U D E I started and envisaged by this great visionary. Finally, some V F L H Q W L À F P L O H V W R Q H V L Q W K H O L I H R I chronological order ending with the naming of a crater on the moon after him.

2 Q H F D Q J R R Q G H V F U L E L Q J K L V S U R À O H 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 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

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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.



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
ÀJKWHUV VRFLDO ZRU 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
TXDOLWLHV ZKLFK PLJKW KDYH LQÁXHQFHG 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'

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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

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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

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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 DIWHU VHDUFKLQJ DQG ÀQGLQJ WHDFKHUV 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.

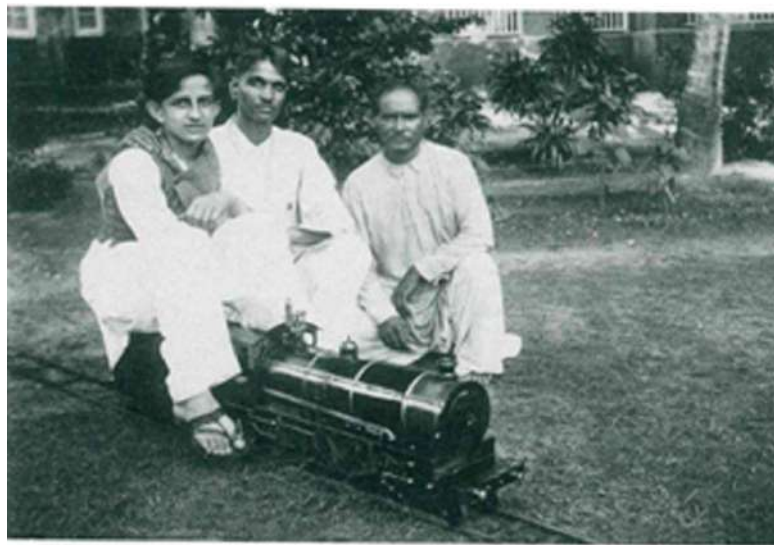
The Sarabhais were Jains and were ritualistic as far as their traditions were concerned, whereas they imbibed Western traits which were considered necessary in the ideal upbringing of their eight children. They were strict vegetarians and Vikram had exclaimed several times that he will remain a vegetarian '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

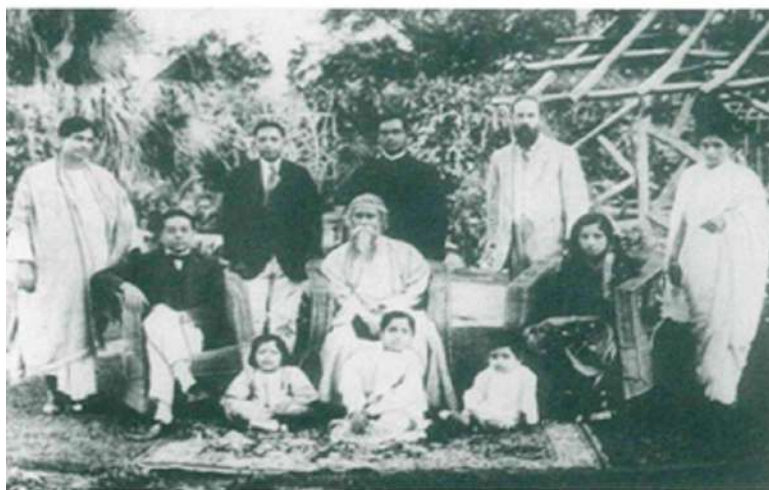


Vikram with the toy engine he made

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 P D Q \ W K L Q J V D W W K H V D P H W L P H Z K L F K U H as well. His memory was sharp, he was very attentive and he F R X O G F R P S U H K H Q G H Y H Q W K H Y H U \ G L I À F precision within no time. There were umpteen languages to be learnt-Gujarati, their mother tongue to Sanskrit, Hindi, English D Q G % H Q J D O L 9 L N U D P E H F D P H S U R À F L H Q W 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, W K H H [D P L Q D W L R Q V W R R N D E D F N V W D J H 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.

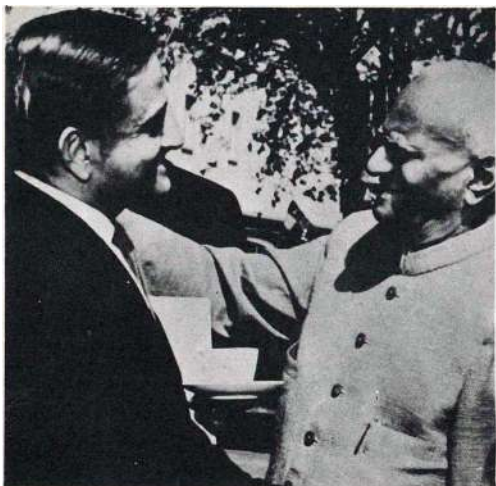
The Retreat School as cited earlier modeled on Montessorian principles, where the highest function of the teacher was to inculcate the interest and enthusiasm, not a ritualistic teaching as is well known. Vikram then went on to give the Intermediate examination at the Bombay University and then proceeded 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.

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 *XMDUDW & ROOHJH *XMDUDW & ROOHJH Z D 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. In 1933, Albert Einstein was forced to leave Germany and go to the United States. The center for science was moving from Europe to the United States. Vikram 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 SUHVWLJLRXV ÀUVW SDSHU ´7KH 7LPH ´LVW. This he presented to the Indian Academy of Sciences in 1942. While at IISc, Bangalore his life took a different turn when he FDPH DFURVV D VFLHQWLÀF JLDQW ZKR KD 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 DZDUG +H KDG ZRUNHG ZLWK VWDOZDUW 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

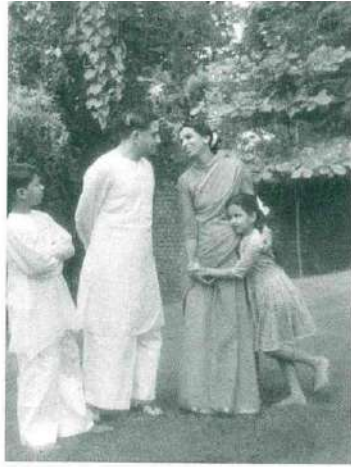
'Premalaya'. Vikram in his leisure time used to wander the road to the Vedanta College run by the Ramakrishna Mission. Vikram by then earned a good name and Bruno Rossi, a pioneer in X-ray Astronomy and Space Plasma Physics made Vikram a frequent visitor to his lab at Massachusetts Institute of Technology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

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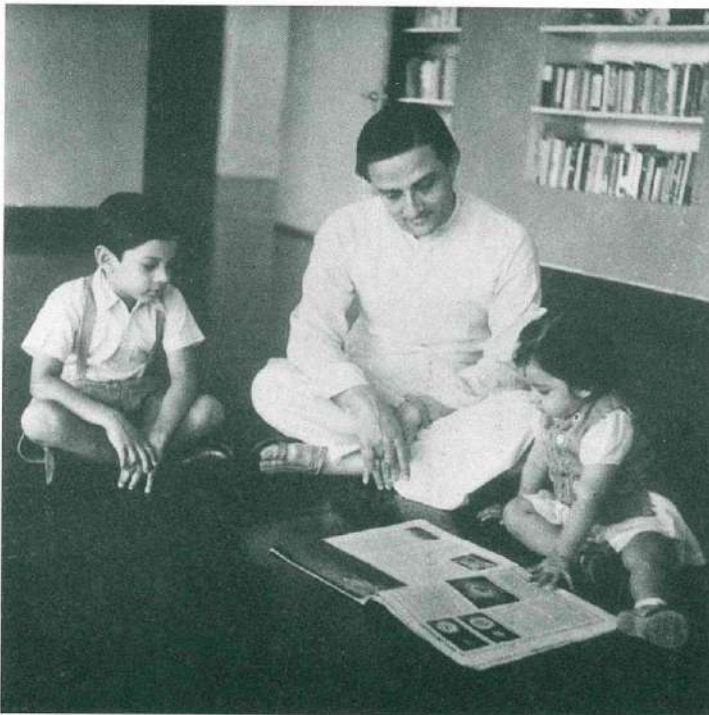


With his wife Mrinalini.

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

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 P X V L F L D Q D Q G 5 D P * R S D O D S U R À F L H Q W % 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 \$ U P \ Z D V N Q R Z Q W R P D Q \ D V D G L V W L Q J X L 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.

\$OWKRXJK ERWK RI WKHP ZHUH QRW NHHQ
wed locks at the early stage of their friendship since both were
HQJURVVHG LQ WZR GLIIHUHQW ÀHOGV ZLW
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
RQH V PRGLÀHG WR WDLORU WR WKH QHHGV
this he believed acquiring if necessary the skills innate to other
IRUHLJQ ODQGV UDWKHU WKDQ ZDLW IRU V
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

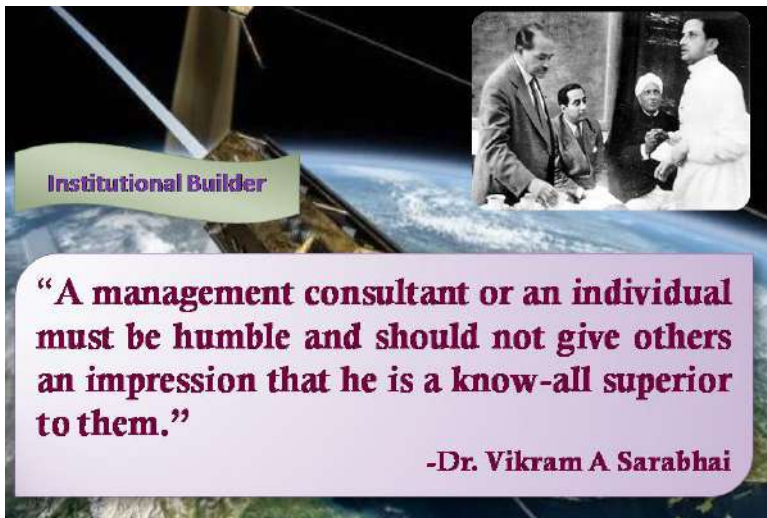
life proved that time is not be wasted but good qualities and discoveries of any nation can become part of ours too in due course of time which can change the face of India. This was all the brain of great Vikram and his special qualities of making a better nation with no ego whatsoever coming in the 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 GD\ V HYHQ DV D ER\ 9LNUDP ÀUPO\ IROOR 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.

Not only in science and technology, Vikram through his
 YHUVDWLOLW\ PDGH D JUHDW LPSDFW LQ
 LV EULHÁ\ WRXFKHG XSRQ LQ WKLW FKDS
 become the Jack of all trades and at the same time master it as
 ZHOO 9LNUDP·V OLIH H[HPSOLÀHG WKDW
 through hard work, sincerity and all the more effective time
 PDQDJHPHQW +LV FROOHDJXH V DQG IULH
 cope up with him since he worked round the clock, did not
 know how to waste time, switched within no time from one
 ÀHOG WR DQ HQWLUHO\ GLIIHUHQW ÀHOG
 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

GHÀQLWLRQ RI SUREOHPV %HIRUH HPEDU 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 SRVVLEOH 9LNUDP SUHIHUUH G D VFLHQWL 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 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). 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.

+ 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

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

+H DGYDQFHG KLV ÀUP E\ GHOHJDWLQJ
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
FRQÀGDQWV RI 9LNUDP ODWHU 3DGP DQDE
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

EHQHÀWV IURP WKH EXVLQHV V SDUWQHUVKL
DOZD\ V NHSW PDQ\ LQÁXHQLDO PHQ DW K
an established scientific person, S.S.Bhatnagar ,Council of
6FLHQWLÀF DQG ,QG XVWULDO 5HVHDUFK &
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
WKL V FRQVWLWXWHV WKH ÀUVW HQWHUSUL
DQG WKH *RYHUQPHQW RI ,QGLD KDYH FR
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,
RIÀFHV DQG ODERUDWRULHV RI WKH YDUL
DGPLQLVWUDWLYH RIÀFHV WKH VWRUHV D
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
VFLHQWLÀF NQRZOHGJH DQG DSSO\ WKL V I
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 ZDV GRQH ZLWK WKH YLHZ RI IRVWHULQJ DPRQJ WKR VH ZKR ZRUN LQ WKH LQG XVWU LQ WKH SUDFWLFDO XWLWLW\ RI DSSO\LQJ 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, 6FLHQWLÀF DQG &XOWXUDO 2UJDQLJDWL 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 IXOÀOO WKLV QHHG ZLWK WKH WHFKQLFDO Labour organization.

(YHQ ZLWK WKH FRPSOHWLRQ RI WKH 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 W K H Q D W L R Q D O O D E R U D W R U L H V R I , Q G L D S 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 D Z H H N W R % D U R G D W R Y L V L W W K L V À U P 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 SHRSOH ZHUH 5DQED[\ &LSOD &DGLOD *OD launched a professionally managed Sarabhai Chemicals which LV VWLOO D UHSXWHG ÀUP LQ DOO LWV JO

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 ZDYHV RI SURÀW LQ WKH PDUNHW 6DUDEK 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.

:KHQ DOO WKHVH RUJDQL]DWLRQDO DF had all the time to dedicate to 'Darpana', his wife Mrinalini's dance academy in Ahmedabad. Mrinalini by then had become DQ LQWHUQDWLRQDO ÀJXUH DQG ZDV WU 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'.

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 WKHUH RQH 0U 0 5 .XUXS DOVR FRQÀUPH ODFN RI HIÀFLHQW PDQDJHUV EURXJKW D 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, QRQ SURÀW QRQ JRYHUQP HQWDO RUJDQL 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 HVWDEOLVKHG ,,0 \$ 7LOO WKH ÀQDO EXLO 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).

The IGY, started in July 1957 was eagerly awaited by scientific community .This came up as an evidence of the 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.

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 RQH FRXOG KDYH H[SHFWHG D GHFDGH RU contribution from them. Each passed way from our midst suddenly, OHDYLQJ D YRLG GLIÀFXOW WR ÀOO (DFK F well-known families. Each could have chosen commerce or industry IRU D FDUHHU EXW GHFLGHG RWKHUZZLVH D 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. 9LNUDP 6DUDEKDL GLG LW LQ WKH ÀHOG R

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.

7 K H , Q W H U Q D W L R Q D O & R X Q F L O R I 6 F L
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

HTXDWRULDO UHJLRQ KDV VSHFLDO VFLHQ
DHURQRPI , Q SDUWLFXODU WKH PDJQHWL
LQ WKH LQYHVWLJDWLQR RI WKH HDUWK·V

This was as earlier mentioned Vikram'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
DV SRVVLEOH DV D ÀUVW VWHS LQ FUHDW
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

2QH RI WKH ÀUVW LQLWLDWLYHV RI , 1 & 2
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
WKH QHHG IRU , QGLD WR LQYHVW LQ WKH À
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
VFLHQWLÀF RUJDQLJDWLQR LQ WKH FRXQW
a few years, our present modest beginning will grow appreciably and
, QGLDQ VFLHQWLWWV ZLOO EH PDNLQJ LPSI
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

WR VFLHQWLÀF ZRUN XQOHVV RQH FDQ DO
RI PDNLQJ GLVFRYHULHV LQ WKH ÀHOGV R

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.

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

ZKHUHE\ RQH FDQ GHÀQLWHO\ ZLWK FRQYL

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

FRXOG WHVW LWV ÀUVW DWRPLF ERPE DQ

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.

7KH URFNHW ODXQFKLQJ VWDWLRQ ZDV RIÀ

Thumba Equatorial Rocket Launching Station (TERLS). Lakshmi Menon’s statement before the parliament had three technical terms- ‘magnetic equator’, ‘ionosphere’ and ‘sounding rockets’.

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

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

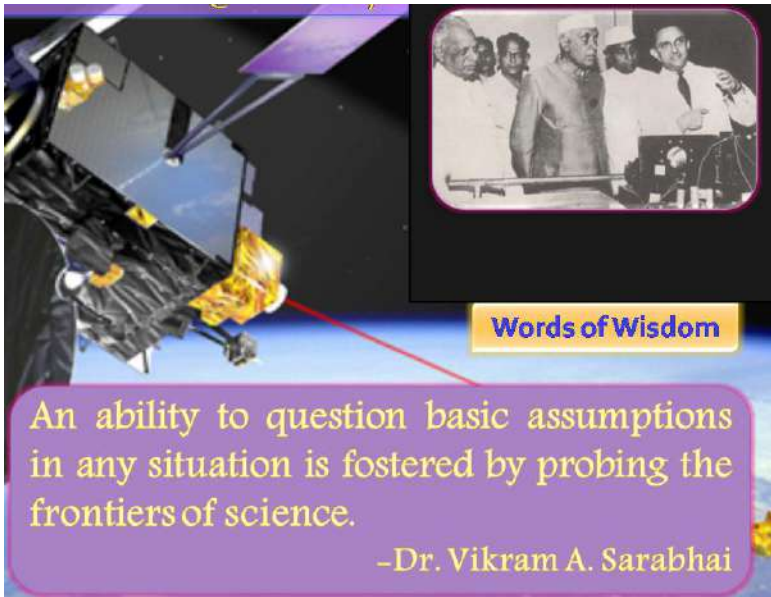
the reach of balloons and is too low for a direct interaction with satellites. Direct sounding of the EEJ is, therefore best

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, Thiruvananthapuram, Kerala.

The Ionosphere

The gaseous envelope of the earth in which we live 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^{25} air molecules in 1cc. This number decreases to about 10^{12} at an altitude of 500 km, a drastic reduction by a factor of more than one trillion (10^{13}). 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).

7 K H U H J L R Q Z K H U H W K H L R Q L J D W L R Q R F F X
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.



6

Now let us see how the Indian Space Program took its
VKDSH ÀQDOO\ 7KH H[LVWLQJ 6SDFH 5HV
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
JURXQG EDVHG UDGLR PHWKRGV LQ LQ
Indian scientists like C.V. Raman and Meghnad Saha laid down
VFLHQWLÀF SULQFLSOHV DSSOLFDEOH WR
DIWHU WKDW RUJDQL]HG 6SDFH 5HVHDU
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.

7 H V W V R Q W K H H D U W K · V P D J Q H W L F À H O G
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
W H F K Q L F D O V X S S R U W D Q G V F L H Q W L À F F R
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 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 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 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 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.

on a better understanding of meteorology of great practical 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
 UHVH DUFK LQ WKH ÀHOGV RI DHURQRP\ FR
 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

J L Y L Q J W K H Á H [L E L O L W \ R I D Q D F D G H P L F V

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

D Q G V F L H Q W L À F S D \ O R D G F R Q V W U X F W L R Q

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

D Q G W H V W D Q G H Y D O X D W L R Q 7 K H À U V W 5
V X F F H V V I X O O \ Á L J K W W H V W H G W K H U H V L Q I

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

F D U U L H G R X W V L Q F H P R U H W K D Q P

balloons from Hyderabad. The balloons fabricated at the TIFR

D U H F D S D E O H R I Á \ L Q J S D \ O R D G V X S W R



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 D Q G Á R D W D W V
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-stagesounding 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
À U H G I U R P P D Q \ O R F D O H V 7 K H 1 L N H \$ S D F K
variety of payloads to study a wide range of topics including
radio astronomy, meteorology, aeronomy, atmospheric
F R Q G L W L R Q V S O D V P D S K \ V L F V D Q G V R O D U
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).
1 L N H \$ S D F K H Z D V W K H À U V W U R F N H W O D X
TERLS in 1963.

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.

'XULQJ WKH ÀUVW SKDVH V ,QGLD V 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 VHH KRZ WKH ÀUVW ÀUP VWHS RI D YLVLRQ 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.

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

NJ ,WV ÀUVW ODXQFK WRRN SODFH LQ WKH VXE VHTXH QW \H DU V DQG WKH ÀQDO C IRXU WHVW ÁLJKWV ZHUH VxFFHV VIXO ,W 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 ODXQFK YHKLFOH NLFN VWDUWHG D VHULH 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 EDVHG RQ 6/9 7KH ÀUVW ODXQFK WHVW ZD 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



📷 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 UHVHDUFK DQG GHYHORS PHQW LQ WKH 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 \$ P R Q J W K H \grave{A} H O G V R I U H V H D U F K D W W satellite based telecommunications, surveying, remote sensing, meteorology, 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.



VIKRAM SARABHAI

THE LEGEND UNVEILED

