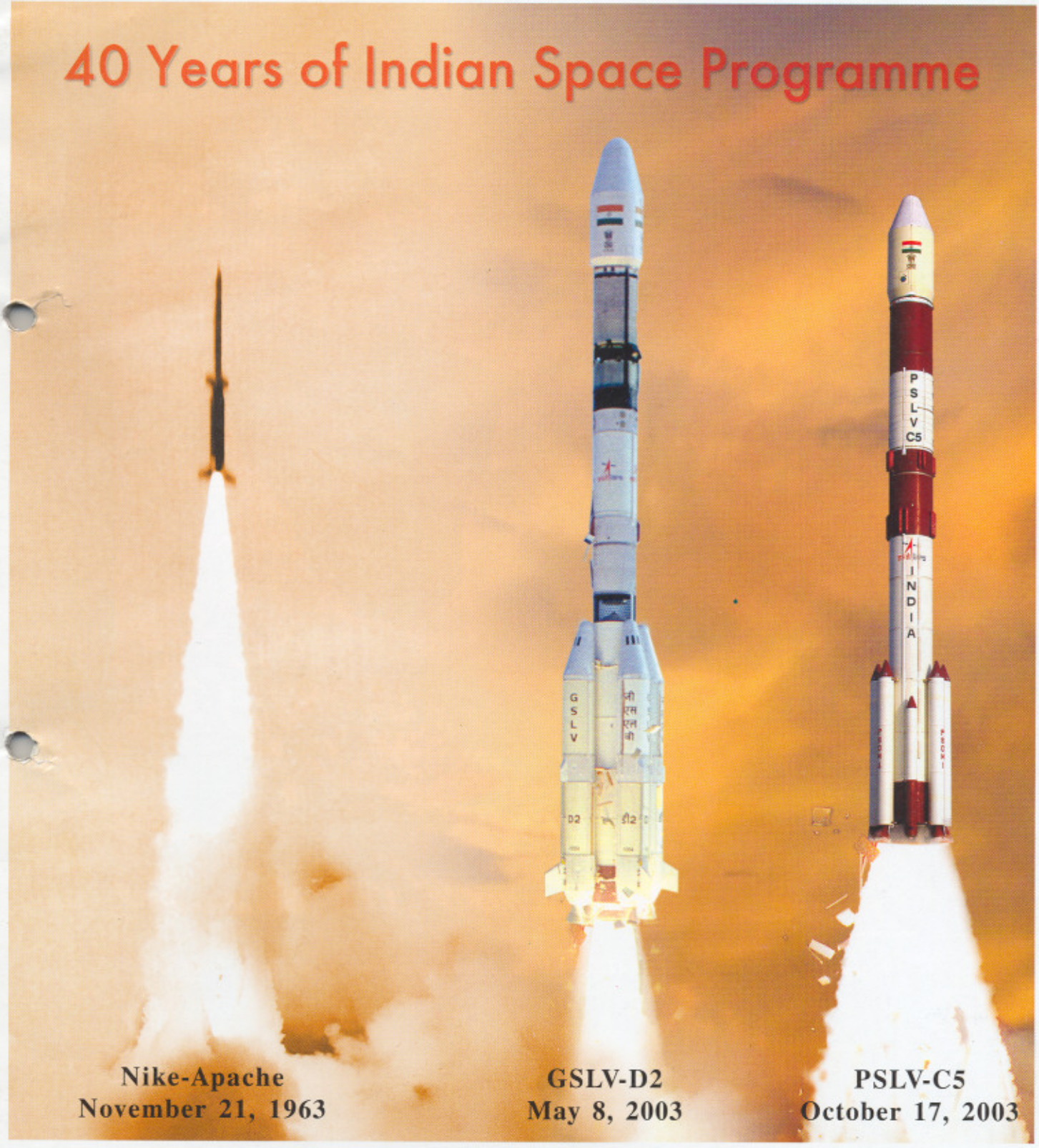
October-December 2003

SPACE india

40 Years of Indian Space Programme



Nike-Apache
November 21, 1963

GSLV-D2
May 8, 2003

PSLV-C5
October 17, 2003

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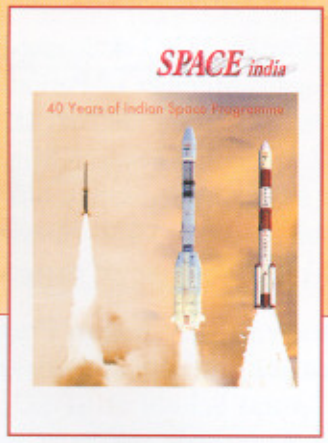
First imagery from RESOURCESAT-1 showing Manasarovar and Rakas Lake in the Himalayas



Cover Page: 40 years of Indian Space Programme – From Sounding Rockets to Satellite Launch Vehicles

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President Visits
Satish Dhawan Space Centre SHAR

The President of India, Dr A P J Abdul Kalam visited the Satish Dhawan Space Centre (SDSC) SHAR at Sriharikota on October 10, 2003. Dr Kalam was shown ISRO's Polar Satellite Launch Vehicle, PSLV-C5, which was in its final stages of preparation for launching India's most advanced remote sensing satellite, RESOURCESAT-1. The President also went around the Second Launch Pad that has reached an advanced stage of completion.

It may be recalled that Dr. Abdul Kalam was the Project Director of India's first Satellite Launch Vehicle, SLV-3, which was successfully launched from Sriharikota in 1980. Since then, ISRO has come a long way in establishing the capability to launch remote sensing satellites into polar orbits using PSLV and communication satellites (upto 2 ton class) into Geosynchronous Transfer Orbit using GSLV, thus making the Indian Space Programme self reliant.

After his visit to the launch facilities, the President addressed the personnel of SDSC at Dr Ambedkar Open Air Theatre. Dr Kalam reminisced his association with the Indian Space Programme. He cited several instances of individuals' commitment and dedication to the task of space programme at various levels, which have made India self reliant in this technology. While appreciating the achievements of ISRO, the President said that ISRO has an important role to play in making India a developed nation by 2020, especially in the areas of resources survey, communication and meteorological services.

Mr G Madhavan Nair, Chairman, ISRO, welcomed the President. Dr K Kasturirangan, Member of Parliament (Rajya Sabha) and former Chairman of ISRO, Mr S Chandramohana Reddy, Andhra Pradesh Minister for Information and Public Relations and senior offici of ISRO were present at the function. Mr K Narayana, Director of SDSC SHAR proposed vote of thanks.

Later, the President proceeded to Dr Brahm Prakash Hall where he interacted with about 250 students belonging to the Space Central School at SDSC and several schools located at Sullurpeta, which is about 17 kilometers from SDSC, SHAR.

The President (Centre) with Mr Madhavan Nair, Chairman, ISRO (Left) and other Senior Scientists of ISRO at PSLV Launch Pad

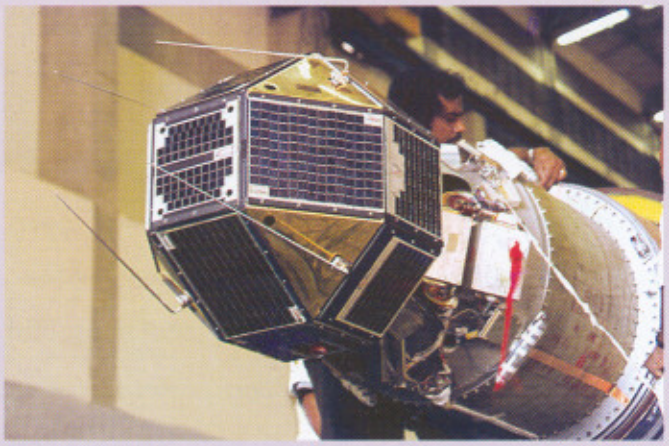
Space Programme and Developed India Vision

President's Address to ISRO Community – Excerpts

... I had the privilege of being a member of this great community for over twenty years. I recall with profound fulfillment my early days in the company of many of you as we were at the starting point of implementing Dr Vikram Sarabhai's space vision. In this island, I have walked with you many times filled with happiness when we succeeded and also we experienced pain when we failed a few times. During all our successes and failures, our great companion was hard work and devotion.

Missions of national importance and significance have been achieved with the given resources due to the highly devoted, expert and dedicated service of the entire space community. From the days of the founder Chairman Dr Vikram Sarabhai, successive Chairmen, Prof Satish Dhawan, Prof U R Rao, and Dr K Kasturirangan have led you with missionary spirit, skill and sensitivity. It had been my privilege to work with all of them in various ways and now I wish once again the present Chairman Mr Madhavan Nair and the space community good fortune and successes in all your new missions. This is my first visit to SHAR centre after it has been named after Prof Satish Dhawan, one of the greatest sons of our country. I cherish every moment of my privileged association with this great technologist, teacher, visionary, administrator and, above all, a wonderful and noble human being. SHAR symbolizes many things to me. It represents the consummation of visions, concepts and high technology; confluence of disciplines and more so of meeting of human minds. You have launched 17 launch vehicles from here attempting the 18th one in a week from now.

... It was on 9th of October 1971 the country witnessed the first ever launch of a sounding rocket - 125 mm in diameter - from SHAR, less than three years after the decision was made to set up the launching station at SHAR. I recollect the pioneering efforts by many stalwarts in building the launch pad and associated facilities. Very soon SPROB was taking shape and other facilities like STEX grew up. I recall the long nights, I and my team used to discuss, the processing and static testing of motors for SLV-3. The untiring efforts by VSSC and SHAR teams ensured that the four types of motors went through their qualification satisfactorily. Parallely, the launch complex facilities were being set up. Along with that, several mechanisms of dealing with a mission, the mission readiness reviews, and the launch authorization board were getting evolved and implemented. The excitement of launch campaign, the tension of count down, the emotions of a launch all have become history and have been deeply etched in my memory. The magnanimity of Prof Dhawan in dealing with



Rohini Satellite integrated fully with SLV-3

the failure of the first launch and his motivating and leading us towards success in the very next flight is one of the basic foundations of a great ISRO culture.

At every stage, SLV-3 team was blessed with some extraordinary courageous people. Mr Sivakaminathan was bringing the C-band transponder from Trivandrum to SHAR for integration with SLV-3. The SLV-3 launch schedule was dependant on the arrival and integration of this equipment. On landing at the Madras airport, the aircraft in which Sivakami was traveling, skidded and overshot the runway. Dense smoke engulfed the aircraft. Everyone jumped out of the aircraft through emergency exit and desperately fought to save himself or herself - all except Sivakami who stayed in the aircraft till he removed the transponder from his baggage. He was among the last few persons to emerge from the smoke and he was holding the transponder close to his chest. This is the level of dedication and the attachment to the project, because people owned this project.

I have witnessed several successful flights and a few failures in this range. The first mission was a failure and we recovered fast and we were ready for the second mission. 18th July 1980 is a memorable day for the entire space community of India. This was the day the space scientists put a 40 Kg Rohini satellite in a low earth orbit through SLV - 3 (Satellite Launch Vehicle) which took off at 0805 hrs; within minutes the satellite was in orbit. This was a great accomplishment for our scientists, especially after an unsuccessful earlier mission on 10th August 1979.

There was jubilation all around. People were thrilled. They were shouting, hugging and lifting each other and were emotionally charged. This was the time Prof Dhawan took me aside and said that we should go to a silent place. Both of us went to the launch pad and sat on the launcher. We watched the waves of the Bay of Bengal in silence. After a few minutes, Prof Dhawan said to me: "Kalam, you know you have been working hard for the last eight years. You encountered a number of problems and failures. You faced them all with utmost courage, patience and perseverance. For all the efforts that you put

The magnanimity of Prof Dhawan in dealing with the failure of the first launch and his motivating and leading us towards success in the very next flight is one of the basic foundations of a great isro culture

in, today we have got the results. I want to thank you for your excellent work. I will remember it and cherish it". I had never come across such a beautiful day till then.

... Another incident I remember is the one that happened during the third launch of SLV-3. The count down sequence was proceeding smoothly. There were two operations to be carried out on the launcher — one for release of the spacecraft umbilical and the other to release the arms holding the vehicle. Both these were pneumatically operated systems remotely controlled from Block House. The arms got released as expected. However the spacecraft umbilical release system failed to respond to the command. This held the count down automatically. There was a suspense on how to go about and the launch managers huddled together to find a solution. Mr M R Kurup and myself volunteered to reach the umbilical system through a ladder to manually release it. Seeing the situation, one young tradesman of SHAR, Mr Pappaiah volunteered to climb on to the launcher and release the mechanism manually. After clearance by the concerned, he accomplished this marvelous feat and the vehicle was launched that day. I can never forget such committed individuals who have been the backbone of ISRO.

... I have been visiting SHAR during almost every campaign. And you have all marched forward steadily and rapidly from those initial beginnings, making every one of us associated with the early days so much proud of you. I have just now seen the professional preparation for the eighth launch of Polar Satellite Launch Vehicle carrying RESOURCESAT. PSLV has become a workhorse and is available not only for national satellites but also for potential commercial satellites. I remember the first successful launch of PSLV on October 15, 1994 with your present Chairman, Madhavan Nair performing the role of Mission Director. Within six months of the second successful development flight of GSLV, which demonstrated the robustness of the design of the vehicle, you are ready for the 8th launch of PSLV. With this you now have two operational vehicles. I also saw the wonderful Second Launch Pad today. It is a remarkable engineering endeavor and a national asset. I congratulate the entire team of ISRO and its partners in making this possible.

Friends, in the last nearly four decades, ISRO has grown from strength to strength to bring the benefits of the relatively new technology of space for the national development. You have made every Indian proud by virtue of your achievements and have ensured a distinct place for India in the comity of nations. In this process you have fulfilled the vision of the founding fathers of Indian Space Programme, Dr Vikram Sarabhai

and Prof Satish Dhawan. With the accomplishments that have taken place in all the aspects of space technology and applications, the country expects more and more from you. The way I know personally about ISRO, I am sure you would more than meet the expectations and make the country proud.

My friend Mr Madhavan Nair, Chairman, ISRO, has briefed me of your future space plans. ... The exploration of the moon through Chandrayaan will electrify the entire country, particularly young scientists and children. I am sure the moon mission is just a start towards further planetary explorations. ... He also told me, that he has got extra 15 kg to allot for any national and international co-operation. I suggested that 15 kg can be allotted for a combined entry package to the moon with a telemetry of at least one channel, with density or pressure measurement or tone ranging alone. This experiment will be very effective since India will be getting the data from the moon's surface.

Personally, I look forward to you coming up with a Reusable Launch Vehicle. Once you bring in a cost-effective Reusable Launch Vehicle, the space applications will grow multifold and in new dimensions hitherto unimagined.

... India has been in the forefront of bringing the benefits of space technology to the common man. Space touches the human beings on his day-to-day life in a variety of ways. I believe that technology is a major enabler for the development of our country. Space technology with its uniqueness can network in many ways. With your strength, you have shown self-reliance in this core area. Even as you do this, there are opportunities to be part of global systems to serve the humanity in general.

The national developmental challenges are many involving integrated action namely: Agriculture and Food Processing, Education and Health care, Information and Communication Technology, Infrastructure and self-reliance in critical technologies. As space technologists, you have the role to play in many areas like education, healthcare, disaster prevention & mitigation, e-governance, urban planning, rural communication, PURA (Providing Urban Amenities in Rural Areas) and importantly Interlinking of Rivers and so on. Technology growth, self-reliance, global co-operation, centres of excellence, networking with industries and academia, contribution to international space law are all parts of this overall goal. The future of space applications for a highly populated nation like India cannot be only in the expanded uses of the now-very-conventional technologies for telecommunication and space imagery. It lies in the design,

I look forward to you coming up with a Reusable Launch Vehicle

development and application of new technologies for innovative missions that must address pro-actively acute problems of rapid depletion of conventional energy sources, drinking water supplies, and deliver solutions for the man-planet conflict that has led to pollution, climatic change and degradation of ecology and the environment.

The ISRO programme upto now has built a capability to build any type of spacecraft system and also launch capability upto GSLV and beyond. Of course with tremendous core competence built in space technology and space systems and integration capability and manufacturing infrastructure coming in the country, it is time for the space programme to add to the economy of the nation. That means, commercially competitive spacecraft, commercially competitive space launch services, will be needed with marketing ingenuity. For this type of mission, we have to create new stream of creative leaders, whose leadership styles move from commander to coach, manager to mentor, from director to delegator and from one who demands respect to one who facilitates self respect.

We have to create new stream of creative leaders, whose leadership styles move from commander to coach, manager to mentor, from director to delegator and from one who demands respect to one who facilitates self respect

... Indian Space efforts are unique in focusing this cutting-edge technology for national development. It has been a pioneering venture always providing challenges. All of you here and in other centres of ISRO along with your industrial and institutional partners throughout the country have immensely contributed to the space revolution in the country. I have cherished my association with you. I see tremendous opportunities for you to contribute to national development.

... We had many successes but a few failures. You are all courageous people involved in huge missions like PSLV and GSLV. I am sure you will succeed with all your expertise and experience, in launching a single stage rocket system with 100 times take off and 100 times landing capability after putting huge satellite systems and spacecraft in the required orbit.

I visualise a scene, in the year 2021, when I will be 90 years old and visiting SHAR Space Port for boarding the Space plane, so that I can reach another planet and return safely as one of the passengers

I visualise a scene, in the year 2021, when I will be 90 years old and visiting SHAR Space Port for boarding the Space plane, so that I can reach another planet and return safely as one of the passengers. I foresee the Satish Dhawan Space Centre, SHAR to grow into an international Spaceport with a capability of enabling launches and landings of the reusable launch vehicles.

I wish every one of you success in all your future endeavours in transforming the nation into a developed country.

PSLV Launches RESOURCESAT-1

In its eighth flight conducted from Satish Dhawan Space Centre (SDSC) SHAR, Sriharikota on October 17, 2003, ISRO's Polar Satellite Launch Vehicle, PSLV-C5, successfully launched the Indian remote sensing satellite, RESOURCESAT-1 (IRS-P6) into an 821km high polar Sun Synchronous Orbit (SSO). The inclination of orbit was 98.76 deg with respect to the equator. The 1,360 kg RESOURCESAT-1 is the most advanced and heaviest remote sensing satellite launched by ISRO so far. PSLV forms an important component of the end-to-end system for natural resource planning and management.

PSLV-C5 lifted off from SDSC SHAR, Sriharikota exactly at the opening of the launch window at 10:22 am with the ignition of the core first stage and four strap-on motors. The remaining two strap-on motors of the first stage were ignited at 25 sec after lift-off. After going through the planned flight events including the separation of the ground-lit strap-on motors, separation of air-lit strap-on motors and first stage, ignition of the second stage, separation of the payload fairing after the vehicle had cleared the dense atmosphere, second stage separation, third stage ignition, third stage separation, fourth stage ignition and fourth stage cut-off, RESOUCESAT-1 was injected into orbit 1080 seconds after lift-off. It was separated after suitable reorientation of the fourth stage-equipment bay combination to avoid any collision with the satellite.

PSLV was originally designed and developed by ISRO to place 1,000 kg class Indian Remote Sensing satellites into polar Sun Synchronous Orbit (SSO). Since its first successful flight in October 1994, the capability of PSLV was continuously enhanced in the past nine years from 850 kg to the present 1,400 kg into an 820 km high Sun Synchronous Orbit. PSLV has also demonstrated multiple satellite launch capability. So far, it has launched seven Indian satellites as well as four small satellites for international customers.

The improvement in the payload capability of PSLV over successive flights was achieved through several means — increase in the propellant loading of the first stage solid propellant motor and second and fourth stage liquid

propellant motors, improvement in the performance of the third stage motor by optimizing motor case and enhanced propellant loading and employing a carbon composite payload adapter. The sequence of firing of the strap-on motors was also changed from two ground-lit and four air-lit to the present four ground-lit and two air-lit sequence.

Specifically, in PSLV-C5, the metallic third stage adapter was replaced by the one built with carbon composites. Also, the liquid propellant second stage was operated at a higher chamber pressure for better performance.

In PSLV-C5 configuration, the 44.4 metre tall, 294 tonne PSLV had four stages using solid and liquid propulsion systems alternately. The first stage was one of the largest solid propellant boosters in the world and carried 138 tonne of Hydroxyl Terminated Poly Butadiene (HTPB) propellant. The maraging steel motor case has a diameter of 2.8 m. The booster was designed for a maximum thrust of about 4,762 kN. Six strap-on motors, four of which were ignited on the ground, augmented the first stage thrust. Each of those solid propellant strap-on motors carried nine tonne of solid propellant and was capable of producing 645 kN thrust.

The second stage employed indigenously built Vikas engine and carried 41.5 tonne of liquid propellant — UH25 (mixture of Unsymmetrical Dimethyl Hydrazine and 25% hydrazine hydrate) as fuel and Nitrogen tetroxide (N_2O_4) as oxidiser. It was designed to generate a maximum thrust of about 800 kN.

The third stage used 7.6 tonne of HTPB-based solid propellant and was capable of producing a maximum thrust of 246 kN. Its motor case was made of polyaramide fibre. The fourth and the terminal stage of PSLV had a twin engine configuration using liquid propellant. With a propellant loading of 2.5 tonne (Mono Methyl Hydrazine and Mixed Oxides of Nitrogen), each of those engines had the capability to generate a maximum thrust of 7.3 kN.

The 3.2 m diameter metallic bulbous payload fairing of PSLV was of isogrid construction and its function was to protect the spacecraft during the atmospheric regime of flight. PSLV employed a large number of stage auxiliary systems for stage separation, payload fairing separation and jettisoning, etc.

PSLV-C5 control system consisted of: a) First stage: Secondary Injection Thrust Vector Control (SITVC) for pitch and yaw, reaction control thrusters for roll

RESOURCESAT-1 sitting on top of PSLV-C5 fourth stage

b) Second stage: Engine gimbal for pitch and yaw and, hot gas reaction control motor for roll control c) Third stage: flex nozzle for pitch and yaw and PS-4 RCS for roll control and d) Fourth stage: Engine gimbal for pitch, yaw, and roll and, on-off RCS for control during the coast phase.

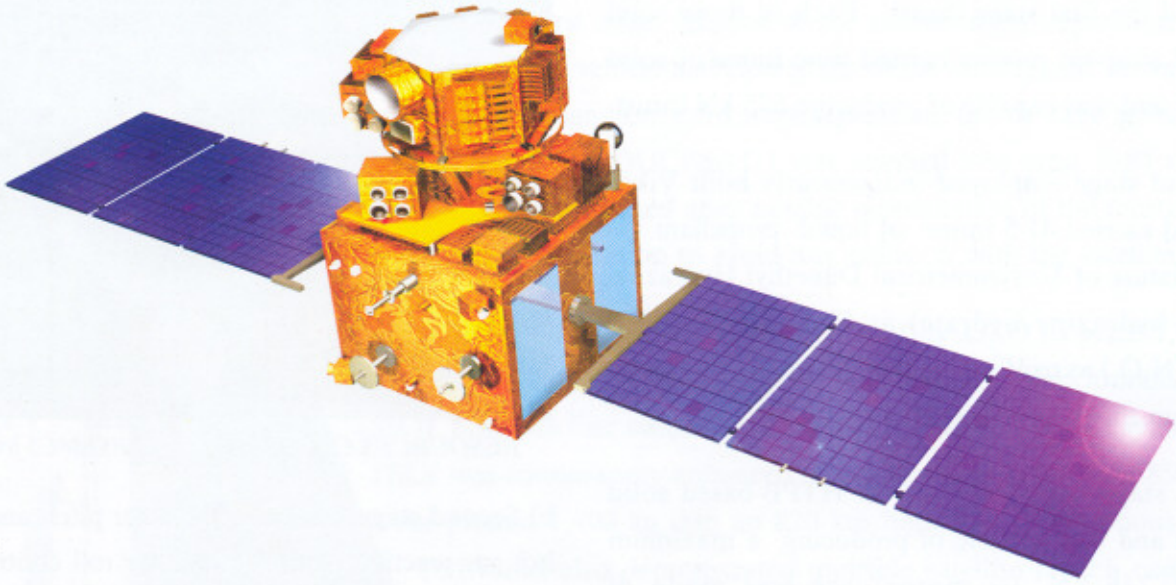
The inertial navigation system in the equipment bay, which was located on top of the fourth stage, guided

the vehicle from lift-off to spacecraft injection into orbit. The vehicle was provided with instrumentation to monitor the vehicle performance during the flight. S-band PCM telemetry and C-band transponders catered to this requirement. The tracking system provided real-time information for flight safety and for preliminary orbit determination once the satellite was injected into orbit.

With seven successive successful launches, PSLV has proved itself as a reliable vehicle for launching Indian remote sensing satellites. Besides, it has been used for launching a geosynchronous satellite, KALPANA-1. ISRO has proposed to use PSLV for India's first unmanned mission to moon, Chandrayaan-1.

The President and the Prime Minister watched the launch of RESOURCESAT-1 by PSLV-C5 live on TV at Delhi. Immediately after the satellite was placed in orbit, the President and the Prime Minister congratulated ISRO Scientists and all others involved in the mission. They conveyed their messages over telephone to Mr G Madhavan Nair, Chairman, ISRO. Mr Satyabrata Mookherjee, Minister of State (Space), who was present at SHAR to witness the launch, stated that with that successful launch, the seventh in a row, the reliability of PSLV as a workhorse launch vehicle for launching our remote sensing satellites was unequivocally demonstrated.

RESOURCESAT-1



The tenth in the Indian Remote Sensing satellite (IRS) series, RESOURCESAT-1 is the most advanced remote sensing satellite built by ISRO. It is intended to not only continue the remote sensing data services provided by IRS-1C and IRS-1D, both of which have far outlived their designed mission lives, but also to vastly enhance

the data services by providing imageries with improved spatial resolution and additional spectral bands. RESOURCESAT-1 carries three cameras:

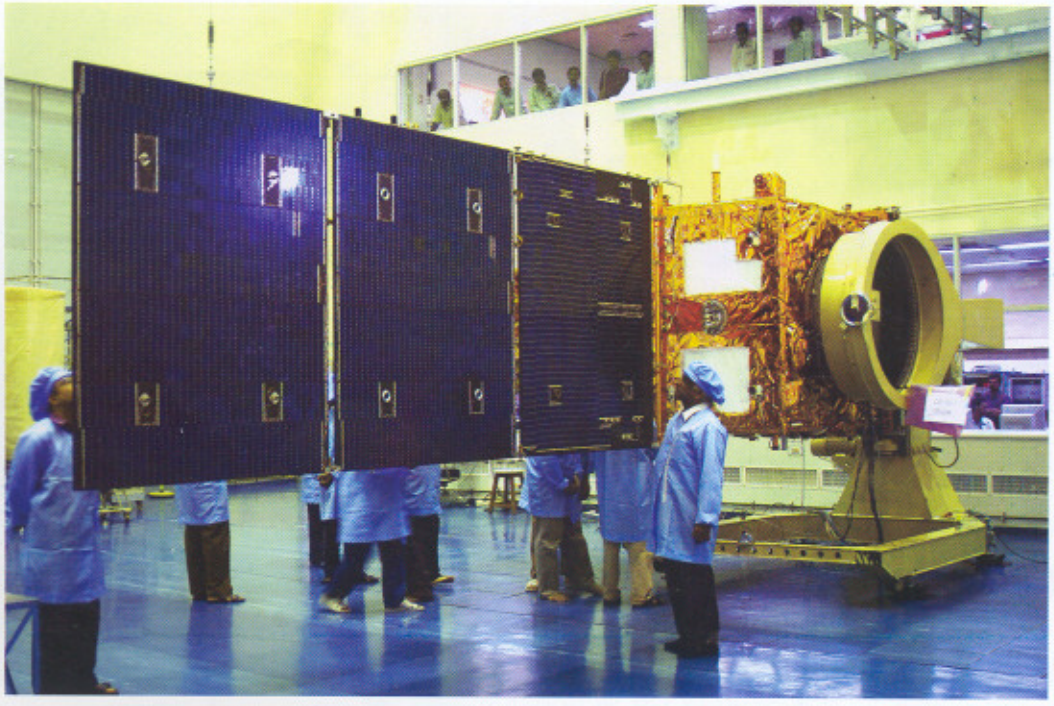
- A high resolution Linear Imaging Self Scanner (LISS-4) operating in three spectral bands in the Visible and Near Infrared Region (VNIR) with 5.8 metre spatial resolution and steerable up to ± 26 deg across track to obtain stereoscopic imagery and achieve five day revisit capability
- A medium resolution LISS-3 operating in three spectral bands in VNIR and one in Short Wave Infrared (SWIR) band with 23.5 metre spatial resolution
- An Advanced Wide Field Sensor (AWiFS) operating in three spectral bands in VNIR and one band in SWIR with 56 metre spatial resolution.

RESOURCESAT-1 also carries a Solid State Recorder to store the images taken by its cameras which can be read out later to the ground stations.

Soon after its injection into orbit, the solar panels on board RESOURCESAT-1 were deployed automatically to generate the necessary electrical power for the satellite. Subsequently, three-axis stabilisation intended to point the spacecraft accurately towards the earth was carried out. Right from launch, the satellite health is being continuously monitored from the Spacecraft Control Centre at Bangalore with the help of ISTRAC network of stations at Bangalore, Lucknow, Mauritius, Bearslake in Russia and Biak in Indonesia.

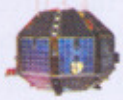
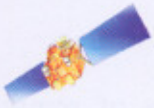
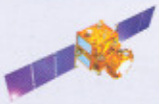
On November 10, 2003, all the three cameras on board RESOURCESAT-1 were tested and the imagery received at the National Remote Sensing Agency's ground station at Shadnagar near Hyderabad, indicated excellent performance of the cameras. With its unique combination of cameras providing imageries with high spatial, spectral, temporal and radiometric resolutions, RESOURCESAT-1 is expected to enhance the remote sensing applications, especially, in the fields of agriculture, land and water resources management, and disaster management.

More satellites for a variety of remote sensing applications are in the pipeline. CARTOSAT-1 with a high resolution camera for mapping applications is planned for launch in the coming year, which



RESOURCESAT-1 undergoing prelaunch tests at ISRO Satellite Centre

Indian Remote Sensing Satellites

Sl No	Satellite	Launch Date	Launch Vehicle	Remarks
1.	 Bhaskara-1	Jun 7, 1979	Intercosmos (USSR)	Experimental
2.	 Bhaskara-2	Nov 20, 1981	Intercosmos (USSR)	Experimental
3.	 IRS-1A	Mar 17, 1988	Vostok(USSR)	Mission completed
4.	 IRS-1B	Aug 29, 1991	Vostok (USSR)	Mission completed
5.	 IRS-1E	Sep 20, 1993	PSLV-D1	Could not be placed in orbit
6.	 IRS-P2	Oct 15, 1994	PSLV-D2	Mission completed
7.	 IRS-1C	Dec 28, 1995	Molniya(Russia)	In service
8.	 IRS-P3	Mar 21, 1996	PSLV-D3	In service
9.	 IRS-1D	Sep 29, 1997	PSLV-C1	In service
10.	 IRS-P4 (OCEANSAT-1)	May 26, 1999	PSLV-C2	In service
11.	 TES	Oct 22, 2001	PSLV-C3	In service
12.	 RESOURCESAT-1 (IRS-P6)	Oct 17, 2003	PSLV-C5	In service

will be followed by an even more advanced version, CARTOSAT-2. Besides, the development of a Radar Imaging Satellite, RISAT-1, which will have the capability to take imageries even under cloudy conditions as well as during day and night has also been approved.

ISRO Commemorates 40th Anniversary of First Sounding Rocket Launch

It was on November 21,1963, that a Nike-Apache rocket roared into the skies over Thumba that heralded the beginning of the Indian space programme. In the four decades since then, more than 3000 sounding rockets have been flown for various scientific experiments. More important is that India has taken significant strides in other areas of space technology as well bringing several benefits to the nation.

The Vikram Sarabhai Space Centre, Thiruvananthapuram, which grew around the Thumba Equatorial Rocket Launching Station, commemorated the 40 th anniversary of the first sounding rocket launch on November 21, 2003. Mr G Madhavan Nair, Chairman, ISRO inaugurated the celebration. Several eminent space personalities, who were associated with the Indian space programme in its early stages of evolution, shared their reminiscences. There was a re-enacting of the first sounding rocket launch with the flight of a RH-200 rocket in the afternoon.

Addressing the gathering over telephone from New Delhi, the President of India, Dr A P J Abdul Kalam, urged the scientists to see how space technology could be used to realise the vision of making India a developed country by 2020.

Mr Madhavan Nair, Chairman, ISRO inaugurating the celebration

Mr R Aravamudan, Hon. Advisor, ISRO, who was associated with the Indian space programme even before the first sounding rocket was launched from India, delivered the Keynote Address during the VSSC Celebration.

Space India reproduces Mr Aravamudan's address:

A Space Saga - The Thumba Years

Keynote Address by Mr R Aravamudan

Forty years in the life of a human being marks the attainment of optimal mental and physical capacity and emotional maturity. Socially, by the time one is forty, one is accepted as a respectable member of the community and looked upon to provide leadership. The birth and growth of ISRO in the past forty years is analogous to this.

Mr Aravamudan & Mr Abdul Kalam toiling to assemble a sounding rocket payload

ISRO has seen distinct phases of development in these four decades. The first decade (1963 - 73), which I would call the Vikram Sarabhai decade, was one of vision, dreams and hopes. This period saw the visualisation of the space profile, the sowing of the seeds of programmes, the harnessing of resources and the rallying of the key manpower.

The second decade (1973-1983) has been the decade of the consolidation of the programmes. I would call it the decade of Satish Dhawan. Projects were delineated,

A youthful Madhavan Nair absorbed in work

government approvals were obtained and the end users of the applications were involved. Early programmes like the SLV, Aryabhata and Bhaskara satellite launches and application programmes like the SITE came to fruition. Foundations were laid for the operational launch vehicle and satellite projects.

The third decade (1983-1993), which was the U R Rao decade, saw peak activity in terms of the development of the subsystems and components of launch vehicles, spacecraft and ground segments. Some operational satellites were established in the geosynchronous and low earth orbits. Regular communications and remote sensing operational services to the nation were established. Experimental launchings of the Indian launch vehicles yielded data on their performance, validating some design elements and revealing inadequacies in a few others, which were subsequently rectified. This was a rich learning phase in our ambitious future programmes.

The fourth decade (1993-2003), which I would call the Kasturirangan decade, saw rich returns from the investments made in the earlier decades. Resounding successes in the PSLV and GSLV programmes and the consolidation of the indigenous capability in the launch vehicle and space systems area bore ample testimony to the attainment of quality and reliability with adequate safety. India became self reliant in Space services and even started providing launch services for the international community.

We are now at the threshold of the fifth decade. Can I call it the Madhavan Nair decade? The Indian Space programme today has become a byword for excellence and is a leading example of how a nation can develop self-reliance in a strategic technological area, starting from scratch and overcoming various obstacles in spite of embargoes and technology denial regimes.

The saga of Indian Space Research has been an exciting one. I was privileged to have been a participant right from its inception. In fact, I was there even before it all began. I am therefore thrilled to share with you some of the excitement of those initial days when we were still a small, close-knit family group.

Those were the days when the core team consisted of a mere handful of young men. We operated with total informality on a budget of a few lakhs. ISRO has, today, turned into a giant with staff strength exceeding 16,000 full time employees and budgets running into thousands of crores per year. Obviously, the informality of those

Readying a Sounding Rocket for launch

days cannot exist in today's environment. ISRO has necessarily turned into a well structured entity.

My induction into the space programme was in late 1962, even before Thumba was formally chosen for locating a rocket station. I was a young electronics engineer working in the Reactor control division of the Department of Atomic Energy at Trombay, when word got around that Sarabhai was looking for fresh electronic engineers to form a core team to set up a small Rocket Launch Pad in South Kerala. This demand came from a group of international geophysicists who wanted to conduct *in situ* vertical soundings from the Geomagnetic Equator.

I was interested in the opportunity since I wanted to get away from the crowd and noise of Bombay and green and peaceful Kerala offered a perfect alternative. I was asked to travel to Ahmedabad and meet Dr Sarabhai to get to know the details at first hand.

I took the Bombay-Ahmedabad train and checked into a seedy hotel. I took an autorickshaw to Navrangapura where the Physical Research Laboratory was situated. The first person whom I met was Professor E V Chitnis, a handsome young man who said that Dr Sarabhai would meet me shortly.

As I was hanging around in the corridor waiting, a Standard Herald car with an open top stopped at the portico and a fair and dashing looking young man dressed in white shorts and shirt stepped out and asked, "Are you Aravamudan?" I said yes and he immediately asked me to hop into the car. He drove up a short distance to an Instrumentation trailer from NASA parked in the campus. Later, I learnt that this was called the Microlock Receiving Trailer. He led me inside and personally explained to me the workings of this trailer and how it received signals from scientific satellites. He then went on to explain how he was planning to do scientific experiments from Kerala, perhaps from near Trivandrum, using rockets carrying measuring instruments. He also described the launch pad, telemetry receiving station, radar and Doppler velocity and position system he hoped to install.

It all sounded like science fiction to me, but I was quite interested mainly because if I took the assignment, it meant my moving down South. Also it involved a spell of training in NASA which sounded quite exciting. But, more than anything else, it was the Charisma of Sarabhai ...the gleam in his eyes when he described his plans ... and his sincerity which attracted me.

My colleagues at DAE cautioned me against leaving a permanent position at Trombay. The Rocket Programme was uncertain, they said and could fold up. But, my mind was made up.

Towards the end of 1963, the preparations for the first launching from Thumba were at their peak. The Nike-Apache Rocket had been flown to Trivandrum from USA and the Vapour Cloud payload had reached. Being hazardous items, the transportation of these from the US was in itself a pioneering effort and many a tale could be written on this.

A Rohini Sounding Rocket soars into the sky

Once the rocket was launched, there was no telemetry or radar tracking, only photography from three stations of the Vapour Cloud. The orange Vapour trail was visible from all over Kerala and parts of Tamil Nadu. This created great excitement. Since the common public had never seen such a sight before, it also gave rise to some hilarious newspaper reports. In fact, the Kerala Legislative Assembly, which was in session then, apparently adjourned temporarily to have a good view of the bright Vapour trail in the western sky!

NASA personnel who had gone to Thumba for the launch had nice stories to tell us about the beautiful Thumba beach with coconut trees all over. They also claimed that they launched the Nike Apache with the help of bullock carts for transportation and their own pocket knives for tools.

Although I was born and bred in the South, I had never visited Kerala before. I had always lived in big cities. First Chennai, then Bombay and later, a brief stint in the US. The contrast between these big cities and Trivandrum was quite stark.

Although Trivandrum was the state capital, it was a sleepy and slow town with nineteenth century tiled houses lost amidst coconut palms. The roads were narrow and curvy with sharp turns and fast changing slopes. For young bachelors like us, who knew no cooking, there were hardly any eating places. All we had were lodging houses with minimal facilities.

At the Rocket Range, the Launch Pad and the Block House had been built and the main roads were laid. But the approach to Thumba was very circuitous. The present road via Veli was not laid and there was no bridge over the Veli Lake.

We had to make use of Public Transport as there were no official vehicles yet and no canteen. So, our day began with a quick breakfast of Idli Sambar at the Railway Station Canteen, which was the only place where we could get food to our taste. We would then pack some snacks and lunch from the same canteen and go to the bus stand, to catch a moffusil bus to

Late Mrs Indira Gandhi at Thumba

Kazhakkutam. We would get down at the bus stand there and walk about a kilometre or so to the range. The whole trip took about an hour.

There were no buildings yet in the range. Our first office was in the Bishop's House and the Church Building. The range was quite large in area and the only means of transport within the range was by bicycle. Those like Kalam, who could not cycle, had to hitch rides with others.

There were no strict working hours and work went on around the clock. Soon the range acquired a Jeep in addition to a Standard Van and these were pressed into round the clock duties. When we got the first bus a few months later, it was a major relief to the employees.

Over the next year, the basic facilities at the Range were established. This included the NASA instrumentation facilities such as the telemetry station, the DOVAP trailer and the MPS 19 radar. The Russians provided a MINSK computer and an Mi-4 helicopter. The French gave us a launcher and a high-speed camera. Soon we had a sea going vessel for range safety surveillance. A Control Centre building was put up on the beach and this is where the first offices and laboratories of the range personnel were located.

During the second half of the sixties, the rate of launchings picked up. Scientists from the US, France, USSR, UK, Germany and Japan brought their payloads and sometimes their rockets for conducting a variety of experiments. The United Nations acknowledged that TERLS was now truly a facility dedicated to the cause of the peaceful use of space. An international advisory panel of eminent scientists from all over the world was formed to periodically meet in Thumba and guide the facility.

It is nice to recall a typical launch day. H G S Murthy was the test Director, coordinating the overall launch activity. Easwardas was in charge of the Assembly and Launch of the rockets. I was the Head of the Ground Support Division which meant that I was in charge of the ground instrumentation like telemetry, radar tracking, timing, intercom and so on. Abdul Kalam was the Range Safety Officer, whose job was to make sure that land, sea and air were clear prior to the launch. His inputs to this were from visual sightings, reports from the helicopter and sea vessel and phone messages from the Airport and other agencies.

The initial launch campaigns provided a lot of learning opportunities especially when serious programmes were started to indigenise the hardware. We started in a small way to manufacture rockets, payloads, instrumentation and ground systems. During this phase we had many incidents which provided us with hard lessons. I cannot, for instance, forget the day when we were launching a small rocket, which required a siren to be sounded three minutes before the launch. When one of my colleagues pressed the siren switch, a thundering noise was heard and the rocket zoomed up. Fortunately it was pointing

in the right direction and no one was hurt and no harm was done. The Test Director, Mr Murthy, was heard asking anxiously, what the big sound was about. We learnt that day, how important it was to isolate the ground leads of the firing circuits from the general ground.

Then there was the series of Nike-Apache launchings with Vapour Cloud payloads triggered by locally designed ignitors. The rockets were to be fired successively. The first launching took off well, but there was no payload release. Determined not to be deterred by a single failure, the order was given to go ahead with the next firing. But, alas! That was also a failure. It then occurred to us to carefully examine the ignitor in the laboratory. To our dismay, we found that the ignitor did not work in a vacuum, while it was fine under normal pressure. The ignitor design was modified and then it rted functioning well in actual flights.

There were, fortunately, no major accidents during the launchings, although there were cases when the rockets went astray and parts were picked up from the surrounding areas. We also worked out a regular system of compensation for fishermen who claimed that their nets had been damaged by rocket debris!

The mid-sixties saw the setting up of the SSTC and initiation of the development of the SLV. Surveys for the Satellite Launch Range were conducted. Towards the late sixties, Sriharikota was identified as the ideal location.

Sarabhai attracted young Indian scientists and engineers m all over the world for the programme. To start with, these hi-tech specialists did not have places to work from. They were housed at first in the Church Building, where special cubicles were built for them.

The initial training and experience gained by the launch team came in handy for the planning and development of the Launch Vehicle, Spacecraft and the Range. Members of the original team were assigned various development tasks. I myself was asked to start the development of the Radar Tracking system for SHAR, in addition to my other responsibilities.

The visit of Dr Sarabhai to Thumba used to be a major event and would trigger feverish activities.

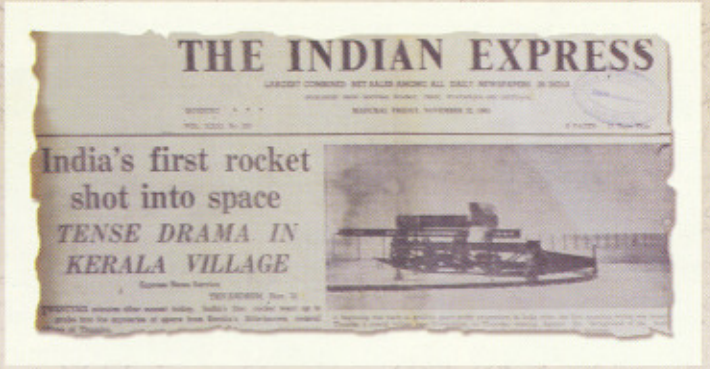
Mr Atal Bihari Vajpayee visiting Thumba in the early 70s

Fresh development proposals would be churned out by the dozen. Some of these would be variations of the same basic proposal. A few live tests would be rigged up to press home a point. Dr Sarabhai would give the same serious attention to all the proposals and clear a large number of them to proceed further. Meetings with him would continue well into midnight. They would start again at dawn the next day and sometimes continue at the Airport until he boarded the aircraft. Some meetings took place on the aircraft itself!

I must describe a particular event involving me to bring out the extraordinary way he worked in those days. The European Launcher Development Organization (ELDO) had just decided to abandon its programme to develop an all-European Satellite Launch Vehicle after a series of failures of its developmental launches from the Woomera Range in Australia. This was in the late sixties. They were scrapping brand new satellite telemetry and tracking stations, which were up for auction as scrap. Sarabhai thought that this was a great opportunity for India to acquire the system at a low price for our own programmes.

We suddenly received a call from Sarabhai to proceed to a remote Northern Australian station called Gove where the auction was being held and bid for the system. A colleague and I were to meet Sarabhai at Bombay

and then proceed to Australia where Mr H G S Murthy would join us. We reached Bombay and were asked to go to the Reserve Bank of India to collect the foreign exchange for bidding at the auction. We called on the Reserve Bank official and explained our requirement. Those were the days of stringent FE regulations and severe scarcity of hard currency. The Reserve Bank official looked at us in amazement and disbelief for having the audacity to demand the release of FE to two unknown novices, that too in the form of an open Demand Draft for bidding at a foreign auction. This was unheard of and he brusquely told us to vacate the premises. We did not know what to do and did the only thing that we could think of, namely, to telephone Dr Sarabhai and give him the bad news. Sarabhai asked us to wait in the outer office and said that he would get back to us soon. Sure enough, we had a feedback soon.


THE INDIAN EXPRESS

India's first rocket shot into space

TENSE DRAMA IN KERALA VILLAGE

Exciting News

Not from Sarabhai, but from the same official who asked us to get out. He rushed out from his office and personally requested us to accompany him inside. He told us to kindly wait for a few minutes and the demand draft would be ready. He wanted to know on whose name should the draft be made.

We were wondering at the sudden transformation of the official. Only later we learned what transpired. Apparently Sarabhai had telephoned the Union finance minister, at that time Mr Y B Chavan, and he, in turn, had personally telephoned the poor official to immediately release the FE — All this while we were standing in the corridor! Such was the charisma and style of working of Dr Sarabhai!

This story would not be complete if I did not describe what happened in Australia subsequently. When we landed at the Gove station, we found to our dismay, a whole array of racks and antenna structures dismantled and piled up in the yard. They had decided that no one would be interested in buying at second hand the highly specialized equipment and decided to chop it up into bits and sell it to scrap part component dealers. We were devastated that so much of our unprecedented effort had gone to waste. Then came a flash of hope. The ELDO official asked us not to worry. He had another identical station intact which he would offer us for a negotiated price. We were then taken from North Australia to the city of Adelaide in the south where we finally managed to negotiate the purchase of a complete ground station at about 10 percent of its original cost and arranged to ship it to Madras. This was later received and installed at SHAR as the first Satellite Telemetry Ground Station.

After the tentative location of Sriharikota as the n launch site, the very first visit to the as yet unexplored area by Dr Sarabhai stands vividly in my memory. The approach road to SHAR from Sullurpeta was not yet laid and so during summer, when the waters had receded, a kachcha road had to be laid using dried leaves and sticks all the way from Sullurpeta over the Pulicat till the Buckingham canal. A temporary bridge had been rigged up of planks laid over boats stacked abreast.

A reception was accorded to Dr Sarabhai at Sullurpeta and a procession of more than 30 jeeps drove over rough terrain to the entrance of the present range, where the forest rest house was located. The procession then drove straight over the sand to the sea front. On the way, quite a few vehicles broke down.

Undeterred, Dr. Sarabhai proceeded on foot and walked along the beach for atleast 10 kilometers, surveying the area. When the party returned to the Guest House, a grand feast was awaiting them, courtesy the Andhra government. After the feast, Sarabhai addressed the local Yanadi tribals in English, the local collector providing the translation. The tribals, who had not ventured much outside their island, believed Sarabhai was the Raja who was going to change their lives.

Towards the end of the decade, the organization of SSTC increased in tempo, the buildings at Veli were ready and the R&D groups were in place. The Rocket

Fabrication Facility and the Rocket Propellant Plant were established and the SHAR facilities started taking shape.

After one of his routine visits to Thumba on December 31, 1971, Sarabhai asked some of us to meet him at the Kovalam palace where he usually stayed (the hotel had not come up at that time) for discussing various proposals. Our discussions went on till well past midnight and I left for home terribly exhausted. By 6.30 am the next day, we were informed that Sarabhai had passed away. It was a great shock and we were all caught off guard. Suddenly the central pillar, which supported the edifice, had collapsed. There was utter despair all round. I clearly recall the day after his demise, when all the senior persons were at Ahmedabad attending the funeral. I was at Thumba, the senior most person on hand. The CISF was just then being inducted into TERLS.

The open sea front of Thumba was causing serious security problems and it was decided to try and locate concrete tetrapods across the beach and as an experiment one tetrapod was moved to the beach. This was strongly opposed by the local fisher folk. There was some clash and the police had to resort to firing to quell the rather excited mob. There was a terrible uproar in the local area and it took a long while to pacify the people, although the plan for locating tetrapods was itself given up. Occurring, as it did, hardly a day after the tragic death of Sarabhai, this caused tremendous distress in our minds.

The Organisation had, however, quickly recovered from this shock and after a brief spell of leadership by Prof M G K Menon, was firmly taken charge of by Prof Satish Dhawan ably aided by stalwarts like Dr Brahmprakash, Prof Yash Pal and others. Decades followed and the Organization steadily evolved into the giant multidisciplinary entity that ISRO is today.

Much of the dreams of the Pioneers have been realised and exceeded. ISRO today is a byword for Excellence and is an example of how a dedicated group of men can achieve tremendous results in adverse circumstances, given the motivation and the leadership.

Mr Madhavan Nair (right) and Dr B N Suresh, Director VSSC (second from left)enjoying the Reminiscences of an exciting era

For me, personally, it has been a most satisfying and rewarding experience. I have been an active participant in every facet of this adventure. What is more exciting is the opportunity given to me to continue to be actively involved in the programmes of ISRO, much after my normal tenure.

I thank the organisers for inviting me to these celebrations and allowing me to share some of the thrill of the early days.

ISRO Satellite to Carry Israel's Scientific Instrument

ISRO and the Israel Space Agency (ISA) have agreed to cooperate in launching the Tel Aviv University Ultra Violet Experiment, TAUVEX, on board ISRO's GSAT-4 satellite planned for launch by India's Geosynchronous Satellite Launch Vehicle (GSLV) during 2005. An MOU for including the TAUVEX on GSAT-4 was signed on December 25, 2003 by Mr G Madhavan Nair, Chairman, ISRO and Mr Aby Har-Even, Director General, ISA at Antariksh Bhavan, Bangalore, the Headquarters of ISRO. ISRAEL's Minister for Science and Technology, Mr Eliezer Sandberg was present at the signing ceremony. The MOU follows the cooperative agreement signed between ISRO and ISA in October 2002. GSAT-4 will incorporate the TAUVEX along with ISRO's own experiments including Ka-band transponder.

The TAUVEX is a telescope that will image the sky in the Ultra Violet (UV) spectrum. The data from the telescope will help in solving astrophysical questions related to star formation, history of galaxies, physics of giant black holes, etc. It could also help in guiding other space telescopes towards selected interesting objects in the sky. The scientific data from TAUVEX will be useful for the Indian scientists to analyse the UV radiation from stellar objects and prepare the scientific community to receive and analyse data from India's own astronomy satellite, ASTROSAT, which is also planned to carry an Ultra-Violet Imaging Telescope besides X-ray instruments.

The data from TAUVEX will be shared between scientists of both the countries.

Mr G Madhavan Nair, Chairman, ISRO (left) and Mr Aby Har-Even (right) sign the MOU as Mr Eliezer Sandberg (center) looks on

The firing in progress

Cryogenic Engine Undergoes Endurance Test

The indigenous Cryogenic Engine for Geosynchronous Satellite Launch Vehicle, GSLV, crossed an important landmark on December 5, 2003, when it successfully underwent an endurance test for more than 16 minutes at ISRO's Liquid Propulsion Systems Centre (LPSC) at Mahendragiri in Tamil Nadu. The test involved the firing of the Cryogenic main Engine with 7.1 tonne thrust for 1,000 seconds, simultaneously with two 200 kg thrust Cryogenic Steering Engines, all mounted on a single block as used in the actual GSLV flight stage developing 7.5 tonne total thrust. The steering engines are used to control the flight path of GSLV during the third stage thrusting.

The turbo-pump fed, regeneratively cooled engine for the cryogenic stage is required to burn for a duration of 720 seconds in actual flight. The latest test marks the conclusion of the qualification of the cryogenic engine, which has undergone accumulated 6,000 seconds testing so far in three hardware.

The development of the cryogenic stage system is also progressing well at LPSC, Thiruvananthapuram. This cryogenic stage, using a combination of two tonne liquid hydrogen and 11 tonne liquid oxygen, is intended to replace the Russian supplied cryogenic stage in GSLV.

Those early days.....
Transporting a Sounding Rocket nose cone in Thumba