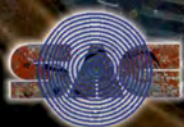


Harnessing space technology for societal benefits

-A brief history of SAC



Space Applications Centre (ISRO), Ahmedabad

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-A brief history of SAC

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**Space Applications Centre
Indian Space Research Organization
Ahmedabad**

January 2011

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PREFACE

SAC came in existence in 1972 as a Centre of ISRO. The activities preceding SAC started in early sixties by Dr. Vikram Sarabhai were merged to form this Centre. The heritage of SAC in that sense is so deep that history of SAC in a way is very akin to the history of Indian Space Program.

SAC was born with and continues to retain its characteristic diversity of activities and people which has led to an impressive array of its achievements in all axes of engagement. SAC pioneered earth stations and continues to excel in complex antenna technologies, started with simple payloads of APPLE and now designs the complex instruments for advanced satcom missions, designed first TV tube sensor of India and now makes the sensors that vie with best in the world and finally SAC is taking lead in space navigation segment and ground segment engineering. The vibrancy of SAC remains unabated and the future is promising.

Capturing history of so many achievements and rich traditions of such a wonderful centre is a challenging work. This volume is the first attempt in capturing the broad sweep of evolution of SAC over fifty years. The authors have deliberately toned down the technical intricacy, put off the claim to exhaustiveness and written in a narrative style of presentation to suit the intended audience of general public. Another interesting aspect of the book is the summary of interviews of former directors of SAC and DECU, which by itself is a valuable record of pioneers' versions.

I congratulate the team of authors for writing the history of SAC/DECU in popular format in a record time. The painstaking work of compiling the book from diverse inputs is highly appreciated. I hope that the book will give a view of history to public and students and inspire future generation of SAC and ISRO.

I wish all readers a pleasant and informative tour of SAC history!

R R Navalgund
Director, SAC



ACKNOWLEDGMENTS

The task of writing the history of SAC/DECU in multimedia and document form was assigned to different teams by Director SAC in the month of August 2010 for their releases coinciding with 'Back to the Future' function and inauguration of new auditorium in the later part of the year. The function was to feature all former directors and hence a record of history was thought appropriate.

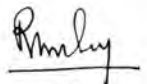
The book team meetings led to co-options and the final team strength went up to ten. This included, apart from core PPG team of Shri S. Ramdass, Dr Puneet Swaroop and myself to include Shri B.N. Mankad for sensors, Dr Rashmi Sharma for applications, Shri Nilesh Desai for microwave sensors; Shri R.G. Gade and then Shri SL Rajashekar for DECU, Shri Arun Bindal for technical facilities and Shri C.N. Lal for welfare. The DECU team lead by Shri Nitin Bhavsar went on to interview former directors and provided the audio records/transcripts. These were pruned to a manageable size and have been featured in the book.

A great dilemma lay in the overall style of the presentation. The current format of writing a chapter with an interesting snapshot and building on that interest to serve the reader with useful information in simple language was thankfully agreed to in general and by Director who was kept in loop as the book was gaining chapters.

It has been a great privilege to work on this project as it brought the greatness of pioneers in sharp focus, increased our awareness of the great heritage and finally made us more enlightened. The purpose will be served if the readers feel like us.

We would like to thank Director, SAC for this opportunity and for constant guidance and encouragement. A large number of people have helped us mainly Shri V S Palsule, Shri S S Valdiya, Dr S B Kibe, Shri A S Kirankumar and we want to thank them all. Shri N.S. Pillai, former Group Director, PPG was kind enough to read the manuscript and provide useful comments. Dr. Namita Priyadarshree, Controller, SAC, Dr. K.S. Dasgupta, Dy. Director, SNPA and Dr. J.S. Parihar, Dy. Director, EPSA gave encouraging comments. Ms Harshida Modi and Ms Priya have assisted in our work.

We acknowledge valuable inputs and suggestions from many colleagues whose names do not feature here.


R P Dubey

Group Director, PPG

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Chapter 1

Beginnings of Space and Technology Applications: The era of pioneers

Snapshot: History walks out of the mighty doors

Themes:

- In the very beginning
- The mind, heart and spirit of pioneer
- PRL: The Cradle of India's space program
- Era of space applications
- Nursery beds of SAC
- Space on track

History walks out of the mighty doors

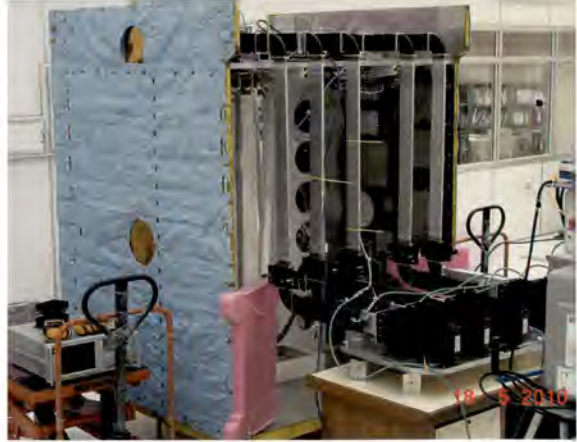
*I*n its sprawling campus, SAC has many functional buildings with hundreds of doors through which thousands of its staff pass in and out every day. But, there are three giant 6-metre tall, towering doors of metallic shutters on three buildings which open on rare occasions. But whenever one of these doors opens, it becomes a special occasion - not only because their occupants will go hundreds of miles up in sky and travel millions of miles but because such openings symbolize the dream come true for a large team. More often than not, opening of these doors have marked the ushering of new era of space based services in the country and sometimes in the whole world. These giant doors simply create history.

Today, as the July sun climbs to pre-noon warmth, one of these doors on the back of building 52 has been opened to hoist its occupant on a waiting trailer truck. With three green flags going up in the air, the huge truck crawls an inch to crack the coconut under its giant front tyre. The ceremony of flagging off the most complex payload to date – the first ever space borne imaging radar of India, is over. The truck moves out from the backyard with a caravan of vehicles on its week long slow journey towards its marriage with RISAT spacecraft in Bangalore. When launched on board RISAT-1, the payload will help India – and the world acquire the uninterrupted views of land and oceans for variety of scientific and societal applications and signal the entry of India in another exclusive club of imaging radar technology pioneers.

A few months back, a truck carrying the first multimedia satellite transponders likewise left the giant doors of the building 35. The payload fared with GSAT-6 will provide the “first ever” space based broadcasting of multimedia contents on hand held mobiles. The lab has earlier delivered the “first ever” navigation payload GAGAN which will help the civil aircraft chart its path accurately using GPS signals.



Yet another opening of one of these giant doors - in the beginning of 2011, this time from building 38, sends the fourth "first ever" of India – the sensor for 3D atmospheric profiling. Earlier, India's highest resolution camera – the Carotsat-2, went out of the same doors. This satellite, already in orbit, has earned India a place in the exclusive club of hawk-eyed nations.



The year 2010 made a sort of record as the giant doors opened six times. Befitting their nature, the six openings mark a peak in history making by SAC and symbolize a crest of technological accomplishments, project planning, individual dedication, team work and leadership. The engineering marvels that went of these doors will lay the foundation for innovative new services in communication, earth observation and navigation for many years.

And who shall lay the foundation of these services? The answer comes not from far away but from many of other doors in SAC. An innovative way of tracking all the ships in coastal areas, production of the distress alert transmitter by industries, forecasts of national production of crops, analysis of lunar terrain, development of software for global acquisitions of images from Indian satellites, opening of new nodes of space based information centres for village and handholding the hundreds of scientists from scores of institutions to analyze the data of forthcoming satellites, are some of the glimpses of innovative services from space right now coming from these doors behind which are motivated individuals and teams of application scientists and engineers.

In future, these doors will open – again and again and to new frontiers of technology and to new history of services in of space based communication, remote sensing, navigation and planetary explorations. But for now we shall travel back in time to unravel the story of the mighty doors and the might of SAC.

As far as anyone knows, human beings are the only creature endowed with a capacity to fantasize. We can conjure up castles in the air. This ability of daydreaming and turning it into reality lies at the root of our intellectual and material progress. Space with its all-enveloping canopy and myriad of stars and galaxies has fascinated mankind from ancient times. The heavens have always aroused awe and wonder.

It must have begun with *Homo erectus* and *Homo sapien* stages of man and evolved from mythology to theories of heavens and heavenly bodies with rise of different civilizations across the globe. Indian and Chinese astronomy, amongst others, were particularly advanced in philosophy, theory and practices of astronomy. The earliest Indian references to astronomy are found in the Rig Veda (2000BC). Astronomical principles were used in astrology for preparing horoscopes and to forecast the future. Developments of astronomy culminated into findings like calculation of eclipses, determination of Earth's circumference, postulations on the gravitation and determination of sun as a star and number of planets under our solar system. There are references to well-known Indian exponents like Yajnavalkya (perhaps 1800 BC) for synch-motion of sun and moon, Brahmagupta (598-668), Bhaskara (1114-1185) and Aryabhata (1500 AD) and later Madhava and Nilakantha, for mathematical theories on astronomy. In 19th century, Maharajah of Jaipur built six major observatories of which the Jantar Mantar of Jaipur is a living example.

India in 20th century owes its progress in space to Dr Vikram Sarabhai (1919-71) who dreamt of space as saviour for millions of Indians. To many, this kind of dream was a fantasy and mere daydream as space connotes high tech and huge capital. India then had no human resources worth the endeavor, was a cash-strapped country and had no toehold in high tech research. But Dr Sarabhai remained unfazed as he

was clear and firmly believed that the space technology was *the answer* to India's poverty and underdevelopment:

"There are some who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the moon or the planets or manned space-flight. But we are convinced that if we are to play a meaningful role nationally, and in the community of nations, we must be second to none in the application of advanced technologies to the real problems of man and society."

Dr. Vikram Sarabhai was, undoubtedly, one of the greatest visionaries that India has produced. Unlike many of great men-of-history, he was born with a silver spoon in his mouth. Instead of leading a life of luxury and abundance, he chose a path of quest to greater things. He leveraged his prosperity, wisdom, education, connections and business-acumen and over all the courage that comes along, for the development of space research and technology in India.

The mind, heart and spirit of pioneer

Dr Vikram Sarabhai had a wonderful mindscape and a sensitive conscience which were rooted in his liberal early education and socially networked upbringing. His charismatic personality was instrumental in transforming his dreams in to reality by contagious motivation of teams. His thinking was unambiguous and his perspective of what lay ahead was clear. An unassuming and creative person, he believed in an individual's dignity. He cared for the younger people and was always ready to provide opportunities and freedom. He believed that a scientist should never shut himself up in an ivory tower or overlook the problems faced by the society in mere academic pursuit.

If the milestones and monuments of space created by him signify the evolution of ISRO, his style of working and his



definition of leadership set the tone for rise of the organization through frugal, earthy and work-centric culture:



"There is no leader and there are no led. A leader, if one chooses to identify one, has to be a cultivator rather than a manufacturer. He has to provide the soil and the overall climate and the environment in which the seed can grow. One wants permissive individuals who do not have a compelling need to reassure themselves that they are leaders"

PRL: The cradle of India's Space program

Physical Research Laboratory was established in 1947 by Dr Vikram Sarabhai. Although the stated aim of PRL was "to serve as a Study and Research Centre for Physics in Western India and help to raise the standard of Post Graduate Education..." the activities of PRL went beyond that. The story of Dr. Vikram Sarabhai's career as a scientist and the Father of India's Space Programme and the growth and development of the Physical Research Laboratory (PRL), Ahmedabad, are very much interwoven. In the words of Prof. M.G.K. Menon (1972):

"Vikram Sarabhai worked in the field of cosmic ray variations and set up a group which was undoubtedly the best in this field and which achieved recognition in international science...In his effort to grow an institution of pure research in Ahmedabad, he was joined by Professor K. R. Ramanathan, who developed research groups in areas of ionospheric, radio and atmospheric physics. And this was the Physical Research Laboratory. As the Tata Institute of Fundamental Research was the cradle of the Indian Atomic Energy Programme, Vikram Sarabhai made the Physical Research Laboratory the cradle of the Indian Space Programme."

The International Geophysical Year (IGY) was launched on July 1, 1957 and PRL became an active participant in the programmes. This led to a great spurt of activity at PRL in a large variety of areas: the cosmic rays, the geomagnetism, solar physics, atmospheric physics and meteorology. This, in turn, contributed a great deal to the evolution of PRL into a space science laboratory.

After Soviet Union launched an artificial satellite Sputnik-1 successfully into the orbit in October 1957, the government, in 1961, assigned the subject of exploration of outer space for peaceful uses to the Department of Atomic Energy (DAE) with the scientific objectives of studying / exploring the atmosphere, electrojet phenomena and astronomy. In 1958, the International Council of Scientific Unions had established Committee for Space Research (COSPAR). On similar lines; in February 1962, India created the Indian National Committee for Space Research (INCOSPAR) headquartered at PRL under Vikram Sarabhai's chairmanship to oversee all aspects of space research in the country, specifically:

1. To advice the Government on the promotion of research in exploration of space and its utilization for peaceful purposes;
2. To promote international cooperation in space research and in the exploration and peaceful uses of outer space by actively participating in the work of the United Nations Committee on the Peaceful Uses of Outer Space and other international organizations with similar objectives;
3. To liaise with the Committee on Space Research (COSPAR) of the International Council of Scientific Unions and other national and international research organizations by participation in the various scientific programmes and also to support national and international activities likely to promote the development of the peaceful uses of space.



Under the umbrella of INCOSPAR, Dr Sarabahi nucleated the Indian space program at two places – Trivandrum for rocketry and associated technologies and Ahmedabad for applications and associated instrumentation

Era of space applications begins

In 1966 Sarabhai managed to convince USA to spare their ATS-6 communication and meteorology satellite to India for one year. India then had no TV broadcasting at all and satellite based broadcasting could reach millions of our rural population and provide mass communication/education via TV. There were learning opportunities. ATS-6 had C band transponders and a Very High Resolution Radiometer-VHRR for meteorological applications. Indian engineers and scientists would get firsthand experience in all its nitty-gritty of dealing with satellite communications, TV broadcasting, program production and its dissemination on one side and VHRR data reception, analysis and interpretation of the same on the other. The satellite communication and remote sensing would leapfrog and land within the province of high technology of space applications generally considered a domain of advanced nations and that too without incurring any heavy investment. But first, to use ATS-6, a communication earth station was required. To this end; a 14m aperture communication antenna facility was established in the year 1967 on a hillock on the west outskirts of a small village called Jodhpur near Ahmedabad. The facility known as ESCES - Experimental Satellite Communication Earth Station, marked the beginning of space based communication activities in India. Several communication engineers from India and abroad were trained at the ESCES in the operation and maintenance of earth stations. ESCES, to this date, is still a highest point in the entire Ahmedabad city.

Nursery beds of SAC

The seeds of major activities that we see today in SAC, primarily the satellite communications and remote sensing,

were sown at various locations in Ahmedabad. Electronics Systems Division - ESD, which was engaged in the design of television sets, television receivers and transmitter equipments was operating from a small make-shift shade in the campus of Government Polytechnic. ESD was headed by DR. B S Rao. Shri O P N Calla, a professor in the Department of Electrical Engineering, BITS, Pilani, Rajasthan was roped in to look after Microwave Antenna Systems and Electronics Division-MASED which functioned from a small premise in Government owned L D College of Engineering. A residential flat in Leena Apartment near H L Commerce College was taken on rent start RSMD-Remote Sensing and Meteorology Division. Padmashri Prof P R Pisharoty, who was also ex director, Institute of Tropical Meteorology (ITM) and the father of remote sensing in India, was heading the RSMD as its director. Some activities of RSMD were being carried out at Sahajanand College and also at PRL. In Chitrakoot Apartment., Wing Commander K R Rao and his team were busy designing communications systems in a division called Satellite Communications Systems Division-SCSD. Administration for all these divisions was carried out from yet another place in Patel Chambers where as Prof Yash Pal, as Director of all these divisions had his offices in Sahajanand College.

Today; when we look back; it becomes difficult to visualize how these diverse, physically far-flung branches could have worked in tandem and as a single tree to achieve a common goal! But they did and did that quite well. Eventually this tree emerged, as if from earth, to grow as a giant organization.

Space is put on track

At national level, it was soon realized that nuclear research and space research were two different ballgames. If nation had to progress in both, equally and rapidly, the two have to part ways. In 1969, space activities were detached from DAE by reconfiguring INCOSPAR as Indian Space Research Organisation (ISRO) with Dr Sarabhai as its first chairman.



The Government of India constituted the Space Commission and established the Department of Space –DOS in June 1972 and brought ISRO under DOS in September 1972.

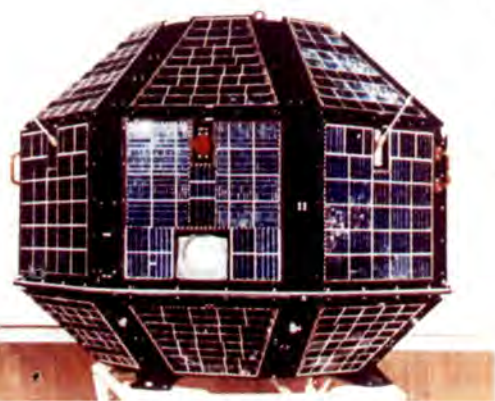
Space Applications Centre – the applications centre of ISRO- was born at Ahmedabad.

Huge premises of ESCES already existed. So, one by one all those scattered units of 'SAC' in Ahmedabad started converging and functioning at a common campus of ESCES; now known as Space Applications Centre or more popularly SAC. ESCES was reduced, then, to a mere entity of SAC. Prof Yash Pal became the first director of the centre. It was evident, right from the beginning that SAC was to concentrate on two principal domains of space applications: Satellite Communications and Remote Sensing. No wonder then that SAC had two separate areas for technical administration: Communication Area CA and Remote Sensing Area-RSA with their respective area chairmen.

RSMD was dissolved in 1975 and what spewed out of it was Remote Sensing Area –RSA in SAC with Prof P D Bhavsar as Area Chairman and Shri D S Kamat co-chairman. Prof. Pisharoty went back to PRL as Professor Emeritus.

India had launched Aryabhata: an experimental satellite, in 1975. SITE experiment had earned a place in history after its one year successful operation during 1975-76. Bhaskara-1

India's first experimental earth observation satellite with microwave and optical sensors was on anvil. Design of an experimental communication satellite was on the drawing board. The new centre was at the doorstep of its great experimental era of 1980s.



Chapter 2

Sights and Sounds from Skies: Space and ground segment of satcom

Snapshot: Antennas to payloads: the journey from
earth to sky

Themes:

- The defining experiments of SITE & STEP
- Satellite Instructional Television Experiment
- The Telecommunications Experiment Project
- APPLE, learning the rope
- Birth of INSAT system
- First step towards the self reliance: INSAT-2
- The bigger is Better: INSAT-3 & 4 Series
- Dawn of New Generation
- Ka Band Propagation Experiment
- Bopal Earth Station
- Maitri Earth Station
- Centre for Space Science and Technology Educations in
Asia & the Pacific

Antennas to payloads: the journey from earth to sky

*A*ntennas are the face of satellite communications. They stick out on earth, on payloads and many rooftops. The stellar journey of SAC in area of satellite communications started aptly with ESCES and ARVI earth stations and spread with chicken mesh antenna of SITE. The route from applications to technology was demonstrated through the antennas as symbols of technology.

The complexity of today's antennas made at SAC is symbolized by a dual gridded reflector antenna - one recently delivered to GSAT-8 payload. This marvel of technology enables two-in-one antenna design using a novel concept of polarization filtering. The fine copper grid on the face of antenna does control one polarization while the second surface behind this controls the orthogonal part of it. The radio waves in two polarizations should be poles apart and should not interfere with each other in their two-way journey of 70000 km from earth to satellite and back. This two in one scheme requires careful analysis of materials, scattering of radio waves from two close interacting surfaces and overall grid structure analysis using a complex software which provides the theoretical evaluation of design and performance. The construction of this 2m antenna is handled by sophisticated industrial methods of etching fine lines of thin copper and large fabrication facilities meant for rocket cases at VSSC.

Going deeper into the payloads which SAC designs for ISRO missions, the complexities of this kind and technological innovations par excellence are packed in each one of them. So one can find solid state filters replacing cavities, the integrated circuits being put in place of discrete components, high power amplifiers replacing the low power ones of yore, and the many more of these things. The result is an increasing diversity of communications from space – in terms of frequencies, power and band width.

Lets' recapitulate this majestic journey for which sky is the only limit.

The defining experiments of SITE & STEP

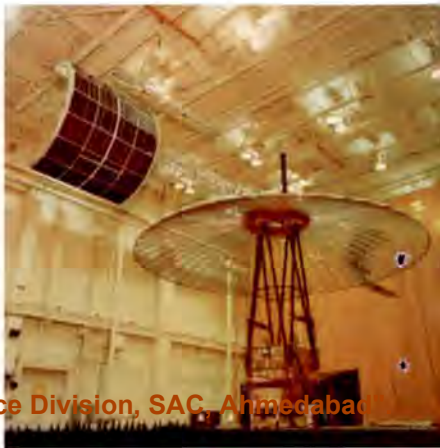
Satellite Instructional Television Experiment

The Satellite Instructional Television Experiment (SITE), conducted during 1975-76 using the USA's Application Technology Satellite (ATS-6), is hailed as one of the first experiment of its kind. SITE demonstrated the potential of satellite technology as an effective mass communication media for a developing country like India. SITE provided valuable experience in the development, testing and management of a satellite-based instructional television system, particularly in rural areas. On August 1, 1975 when 2400 TV sets came alive in as many small villages receiving programmes directly from a geosynchronous satellite located 36000Kms over Kenya. The world saw an experiment as the first of its kind.

The TV sets, augmented with 10 ft. parabolic antennae and front-end converters, were placed in isolated villages in parts of six States of India - Rajasthan, Bihar, Orissa, Madhya Pradesh, Karnataka and Andhra Pradesh. Pij village in Gujarat acquired the first rural TV transmitter in India which provided programmes in local language along with common programmes from Delhi via satellite.

Apart from its hardware and "overall" responsibilities, ISRO took up the evaluation of the experiment, in terms of both technical performance and social effects. In order to do the latter, a large team of social scientists was created in ISRO and they not only did a summative evaluation of SITE, but also provided valuable inputs to programme producers through pretesting of programmes, generation of audience profiles and needs assessments and feedback after transmission.

Overall, SITE established that the extension of communications infrastructure to remote areas is not only feasible and that it can contribute concretely to promoting national development. SITE was an exhilarating





experience for everyone involved. It brought a large number of scientists, engineers, sociologists and programmers close to the rural reality. From all accounts, SITE was a successful experiment and it achieved both its social and technical objectives, thereby paving the way for satellite based television system for India.

Concurrent with SITE, two major experiments were carried out to study propagation of radio waves in the 13 and 18 GHz bands in order to establish their usefulness for satellite communication at these frequencies in the high rain-rate conditions encountered in many parts of our country. This involved setting up a number of transmitting stations spread over the country. We were building the receiving and decoding equipment for signals from the Very High Resolution Radiometer (VHRR) aboard ATS-F. This radiometer, rather similar to the types planned for various GARP satellites, capable of generating a cloud and ocean-surface temperature map once every 20 minutes over the Indian ocean and Indian landmass with a resolution of 5 km. SITE in Summary provided a basket of graceful opportunity to Indian Space enthusiasts. Technology in one shot we got to Direct Broadcast, the infrastructure of program production; weather satellite data reception design of ground terminals and over and above a team raring to go amidst a constabulary of believes.

The Satellite Telecommunications Experiment Project

SITE was followed by communication techniques developmental project called Satellite Telecommunications Experiments Projects (STEP), carried out with the Franco-German satellite, SYMPHONIE during 1977-79. This was an icing on the cake of SITE.

There were a lot of 'firsts' to be scored in the area of domestic use of satellite communication; the experiments planned included the use of an indigenously developed transportable terminal for remote area communications. This would also have a capability of television transmission. Using Digital communication we made a head way in the multiple access mode for trunk telephony for the first time. Other experiments included developing necessary hardware for more languages to be transmitted with a single TV picture using different techniques and integrating the existing trunk automatic telephone exchanges using satellite circuits provided by Symphonie.



A Transportable Remote Area Communication Terminal (TRACT) was indigenously designed by the Space Applications Centre and formed a part of the STEP ground equipment. TRACT was primarily earth station equipment mounted on a truck with antenna assembly, dismantlable for transportation and re-assembly at the site every time TRACT moved. STEP started with a live TV transmission using TRACT from Amreli in Gujarat. The Indo-Pak cricket Test matches in 1978 were broadcast from Lahore, Pakistan enabling the Indian viewers to see live cricket matches played in a foreign country, for the first time.

Emergency Communication Terminal (ECT) was built to exhibit the use of a small jeep transportable/air lift-able terminal to provide speedy and reliable communication via satellite for supporting relief work during emergencies. This led to the development of Disaster communication related activities in the Centre. ECT was put to actual use during the 1977 cyclone in Andhra Pradesh.

APPLE, Learning the rope

Ariane Passenger Payload Experiment or APPLE, India's



first experimental geostationary communication satellite was conceived in 1975 in response to the invitation from the European Space (ESA) agency for flying passenger payloads free of cost on board the developmental flights of Ariane launch vehicle. Planned as a forerunner for future operational domestic communication satellites, APPLE incorporated state of the art technologies like 3-axis body stabilization with momentum bias system, deployable solar panels, orbit and attitude control and propulsion systems along with a C-band communication payload for conducting a number of digital and advanced communication and socio-educational application experiments. Built in a record time of less than 36 months during 1977-1980, the spacecraft was launched onboard the third developmental flight of Ariane launcher.

The APPLE Communication Transponder (ACT) designed by SAC was envisaged to be the torch bearer for payload design, fabrication and space qualification for the future satellites of the planned Indian National Satellite (INSAT) system. The payload was configured to be fully compatible with the ground segment already available through (STEP). It consisted of a fully redundant C-band communication transponder. The design work for various subsystems began at SAC in the first quarter of 1977. The engineering model was completed by the end of 1978. A rigorous quality assurance programme encompassing all aspects of material and component selection, design and derating factors, fabrication techniques and test & evaluation was carried out to achieve high reliability.

The flight models were delivered by the first quarter of 1980.



"May I, first of all, madam Prime Minister, request you to accompany me to Ahmedabad via APPLE and meet, some of the ISRO people who made this mission possible"...Prof.

Satish Dhawan

"Digitized and Archived by Library and Information Resource Division, SAC, Ahmedabad".

Packet Switching (RAPS) and Computer Networking. A Small Communication Terminal (SCOT) was also designed & developed. In addition, Digital Communication Multiple Access (DCMA), Television with Multiple AudioPulse Code Modulation (TVMAPCM) and Computer Network Experiment (COMNEX) etc were carried out.

Birth of INSAT System

In late sixties through early seventies ISRO undertook several studies in collaboration with international entities like Massachusetts Institute of Technologies (MIT) - Lincoln Laboratory (LL) along with experts from NASA, General Electric and several other agencies in USA in configuring the INSAT system. The study team submitted report in March 1971. The original program planning by Department of Atomic Energy (DAE) involved building and launching of three satellites over the period of 1975-1985. The experience gained through SITE and STEP experiments built the confidence towards the conceptualization of Indian National Satellite System (INSAT).

The INSAT system was conceived as an operational system with multipurpose and multiuser satellites as its mainstay. The INSAT-1 satellite series was designed by ISRO and built by Ford Aerospace. Despite APPLE experience the commercial sourcing was aimed towards quick acceptance of SATCOM technology Ford offered to build a three-axis stabilised platform, necessary for meteorological cameras to work on a continuous basis. Because of INSAT's unique multipurpose design, INSAT-1 used an asymmetrical solar array in order to ensure a clear field of view into cold space for the radiation cooler of the Very High Resolution Radiometer (VHRR) earth imaging instrument. The solar sail was deployed to offset the asymmetric solar pressure on the solar array.



INSAT-1 provided two S Band high power TV broadcast and twelve 12 C Band telecommunications national coverage transponders, in addition to also providing meteorological services. INSAT-1A went up in 1981. When INSAT-1B was launched on 30 August 1983, it was not until mid-September that Ford and Indian controllers succeeded in deploying its solar array. By then it had been stationed at 74°E in place of INSAT-1A. Full operational capability was achieved in October 1983. It continued to operate into 1990 with all its 4375 two-way voice or equivalent circuits in use. Around 36,000 earth images were returned. Eleven of its 12 C-band transponder and its 2 S-band transponders provided direct nationwide TV & communications to thousands of remote villages, plus a detailed weather and disaster-warning services. Around 35,000 indigenously built 3 to 3.6 meter diameter, receive only terminals were in place to supply rural communities with social and educational programs. It was relegated to spare status on 17 July 1990 with the launch of INSAT-1D.

The INSAT-1C was launched on 21 July 1988 from Kourou for location at 93.5°E to bring the INSAT system to full capacity. Half of the 12 C-band transponders and its two S-band transponders were lost when a power system failure knocked out one of the two buses, but the meteorological Earth images and its data collection systems were fully operational. Earth lock was lost on November 22, 1989 and the satellite was abandoned.

The experience gained in INSAT-1 gave the confidence that we can design communication satellites and time had come to realise this indigenously.

SAC successfully installed and commissioned **INSAT 1 Satellite Control Earth Station (ISCES) Project** which included two C band Satellite Control Earth Stations, an S band receive only station and a DCP Transmit System with Communication Control for the Master Control Facility (MCF) at Hassan on February 1982.

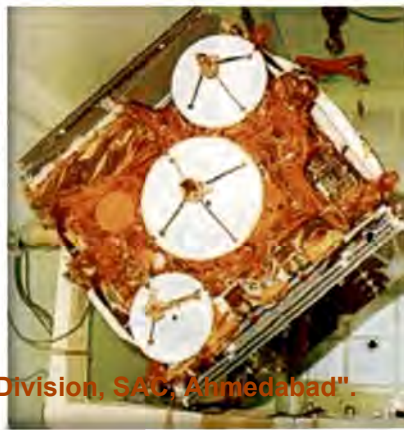
A Receive only system in Lower Extended C band, C band and S band at Jalna for the **Wireless Monitoring Organisation** was established by SAC under the Monitoring Earth Station for Satellites (MESS) project. The system is capable to receive radiated signals (SCP, Radio Networking, wideband FDM/FM and TV carriers) from any of the Satellites in the geostationary orbit arc of interest to India, measure different parameters, identify modulation of individual carriers with a facility of decoding the information and automatic logging/retrieval of measured parameters.

First Step towards the Self reliance: INSAT-2

The INSAT 2 program at ISRO was underway flight from 1983 so as to develop an indigenous multi-purpose GEO spacecraft that relied heavily on the previous Ford Aerospace design and became the second generation INSAT series, like the INSAT-1 series, the INSAT-2 series too was a multi-purpose satellite family for telecommunication, television broadcasting and meteorological services.

The INSAT-2 operational satellites were built with enhanced capabilities. The INSAT-2 meteorological sensor VHRR had a 2km resolution in VIS and 8km resolution in the IR spectral ranges. The INSAT-2C was launched by Ariane on Dec. 6, 1995, INSAT-2D on June 3, 1997 (along with Inmarsat 3F4) and the INSAT-2E on April 2, 1999.

SAC from its experience in building the communication transponder for the APPLE went on to build all the required transponders and the met payloads for the INSAT-2 series. This also led to establishment of several state-of-the-art facilities for fabrication, testing and qualification of communication payload systems within the centre. The area of expertise extended further to the high frequency ranges of Ku and Ka-bands. SAC also designed & developed all the Antenna sub-systems of these satellites. These led to the establishment of very high degree of mechanical precision workshops and elaborate test facilities within the centre.



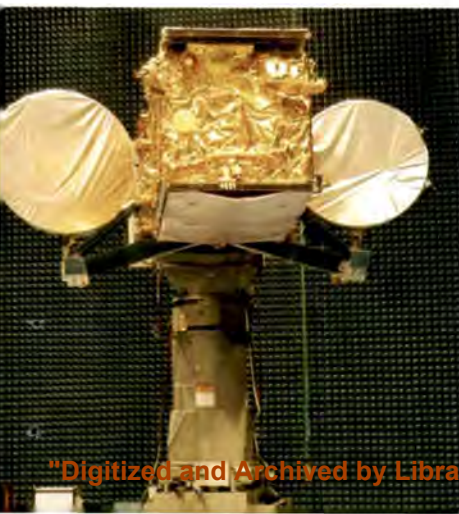


The bigger is better: INSAT-3 & 4 Series

INSAT-3 was again a multipurpose satellite design, providing telecommunications, television broadcasting, meteorological and search & rescue services.

INSAT-3A carried twenty four transponders - twelve operating in C-band, six in Extended C-band and six in Ku-band. Nine of the twelve C-band transponders provided expanded geographical coverage, while the remaining three had an India coverage beam. INSAT-3 also carried a Ku-band beacon. A Data Relay Transponder (DRT) operating in UHF band was incorporated for real-time hydro-meteorological data collection from unattended platforms located on land and river basins. The data was then relayed in extended C-band to a central location. It also carried a transponder for Satellite Aided Search and Rescue (SAS & R) as part of India's contribution to the international Satellite Aided Search and Rescue program. INSAT-3A also had meteorological instruments.

INSAT-3B and INSAT-3C were launched in March 2000 and January 2002 respectively. INSAT-3B replaced the lost INSAT-2D and carried a pure telecommunications payload of C, Ku and S band transponders. INSAT-3C carried 30 C-band and two S-band transponders. Another two satellites, in the INSAT-3 series INSAT-3D and INSAT-3E were planned for launch through 2005. INSAT-3E had two deployable antennas and one fixed antenna.



INSAT-4A and 4B provided services in Ku and C-band frequency bands. The Ku transponders to cover the Indian main land and C-Band transponders to cover an extended area were exclusively designed and developed in the centre.

India's Geosynchronous Satellite Launch Vehicle (GSLV-F02), with INSAT-4C on board, was launched

from Satish Dhawan Space Centre SHAR (SDSC SHAR), Sriharikota on July 10, 2006. However, GSLV-F02 could not complete the mission. Subsequent to the loss of INSAT-4C, SAC accepted the challenge to deliver INSAT-4CR spacecraft configured with exclusive Ku band employing the I-2K Bus within a very short span of one year. INSAT-4CR carries 12 high-power Ku-band transponders designed to provide Direct-to-home (DTH) television services, Video Picture Transmission (VPT) and Digital Satellite News Gathering (DSNG).



Dawn of New Generation

GSAT-4 communication system with regenerative payload was planned to operate in Ka-band with narrow spot beams and wide bandwidth with relatively small size antennas for both transmission & reception. Ka-band payload has bent-pipe transponder as well as regenerative transponders. The main objective of Ka-band regenerative transponder was to gain experience in on-board processing and to support wide-band & narrow band services requirements of the future. GSAT-4 also had Satellite Navigation payload (GAGAN) to provide position accuracy of better than 5m needed for precision landing of civilian aircrafts. This revolutionary satellite could not be tested due to launch failure.

GSAT-5 Communication Payloads will add two new C-Band service coverage areas, i.e. Global beam shaped to landmass coverage & Antarctica beam. The Payload system incorporates several new technology elements supported by SAC; like indigenous (BEL make) TWT & in-house developed linearizers and in-house developed C-Band Dielectric O-Mux, indigenously fabricated DGR Antenna etc.

GSAT-6 is a Multimedia Mobile GEO Satellite to be jointly used by ISRO and Devas Multimedia Pvt. Ltd. The services provided by GSAT-6 include: Entertainment and Information

services to subscribers in cars and vehicles through Digital Multimedia Consoles and Multimedia Mobile Phones, BSS and MSS services.

GSAT-11 will cater to the present & future needs of large capacity demand, leverages on matured technologies on-board as well as on ground to derive maximum out of the available resources. GSAT-11 provides regional HUB-based connectivity to users grouped in a cluster of four beams. Regional HUBs are also connected with each other via OFC links to provide inter regional/national connectivity. The payload architecture with High gain spot beams groups managed by Gateways and Star networks will extend the reach of Indian broadband infrastructure to households, educational institutions and business enterprises it can provide service to thin routes as well as connect fiber backbone networks. 20GB bandwidth of GSAT-11 will become ISRO's answer to bridge the rural-urban digital divide in India

Ka-Band Propagation Experiment

The Ka Band Propagation experiment has a broad objective of modelling the rain attenuation and other propagation impairments in Ka Band. It is proposed to be conducted using the transmission from the beacon placed onboard a geostationary satellite with ground receivers located at different places in India spread over diversified rain conditions. Moreover, it will also carry out the measurements of associated meteorological parameters like rain rate, vertical profile of rain, rain drop size, humidity, temperature etc. using collocated meteorological instruments. The experiment promises development of the impairment models and improved algorithms that will facilitate the designing of the future satellites in higher bands.

Bopal Earth Station

SAC has also recently established a state-of-the-art 9.3m C/Ku-band Earth Station at its Bopal Campus partly to support

the experimental modules of the UN course on SATCOM and SATMET. Equipped with an Azimuth-Elevation drive, the station is capable to communicate with any satellite within the visible geostationary orbital arc. Station has capability for four simultaneous uplinks and downlinks. The baseband equipment with a variety of features like FM, MPEG, Audio/Video, Data, DVB, SCPC/MCPC and IP Encapsulator along with a complete SATCOM Lab make this earth station unique and ideally suited for training and as well as for communication purposes.



Maitri Earth Station

A SATCOM link between Indian Station Matri (71deg S, 11 deg E), Antarctica & National Centre for Antarctica and Ocean Research (NCAOR), Goa (India) using geo-stationary satellite, Intelsat IS-1002 was established. The link was established at normal C-band & designed to operate at very low elevation angle of around 5 degrees. It supports 1 Mbps data rate for the video conferencing, Internet accessing/ web browsing, video streaming and file transfer applications. The installation of earth station at coldest and driest continent on the earth sets a new landmark in ISRO's SATCOM programme. The system is configured with full redundancy considering the isolation of the place from rest of the world. All the electronic-subsystems are designed to operate satisfactorily in the extreme cold temperatures.



Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP)

In response to the UN General Assembly Resolution (45/72 of 11th December, 1990) endorsing the recommendations of UNISPACE-82, the United Nations Office of Outer Space Affairs (UN-OOSA) envisaged the establishment of Centres for Space Science and Technology Education in the



developing countries. In 1994, a UN team conducted an evaluation mission of six countries in Asia-Pacific region, and UN-OOSA selected India as the host country for establishment of Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP).

The Centre is hosted by the Government of India with Department of Space (DOS), as the nodal agency. DOS has made available appropriate facility and expertise to the Centre through the Indian Institute of Remote Sensing (IIRS), at Dehradun, Space Applications Centre (SAC) and Physical Research Laboratory (PRL), at Ahmedabad.

The goal of the centre is to develop, through in-depth education, indigenous capability for research and applications in the core disciplines of

- Remote Sensing and Geographic Information System (RS&GIS)
- Satellite Communications (SATCOM)
- Satellite Meteorology and Global Climate (SATMET)
- Space and Atmospheric Science (Space Science)

as well as data management. These programmes are expected to result in the development and growth of capacities that will enable the member countries to enhance its knowledge, understanding, and practical experience in those aspects of space science and technology that have the potential for a greater impact on its economic and social development, including the preservation of its environment. A set of standard curricula developed by the United Nations is adapted for the educational programmes. The Centre is affiliated to the United Nations and its educational programmes are recognized by Andhra University, India.

Since 1997, SAC has been involved in conducting the nine months duration training programmes in the field of Satellite Communications (SATCOM) and Satellite Meteorology and Global Climate (SATMET). These courses are organized once in two years (alternate years). So far SAC has organized seven courses each in SATCOM and SATMET.

The post graduate courses are organized in two phases. The Phase I is conducted in India for 9 months. The Phase I

consists of core modules where the emphasis is on the development and enhancement of knowledge and skills through classroom lectures, tutorials and hands on experiments/practical's. This is followed by pilot projects, giving practical training towards how the skills gained can be used for solving problems by applying input from space as one of the information content. At the end of Phase I, successful candidates are given post graduate diploma by the centre.



During Phase II, each returning student is expected to carry out an approved project in his or her home country for a period of one year. The project is formulated jointly by the scholar and his/her advisor in consultation with the sponsoring organization, in an area relevant to the development of their country. This gives an opportunity to the scholar to apply their knowledge and training received to tackle a 'real life' problem, where space input can be used.

SATMET Course and associated facilities

Meteorological information and their timely and real-time delivery are of utmost concern to the region of Asia Pacific. This region covers countries many of which experience the typical Tropical weather systems - especially Tropical cyclones and monsoons (both summer and winter) - and a few other mid-latitude weather phenomena. Issues related to climate change, global warming, sea level rise, ozone depletion, etc are of great relevance countries of this region. SAC conducts a comprehensive Post Graduate Training Programme on the subject with a complete treatment of principles, applications and prospects of using the technology to solve grass-root problems of nature concerning state and dynamics of atmospheric processes in the region. The operational satellite data available in the region namely, INSAT, METEOSAT, GMS and NOAA, are used extensively during the training course. So far 120 Meteorologists from 22 countries in Asia-Pacific region have undergone training in the field of Satellite Meteorology.

SATCOM Course and associated facilities

Satellite communications can surmount natural barriers of the Asia-Pacific regions and bring the advantages of the advanced

communications to every corner in a cost-effective and timely manner. Accordingly, the Centre has formulated a postgraduate educational programme to cover the basics of communication systems and provide an in-depth orientation to the understanding of projects in the field. The course enables the students from participating countries in preparing satellite based communications projects, policy, definition, establishment of communications systems, use of operational systems, public awareness on the benefits of satellite based communications technologies in the improvement of the quality of life. A state of art Satellite Earth Station for conducting Communication Experiments exists at the Boapl Campus. More than 115 Engineers from 16 countries in Asia-Pacific region have benefited from the SATCOM course.

SAC has established hostel facilities of International standards with all modern amenities including kitchenette for 9-month stay of the course participants.

Chapter 3

Knowing without nearing: A Saga of Remote Sensing Activities

Snapshot: The silent approval

Themes:

- Remote Sensing
- Platforms held the key
- Bhaskara-1: “Return of the prodigal son”
- Post Bhaskara era
- IRS-1A on the drawing board
- A jewel in the crown
- Sensing the weather
- Watch on Oceans
- Workhorse sensors for earth resources
- Eagles in Space
- A torch in daylight: Microwave Remote Sensing
- The tough nut cracked ... at last!
- Future is bright but challenging
- Applying the Information: The taste of pudding
- Applications : The last mile of space observations
- Spectrum of applications projects
- Atmospheric and Oceanic Applications
- Planetary Applications
- ISRO's CAL/VAL Program
- Getting ready for new missions

The silent approval

'Madam did not say anything!'" Murmured a colleague in disappointment.

'But she neither said no....'" Whispered an experienced old man in reply.

That was the conversation taking place in low decibels at the Prime Minister's Office-PMO in New Delhi. The period was early seventies. A group of young scientists and engineers headed by the old and honorable Prof P R Pisharoty was making a slide show presentation to the then Prime Minister of India; Mrs. Indira Gandhi. Using overhead projectors; they were showing their recent findings of wilt disease in its early stage that has afflicted the coconut groves of Kerala. This astonishing information could be detected; even before it was visually apparent and much in advance, because of technique called aerial remote sensing that they had applied over the region. The team was attempting to impress the Prime Minister on the importance of remote sensing techniques for national resource development and societal benefits. They were urging the government to allocate funds and give green signal for furtherance of the activities in India. Mrs. Gandhi patiently sat through the entire presentation but (she) left the place; moment the screening was over and without uttering a word. A senior colleague of Prof. Pisharoty was disappointed with this and asked his boss: 'Sir, madam did not say anything!' To this the professor replied: "But she neither said no! My hopes are alive and we will get what we want"

Needless to say that the funds were allocated that saw the seeds for Remote Sensing activities to germinate and to become a big banyan tree in the years to come.

The above episode was narrated by none other than Prof Pisharoty himself when he was felicitated on his 80th birthday in Vikram Hall, SAC on his becoming an octogenarian. Movements for remote sensing were initiated much before the above event that took place at PMO. But it certainly got a boost after the go-ahead was given. What was crawling was lifted to stand erect on its legs and the first forward steps were in the making!

The humble beginnings of remote sensing have culminated in development of an array of EO sensors and microwave payloads with their complete data processing chains. The applications beginning with coconut wilt disease have snowballed into a multidimensional program with projects, institutions, mechanisms galore in the country. The data products and software activities touch the entire gamut of satellite data disseminated within India and from 20 odd ground stations in the world.

Let us rise above the beginnings to have a better view of the varied terrain of remote sensing story.

Remote Sensing

Although the word 'remote-sensing' is very much in vogue, it is hardly fifty years old! To see anything in an illuminated condition and trying to figure out what it is; without touching it, is a coarse definition of remote sensing. To have synoptic view people have flown cameras attached to the belly of a pigeon or tied to a balloon and later on in the belly of an airplane by cutting a hole in it and fixing the camera pointing

downwards. Viewing earth from space has grown increasingly sophisticated and has evolved from simple photographs to quantitative measurements of Earth properties such as temperature, gaseous concentrations and elevation of land and ocean. Imaging Earth from space has resulted in major scientific accomplishments; these observations have led to new discoveries, transformed the earth sciences, opened new avenues of research, and provided important societal benefits by improving the predictability of Earth system processes.

Platforms held the key

Remote Sensing Area –RSA, borne out in 1975 from erstwhile Remote Sensing and Meteorology Division, started with a portfolio of R&D activities like earth resource surveys, space meteorology, geodetic studies, space based remote sensor development, software for photo-interpretation etc.

It is a common practice to use aircrafts and spacecrafts as platforms for remote sensors for Earth observation. Though; high flying balloons have been used for fundamental research in Cosmic rays, Astronomy etc., its use as a platform for earth resources survey has not been fully exploited. Considering the merits and economic feasibility of using stratospheric balloons as a remote sensing platform, SAC had started a Balloon Resources Inventory Development (BRIDE) in 1975. The payload used for the first experiment essentially consisted of three Hasselblad cameras with different film filter combinations so as to provide photography in panchromatic black and white, IR black and white and IR false colour. The three cameras were mounted on a platform, which was servo-controlled to keep a fixed direction in azimuth irrespective of the balloon rotation. An electronic programmer on board provided automatic command for exposing the cameras. The instrument was kept inside a cane cage with proper shock absorbers to protect the cameras from the landing shocks. A preliminary study of the photographs produced by the instruments had shown that a lot of features can be identified

like agricultural lands, forests, waste lands, lakes, river courses and drainage patterns, roads, settlements etc. The crops gave distinct and specific red colour tones in the IR colour diapositives.

The hasselblad cameras were used extensively during 1975-1977 for aerial remote sensing in ARISE project for surveys Anantpur and Patiala and later over Panchmahals and Idukki. These aerial photos provided first experimental opportunities to resource scientists in photo-interpretation, filed survey techniques, rectification, cartography and project management. The requirements of interpreting film diapositives both from aerial surveys and later from Landsat-1 provided early experience in applications and gave a spurt to instrumentation development related to photo-interpretation and ground truth data collection. Till early 80's SAC has developed a variety of photo interpretation equipment and a ground truth radiometer and transferred the technology to industries for mass production. This paved the way for spread of remote sensing amongst the research groups in institutions and universities.

Bhaskara-1: "Return of the prodigal son"

Observing earth from space holds the key to large area repetitive coverage. To train the cameras towards earth from a free flying satellite requires use of a technique called spin stabilization. Bhaskara-1, Satellite for Earth Observation (SEO) the first earth observation satellite of India was one such spin stabilized satellite. It had both optical and microwave sensors onboard. In early 1975; development of a space based TV camera for satellite was initiated at SAC. Making a satellite payload was a challenge. Procurement of components and making them space qualified was a stupendous task. Super Vidicon TV tube was the light detector used in the TV camera whereas SAMIR - SATellite MICrowave Radiometer was the microwave payload for Bhaskara-1.

Vidicon TV tube was an area array detector that could take pictures of the earth below in 1km X 1Km resolution. One biggest disadvantage of Vidicon tube was that it required 10 kilovolts level high voltage to multiply the electrons generated by the photon detector since the intensity of the sunlight reflected was not enough to make full use of Vidicon's dynamic range. Designing a high voltage generator was a demanding task. There was a mechanical shutter in front of the camera lenses similar to film cameras. The payload underwent exhaustive testing at all stages including post spacecraft integration and on launch pad. The satellite was launched with India's first space based remote sensors onboard by a Russian launcher, from Russia in June 1979.

Once in orbit and all system checks went through and the camera was switched on. But no picture was forth coming. Cameras could not be operated. Four years of sweat and blood had gone to drains or so it was felt. Simulation studies were carried out on bench and in vacuum. Committees were formed to look into the anomalies. It turned out that, probably, some micro air bubbles that have got trapped inside the insulation potting that was applied around the high voltage were causing corona. A decision was taken not to operate the optical payload again as the corona may damage other subsystems. SAMIR, however, was functioning well. After eleven long agonizing months of expectations and disappointments, and presuming that air bubbles have escaped, a calculated risk was taken to switch on the cameras. And it started beaming beautiful pictures of the earth below. There was a wave of jubilation across the organization. And Dr. George Joseph proclaimed: *"The Prodigal son has returned"*. There was a renewed faith in our ability to master the space technology. Work on Bhaskara-II began. The wisdom of one payload was used. Bhaskara-II with similar optical and microwave payloads launched in November 1981 worked satisfactorily.

Technologies used during Bhaskara's days were state-of-the-art then but primitive by today's standards. Printed circuit boards (PCBs) were of two layers. They were designed with

Bishop Graphics: those magenta and blue self sticking plastic tapes on Mylar sheets. Turrets mounted on the periphery of the PCBs acted as input /output ports for signals and supplies. Electronics were realized through discrete analog and digital integrated circuits of the type Operational Amplifiers (Op-Amps) and the Transistor Transistor Logics (TTLs) and their variants. Optics and mechanical structures were simple as possible. Payload data rate was at mere 400 Kilobits /second. Ground testing gear was done through Tektronix oscilloscope which had a built-in hard-drive for storage and archival.

Post Bhaskara era

Success of Bhaskara tremendously boosted confidence of engineers and scientists at ISRO in general and SAC in particular that given an opportunity they can prove their worth in designing, testing and fabrication of space hardware. Charged Coupled Devices-CCDs had just begun to surface the emerging sea of photon detectors but it had no space heritage. While Bhaskara-I payloads were under development; SAC initiated development of optical sensors using CCDs as the detector element. An experimental aerial flight, employing a CCD sensor, was also carried out.

ISRO was ready to embark on design of operational remote sensing satellites that would be state-of-the-art and vie for serious and meaningful quantitative measurements of Earth's properties and resources. The users would be resource scientist, planners, decision makers, meteorologists, oceanographers and agriculture ministers within India and throughout the world who would be given professional, usable product. That called for utmost care, concentration and seriousness.

In order to define the payload and spacecraft parameters of this indigenous operational remote sensing satellite system, a Joint Experiments Program (JEP) was undertaken during

1981-82, in which various ministries and departments of central government were contacted to interact with SAC. Six projects under the broad disciplines viz. agriculture, forestry, hydrology, oceanography, geology and geography were identified to work upon. Within these disciplines a number of specific projects were carried out along with the user organizations/departments. Finally; what churned out of the exercise from each of these regulated activities were synthesized to derive base line IRS mission parameters related to sensors and data applicability. Later a nation-wide program on it utilization was launched and users across the country were put on board. The projects related to agriculture, forestry, environment, geology etc were formulated. Application scientists of SAC traveled far and wide to elicit collaboration from institutions and government departments.

IRS-1A on the drawing board

Adoption of new technologies in IRS-1A changed everything downstream. Fresh men-power was infused. New buildings came up with big laboratories each for onboard electronics, ground checkout, optics and detector characterization. A large clean room (known as integration room in those days) with class 1000 cleanliness was established with air cushioned optical benches and *clean tents* of class 100, accurate light sources for calibration, lens and mirror characterization gears etc. VAX 11/750 computer system was commissioned for payload data acquisition and processing to extract payload performance parameters. Mechanical staff was strengthened. Vidicon tube with an area array detector was replaced by a 2000 element linear CCD.

IRS-1A cameras (and there after all CCD based cameras) were known as LISS-Linear Imaging Self Scanned cameras because they did not have mechanical scanning and relied on the line strip of detectors sweeping the earth surface. There were three cameras onboard IRS-1A: LISS-1, LISS-2A and LISS-2B. LISS-1 had a spatial resolution of 72m and a swath of about

147km. Both LISS-2s had double the resolution that of LISS-1 and half as much swath. Both took pictures in magenta, blue, yellow and green colours.

The high reliability requirements of space qualified hardware calls for specialized techniques in their fabrication, testing and integration using sophisticated tools. The Payload Fabrication Facility (PFF) which was set up in SAC in October 1975 was entrusted with these tasks, with a view to prepare itself for building payloads for the SEO Project. The Test Evaluation, Standards and Calibration (TESC) group ensured quality and reliability of components, subsystems and entire payload. With time this activity evolved in full-fledged test facilities for environmental, electrical, mechanical, high power and shock and vibration analysis of all systems. India's first operational remote sensing satellite IRS-1A was launched on 17th March 1988. It worked flawlessly for years on. Just after three years of IRS-1A's operation; its identical twin IRS-1B was in space. Both 1A and 1B lived more than their designed life enriching our knowledge of earth resources and phenomenon.

Then came the IRS-1E (E for engineering model) which was essentially IRS-1A refurbished and recalibrated for its sacrificial role as '*payload*' for the first developmental flight of our home grown rocket: The Polar Satellite Launch Vehicle - PSLV. But PSLV did its job and hurled it into space, in September 1993. IRS-P2 and P3 went on the second and third developmental flights of PSLV.

A jewel in the crown

SAC then engaged in designing IRS-1C- a truly high resolution, civilian remote sensor that no country had ever developed before. There was a drastic change in the architecture of camera. For the first time we used mirrors to magnify the scene instead of lenses for the payload of IRS. Its optics was a truly extraordinary design where three mirrors, in

off-axis configuration, were placed to realize a telescope. Its spatial resolution was 5.8 m which was unprecedented at the time. Three CCDs were kept in a line, optically, to increase the swath. Entire camera could be rotated sideways to improve *revisit* frequency. To realize it, the infrastructure was strengthened. New bigger clean room, high-speed data acquisition and processing computer system, optical fibers to transmit payload data from clean-room and thermo-vacuum chambers and up-graded test and calibration apparatuses and procedures were put in place. IRS-1C was launched by a Russian rocket on 28th December 1988. In a single stroke the satellite redefined the whole scenario of high-resolution remote sensing. The American company Earth Imaging, termed it as “a jewel in the crown” of remote sensing satellites. Identical twin IRS-1D went up on first commercial flight of PSLV (PSLV-C1) on 29th September 1997. Both 1C and 1D exceeded their design life in space.

Sensing the weather

While cameras for remote sensing satellites were being designed; SAC had put parallel effort to address the need for instruments for meteorology and weather forecasting by placing instruments on platforms that are stationary with respect to earth. India had conceived INSAT series of satellites for communication, TV and radio broadcasting. These are geostationary satellites providing stable earth viewing platforms. INSAT-1 series of satellites were designed and fabricated to our specifications at Ford Aerospace Company, USA and carried Very High Resolution Radiometers-VHRR instruments for meteorology applications. VHRR had 2km X 2km spatial resolution for visible band and 8km X 8km resolution for thermal bands. In a span of about eight years from 1982 to 1990 four INSATs (1A, 1B, 1C and 1D) were launched.

Simultaneously we initiated indigenous design of INSAT. Design and development of indigenous VHRR as scanning

cameras operating in visible and thermal bands was realized at SAC. These were designed to capture the entire globe or scan the Indian sector – every half an hour. The first indigenous INSAT satellite the INSAT-2A was launched on October 7th 1992 by an Arian launcher. It carried VHRR instrument with improved resolution of 1km X 1Km for visible and 4Km X 4Km for the infrared bands. This was followed by INSAT 2C in December 1995, INSAT-2D in June 1997 and INSAT-2E the last in series of INSAT-2 in April 1999.

Watch on Oceans

Oceans affect climate, atmospheric processes, cloud formation and rain. Ocean biology is important for marine products. Physical oceanography has practical benefits for sea faring. The design of sensors for ocean observations requires clear understanding of how oceans interact with electromagnetic radiations. Since oceans are vast and devoid of geometry, a of coarser spatial resolution and large swath was required. Besides, ocean reflectance is feeble and varies very little, enhanced radiometric resolution to 1000 levels or even more is required. So feeble is this reflectance that even atmospheric scatter dominates it. Apart from atmospheric correction, water turbidity, chlorophyll contents and dust particles in the atmosphere are some factors that dictate the number of spectral bands in which a meaningful image must be taken. Hence ocean sensors have high spectral resolutions as compared to land sensors.

Oceansat-1 India's first satellite dedicated to the study of ocean behavior was designed and launched in May 1999 by PSLV-C2. It had eight spectral bands, coarse spatial resolution of about 200m and a swath of 1400 km. It could dissect intensity variations to 1024 levels. Recently in September 2009, Oceansat-2 was launched that carried more precisely defined eight bands and also an infrared band. It is as on date the only global system for ocean observations.



Workhorse sensors for earth resources

There was a need for a satellite that would address requirements of agriculture, geology, mineralogy, hydrology, forestry, urban planning, snow cover and glacier monitoring, disaster management and mitigation, all in a single stroke! Resourcesat was born out of such necessities. Resourcesat-1 had multiple

cameras. AWiFS –Advanced Wide Field Sensor a low spatial resolution sensor with 80m resolution in three spectral bands, LISS-3 multi spectral camera having 23m resolution and LISS-4 multi-spectral camera with 5.8m feature detecting capability became the payloads for Resourcesat-1. This satellite launched in October 2003 became an instant success not only in India but around the world.

Operationalization of PSLV enabled India to launch remote sensing satellites more frequently. That only meant more number of payloads to be developed at SAC at a faster pace. This called for one more upgrades in facilities. A gigantic clean room with nearly seventeen hundred cubic meters of space was created in a new building. A windowless hall, this clean room one of the largest such dirt-free areas in ISRO can boast its capability to handle simultaneous assembly and testing of 6 to 7 payloads. This has state-of-the-art optical calibration sources, vibration free optical benches, cryogenic coolers to test infrared cameras and latest lens and mirror testing apparatuses. A matching state-of-the-art computerized payload checkout facility provides connectivity to all payloads through a gigabit optical fibre.

Eagles in Space

SAC got confidence to build high resolution instruments from development of sub-meter resolution TES a technology demonstrator built and flown in 2001. Probably India was the second country after US to have designed, developed and flown such a high definition sensor at that time.

Cartosat-1 which had a spatial detecting capability of any earthly feature measuring 2.5m X 2.5m or larger had two identical cameras; none of which looked straight down! One was looking in the forward direction (A FORE Camera) by an angle of $+26^\circ$ and other in the reverse or backward direction (An AFT camera) by -25° with respect to nadir – a point directly below the satellite. This arrangement gave it a capability to see the same scene through two different angles. Stereo images from pair of views help make what is called Digital Elevation Models –DEMs of any undulating terrain giving height or depth of any location on the terrain. Cartosat-1 was put in orbit in May 2005.

Cartosat-2 series signaled the design capabilities for very high resolution optical sensors. The latest satellite the CARTOSAT-2B was recently hurled into space on 12th July 2010. It beams images with spatial resolution of 80 cm from 500 km altitude. CARTO-2A went up in space on 28th April 2008. The design of these sensors have involved venturing into new high technology areas of composites, light weight large optics, stabilization mechanisms, high speed data handling etc. The next generation of these mapping satellites will feature even better resolutions and still more advances will come from their versions meant for continuous watch from geostationary orbits.

Going to the moon: Sensors for planetary observations

Chandrayaan-1 carried 11 payloads of which 5 were from India. SAC developed two payloads – TMC and HySI and supported the work on Moon Impact Probe.

Terrain Mapping Camera-TMC is the world's first high definition (5m geometric resolution) stereo camera that views the surface of the moon from three different angles: $+26^\circ$, Nadir and -25° providing 3D view and height information of

the terrain below. TMC has an innovative design. It uses a single lens for fore, aft and nadir cameras using folding mirrors for fore and aft views. At the output, the three images fall on separate detectors. This innovative design has made the camera ultra compact and The TMC has remained a work-horse instrument for Chandrayaan-1. It has beamed back crystal clear stunning 3D images of moon's terrain.

Hyper Spectral Imager – HySI has a ground resolution of about 80m but is capable of resolving spectral information in 64 contiguous bands – covering visible and near infrared regions. The HySI uses wedge filter along with the area array detector to resolve the spectrum in 512 spectral bands. Eight bands are grouped together to form 64 contiguous bands. The primary aim of HySI is mineral mapping of moon's crust. The imager has sent excellent images of the moon and scientists have interpreted them to show the occurrence of minerals like Thorium, Uranium, Iron and Titanium etc.

Moon Impact Probe – MIP

The first job that Chandrayaan-1 had performed after reaching the intended orbit round the moon was to release MIP. MIP demonstrates the technologies required for landing a rover at a desired location on the moon. While descending, the MIP took pictures of moon terrain below through a video camera that was developed at SAC through reengineering and ruggedization. Our Indian Tri-color was painted on four sides of the impactor and thus it established presence of India on moon.

A torch in daylight: Microwave Remote Sensing

Since the visible portion of the electromagnetic radiation is extremely small as compared to the rest of EM spectrum, it becomes obvious that much more additional information can be extracted by widening the spectral reach of sensors. For

example, microwave region that starts from 1mm and extends up to 1m of wavelength is more than thousand times wider and infrared similarly is 100 times wider than the visible portion (.4-.7 micrometer). Microwave radiation can penetrate clouds, fog, and haze, can go to some depth into the soil and is sensitive to moisture contents and the geometry of the object. Most microwave sensors are *active* sensors meaning they carry their own *microwave torch* to '*light-up*' the object being sensed as opposed to passive electro-optical sensors that depend on sunlight for their operation. This is a tremendous advantage as it gives a day-night all weather remote sensing capability.

The needs of ocean and weather observations and sea-ice monitoring through clouds in the polar-regions also emphasize the necessity of developing a large number of microwave remote sensors. The lack of sunlight during the Arctic and Antarctic winters does not prevent microwave sensors from providing data on the fractional coverage and extent. The all weather sensing capability of microwaves is also important for resources areas like studying crops in the kharif (monsoon) season and for mapping flooded areas when the sky is covered with clouds etc and not to forget its strategic importance.

Work on microwave components especially antennas, feeds and horns has a heritage from MASED and later Microwave Division MID. Over the years, the activities diversified beyond the normal antenna and feed development to the development of various sub-systems like parametric amplifiers, microwave transistor amplifiers, solid state microwave sources, frequency multipliers, mixers, circulators, waveguides and coaxial components. In order to produce highly reliable, compact and light weight circuits, the microwave integrated circuit (MIC) facility was also established. The experience gained was utilized in designing and developing ground based and airborne radars and microwave communication systems and subsystems to fulfill the requirements of SAC and ISRO.

Like its optical cousin, the microwave sensor development activities also followed a step by step developmental approach.

First sensors were airborne sensors. An X-band side looking Airborne Radar (SLAR) and a C-band airborne Synthetic Aperture Radar –ASAR was the first to be developed. Disaster management SAR - DMSAR followed soon and had 1-30m of spatial resolution and a swath of 6 to 75 kms. DMSAR is being regularly utilized.

Bhaskara –I and II carried SAMIR payload which was a radiometer operating at 19 Giga Hertz (GHz) and 22 GHz for study of ocean-state, water vapor, liquid water content in the atmosphere, etc. In 1999, a more complex Multi-frequency Scanning Microwave Radiometer (MSMR) was flown onboard Oceansat-1 (IRS-P4). Oceansat-1 gave services for almost a decade. Recently, in 2009, Oceansat-2 was launched with Ku-band pencil beam scanning scatterometer as microwave payload along with upgraded optical payloads the Ocean Color Monitor –OCM-II. Both SAMIR and MSMR were passive radiometers having coarse spatial resolution, suitable only for oceanographic and atmospheric applications. The space-borne imaging radar was far away.

The tough nut cracked ... at last!

An active microwave imaging sensor like Synthetic Aperture Radar (SAR), is an ideal sensor for agricultural applications as well as flood monitoring, damage assessment in natural calamities and oceanography as radar backscatter is sensitive to soil moisture and surface roughness. In that sense it surpasses optical instruments.

The basic principles that the spatial resolution is directly proportional to wavelength and inversely proportional to aperture apply both to optical and microwave sensors. Hence getting equivalent resolution from optical and microwave systems dictates the size of aperture or antenna of microwave sensor in kilometers range. This is simply impractical. However, for an active microwave instrument like radar, a

technique of artificially increasing the dimensions of antenna by aperture synthesis has been developed. This is achieved by precisely measuring the phase and Doppler.

Concept is fine but realization is akin to cracking a tough nut. SAR development requires mastering sophisticated radar technology and complex SAR data processing algorithm. The learning from ASAR and DMSAR has been useful in designing the RISAT-1 Radar Imaging Satellite that will carry India's first spaceborne SAR operating at 5.35GHz which became a reality in September 2011.

RISAT-1 is a multi resolution, multi-swath, multi polarization SAR instrument capable of giving 3m, 12m, 25m, and 50m geometric resolution on demand. One unique feature of the payload is its ability to switch over to an option called Hybrid Polarimetry. In this option the resolution will improve to 6m in place of 12m. The SAR of the RISAT-1 is configured on a dual receiver concept, providing identical resolutions and swaths in simultaneous operation of co- and cross-polarization or Hybrid Polarimetry. There is a dual polarized active antenna with 288 radiating elements. Antennas are printed microstrip patch arrays. A host of new developments like miniaturization of microwave circuits and components, algorithm development, a novel Near Field Antenna Measurement Facility, etc took place. Cracking of coconut under the tyres of truck carrying RISAT-1 during its flag off symbolized not only of an auspicious event but also of cracking of a tough nut of designing, fabricating, developing and testing of a complex imaging radar!!

Future is bright but challenging

The microwave sensor development team is afoot to develop an L-band SAR as a successor to RISAT-1 payload. It will have compatibility similar to present one besides some enhanced features like additional linear Polarimetry Mode and onboard

real time data processor. Interestingly the Chandrayaan-2 slated for 2013 launch will also carry an L-band MoonSAR that will operate from 100km lunar orbit.

Another challenging assignment taken up is development of millimeter wave sounder that exploits the atmospheric opacity to sense the atmospheric temperature and humidity profiles. Sounders have an amalgamation of channels at which the atmosphere is opaque for sounding purposes and at which the atmosphere is transparent for correction of the surface contamination. Two distinct sounders are being planned one a Temperature Sounding Unit (TSU) operating in oxygen absorption band at 50-60 GHz and the other the Humidity Sounding Unit (HSU) operating at 183 GHz. These sounders will be flown on ISRO's mini bus IMS satellite.

In order to provide boost to climate research with high repetivity of data over the globe, MeghaTropiques satellite is planned as a joint Indo-French collaboration effort. It will have three payloads: MADRAS –an imaging microwave radiometer operating in five microwave frequencies, SAPHIR –Sounder for Atmospheric Prfiling of Humidity in the Intertropics by Radiometry and SCARAB – Scanner for Radiation Budget a broadband radiation measurement. IRS bus will be utilized and satellite will be launched through PSLV.

Applying the Information: The taste of pudding

The image data that is sent to the ground stations are *raw* in real sense of the term. They are in such a shape and condition that they cannot be used directly in that form. This is because the space hardware has to be *simple as possible* (to improve reliability); so all complexities are transferred to the ground segment.

First the volume of data that is poured out from a satellite is enormous –something of the order of 10 gigabytes for a LISS-III type of sensor on board Resourcesat when its eyes make a

single glance from Kashmir to Kanyakumari! This is only for a single camera and there will be more than one sensor on a typical satellite. First this huge amount of data has to be stored before anything else can be done on it. A lot of processing goes in before a final product is made. Each picture element has to undergo intensity correction (called radiometric correction), positional or spatial correction (also called geometric correction), then registering of each pixel with respect to corresponding pixels of other spectral bands, filtering of noise and other redundant information, corrections due to spacecraft jitter, corrections due to earth curvature etc etc. The above processing mentioned is only representative and not exhaustive. The processing of data from SAR sensors is even mind boggling! In a nut-shell it is an involved activity. And this has not gone out of sight of the visionaries and pioneers of remote sensing in India.

Obviously it is beyond the human capability to do such a massive amount of number crunching. Computers are required for the purpose. Initially they started with DEC-10 with punched-cards for loading the program. Then they migrated to VAX-11/780. Now an approach called distributed processing is followed using very high performance servers and work stations. From late 70s to early 80s saw computers converting raw data into final data products in photographic and digital formats using Fortran coded software modules used for image analysis like histogram stretching, classification, principal component analysis, density slicing etc. These were used for airborne MSS and Landsat MSS.

After the launch of IRS-1A; the emphasis was shifted to generating photo-products as against digital products and hence elaborate photo-lab facilities were established. IIPS, INDIPS and ISRO-Vision software were developed. Simultaneously experimentation on parallel processing was also initiated. Next decade saw strengthening of the image processing software to make it robust, fast and user friendly resulting in quick turn-around time. Ground Control Points (GCPs) library was incorporated for generation of precision

products. Full-India mosaic products were generated for the first time using WiFS as well as LISS data. By the turn of 90s IRS-1C data were regularly received by over sixteen station world over.

Oceansat-1 was India's first satellite dedicated to study of oceans. For the first time derived geo-physical parameter products were operationally generated. Software development is a continuing activity but the two packages developed during the time frame are worth mentioning. They are SAPHIRE for generating high precision ortho-images from IRS-1C and Cartosat missions and SARDA for processing Interferometric SAR data from ERS-1 and ERS-2 satellites. Sharpness of the high resolution sensor imagery can be improved by a technique called Point Spread Function. PSF as it is known was incorporated in the generation of imageries for Cartosat-2 and subsequent all high resolution missions. Hyperspectral processing capabilities were developed and exploited for IMS-1, AIMS and Chandrayaan-1 HySI data. Establishment of Payload Operations Centre at SAC for Chandrayaan-1 to generate higher level data products from TMC and HySI sensors and prepare data archives at ISSDC.

Development of expertise in many area of software development has emerged. SW development for data processing from imaging and non-imaging sensors of Earth, Atmospheric, Oceanographic and Planetary missions are taken up. Also development of advanced image processing techniques for Planetary, Lunar and astronomical data is in pipeline.

Applications : The last mile of space observations

Remote sensing has enabled mapping, studying, monitoring, modeling and management of various resources like agriculture, forestry, marine, geology, water, ocean etc. and studies of oceans, atmosphere, snows and glaciers etc. It has

further enabled monitoring of environment and thereby helping in conservation. In the last four decades it has grown as a major tool for collecting information on almost every aspect on the earth's systems' processes. With the availability of very high spatial resolution satellites in the recent years, the applications have multiplied. No walk of life can be imagined that is not touched by remote sensing directly or indirectly. Applications activities fall under the umbrella of National Natural resources Management System – NNRMS which supervises the optimal utilization of country's natural resources by providing for a proper and systematic inventory of natural resources available using remote sensing data in conjunction with conventional data/techniques. In doing so, NNRMS adopts various advanced technologies of satellite and aerial remote sensing; Geographical Information Systems (GIS); precise Positioning Systems; database and networking infrastructure and advanced ground-based survey techniques.

The systematic implementation of remote sensing applications in the country goes back to implementation of IRS-UP which oversaw the assemblage of critical mass of technologies, teams and collaborative networks. Department of Space initiated and SAC took the lead in establishing institutional networks in form of state remote sensing centres. Some of the important projects carried out in the country include groundwater prospects mapping under Drinking Water Mission, mapping of wastelands, land use and urban sprawl, Grassland Mapping, Biodiversity Characterisation, Snow & Glacier Studies, Land Use/Cover mapping, Coastal Studies, and delineation of forest density and types. The projects proved a success in many ways. For example, ground water potential maps prepared using remote sensing data when used in conjunction with ground surveys improved the accuracy of drilling 275800 wells to over 90 per cent. Similarly in conducting land use surveys, national mapping was done and a new classification system evolved. Operational information of this kind won over the sceptics, enlarged the user base and helped develop the technical and managerial expertise of large area projects handling. The volumes

demanding by many of these projects gave rise to nascent Indian geospatial industries. The partnership now includes a number of Central and State Government departments, industries, and academic institutes apart from state centres and leading research centres like IITM, FSI, GSI, NIO, NPOL, IMD, NCMRWF etc. in addition, SAC played a pivotal role in training and capacity building in the country through direct training, curriculum design, support to professional societies.

Forecasting Agricultural output using Space, Agrometeorology and Land based observations (FASAL), coral and mangroves Studies, climate change projects are of recent origin. A new dimension to RS applications is the planetary studies including study of geology, biology and mineralogy made possible because of success of Chandrayaan-1. The lineage will continue with future lunar and mars missions.

Spectrum of applications projects

FASAL (Forecasting Agricultural output using Space, Agrometeorology and Land based observations) is the flagship programme under RS application for agriculture. Production forecasting of major crops at national (kharif rice, rabi rice, wheat, jute, potato, mustard) and at district level (wheat, cotton, mustard, sorghum, sugarcane) in the country is routinely carried out every year. Synthetic aperture radar (SAR) data is being used for national kharif rice production forecasting. Study of glaciers has assumed lot of significance due to the awareness on global warming because they control the later and are also source of water for the rivers. SAC has taken up a number of studies for inventory, monitoring and retreat of glaciers of Himalayas

Another important area of RS applications is mapping the degradation of the land under the influence of natural and anthropogenic causes in arid, semi-arid and dry sub humid

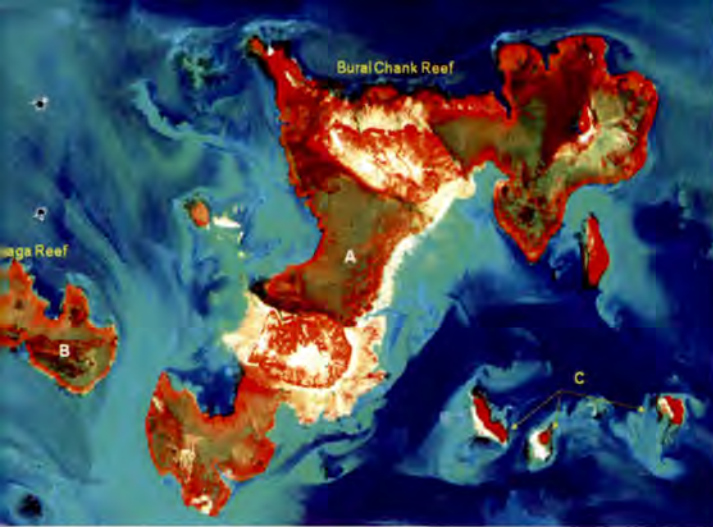
conditions. Desertification status mapping of entire country using multitemporal Resourcesat-1 AWiFS data has been carried out. It has been estimated that 105.48 m ha area of the country is under Land degradation. About 82.5 m ha area is under desertification.

Since time immemorial sea shores and rivers sides have remained the most sought after territories for human habitation. mangroves and coral reefs which have profound effects on the coastal ecosystem have come under pressure. The work done by SAC on coastal zone like coastal landuse, mangrove maps at dominant community level, coral reef maps at eco-geomorphological levels laid the foundation for regulatory mechanisms for protection of coasts. Coastal Zone Information System (CZIS) for entire Indian coast. Models have been developed for preparing integrated coastal zone management plans and identifying suitable sites for mangrove plantation.

India is a maritime nation with a long coast line and a huge exclusive economic zone as big as Indian landmass. Starting with small experiments under IRS-UP, an operational system of informing fishermen on location and abundance of fishery resources has been implemented using synoptic observations of temperature and ocean color from space-borne sensors like NOAA AVHRR, Oceansat etc. The fishery forecast now reaches a level high success (70 -80 %) and improved catches (70-200%).

Atmospheric and Oceanic Applications

Meteorology and Oceanography have been of keen interest to ISRO since inception of remote sensing program in early 70s. The launch of Bhaskara-I and II, INSAT series, availability of data from NOAA, launch of SEASAT, International MONEX Programme etc have been a boost to these activities. Atmospheric sounding for study of monsoon over Indian sub-



continent was carried out as early as 1979 in a project called MONEX (Monsoon Experiment) over Arabian sea and Bay of Bengal using Omega-Usonde launched from the RV ship Gaveshani. The data from geostationary satellite INSAT had been in operational use in IMD for various applications since mid 80s.

The gamut of applications now covers upper air and boundary layer parameters, cloud dynamics, rainfall estimation, oceanographic parameters, and numerical modeling etc. It has emerged as the core group of researchers in the country handling satellite data from optical, thermal and microwave regions of the electromagnetic spectrum and developing unique algorithms for parameter retrievals and their utilization. The satellites, IRS-P3 with the sensor MOS onboard and OCEANSAT-I, with MSMR and OCM payloads have given a fillip to these activities in terms of real time utilization of satellite geo-physical information and enhanced user interactions. The supply of data is assured given a large number of ocean colour sensors, microwave instruments, etc. on the anvil globally and from forthcoming Indian missions like OCEANSAT-II, RISAT, INSAT-3D, Megha Tropiques etc.

In order to maximize the utilization of satellite data, especially from Indian missions, an umbrella program "Meteorology and Oceanography program (MOP)" was formulated. **Major** thrust areas under this program were atmospheric and oceanic numerical modeling and satellite data assimilation for improved predictability under Extended Range Monsoon Prediction (ERMP) and Ocean State Forecast (OSF) experiment. A pilot project was carried out to demonstrate the end-to-end usage of ocean information in collaboration with other national institutes. The ocean state information was provided to the ISRO's Space Capsule Recovery Experiment

Module (SRE-1) during January 2007. Under agreement with India Met Department (IMD), operational procedure are being developed for processing data from INSAT series of meteorological satellites (i.e. INSAT-3A, Kalpana-1, and INSAT-3D) to produce images, calibrated and geo-located binary data and geo-physical retrievals for various atmospheric and environmental parameters. This system is called as IMDPS (INSAT Meteorological Data Processing System). A Fast Track system capable of processing INSAT-3A and Kalpana-1 has already been designed and implemented at IMD.

Planetary Applications

ISRO's Chandrayaan-1 mission catapulted the organization's voyage into the field of interplanetary science and applications. Detailed analysis of the data received from Hyper Spectral Imager (HySI) was undertaken for an impact crater called Lalande crater on the near side of the moon surface. HySI images are much better in spatial resolution and spectral content compared to previous data of the crater from Clementine (NASA mission). Spectral data has also been used to generate titanium and iron abundance maps of Lalande crater. Parts of the Mare Orientale basin on the extreme western edge of the near side were covered by Chandrayaan-1. This basin was not investigated since Apollo.

ISRO's CAL/VAL Program

To support the generation of high quality climate data set, post-launch validation of derived geo-physical products and calibration of sensor data, it was necessary to establish a fully controlled and well equipped site for measurements of various parameters. Under Meteorology and Oceanography Programme MOP-II, CAL-VAL (Calibration-Validation) site at Kavaratti in Lakshadweep was conceived and buoy-based data collection platforms were deployed 30 km off Kavaratti in deep-ocean between Kavaratti and Agatti islands.

Applications teams are right now engaged in preparing for use of data from forthcoming missions - MEGHA-TROPIQUES (MT), INSAT-3D, RISAT and SARAL. In each case multi-institution arrangements are being worked out for wider use of data from flowing from these missions. Training, data and financial support are provided under SAC coordination.

ISRO-CNES joint mission Meghatropiques will help study the convective systems and their influence on tropical weather and climate. The major challenge of the project is the retrieval of geophysical parameters from MT sensors. SARAL (Satellite for Argos and AltiKa) Utilization Program, under the framework of ISRO-CNES scientific cooperation for oceanographic research, aims at using Ka-band (35 GHz, 500 MHz) altimeter (AltiKa) in SARAL to improve the understanding of both time varying ocean circulation and time invariant geophysical characteristics of the sea floor. AltiKa will also contribute to monitoring of sea level rise, sea state and forecasting, marine meteorology, land hydrology, and monitoring of inland and polar ice sheet.

INSAT-3D Utilisation preproject is aiming to generate improved geophysical parameters and their applications for improvement in (i) Numerical weather forecast in various temporal scales, (ii) Cyclone track and intensity forecast, (iii) Ocean State forecast, (iv) Agricultural monitoring and forecast, and (v) Fire monitoring. Major thrust will be given to the available sounder data, combined use of imager and sounder data for key atmospheric and oceanic process, and the integrated application for agrometeorological studies. SAC is coordinating the user readiness for using Synthetic aperture radar (SAR) data from Radar Imaging satellite (RISAT-1) for studies on soil moisture, snow, flood, forestry, topography, agriculture, geology, coastal and ocean sciences. RISAT-UP plans are drawn from the heritage projects like ERS-1/2, Radarsat-1/2, JERS-1, SIR-C/X-SAR, ALOS-PALSAR.



Chapter 4

Snapshot: A humane touch of technology

Themes:

- Space For Societal Development
- An Experiment in Social Broadcasting
- The Era of Interactivity
- Doctors at a Distance
- TV is the Teacher
- A window to space for every Village

A humane touch of technology

The large group of inmates sat quietly in the courtyard of Sabarmati jail. Anticipation was in the air. Every one looked at the terminal and the dignitaries on the dais. The small display is to come alive through a satellite network. The isolation borne out of their deeds was soon going to be over at least in one respect and symbolically through a gentle touch of technology. The jailors are somewhat relieved as need for carrying their slippery baggage to civil hospital is going to ease.

Today on October 2, 2009 satellite connectivity through Edusat will link the Sabarmati jail premises with Civil hospital easing the burden of shifting them for medical assistance. The VRC terminal is the latest in the series of hundreds of such outreach kiosks built around the backbone of satellite network.

The story of bridging the user with services via satellites is one of the dreams with which the foundation of ISRO was laid. The last mile connectivity of ISRO is the job well done by DECU.

A brief time travel would unravel this fantastic journey with its beady mix technology, sociology, arts and expressions.

Space for Societal Development

ISRO began establishing that a satellite system can indeed contribute to the development of a nation. However, before trying out the satellite system it was necessary to carry out some controlled experiments to prove and demonstrate that the television can contribute to the nation's development. Accordingly, it was decided to start a programme on agriculture – Krishi Darshan - giving information to the farmers on how to increase the crop yield. Krishi Darshan was also an experiment to see how to make the use of television for farmers in a limited area around Delhi.

The next logical step was the initiation of the Satellite Instructional Television Experiment – the 'SITE' programme, hailed as 'the largest techno-social experiment in the world' during 1975-76. SITE officially started in September 1969, with signing of the memorandum of understanding between Atomic Energy & NASA of USA and the work started on developing the hardware as well as software required for this experiment.

2400 villages from 6 states were selected where the Direct Reception Sets (DRS) were to be deployed. The selection of the states, districts and villages was based on criteria of backwardness. From the States of Orissa, Madhya Pradesh, Bihar, Karnataka, Rajasthan, Andhra Pradesh, such villages had to be selected which had the facility of electricity. Hence, 'Operation Electricity' was launched to find villages which not only had electricity but that electricity was available in a public place like panchayat or a school building.

As a part of SITE, ISRO had the end-to-end responsibility of producing, broadcasting, reception of the software, getting audience feedback and social science evaluation of these programmes. Initially, the All India Radio (AIR) set up three bases in Hyderabad, Cuttack and Delhi for programme production and a TV studio for playback and transmission of pre-recorded TV programmes was built in Ahmedabad. To begin with, science based programmes for school children were produced. Soon, AIR realized that producing science based programmes was not their cup of tea.

Dr. Sarabhai was convinced that a dedicated agency was required to produce quality educational and development programmes. He was also convinced that the agency should be outside the government structure. The Audio Visual Instructional Division (AVID) was especially created to work for the software requirements of SITE and also parallel a Centre for Audio Visual Education Communication (CAVEC) was proposed to be created as part of Nehru Foundation. Dr. Sarabhai was in correspondence with agencies like the Family Planning Foundation, and the Ford Foundation looking for financial support for the proposed activity. If Dr. Sarabhai had survived, given the institution builder that he was, in those days itself, Ahmedabad would have probably had an institution specializing in Research, Training, Production of Education and Development oriented software.

To take care of software requirements of SITE, an in-house Software Systems Group (SSG) under the Chairmanship of Prof. Chitnis was then formed in SAC. Around 400 programmes had to be produced to sustain four hours of daily transmission. Most of the programmes were simultaneously produced in two languages and when SITE was launched in 1975, the satellite and ground equipment had the capability to beam the programmes in two different languages.

The approach to Science programme production to some extent was influenced by the approach adopted by the Children

Television Workshop, USA for the Sesame Street series. This led to the development of research based programming, leading to development of research studies like Audience Profiles, Needs Assessment, Pretesting, etc. It also gave an understanding into the team mode of production, where the producer, researcher, writer, and the content expert, all from different fields of specialization had to work together to produce an effective educational programme.

An Experiment in Social Broadcasting

To counter weigh the centralizing force of a satellite communication, the decentralizing Kheda Communication Project (KCP) was started with limited broadcast systems, which are now called the Low Power Transmitters (LPTs). Thus, KCP could broadcast either local television programmes or national satellite television programmes. To facilitate programme viewing, 651 community TV sets were installed in public places like schools and panchayat offices covering 400 villages in the radius of 35Kms. The village audiences gathered in evening to view the broadcasts. The responsibility of ISRO was producing the development oriented programmes. This transmission of the local programmes was started in 1975 and continued till October 1989.

The programme production staffed with qualified production personnel and researchers made it an ideal setting for testing the effectiveness of television as a 'participatory interaction communication channel' for rural development. The KCP was thus different from SITE as it involved close interaction, frequent feedback, and even audience participation in programme production. This was possible because of physical proximity of the audience and the production agency.

KCP became an important learning experience in development oriented programmes. The major area of programming were firstly information oriented, - Hardcore

programmes in areas of Agriculture, Health, Animal Husbandry, etc., and secondly, - social change oriented areas of soft core programmes like programmes for women, children, and social issues like untouchability, gender inequality, Dowry system, etc.

The research based programme production approach was applied, and in the long run, it led to the development of several approaches to development oriented programme production. Besides the normal Top-Down approach, it developed the Bottom-Up and Horizontal Approach to communication. It also led to field oriented Problem Solving programming, leading ultimately to the concept of Participatory programmes for development. The experiences in each of these areas in the KCP were not only unique but probably unparalleled anywhere.

The Kheda Communications Project received the IPDC-UNESCO prize for Rural Communication in 1985. To institutionalize ISRO's experience in this area, these activities were spun off from the Software Systems Group (SSG) of Space Applications Centre (SAC) into the Development and Educational Communication Unit (DECU) in December 1983. DECU was formed as an independent entity with a role to meet the goals of ISRO in promoting the usage of space technology for the benefit of common people.

The Era of Interactivity

SITE and KCP were projects mainly in dealing with broadcasting. After the launch of INSAT, a very rapid expansion of the Doordarshan networks was witnessed. Doordarshan was adding one transmitter every day for almost a year. This led to a great requirement of trained manpower. DECU became a training institute for Doordarshan, and conducted several other training programmes.

After the above experiences in broadcasting and training,

attention was directed towards interactive networks. Realising the limitations of broadcasting in an educational and training situation attention was paid to one-way video & two-way audio networks. Initially, the idea was to get the return audio via satellite, but the rapid expansion and improvement of the telephone networks and increase in availability of STD facility led to the return audio via PSTN being used. After initial experimentation, the first network was established in Gujarat with SIRD (State Institute of Rural Development), but the activity got a major boost when the demonstration was successfully conducted at Indira Gandhi National Open University (IGNOU) and it decided to use this one on an ongoing basis. The Training and Development Communication Channel (TDCC) network was declared operational by the Prime Minister (February 1995) and subsequently operational networks were established in Gujarat, Madhya Pradesh, Karnataka, Orissa, and Rajasthan. In almost all the cases the network was funded and operated by the State Governments.

With the growth in technology, the above concepts of broadcasting and interactivity were transformed into VSAT (Very Small Aperture Terminal) networks which would have all the above elements and which could also be used for data broadcasting and E-governance. This led to the development of Gramsat networks for Orissa, North-East Region and Andaman & Nicobar Islands.

Doctors at a Distance

The VSAT technology was also adopted for Telemedicine. This activity started after reading a write-up in the local Ahmedabad newspaper of an agency in Ahmedabad that had developed Telemedicine software and had initiated some activity in and around Ahmedabad. The agency was invited for discussions and to make a demonstration in Bangalore. A pilot project was undertaken and in a short period of three years the network grew to cover fifty hospitals (1999-2002).

The ISRO Telemedicine programme, which started in 2001, has been connecting remote, rural & medical college hospitals and Mobile Units through ISRO Satellites to major specialty hospitals in cities and towns.

The Telemedicine connectivity covers the areas of Jammu & Kashmir, Ladakh, Andaman & Nicobar and Lakshadweep Islands, North-Eastern States, mainland states including tribal districts of main-land states like Kerala, Karnataka, Tamil Nadu, Chhattisgarh, Punjab, West Bengal, Orissa, Andhra Pradesh, Maharashtra, Jharkhand, Rajasthan, etc. The Telemedicine network has been further expanded to cover the areas of Mobile Tele-health and Continued Medical Education (CME). Presently, the ISRO Telemedicine network consists of about 382 hospitals, wherein 306 remote/rural/district/medical college hospitals and 16 Mobile Telemedicine units are connected to 60 specialty hospitals.

TV is the Teacher

The priority requirement of distance education to the masses subsequently translated into the launch of the India's first thematic satellite dedicated exclusively for educational services - the 'EDUSAT' (GSAT-3), launched by GSLV-F01 in September 2004.

The Edusat was launched with the objectives of supplementing the curriculum-based teaching, imparting effective teachers training, providing access to quality resource persons and new technologies, thus finally resulting in taking education to every nook & corner of India. Edusat is primarily meant for providing connectivity to schools, colleges and higher levels of education and also support non-formal education including development communication. The satellite was specially configured to reply through audio-visual medium, employing multi-media multi-centric system, to

create interactive classrooms. Edusat has multiple beams transponders covering different parts of India - five Ku-band regional spot beams covering northern, north-eastern, eastern, southern and western regions of the country, a single Ku-band national beam transponder with its footprint covering the Indian main-land region and six extended C-band transponders with their footprints covering the entire country.

Edusat provided a wide range of inter-active educational delivery modes like one-way TV broadcast, video conferencing, computer conferencing, web-based instructions, etc. The Edusat Utilisation was implemented in three phases i.e. pilot, semi-operational and operational phases. The Edusat pilot projects were initiated in Maharashtra, Karnataka, and Madhya Pradesh. The activity of defining the semi-operational and operational phases has been started. To trigger the process of national planning for Edusat utilization, a National Consultation was organized (July 2003). Subsequently, Regional Consultations were planned. This was followed by discussions with agencies like IGNOU, Anna University, CIET/NCERT, TTTI for the semi-operational phase. Discussions were also held with MHRD to evolve an operational organizational structure for Edusat.

While pilot phase has been completed, the semi-operational and operational phases have been put into implementation. Currently, under the EDUSAT utilisation project, ISRO has deployed 72 Edusat networks in 23 States & three Union Territories covering almost the entire country including all islands (Andaman & Nicobar and Lakshadweep), North-Eastern states and Jammu & Kashmir. The implementation in remaining states is under progress. ISRO has set up networks for users' with special requirements like Blind People's Association (BPA) (Visually challenged), RCI (Rehabilitation Council of India – Mentally challenged), Father Felix, Museums, etc. As part of the Edusat, a 'Science Channel' is on the anvil.

A window to space for every village

The Village Resource Centre (VRC) programme was initiated by ISRO during the year 2004 to facilitate overall development at village/community level by delivering the variety of space technology enabled products and services directly to the grassroots.

VRCs - being implemented in association with selected NGOs, Trusts, Universities/institutions and Government agencies - are envisaged to serve as a prime delivery system in the rural areas, for the services such as vocational/non-formal education, healthcare, local weather, environment, advisories on agriculture, fisheries, livestock, livelihood support, etc. Further, with the participation of stakeholders at local/different levels, VRCs are also able to provide a variety of other services such as information on price, market, pests & diseases, govt. schemes, e-governance related, job opportunities and a host of other ICT based services, and act as local helpline. VRCs are provided with fully interactive VSAT based communication facility linking them to selected knowledge/expert centres/hospitals. Spatial & non-spatial data/information relevant to land & water resources management at village/micro-watershed level is being made available at VRCs. The VRC programme is being implemented in a phased manner.

The first sets of VRCs were set up in Tamilnadu in association with MS Swaminathan Research Foundation, Chennai in 2004. At present, there are 473 VRCs spread over 22 States/Union Territories. The programme is being implemented in association with selected NGOs, Trusts, Universities/Institutions and Govt. agencies, and as of now there are 44 partners/associating agencies involved in the programme.

Chapter 5

Space tells the place: Navigation system development

Snapshot: Ultimate link of Time to space

Themes:

- Learning Phase
- GAGAN: the augmentation system
- Indian Navigation Systems takes root
- Frequency and Modulation
- Phase-centred Antennas
- Unique signal Structure
- User Receivers
- Satellite ephemeris
- Atomic Clock

Ultimate link of Time to space

*W*atches generally connote not just time but also beauty of design and craftsmanship and more often than not mass manufacturing. But the one which is ultimate in time precision is neither accessible as a time piece nor is a piece of beauty or a mass produced item. It is actually a piece of scientific and technological marvel. Yes, the atomic clock involves the craftsmanship of highest technology. Its name denotes a kind of grandness not associated with anything else meant for time telling.

Development of atomic clock is crucial to navigation as a link between time and distance for the orbital messengers called navigations satellites. Each carries one. Design of such a clock has been one of the central challenges to the realization of Indian dream of its own navigations system.

The entangled wires and connected apparatuses in the lab of satcom and navigation area looks pretty ordinary till someone tells you that this is country's proud prototype of the atomic clock based on the electronic transitions of Rubidium atom. Once developed fully with its cousin unit from Delhi, the clock will go in the constellation of IRNSS and account for a large portion of precision in location accuracy of the India's maiden navigation system.

The payloads for IRNSS being developed at SAC signify the pinnacle of design experience not only in area of atomic clocks but in RF systems and signal structures as well.

Satellite Navigation System

As Navigation is related to position on earth, this discipline is tied up with measurements on earth on one side and technologies of finding locations from space on the other side. In that sense the quest of satellite navigation at SAC brought the two very distinct branches like Satellite Geodesy under Remote Sensing Area and the Receivers Technology under Satellite Communication Area on a single platform. This was a totally new branch for SAC and considerable learning was needed.

Learning phase

Convergent thinking on geodesy and satcom resulted in the development of first Navigation Receiver called Geo-receiver at SAC during 1975. This was developed to find the user location based on the Doppler correction technique available with Naval Navigation Satellite System (NNSS) of USA. A total of six receivers were developed during 1975-76. Four Geo-receivers were used by SAC Geodesy and Data Products team for survey related activities while two receivers were given to Survey of India for their experiments. Meanwhile system studies were done for developing navigation receivers using RDSS system of Geostar in 1980's. Subsequently a GPS Receiver was developed as a R&D activity. System studies on GAGAN provided learning opportunities in the area of augmentation and error corrections. During 2006-07, efforts were made to develop the GLONASS receiver but did not fructify.

GAGAN: the augmentation system

As part of ISRO's activities under Indo-EU Cooperation, the project GAGAN (Geo-Augmented GPS Aided Navigation) was conceptualized in 1992-93 which, after discussions with Civil Aviation Authorities, was formalized in 1996. GAGAN was to be part of Wide Area Augmentation System (WAAS) proposed by International Civil Authority Organization (ICAO) towards their initiative on future navigation systems based on corrected GPS signals. After initial planning at Department of Space level, a project proposal of GAGAN

was prepared by ISRO and initial study of GAGAN was completed in 1998. GAGAN, now a joint project of ISRO and Airport Authority of India, is executed with involvement of SAC, ISAC and ISTRAC. GAGAN will consist of a space segment and a ground segment. While SAC is responsible for payload development and deployment of ionospheric correction stations, ISAC is responsible for spacecraft development and ISTRAC is pitching with Master control stations.

The space segment, after many variations, has essentially become a bent pipe transponder operating in L band. The ground segment comprises of TEC (total electron count of ionosphere) measurement stations over India, which were initially in 8 locations but now are expanded to cover 18 and will finally go up to 22 locations. The multiple locations stations established by SAC, measure TEC and transmit it via VSAT network to a master ground station. Based on above inputs the master station generates a error message signal very similar to GPS Data stream with identical spectrum characteristics that of GPS (GPS Like Signal) and transmits it to GAGAN in C band. The GAGAN payload, a C x L bent pipe transponder broadcasts this GPS like signal as an augmented GPS signal in L band to all its intended users. Any user having a SBAS (Satellite Based Augmented System) receiver under the GAGAN coverage can utilize this signal for improving its position accuracy. However GAGAN, the augmented signal is specially meant for civil aviation and for cat-1 automatic landing in all weather conditions. The service area of GAGAN signal for getting an improved GPS accuracy (less than 6 meters) is over Indian Flight Region. SAC has developed an error correction model, based on TEC measurement and estimates.

The development of GAGAN payload was initiated in 2004 and first payload was slated for launch in 2009 but suffered a setback due to the launch failure. It will now be launched on GSAT-8 to provide navigation services in India. GAGAN will have three payloads for (A) C x C Payload for ranging (B) C x L1 and C x L5 GPS like signals for augmentation.

Indian Navigation System takes root

In order to achieve self-reliance in the strategic sector of Satellite based Navigation, the country proposed Indian Regional Navigation Satellite System (IRNSS) during 2004-05. The plan was to provide independent navigation services in India and 1500 km periphery around it using seven satellites in a mix of geostationary and geosynchronous orbits. The entire system was to comprise of Space segment, ground segment and user segment. The activities related to the development of payload, an important part of space segment for IRNSS satellites, were entrusted to SAC. SAC was also given the responsibility of developing user receivers for IRNSS. The development of IRNSS technologies has formidable challenges for SAC.

Frequency and modulation

The frequencies used in L-band were already occupied by other Navigation systems like GPS, GLONASS, Galileo etc. Only one frequency in L-band was available. Hence a payload with a mix of one frequency in L band (L5) and other in S-band had to be developed. Normally all existing as well new Navigation Systems put multiple signals on a single frequency for interoperability, compatibility with other global systems as well as for their own secret or secured services. In addition, to meet the special (futuristic) requirement of very low signal acquisition at ground receivers, a pilot signal (on board) is also accommodated on very same frequency. Managing so many signals on a same frequency with a restriction of achieving a constant envelope was a big challenge and SAC had to adopt for an upcoming and new technology of BOC modulation with interplexing scheme for phase compensation. – as against all other earlier well proven systems of rectangle BPSK modulation.

Phase-centred Antennas

The on-board antenna operating at diverse frequencies with coincident phase centres is another big challenge. SAC has finally successfully designed a composite helix, phase-centred antenna structure operating at L and S bands.

Unique signal structure

Other problem originates from late entry as IRNSS services are required to be at par with second generation navigation satellites of the world. This demands that the location signals reach right inside the buildings. This dictates a signal structure with low bit rate, highly efficient error-correction and interleaving schemes, sub frame structure for faster “Time to first fix”, messaging facility for futuristic applications. This challenge has resulted in the development of number of algorithm, hardware and simulations to realize a 25-bit, four sub frame, signal structure for IRNSS.

User receiver

Developing user receiver compatible with low-bit rate signal structure was another challenge. Since the transponder had BOC modulation, and operational receivers of this kind were not available in the world, the design heritage was non-existent. Designing a receiver for low bit rate of signal in presence of wide spread in the carrier was a itself a big challenge. These challenges were handled by SAC and now a breadboard version of IRNSS receiver for Interplexed BOC modulation is ready.

Satellite ephemeris

Determination of the orbit for geostationary satellites is inherently difficult. In navigation situations, this is a challenge since ephemeris accuracy directly affects the location errors. In order to improve the orbit determination, SAC proposed and developed CDMA ranging technique. And according to above requirement a C x C bent pipe transponder is also accommodated in IRNSS satellite which can support 6 simultaneous ranging signals.

Atomic clock

Timing signal are critical to location accuracy in satellite navigation services. Standard method is to use atomic clocks – the best known devices to mankind. SAC has undertaken the challenge of developing an atomic clock. A prototype Rubidium Atomic clock has been realized. The work on physics model is progressing well at the National Physical Laboratory. The first of IRNSS payloads will be dispatched from SAC in 2011 and hopefully the satellites would start entering the constellation by next year.

Chapter 6

The changing face of an earnest spirit: The organizational changes in SAC

Snapshot: Changes make SAC evergreen

Themes:

- The Heritage
- SAC as Centre
- Definitive Stage
- Thrust stage
- The Wisdom of 2010
- SAC of 2010

Changes make SAC evergreen

The fluids move in response to gravity and surface slopes. By analogy, organizations respond to changing goals and environment by rearranging its resources. The fluidity of organization is one outstanding feature of ISRO in general and SAC in particular.

Right from its inception, ISRO through the practices of its heritage units has evolved a method of organizing its activities by a mix of matrix and hierarchy which by design leads to dynamism. Little does one realize the role this aspect plays in wonderful achievements ISRO, despite being a government department, has amassed over the years. The beauty of this fluidity is seen for SAC over its more than four decades of evolution as a centre of ISRO.

What has been captured here is the reorganizations which took place about dozen times in last forty odd years of SAC. What is left out is the matrix method of dynamic re-arrangements of teams for specific tasks related to missions and projects. These are simply too many to be recorded going by the number of payloads SAC has contributed to the missions of ISRO.

SAC started by simply aggregating the predecessor units in ESCES campus in 1972. Need for coordination led to the clear divisions of satcom and remote sensing. Over the years as microwave technology

matured, the migration to full fledged earth observation activities around microwave technology was assimilated. The navigation as an activity, despite heritage, features only recently. Reorganizations have also accommodated people with exceptional contributions. To that extent organization has given importance to personalities as well as the functions.

The building of huge technical facilities for engineering fabrication and test and evaluation labs for reliability engineering required for mission critical projects lead to establishment of separate areas for technical support.

Today SAC has nearly 2000 employees organized in different technical areas and groups apart from administrative divisions. SAC has been headed by distinguished scientists as its Directors. Renowned scientist Prof Yash Pal was its first Director. Distinguished scientist Dr R R Navalgund, an alumnus of IIT and TIFR, is the ninth and the current Director of SAC.

Experimental Satellite Communication Earth Station (ESCES) was set up in 1965 with the basic objectives of experimentation with satellites, research and development in the field of satellite communications and training in satellite communications technology. Electronics Systems Division (ESD) was set-up in 1969 mainly to develop the hardware requirement of the ground segment for Satellite Instructional Television Experiment (SITE) and also to deploy, operate and maintain the direct receivers during SITE. Microwave Division (MID) was working on various systems at microwave and millimeter wave frequencies to meet variety of requirements from different users and also initiated microwave remote sensor development. History of MID can be traced to the creation of Microwave Antenna Systems Engineering Group in 1971, part of which was merged with Electronics Corporation of India Ltd.

Remote Sensing and Meteorology Applications Division(RSMD) was set up to carry out research and to adopt space technology for earth resources survey and management.

Software Systems Group (SSG) was responsible for software activities of ISRO connected with SITE. The responsibilities included experiment design, selection of villages for installations of TV sets, production of programmes, preparing audience profiles, pretesting of programmes, and activities connected with research, feedback and evolution of SITE. This group was consisting of Research and Evaluation cell, Production Cell and Co-ordination and Operations Cell.

In addition to above, SAC also had System Engineering Group to look after system engineering aspects and a SITE Management Office (SMO).

SAC as a Centre

Space Applications Centre (SAC) came into being in the year 1972 with Prof Yash Pal as its first director and Shri S R Thakore as first Controller. The Centre integrated all the above space application activities going on the city. SAC started with a unique diversity of skills amongst 800 odd staff. To meet the requirements of SITE and remote sensing experiments, a diverse group comprising hard core engineers, physicists, agricultural and forestry scientists, social researchers, film producers, management experts were available. The efforts of SAC were finally concentrated in two primary areas, viz satellite communication, and remote sensing and meteorology.

The formal division of SAC into two areas focusing on remote sensing of earth resources, meteorology and weather forecasting and Communication, including satellite broadcasting took place in 1975. Communications Area (CA) was headed by Shri N.Pant, as Chairman with Shri OPN Calla as Co-chairman. Prof. P D Bhavsar became chairman of Remote Sensing Area (RSA). Test, Evaluation, Standards and Calibration Facility (TESC) headed by Shri S R Naik and Engineering Services was headed by Shri M.U.Bhakta. Planning and Projects Group (PPG) had a very important role with Prof. E V Chitnis as Chairman and Shri P P Kale as Co-Chairman. Shri N Sampath and Shri P Panikar played important roles in PPG and technology transfer activities. Prof. E V Chitnis was also the chairman for Software Systems Group (SSG) which eventually became DECU.

This basic structure of SAC has led many people on path to their prominence. So people like Shri N Mohanty, Shri M.M. Shah, Shri Pramod Kumar, Shri M.S. Kodikal, Dr. O.P.Rastogi, Shri Leo Lasrado, Shri R.C.Garg were heading different divisions within communication area and later on became

leaders of these functions. Similarly, Shri D.S.Kamat, Dr. Baldev Sahai and Dr. George Joseph who were heads at the remote sensing area took important responsibilities in the Centre. Shri K S Karnik, Shri B S Bhatia and Shri B C Agarwal were heading the functions of SSG and later shouldered important responsibilities in DECU. Dr. TA Hariharan made important contributions

Development and Educational Communication Unit (DECU) was established in 1983 as an outgrowth of the “software” activities in TV program production and social research initiated for the Satellite Instructional Television Experiment. With Shri Kiran Karnik as its first director, DECU started with mandates of program production, development and adaptation of video hardware, communications research, training, consultancy and studies in fields of interest to space applications. Its major tasks on hand included: i) the Kheda Communications Project (KCP) ; (ii) Training, especially of Doordarshan staff; and (iii) Studies and research. In 1988, DECU was reorganized into four groups with Shri B S Bhatia as Deputy Director. Shri K Viswanathan played major role in program production and Shri G C Jain contributed to studio video technologies. The next major reorganization took place in 2006 after realizing that a different structure is needed to handle responsibilities like content generation and satellite networks establishment.

Definitive stage

The era of SITE, STEP, Bhaskara was over. IRS missions and Insats were emerging as long-term national systems. Clear picture of space services in communications and earth observation and new vistas in space applications like microwave remote sensing, satellite geodesy, satellite navigation, search and rescue, mobile satcom services etc were emerging. With this backdrop SAC underwent its most defining reorganization. The concept of Deputy Director, Group Director and Division Heads were formalized. With

DECU having spun off, SAC was divided into four entities: Satellite Communications Area (SCA) under Shri O P N Calla, Remote Sensing Area (RSA) under Dr. George Joseph and Microwave Remote Sensing Program (MRSP) under Shri O P N Calla as Program Director and Technical Support Services Group (TSSG) under Shri Leo Lasrado.

Shri K Narayanan and Dr. K N Shankara emerged as leaders of different technical units under satcom while Shri A K S Gopalan and Shri A R Dasgupta took major responsibilities under remote sensing. Shri V Ramaiah, Dr Dipti Rastogi, Shri A S Kiran Kumar, Dr Ram Rattan, Shri K angchenchaiah made important contributions.

With Microwave Remote Sensing Programme, SAC took lead in the ISRO/DOS initiatives on active/passive microwave remote sensing satellite payloads and user preparation. Shri N S Pillai, Shri S S Rana, Shri S B Sharma and Shri V R Gujaraty played important roles and went on to lead various functions within the program. In 1989, MRSP was formalized as Microwave Sensors Development Group (MSDG), headed by Shri R C Garg, under Remote Sensing Area to develop the Microwave Sensors required for ground based, airborne and space borne remote sensing missions.

Reorganized TSSG brought out important contributions from Shri S R Naik, Shri R C Garg and Shri M M Shah. Shri N Narasimhan, Shri N C Bhavsar, and Shri P L Kumar made important contribution in the expansion of technical facilities.

The initial directions of growth were confirmed by beginning of nineties and there was need to consolidate the base structure into more focused activities. This happened in the reorganization of 1994. It also signaled arrival of new activities like Reliability & Quality Assurance and Organisational Development & Training Cell on their own. Shri K

Bandyopadhyay, Dr. R R Navalgund, Shri V K Gard, Dr H O Gautam, Shri Raghubir Singh and Shri P Dhar emerged as important leaders in this period.

In 1996, Shri AKS Gopalan was designated for the first time as Associate Director of SAC. The year saw major changes in Satcom area as it was divided into two to take care of the applications including ground hardware and the space hardware separately under Dr D Rustogi and Shri N Mohanty respectively.

Soon remote sensing area followed suit in 1998 when sensor, data processing and applications were separated out under Dr V S Iyengar, Shri A R Dasgupta and Dr. R R Navalgund respectively as deputy directors. Under these areas, Dr J S Parihar, Dr S R Nayak, Dr K L Majumder, Shri A S Kiran Kumar, Shri K Nagachenchaiiah and Dr. Ram Rattan played key roles. The formation of meteorology and oceanography group under Dr M S Narayan was an important move in this phase as activities related to atmosphere and oceans were focused and eventually led to establishment of important services like weather forecasting, cyclone predictions, ocean state forecasting etc in the country. Meteorology and oceanography group was relocated to Bopal campus and played an pivotal role in functioning of the CSSTEAP activities which were centred around Bopal campus.

Reliability and Quality Assurance activities were reorganized once more in 1998 with Shri P Dhar as group director and Shri P L Kulkarni as a head of division.

Thrust stage

In order to provide a thrust to the convergence of Satellite Communications and Information Technology for commercial and social applications, SATCOM & IT Applications Area (SITAA) was formed in 2000 with Shri A R

Dasgupta as deputy director. This Area carried out advanced R & D in wide band services, high speed networks, mobile satellite communication services, satellite navigation services, data broadcasting etc. Dr K S Dasgupta and Shri K Bandopadhyay held key portfolios. DES was named as SATCOM Experiments Operations Group – Delhi (SEOG-D) under Shri M L Hasija.

Antenna development for communication satellites, earth stations and microwave sensors were carried out separately under MISA and SEDA. Compact Antenna Test Range was established at SAC for development of antennas both for communication and remote sensing. With a view to consolidate the antenna development activities in this Centre for space, air and ground applications, the activities being carried out at different entities were brought under Antenna System Group under Dr S B Sharma in 2002. ASG had to cater to antenna requirements for both communication and microwave remote sensing payloads.

In the same year, Satcom activities were bifurcated into system and technology areas with Dr H O Gautam and Shri V K Garg as deputy directors. Technology area catered to R & D and technology development and design of advanced communication payloads and special payloads. The systems area focused on operational satellites like INSAT/GSAT which were to be configured, fabricated, integrated, characterized and delivered to ISRO missions. Systems area was involved with industries in a major way to fabricate and test the payloads while Technology area was responsible for transferring the technology developed to the industries for production and supply to the INSAT Programme.

In 2003, Remote Sensing activities was rearranged by combining the Remote Sensing Applications Area (RESA) and the Signal, Image and Information Processing Area (SIIPA) into a single entity called Remote Sensing Applications and Image Processing Area (RESIPA) with Dr. K L Majumdar as

deputy director.

Microwave sensors development activity at SAC was emphasized by creating an independent Microwave Remote Sensors Area (MRSA) in 2004. MRSA under Shri S S Rana was consolidate and continue the important developments like high resolution multi-mode space and air-borne Synthetic Aperture Radar (SAR), Scatterometer, Altimeter and Radiometers for Satellite missions such as RISAT, Oceansat-2, Megha Tropiques, etc.

The following year, Shri O P Kaushik was designated as deputy director of satcom systems area and the Antenna Systems Group was upgraded as Antenna Systems Area and Dr. S B Sharma was designated as deputy director.

The wisdom of 2010

Although the technical support areas for electronics, mechanical engineering and reliability remained unchanged for a long time, the mechanical engineering activities were reorganized in 2009 for better coordination. Mechanical engineering comprises design, development and realization of communication, remote sensing and navigational payloads. As differential loads were experienced in scattered units, a consolidation was needed to synergize the activities like design, development, machining/fabrication and testing. Constitution of Mechanical Engineering Systems Area (MESA) with Shri D Subrahmanyam was a step in that direction.

The last reorganization completed in the beginning of 2010 represents the important role SAC is going to play in the area of Satellite Navigation which is to be emphasized along with communication payloads. Accordingly, Satcom Payload Technology Area (SPTA) and the Satcom Payload Systems Area (SPSA) were merged to form Satcom and Navigation Payload Area (SNPA) with Dr K S Dasgupta as deputy

director. Also, towards synergizing the ground hardware activities of satcom and navigation, the erstwhile Satcom and IT Applications Area (SITAA) was re-designated as Satcom and Navigation Applications Area (SNAA) with Shri V S Palsule as deputy director.

Changes in remote sensing applications are likewise reflected the recent reorganization. Towards studying the Earth, Atmosphere and Ocean interactions and processes leading to climate change and to focus the studies on planetary sciences, the Remote Sensing Applications Area was reorganized as Earth, Ocean, Atmosphere, Planetary Sciences and Applications Area (EPSA) with Dr J S Parihar as deputy director.

The story of reorganizing the activities will continue in future and as a pattern this might take place every five years or so. As 2011 knocks on the door, many stalwarts will superannuate and SAC has a major challenge of bringing forth the new leaders for the current and future roles.

SAC of 2010

As of December, 2010, technical activities in SAC are divided into eleven major entities with library and construction divisions providing important support. The following are the Technical Areas / Groups and their heads:

Director	:	Dr. R R Navalgund
Associate Director:		Shri A S Kiran Kumar
Director, DECU:		Shri V S Palsule
Controller	:	Dr.(Smt.) Namita Priyadarshee

1. SATCOM & Navigation Applications Area (SNAA)
(DD: Shri S S Valdiya)

2. SATCOM & Navigation Payload Area (SNPA)
(DD: Dr. K S Dasgupta)
3. Sensors Development Area (SEDA)
(DD: Shri DRM Samudraiah)
4. Earth, Ocean, Atmosphere, Planetary Sciences & Applications Area (EPSA)
(DD: Dr. J S Parihar)
5. Signal and Image Processing Area (SIPA)
(DD: Dr. P K Srivastava)
6. Microwave Remote Sensors Area (MRSA)
(DD: Shri Tapan Mishra)
7. Electronics Support Services Area (ESSA)
(DD: Shri V N Kaduskar)
8. Mechanical Engineering Systems Area (MESA)
(DD: Shri D Subrahmanyam)
9. Systems Reliability Area (SRA)
(DD: Shri R K Dave)
10. Antenna Systems Group (ASG)
(GH: Shri Rajeev Jyoti)
11. Planning & Projects Group (PPG)
(GD: Shri R P Dubey)
12. Library & Documentation Division (LIB.)
(Hd.: Smt. D R Patel)
13. Construction & Maintenance Division (CMD)
(Hd.: Shri Rajesh Ranjan)

(DD: Deputy Director, GD: Group Director, GH: Group Head, Hd: Head)
Chapter 6

Chapter 7

A life and living of beauty: The campus and welfare

Snapshot: Of birds, bushes and buildings

Themes:

- SAC gets peak of City
- Building in SAC Campus
- Welfare & Housing
- Staff Associations
- Security and CISF
- Vikaram Sarabhai Space Exhibition

Of birds, bushes and buildings

As the November sun ascends towards zenith, the gold of sunbeam is turning silver. Step plaza lawns are shimmering golden green. The ear-bud like flower bunches hang amidst the dark foliage of tree jasmines lining the Site avenue. Over their canopy and on top of the ESD building an eagle is perched on top edge of the equator-facing antenna, not far away from the twig nest in neem tree, from where it flies away in a lazy circle to a small flock of eagles circling the eastern slope of Jodhpur hillock in anticipation of the long joy rides in the upwelling thermals.

The ageing neem tree watches the daily routine of bunch of barbblers and squirrels foraging on its foot for little morsels. A little far off, the trays hanging from kodia tree are providing feast to parrots who are tolerating the audacity of lone squirrel partaking the grains right from their beaks. In the tree groves on the ridge, a couple of peacocks are preening their glistening feathers. The bunch of playful langoors is perched on the trees near the main canteen.

In the midst of this rich ecosystem, the brick red – pink new auditorium building with its glass front stands with inviting looks and in all the glory proclaims its supremacy in architecture and technology. The lawns and trees planted around the building are collaborating with its beauty. The inaugural is still few days away.

Located atop the stabilized sand dune hillock, SAC main campus has

7000 trees, 20 lawns, 90 buildings, two auditoria, three canteens, a kiosk, an exhibition centre and still one fourth of SAC is left in natural form and hence a home to all kinds of indigenous flora and fauna. 2000 employees with 1500 others come every week day to work here. A much smaller number comes to Bopal campus and miniscule to its Delhi campus. The new piece of 40 acre land acquired in Bopal is going to develop as fourth campus – and of all the green buildings.

Within few kilometers from main campus, the colonies of SAC are models of living convenience. SAC Central School is teeming with students who excel each year to take the school to newer heights of glory. The new blocks are rising in Vikram Nagar colony. The public exhibition is going to expand.

Every patch of land used by SAC bears its Midas touch. And life and work at SAC seem like an oasis of a living ecosystem amidst the heaps of city sands.



Requirement of setting up earth station with clear view of horizon led to locate the ESCES and its earth station at the peak of the city called Jodhpur tekra falling in Jodhpur village. Jodhpur village, now a suburb of Ahmedabad; was, then, situated at some 20km from the heart of Ahmedabad city. A narrow, kachcha, rough approach road of yore lay on the north of the village and touched the campus where ESCES was positioned. The road in westward connected to other villages like Bopal, Ambali and Ghooma.

This site, which was to become sprawling Space Applications Centre in September 1972, was then covered with thorny shrubs, tall trees and dense thickets on an undulating terrain. Some of the patches of the vegetation were so dense and impenetrable that one would wonder whether any human has ever set foot, after the formation of earth, on these islands of undergrowth! Nevertheless, this miniscule ecosystem was home and heaven to myriads of 'other forms' of life: animals, birds and insects. Jackals, porcupines, rabbits, hares, cobras and varieties of other reptiles, mongoose, huge monitor lizards, garden lizards, rats and rodents, color changing chameleons etc were part of this bionetwork.

The feather-winged kingdom was represented by peacocks, peahens, parrots, kingfishers, kites, vultures, partridges, warblers, quails, wood peckers, copper-smiths, paradise fly catchers, green bee eaters, green pigeons, pied cuckoos, golden orioles, and even one of the most endangered of bird species : the Stone Curlews. The site, even today, can boast of harboring many of the fauna mentioned here. ESCES marked the beginning of space based communication activities in India. Several communication engineers from India and abroad have since been trained at the ESCES in the operation and maintenance of earth stations. ESCES, to this date, is still a highest point in the entire Ahmedabad city.



Buildings in SAC campus

SAC started with heritage round buildings called O&C Buildings near ESCES earth station – together they even now stand as symbol of SAC. Due to the need for clear view horizon, buildings around the centre need permission for vertical dimension. Director building and ESD building came later. By end of 70's, the present SAC campus had about 20 buildings against the 92 at present. Being located on hillock and running along the road on both east and west slopes, SAC had two entrances named as main gate on the eastern slope and RSA gate on the peak of the hillock. Apart from building with RCC roofs, SAC had about half dozen shades (buildings with roof of cement sheets which housed administration, accounts, CISF, bank and post office. Now these are being demolished to create new buildings. The bank and post office are brought outside the security zone. The new canteen building is coming as first green building. The two dining halls for VIPs have been renovated and the canteen at Bopal campus is being expanded to cater to larger numbers moving to that campus. The KIOSK introduced out side the secure zone during 2003 is providing a la carte catering on contract basis.

Welfare & Housing:

Space Applications Centre has 5 housing colonies located close to SAC consist of different types of quarters (A,B,C,D,E, hostel blocks of C-type and E1 type bungalows). The total number of quarters of around 1000 conforms to the government guidelines. No wonder people taking up a job in SAC move first to these quarters. DOS Housing colony Vikramnagar and Vastrapur have multipurpose community-hall for the benefits of staff to organize social and family functions/get to gather with a nominal charge. Staffs residing in different housing colonies have their welfare associations to organize common activities/ functions/ festivals.



Kendiya Vidyalaya (Central School) funded by DOS was started on 15.12.1980 with the inaugural by Prof. Yash Pal then Director, SAC in the current building of Vikram A Sarabhai Space Exhibition. Now the school runs pre-primary to class-XII with science stream classes in its own building in DOS Housing colony Vastrapur.

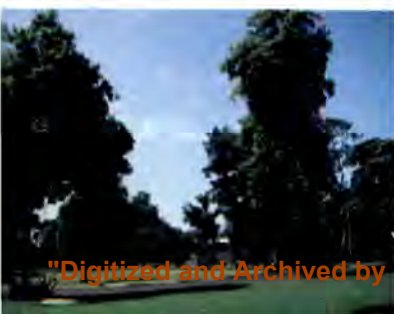
Medical facilities in SAC started around 1977 with a full-fledged dispensary consisting of three doctors located in SAC campus. These were re-located to different places in city but now operate in three major colonies viz. Vikramnagar, Vastrapur and Antarixnagar. Contributory Health Service Scheme (CHSS) started in the year 1980 has grown into vast network of panel consultants, laboratories, authorized medical officers, hospitals, nursing homes, etc. currently SAC is conducting geo-tagging of all employees for betterment of this facility.

Apart from group insurance, SAC has implemented accident, disability, sickness and death cover to employees under two schemes available under Vikram A Sarabhai Trust (VAST) - Scheme of Assistance to Families in Exigencies (SAFE) and VAST Insurance Scheme Whenever Accident Strikes (VISWAS).

SAC actively participates in voluntary blood donation programme with the help of Indian Red Cross Society 2-3 times in a year. This helps in sourcing the staff requirements through Indian Red Cross society.

To support the sports and recreation activities for the staff of SAC, a forum of SAC Sports & Recreation was established in 1982. This forum was re-named as SAC Sports Council (SSC) in 1987. SSC conducts sports and cultural activities which includes different sports/games & athletic meets and celebration of annual day.

Other welfare measures include Benevolent fund of SAC and Credit Society, Creche, Credit society, SAC & PRL Stores, SAC



Co-operative consumer store etc.

Staff Associations

SAC Staff Welfare Association (SACSWA) was established about 3 decade back with the scope of helping the staff for their different grievances. ISRO SAC Karmachari Mahamandal (ISKM) was established in the year 1978 to represent as JCM. The aim of ISKM is support the grievances of Group-C & D staff and also to take up to SAC management and DOS through various forums. In the year 2008 a group of ISKM staff were separated out willingly and formed another association named as SAC Employees Welfare Association (SEWA). Technical and Scientific Assistant Association (TASA) was started to take care the grievances of technical & scientific assistants of SAC. Scientific and Technical Personnel Association (SATPA) was started after merging the TASA and officers categories.

Security and CISF

Central Industrial Security Force (CISF) earlier known as Central Security Force (CSF) was deployed in SAC on 08.04.1976 for security and safety of equipment, materials of SAC & DECU. Before deployment of CISF at SAC campus, private security guards were posted for security purposes. Fire wing under CISF was introduced in 1977 considering the safety aspects of fire. At present the total strength of CISF is around 150. The entry to SAC is through a computerized access control started about a decade ago. The biometric identification is planned for future.

Vikram Sarabhai Space Exhibition :

Vikram A Sarabhai space exhibition was established in 1985 with the objectives of disseminating the knowledge of Indian Space Programme in general and of SAC in particular to school children and common people. This exhibition was up graded during the year 2000 adding number of models, video clips, posters, displays etc.

ANNEXURE

- I - Tenures of Directors
- II - Excerpts of Interviews with Directors of SAC & DECU

Director's of SAC from Year 1973 – 2010.

Period	Name
1973 – 1981	Prof. Yash Pal
1981 – 1985	Prof. E V Chitnis
1985 – 1986	Prof. P D Bhavsar
1986 – 1987	Shri N Pant
1987 – 1994	Shri Pramod P Kale
01-02-1994 to 31-08-1998	Dr. George Joseph
01-09-1998 to 31-10-2002	Dr. A K S Gopalan
31-10-2002 to 04-07-2005	Dr. K N Shankara
04-07-2005 onwards	Dr. R R Navalgund

Controller's of SAC from Year 1973 – 2010.

Period	Name
01-02-1975 to 05-04-1982	Shri S R Thakore
31-01-1989 to 15-04-1997	Shri M M Shah
	Shri R Rambhadran, IAS
	Shri AWP David, IAS
15-04-1997 to 21-04-2003	Smt. V T Sheth, IPS
30-10-2003 to	Shri MD Mankad, IAS
01-01-2004 to 27-03-2005	Shri S K Sharma
28-03-2005 to 21-01-2007	Shri A S Patel, IAS
22-01-2007 to 30-11-2007	Shri N Narshimahan
30-11-2007 to Continuing	Dr. (Smt.) Namita Priyadarshee, IFS

Director's of DECU from Year 1973 – 2010.

Period	Name
Dec. 1983 to 05-09-1993	Shri K S Karnik
06-09-1993 to 31-10-2006	Shri B S Bhatia
01-11-2006 to 13-03-2008	Dr. M Y S Prasad
13-03-2008 to 07-10-2010	Dr. K S Dasgupta
08-10-2010 onwards	Shri V S Palsule

Period	Head/GD, PPG
	Prof. E V Chitnis
	Shri P P Kale
	Shri Kiran Karnik
	Shri N Sampath

10-06-1988 to 28-10-1999	Shri BGV Subrahmanyam
29-10-1999 to 31-10-2003	Shri N S Pillai
01-11-2003 to 31-03-2008	Shri S K Sharma
01-04-2008 to Cont.	Shri R P Dubey

List of Padma Awardees from SAC till December-2010

Padmshri:

1970 Dr. P R Pisharoty
 1984 Shri K Narayanan
 1984 Shri Pramod Kale
 1984 Shri N Pant
 1985 Prof. D S Kamat
 2004 Dr. K N Shankara
 2007 Shri Kiran Karnik

Padma Bhushan:

1966 Dr. Vikram Sarabhai
 1985 Prof. E V Chitnis
 1999 Dr. George Joseph

Padma Vibhushan:

1972 Dr. Vikram Sarabhai

- KCP of DECU received IPDC – UNESCO prize in March, 1985 with Certificate & Cash award of US \$20,000/-.
- Dr. P C Pandey: Hari Om Ashram Vikram Sarabhai Award for Year 1986-87 in Atmospheric Sciences & Hydrology.
- Col. N Pant: Aryabhata Award & ASI 1995.



**Life and times of Dr Vikram Sarabhai –
The father of Indian space program**

Born on August 12, 1919 at Ahmedabad in an affluent family, Vikram had his early education at an experimental Montessori school specially established by his parents in the home premises. The school grew to be unique and encyclopedic in size as mechanical workshop and laboratories for physics and chemistry were added and highly educated and competent teachers of different subjects were deployed. Instead of following a syllabus, the need for an all-round individual growth was emphasized. Working on the machines gave the future scientist opportunities to exercise his resourcefulness and skill. His love of mathematics and science claimed his attention much more than any other. The examinations were postponed to matriculation stage.

He went to Cambridge for higher studies and obtained B. A. degree in Physics and Mathematics (Tripos) in 1939. For post graduation, Vikram decided to study Cosmic Rays. Due to Second World War, he had to return to India, where he joined the Indian Institute of Science, Bangalore, to continue the study under the Nobel Laureate, Prof. C. V. Raman. In 1947 at the age of 28, Vikram Sarabhai was awarded Ph.D. degree of the Cambridge University for his thesis on "Cosmic Ray Investigations in Tropical Latitudes."

The Sarabhai family, known for its enlightened outlook, sophistication and culture, had a very wide circle of friends. Moreover, Gandhi's presence in Ahmedabad attracted great personalities - many of them, like Gurudev Ravindranath Tagore, J Krishnamurthy, Motilal Nebru, Jawaharlal Nehru, Maulana Azad, Sarojini Devi Naidu, Shrinivas Shastri, C F

Andrews and Sir C V Raman, including Gandhi himself, put up with the family for sometime at least. These contacts had an influence on his personality.

After his return from Cambridge in 1947, Dr Vikram Sarabhai started his career. He established Physical Research Laboratory (PRL), Ahmedabad, Ahmedabad Textile Industry's Research Association (ATIRA), Ahmedabad, and took over the management of Sarabhai industries in Vadodara and became a Director of Calico Mills owned by his family. And he was just 29. In next 23 remaining years of his life, Dr Sarabhai created 14 more institutions like well-known IIM Ahmedabad, NID, Community Science Centre etc.

Vikram Sarabhai died on December 31, 1971 at Kovalam, Thiruvananthapuram, Kerala. In a befitting honour to this great Scientist, SSTC, Thumba Equatorial Rocket Launching Station (TERLS) and associated space establishments at Thiruvananthapuram were renamed as the Vikram Sarabhai Space Centre. International Astronomical Union at Sydney decided that a Moon Crater BESSEL in the Sea of Serenity will be known as the Sarabhai Crater.

Dr. Vikram Sarabhai's name will remain inseparable from India's space programme. Over and above of being a visionary and institution builder, he was a very warm human being with tremendous compassion for others. He was a man who could charm and win the hearts of all those who came in contact with him. Vikram was a dreamer par excellence and taught many others how to dream and to work towards realising the dream. The success of India's space programme is a testimony to this. Dr. Sarabhai was a "rare combination of an innovative scientist, forward looking industrial organiser and imaginative builder of institutions for the economic, educational and social upliftment of the country". A large part of his time was taken up by his research activities and he continued to supervise research till his untimely death. Of nineteen people who did their Ph D work under his supervision, many went on to spearhead India's space program in different capacities.

Prof P. R. Pisharoty was born on February 10, 1909 in the town of Kollengode in the Indian state of Kerala. He completed his early education in Kerala. Having done his Physics BA honours from St. Joseph's College, Trichinopoly, Madras state, he went on to do his MA (Physics) from Madras University. He then worked as a college lecturer in Physics at Loyola College at Chennai during 1932-1941. During the summer vacations he used to work under Prof. C. V. Raman at the Indian Institute of Science, Bangalore. On the recommendation of Prof C V Raman, Prof Pisharoty joined the India Meteorological Department in 1942, where he carried out research on thunderstorms, western disturbances, movement of monsoon depressions, orographic rain, etc. He then joined the University of California for further studies where he worked under meteorologist Jacob Bjerknes. He published two reports titled 'Some aspects of geostrophic poleward sensible heat' and 'The kinetic energy of the atmosphere'. He obtained his MS (in Meteorology) and PhD degrees by 1954.

On returning to India, Prof Pisharoty became the Director of Colaba and Alibag Magnetic Observatories in 1959 and Founder Director of the Indian Institute of Tropical Meteorology, Pune in 1962. In 1967 he retired as Director of the Institute of Tropical Meteorology and joined the Physical Research Laboratory, Ahmedabad as a senior professor at the invitation of Vikram Sarabhai. At this point he was entrusted with the job of introducing remote sensing technology to India. His pioneering experiment on detection of coconut wilt-root disease using Soviet aircraft and US equipment was considered to be the first success in remote sensing in India.

Prof Pisharoty served as the Director, Remote Sensing and Satellite Meteorology, at Space Applications Centre, Ahmedabad during 1972-75. He was a Member of the Scientific Advisory Board of World Meteorological Organization from 1963 to 1968 and later its Chairman. He also served as the Vice-President of the International Association of Meteorology and Atmospheric Sciences, and as a member of Joint Organising Committee for Global Atmospheric Research Programme from 1969 to 1977. He worked at PRL until the early nineties when he retired for health reasons.

Prof Pisharoty was elected a Fellow of the Indian Academy of Sciences in 1957 and a Fellow of the Indian National Science Academy in 1978. In recognition of his contributions, he was awarded the prestigious Padma Shri national civilian award of the Indian government in 1970. He was the first recipient of the Raman Centenary Medal in 1988. He was awarded the IMO Prize by the WMO in 1989. He also received the K. R. Ramanathan Medal established by Indian National Science Academy in 1990.

Prof Pisharoty died on the morning of September 24, 2002 at Pune, at the age of 93. The Indian Society of Remote Sensing renamed the Indian National Remote Sensing Award to 'P. R. Pisharoty Memorial Award' in his memory.



Journey from the day of joining ISRO

Vikram used to do Cosmic rays and so did I. We used to meet often at TIFR and talk about the possibilities of using space. Once there was a meeting in Ahmedabad and Prof. Dhawan came and held my arm and said: 'Yash, you keep on talking about doing this and that.

Why don't you leave fundamental science for five years and come to Ahmedabad? We are going to set up Space Applications Centre and somebody has to do it'. Though I had an offer to become Chairman, UPSC, I thought what will I do at UPSC at 44? Then Dhawan pressed me and I came to ISRO. At that time there was an office at Sahajanand College. There was Chitnis and Karnik. There was Wing Commander Rao and others. All were busy planning for SITE (Satellite Television Instructional Experiment). There were components of what is now SAC distributed all over the city. People were enthusiastic. We were to design all the hardware for direct reception TV including low noise amplifier. We had to test it at US.

Space Applications Centre has to get into remote sensing and who will design sensors for remote sensing? Pisharoty used cameras from France and occasionally flew on helicopters. There was no Satellite Remote Sensing. I did not agree to the idea of sending half a dozen people to US, for training. I picked up George from TIFR who was working on infrared astronomy. Remote sensing also requires a lot of data processing so I went to Kamat who had just finished building the first digital computer at TIFR. I also persuaded Sahai as well. So George, Kamat and Sahai built their teams and started working on satellite remote sensing. We needed to develop programs for SITE so we roped in a few social scientists. Bhatia suggested starting utilization cell for communication and then I thought why not for remote sensing as well even before we built sensors. Philosophy was to create user interest in the program of Remote sensing right in the beginning just like in the case of Communications.

Challenges

Nowhere social scientists and engineers were working together as in SITE. We had difficulty in making programs in villages with half an inch, one fourth inch tape cameras. We had to build time base character as buying entailed huge time lapse and money. We made science program for children. We had installed direct reception TV sets in thousands of villages, but villages were without any laboratories. How to explain to the kids the fundamentals of science? I didn't know what to do. What science program to make. Just you can't lecture about things which they haven't done, which they haven't touched. I thought what the hell I have come into? How do I get the science program made? But then suddenly it occurred to me that the objective of science program would be to help children realize

that science is everywhere i.e. in kitchen, in the fields, in bullock carts, in village ponds, birds, trees everywhere. Then we had problem about studio. I somehow managed to get two small rooms for the studio from Bombay Municipality. The SITE started working. But we still had our share of problems. Antenna broke and flew away when first wind came. But things started settling down and SITE was a tremendous success.

Give excitement of challenge to people. For example when SLV-3 was to be launched, I thought of real-time relay of the event. But there were no links between SHAR and Madras. I made a plan of using Balloon based transponder. We did make a Balloon based transponder in just three days. But unfortunately the tether got cut and we lost the Balloon with transponder onboard.

About Chandrayaan

We could reach moon because ISRO has developed excellent accelerometers. There may have been pitfalls here and there, but now people are more than happy that we have been able to reach moon. We should do something different all the time and seriously. I don't think common people raise this question about Chandrayaan or our space program. Personally I feel that when we want to do science, instruments can do better than man. For a while you may do it (send man in space) but if you want to do really great science then you should really build great instruments and there were some great instruments onboard Chandrayaan. It's not how many times you have covered the moon but how much you have uncovered from the moon.

On DECU

Vikram used one word very often: demystify. Demystify difficult things Bring all together and you can do a most difficult project. Why can't DECU take the responsibility of telling ISRO, that we like to demystify your technology in many cases. Initially DECU had friction with All India Radio and Door Darshan. They thought it is their responsibility to make programs and broadcast. But they could not make science programs as we had made them. DECU should aim to become not a channel of ISRO only. If you want to become something like a public television in America you need independence of ISRO. And a great effort has to be put for that. You have fantastic group of people. Use imagination; make new type of programs, new things.

About another opportunity to become Director of SAC

What will I do and whom shall I lead, if I become 45 years of age again. Here, all are capable persons.

Prof. EV Chitnis [1981 - 1985]



I joined Physical Research Laboratory in 1953. I opted to do research in cosmic ray physics under Vikram Sarabhai. My interest was to study the arrival directions of primary cosmic rays with energies above 10^{13} ev. These high energy rays produce extensive air showers called Bhabha-Heiler showers. The showers were detected with an array of scintillation counters. In two years, 1956-58, I recorded at Kodaikanal, in South India, about, 200,000 shower events. In those days there was no computer in India, to analyze the huge data. So I proceeded to MIT, Cambridge, Mass, USA, to use the IBM-704 computer. On completion of analysis and publishing the paper jointly with Vikram Sarabhai and George Clark, my collaborator, I joined the group which was working on a very advanced and ambitious project of constituting scintillation-fiber chamber to study λ^0 particle. An experiment was set up to test the chamber at Brookhaven National Laboratory, on Long Island, near New York. A powerful beam from Laboratory's Cosmotron was utilized. At this juncture X-ray Astronomy field was emerging-thanks to my mentor at MIT, Prof. Bruno Rossi's vision and initiative. Those were the best times for space research. I was doing well at MIT and was looking forward to an exciting research career in the new and happening field. At this point of time Vikram Sarabhai urged me to return to PRL. He had envisioned the idea of initiating an Indian Space Programme. When I told my colleagues at MIT who were involved in building X-ray, γ -ray and plasma payloads for satellites, that I was leaving MIT, to start with Vikram Sarabhai an Indian Space Programme, they just could not comprehend the audacity of the idea! This lack of comprehension was quite understandable. In 1960's India was experiencing food shortage and was importing wheat through PL-480 agreement with the USA. My MIT colleagues assured me that they would welcome me back if the Indian Space Programme failed! I never regretted the decision to join Vikram Sarabhai to become a co-founder of space programme in early 1962. It was a once-in-a life time opportunity.

We felt from the beginning that India needed the Space Application Programme in areas of agriculture, health, education etc. The Space application technology provided speed, reach and accuracy for dissemination of information to the people located at remote and far flung isolated areas of the country-we firmly believed!

Even though Indian Space programme was initially launched as a Space Science programme to augment PRL's ground based programme, with in-situ observation with sounding Rocket-born payloads, it soon acquired the space applications orientation. The Satellite Instructional Television Experiment (SITE) was the first giant step in the direction. Its planning was initiated in 1967-68 and MoU was signed with NASA to provide ATS-6 satellite in September 1969. SITE was the largest and the most comprehensive communication experiment ever undertaken. Incidentally Vikram Sarabhai assigned to me the charge of this experiment. SITE was multidimensional and covered a range of disciplines-technical, social and management. It provided unique challenges for television both in the technical as well programme production fronts. The other challenges included social research and evaluation and planning and management of a satellite based television system.

Kheda communication project another trail blazing project which was conducted concurrently with SITE was continued post SITE for a decade as a laboratory for rural communication. It brought to SAC/DECU international recognition, for their pioneering work in using television for development. Kheda/ SITE and later Jhabua truly gave social meaning to Space technology. Indian Space technology acquired humane face and really became the technology for the people!

Post SITE, SAC had many more opportunities in satellite communication. STEP and APPLE are worth mentioning. All experiments were learning experience for the operational system INSAT. Equally important Space Applications effort was systematically and assiduously mounted in the remote sensing area. It has been sustained and augmented with commendable dedication over four decades. It has not only gained worldwide recognition but it has also been very productive and fruitful for country's development.

The whole of SAC community, in my view, deserves credit for their service to the country.

Milestones & Achievements:

SITE, Kheda, Bhaskara I & II, APPLE payload and APPLE utilization, INSAT-II payloads development-Communication and VHRR, Insat-Master Control facility, IRS satellites. It has been an enjoyable journey.

DECU to be proactive

A bit of frustration is absolutely important. Unless you are frustrated with your present you will not seek your future. So the process should go on. I am detached and ignorant about the present state of DECU. Solving problem is the job of the present DECU Director.

DTH

DECU should not be burdened with the day to day production. Some production will be useful. But daily production schedule may lead to loss of creativity.

Lead SAC again

Some of the things I would like to see as operational like RADAR Satellite.

Strength and Uniqueness of SAC/DECU

I still remember after so many years the expression of amazement by a young engineer from British Telecom. He was impressed by our achievements in satellite communication. The realization of the state of the art hardware and its operational reliability. At the same time he witnessed the experiment and Video production – especially he marveled at the making of puppets on the campus. That said all about the uniqueness of SAC. Where else would one find a regular string of visitors- Scientists, Engineers, Scholars, Journalists, Artists, performers like S. Chandrashekar, Phillip Morrison, Arthur Clarke, Wilbur Schram, P N Haksar, Habib Tanvir, Mahapatra, Ramesh Thapar, George Varghese, Ela Bhatt and Indian Astronauts spending time to know / familiarize with a wide spectrum of our work. The interactions with variety of stalwarts and many others have been inspirational and rejuvenated the SAC community time and again. The tradition of SAC/ DECU must continue to keep the centre deep and broad in its outlook. Professor Satish Dhawan once remarked to me “Chitnis, you have a collegiate environment at SAC. Keep it up!”

Areas of Improvement

Improvement should come from within through self assessment.

Goals set by Sarabhai

Sarabhai's vision was fantastic. He shared it with everyone around. That led to commitment of one and all. They became autonomous and active. I think ISRO/SAC have done a good job. He would have been satisfied. In some areas we have exceeded his expectations.

Message

SAC has enormous talent and vitality. It is for the leadership to harness it.

Prof. P.D. Bhavsar [1985 - 1986]

Initiation of Space Program

I joined Dr Sarabhai in 1948. He was already engaged in Space Research by studying Cosmic Rays. The word Space Research was not yet coined. It was an indirect way to probe the Space. After getting my doctorate at PRL I went to USA in 1958, on leave of absence, as a Research Fellow at the University of Minnesota. They were studying Cosmic Rays at high altitudes with the help of balloons. It was a part of the Space Program of USA. In 1959 Dr. Sarabhai told he would like me to return to India and help as we were to start our own Space Program. In USA I was already collaborating with NASA and a French scientist Prof Blamont. Before returning I planned experiment to study the upper atmosphere by releasing Sodium vapour clouds with the help of Rockets.

I returned to PRL in 1962. By that time India's space program, INCOSPAR, had already started. All the work was in a Project mode. The first Project was to set-up Thumba Rocket Launch facility (TERLS). I was appointed Project Scientist for the first experiment to be conducted from TERLS. As a joint experiment, Rockets were of USA, payload was to be supplied by France and launch of rocket and collecting and studying the data was the responsibility of India.

From 1965 onwards I was asked to co-ordinate the scientific experiments that had to be conducted as the Scientific Co-coordinator. In addition I was also given the responsibility as Head, Space Physics Division at Space Science and Technology Center (SSTC) a new unit setup at Trivandrum. In 1968 all Projects of INCOSPAR were consolidated by creation of ISRO. After Dr. Sarabhai's death, in 1972, I organized an all India Conference as a Convener, based on his ideas and plan, in Ahmedabad. Scientists from Universities and Government of India's Laboratories, Ministries, and Departments of the Center and the States participated. A plan of actions by ISRO, for applications of Space Technology and use in the country, for the coming ten years was defined. Prof Dhawan became Chairman ISRO, and I became Scientific Secretary and moved to Bangalore.

There was no SAC earlier, it was called ESCES. Main emphasis was on satellite communication and training for its use. Remote Sensing was still a new thing for the world. In 1968 USA had announced a program to launch a series of ERTS satellites. ERTS was to photograph the Earth at 80 meters resolution and the imageries were going to be given free of cost to users all over the world. We had planned to receive the imageries. Prof. Pisharoty had started work by taking photographs from a helicopter for early detection of coconut disease in Kerala. That was the first Remote Sensing experiment conducted in India to prove the usefulness. When NASA sent to SAC a set of imageries of India they were sealed up in a cupboard because there were objections from the Defense and we had no agreement with the USA. The ERTS imageries remained unused till 1976.

Prof. Dhawan wanted to get the Remote Sensing Program to start in a big way to acquire the complete technology including our own satellites. I became Chairman, Remote Sensing Area at Ahmedabad, SAC, in 1976. For ten years I worked for Remote Sensing at SAC. Last three years I also worked first as Associate Director and then as Director SAC.



In TEN years of your leadership how the Remote Sensing had developed and come to this level?

Up to 1976 Remote Sensing Division was a loose group of scientists working with Dr. Pisharoty. I planned out how to go about. I emphasized on developing the program from the scratch. We had to learn to make instruments, to make satellite payloads, collect and store the data, and analyze and interpret the data by visual and computer techniques. Ground truth was also required. So I made four divisions: Dr. George Joseph to Head a Division to develop instruments and payloads, Kamat as a Head was given the responsibility of data handling and data interpretation using computer based methods and the software and hardware and Dr. Baldev Sahai was given the responsibility of generating aircraft imageries and to learn the techniques of data interpretation both first by visual and then by numerical methods. Arup Dasgupta was made Manager, User co-ordination and Applications. It's a long story, but ultimately we achieved what we had planned in this venture.

Uniqueness of SAC/DECU

So far this Centre has worked well. I would say, it had able Directors and they have contributed and faced the challenges of the time. I believe that we have enough talent and I don't think we will lack that. There will be people who will come out with new ideas which could lead to projects and programs. And I think DECU should not stop generating programmes. If necessary, it can even start its own TV broadcast channel.

Another Chance as SAC Director

Now space program is so well established, so I don't know what more can we do except look in applications where there is a lag, to take up that challenge and see that the gap is filled and used properly.

Evaluate what we are doing and how far we have fulfilled

Well, Dr. Vikram Sarabhai had said that we don't want to do all this for glory. So, if we have capability and enough means to participate in interplanetary research or going beyond that, there is no harm. But, we should always keep in mind the social aspects and utility or utilization aspects. That should be our first priority.

Message to young Generation

My message is that if you use your energy fully with confidence you will always succeed. Now the life is becoming such that the lure of wealth and pleasure takes away most of the time of the younger generation. And they are forgetting their duties towards the society. They want all the good things of the society without fulfilling their duties towards the society.

Shri N. Pant [1986 - 1987]

Initiation of Space Programme

It has been a very very fulfilling journey. Through the experience and confidence gained by ESCES, we undertook India's first commercial earth station project which was at Arvi, near Pune. It was given by Indian telecommunications. Those days it was known as Indian overseas communications services and now with Videsh Sanchar Nigam. Then came the SITE project. It was a huge team effort involving complex hardware, software, applications, all things clubbed together. Of course after SITE, I went to SHAR and then to ISAC, and while I was at ISAC, I looked after SAC for one year. So it has been a long journey.

Space Technology for Societal Issues

Space is a very important factor, particularly for a country like India, because SITE project was itself conceived on that basis, as to how to provide the best television coverage to the country. At the time it was mostly terrestrial. SITE demonstrated that satellite based distribution is the best option for our country. And we subsequently proved also, instead of hardly eight or ten stations, we have now over 1000 stations, we came up in the span of five six years. We are the only country in the world, which has a satellite fully dedicated to education. – EDUSAT. Problem is everybody is asking what is happening to EDUSAT? The answer is it lies on the users. How they use it. Some states are utilizing it wonderfully, and some states have not adequately utilized it.

Leadership of SAC

Many projects in ISRO are a multi department, multi users and multi faceted in nature. Because one centre cannot do everything, as SAC is a part of ISRO, so the leadership is there, and each one is doing their own activity complementing and supplementing each other. SAC has lot of interaction with other departments and also with users, so that is a very plus point.

Remote Sensing

You mentioned resolution, different applications require different resolutions, so you have to make a satellite to make it suitable and applicable to that particular requirement. This is one aspect. Now remote sensing area itself has two aspects one is the hardware aspect, to make the necessary hardware that gives you that picture. But more important is the utilization of that picture. So that is the one where different specialists come in to play. So we should rope in more institutions and academicians for their expert use of these data.

Should India spent so much on a project like Chandrayaan?

See what I would like to say is, each individual has his own thinking and we cannot change it. Many things we do keeping futuristic aspect in mind. The portion of money we spent on space project as compared to the other countries is very very small. If you don't spend money on these missions and once you have lost the race you will never be able to gain it. You do not know what you are going to get on moon after about 50 years. So to understand the science and also ensure to make the presence feel among the space faring nations, such planetary missions are essential. Once we had to make only 4 hours of programme. And it was a huge task that we had to do that to set-up in Mumbai. Our worry at that time was not technological as equipment making was perhaps understood well. Our worry was how we would make 1500 hrs of programme. That was our biggest worry. Now what will



ISRO gain by making one hour programme or a two hour programme or going for DTH. What is the content of that programme? What you want to use it for? We have made EDUSAT for this vision only. We have to provide transponders for telemedicine for this is again a societal use.

If you have a good software then any channel will buy it. There is no problem about it. See creativity is a different part. But an organization entering in to this is a commercial venture. That really non-commercial ventures like EDUSAT, telemedicine etc we have always done it. The village resource centres is being contributed by ISRO. And we have dedicated satellite for this.

We look at it slightly differently. Our aim is to make our country industry self reliant in this thing and once it is done we could even disbandage from it. ISRO is not a part of it. In America everything is done by industry. So this country must be doing it. DECU's aim should be to make these commercial producers such that they can make programmes which are to our liking to which are confirmed to our aims and etc. If that is done nothing like it.

Areas of Improvement

You have always scope of improvement. There is no doubt about it. Keep pace with latest happening. What is happening elsewhere we are not worried or behind to do this, and some of these things, we are on our own. Particularly in application areas we are quiet innovative in many places.

See as far as I see more than 90% what we do is application based and whatever we are doing is straight away used by the users. Our transponders and navigation system are used by them. Tele-education and telemedicine are straight away application based activities. But, we need to improve their functioning and for which lot of R&D has to be done.

Advise to the younger generation

My main advice to the younger generation is to keep yourself committed, go for job satisfaction and never be satisfied easily. Your progress depends on how hard you make yourself to satisfy yourself. Because enemy of good work is not bad work but is better work. So you must try to be better and better and better. The younger generation is quiet good; there is no doubt about it.

Shri Pramod P. Kale[1987 - 1994]

Starting in 1963 I worked on early projects like TERLS, ESD, SITE, and INSAT. After the SITE project was completed I was busy making proposals for INSAT- 1 satellites (I was earlier on working on studies for the INSAT System), and was transferred to Bangalore.

I returned from Bangalore in 1987, after a gap of ten years to SAC.

My first major initiative was bringing out a full- fledged Atlas for the ground-water & water below the ground. 1986-87 were drought years for Gujarat. SAC and NRSA were working with the 'National Drinking Water Mission' & were able to successfully demonstrate, how to get water below the ground level. But the real achievement really came up when our team developed complete payloads for IRS-1A, 1B & 1C. Parallely we were working for the payloads for INSAT-2 Series which was coming-up & started working on two prestigious programme 'IRS & INSAT'.

Sustain SAC leadership in making Payloads

In my view to sustain leadership, SAC requires a full-fledged support from industry because after completing in-house development & replicating outside, under our supervision; SAC can concentrate on newer areas. In recent years while working in Remote Sensing area similar payloads were developed for Chandrayaan. SAC is now supposed to participate & develop GNS (GAGAN), and RADAR payloads in RS systems. Just like NASA which started making different kinds of communication satellites, but then they started getting it done outside and NASA itself focused on developing technology & new ideas. Our satellites & payloads requirements will grow and this will be challenging venture and tasks for young people who will be involved in high-quality new research assignments.

Chandrayaan and the Role of SAC

RS & SATCOM Payloads development work is best suited for SAC, but when it comes to landing on the surface of a planet or moon & carrying out observations there, we require different type of instrumentation & disciplines, some of which are available with PRL. However we really need to look in completely different instrumentation and R&D which would be necessary the moment landing takes at alien place. Similar things may be used in the near future for Chandrayaan-2, inter-planetary or manned-space-flight missions, requiring a completely different kind of work.

Cost-benefit Aspect of Space Technology

I recall a situation of 1963, when our first rocket was launched the next day the newspaper headlined 'We want rice & not the rockets'. In my view most important thing that the people don't realize is, that when large amount of money is spent, it is large with respect to certain numbers, people are familiar with. Comparing with IPL, money spent on our programmes, is very small. With INSAT Satellite after SITE we had a small national network of TV stations in 1982 for the ASIAD games and today we have one of the largest TV & Radio-Network in whole world with close to about 1500 transmitters connected with satellites. I suggest people have to look at benefits they get because of communication satellites. Same is the case with our RS-satellites. However people don't ask this



question when it comes to Chandrayaan even when they don't see direct benefits out of it they are tied to emotions.

Strengths/ Uniqueness

The key strengths of SAC grew after the 1965 with ESCES, ESD, SCSD, MID, RSD, etc. All groups came together & worked towards a specific mission. Having multi-disciplinary people from all over the country in one state, with aptitude for innovation and freedom for doing things, was the main strength, I think and uniqueness in SAC, and we have to build upon that particular strength.

Areas of Improvement

Dr Sarabhai was very concerned about our entire programme as we had to go back to Planning Commission and he opined five years wasn't adequate to make a nuclear power reactor, satellite or a rocket launch-vehicle & hence 'Atomic-energy' & 'Space' should have a ten-year profile and for the first time our decade-profile was issued by him in 1969. We still follow a ten-year profile. Recently in Delhi in the month of the August 2009 ISRO discussed vision of next 25 years but how much of this got communicated to all staff members is not clear. People need to read more, make use of library. So the areas of improvement is the sharing of vision by Director & all concerned in ISRO as to what exactly we need to do in future. RS & SATCOM is targeted. Space applications like GIS & Navigation still require a large amount of work necessary for our urban as well as rural population.

Near or Far from the Vision of Dr. Sarabhai

With the launch of the GSLV though not in ten years as planned most of what was written in 1969 based on Dr. Sarabhai's ideas, to that extent we have proved ourselves.

A new vision is not really a kind of a thing that is necessary but we must have continuity. Self-reliance, use of S&T for development, education-are all part of the national goals. Our goal cannot be separated out. Each person has to have his own-goal, understand society's-goal & national-goal & when they converge then we get progress. What we need to look at is convergence of goals. People need to have a view, "I may want to develop one instrument. As long as it is limited to me it's okay but when used all across, then I must redefine its common-acceptance & everybody should really share that thing".

Message for Young Generation of ISRO

A large number of people now-a-days I come across don't write & don't communicate but are busy with mobiles & verbal correspondences. SAC has all the facilities, but no specific idea is seen happening if not written & planned. With personnel strength of 2,200 the story is completely different compared to our beginning the work in 1963 when there were five to six people only. Full dedication & study of subject details is required to realize a dream.

Dr. George Joseph [1994 - 1998]



Evolution of Remote Sensing at SAC

The remote sensing (RS) activities at SAC was initiated under 'Remote Sensing and Metrology Division', lead by Prof. Pisharoty, who is considered the father of Remote Sensing in India. When Prof. Yash Pal took over as Director, SAC, he realized that if one wants to play a meaningful role in applying this technology for national development, we need to develop all facets of remote sensing- such as sensor development, data product generation and demonstrate remote sensing applications. Prof. Yash Pal realized that if applications of RS have to happen in user agencies, there should be a link between ISRO and user agencies and he established a 'Utilization Cell'-in his own words an 'end-to-end' concept. I had the privilege to head the sensor development activity.

We have developed a gamut of sensors for ground, aircraft and satellites. In fact, when we launched IRS-1C in 1995, it was the best civilian RS satellite providing highest spatial resolution. We have also flown a number of advanced microwave sensors. RISAT when launched will be one of the best SARs in orbit. The presence of multi-disciplinary team at SAC, helped us to conceive sensors which meet the needs of the applications. Our approach was not to develop the best sensor, but develop those sensors which can be best for applying remote sensing for national development. The data provided by the IRS satellite is comparable to the best in the world and hence are being sold internationally. In the areas of image processing and RS applications also we did very well. We could apply RS at national level in diverse areas such as crop production estimation, ground water targeting, coastal zone management, wetland mapping etc.

Sustaining the Leaderships:

It depends on how we motivate the younger generation to take up challenges not only for their career progression, but also how to apply space technology to help the society at large. The fact that SAC is doing better and better over the years, the leadership is able to do this.

Success of Chandrayaan.

The best way to convey my ideas on relevance of Chandrayaan is to quote from the preface of study report of the Lunar Mission Study task force, which I had the privilege to chair "Just a few decades back man never imagined that he would set foot on the moon. Decades from now, human colonies on the moon could become a reality. India should also be in the forefront of this challenging and exciting endeavor. The Indian mission to moon should be seen beyond the scientific result it produces. Studies have shown that moon could serve as a source of economic benefit to mankind and could be of strategic importance." Any invention or discovery does not give immediate benefit. There are many ways in which resources from moon or moon-based activity could be of immense benefit to mankind. Launching spacecraft to moon is only one aspect. Another important aspect is In-situ Resource Utilization (ISRU). India should be working in this area also.

Outreach of ISRO?

Probably we should have more aggressive outreach activities. People at grass root level who use the space technology understand its potential. What is missing is the awareness of public at large about the societal benefits the space technology can provide.

Concept of Television- Entertainment Vs Education

The concept of television what Prof. Sarabhai envisaged through SITE was empowering the people. Now we are in the era of commercialization, which you cannot stop. I have nothing against entertainment; I am against the advertisement that goes along with that. It does not jive with certain situation in our country. In a place where one can't have one meal, telling them "Boost is the secret of my energy" doesn't make sense. Every commercial channel in the country should be told that 50% of their prime time telecast should be for societal benefits.

Again be the Director, SAC

It is difficult to turn back the clock and imagine how I could have done better. SAC has been doing extremely well both in hardware and applications. There is always scope for improvement. With the advancement of technology we could widen applications. I have been advocating for some time to have a RESOURCESAT in GSO, which is unique and has lots of applications. As new national needs come up we should rise to the occasion to find out how space technology can contribute.

Strength and Uniqueness of SAC

The Strength of SAC is its highly talented and dedicated staff and a section of them is the best you can think of anywhere else in the world. The uniqueness of SAC is the multi-disciplinary character. We have people from every branch of science and technology. If people can make full use of this multidisciplinary character by interacting, it enriches one professionally and the quality of output also improves.

Dr. Sarabhai's Goal

Our focus is always societal good oriented. To a large extent, we could accomplish many programmes of societal relevance – ground water targeting, tele-health, tele-education, etc. Even mission to moon is going to benefit people in the long term. Of course we can do better and we should do more, we cannot be complacent.

Message

Irrespective of how powerful a rocket you make, how best a satellite you make, the last mile of linking the applications to the people, is done here. So can we think of how we can wipe the tears of the poorest of the poor by applying the space technology to their benefit? How we can be innovative in doing that, at larger pace and at national level? This should be the goal of each one of us. We have the capability, the idea is how innovative we can be. So I would say SAC and DECU have the major responsibility of realizing Prof. Sarabhai's dream and ensure the tax payers money that I and you get is really justified.



Dr. A.K.S. Gopalan [1998 - 2002]

Journey, Major Milestones & Achievements of SAC

I joined Department of Space then as a system engineer. We were working on various new technologies required for satellite experiments, which was a dream child of Dr. Vikram Sarabhai. I was asked to develop technologies relating to television transmitter for Pij and that was accomplished quite well to distribute television signals to Kheda district. The programmes were produced in SAC and we were involved very closely with the program producers. Soon I switched over to Remote Sensing Area in a division called Image Processing and Data processing Division. Prof. Bhavsar was heading the whole Remote Sensing Group. In process of designing Bhaskara payloads; we went through activities which involved the user agencies to define what they want and we designed the system according to their requirement. By 1988 the first IRS was launched. Then came IRS-1C, 1D, with a resolution of 6 meter, which was globally one of the best at that time. This also triggered Antrix to go for business making the IRS system a global one. Before that Apple project was conceived and payloads were delivered by SAC, and through these experiments, we got into the development of a satellite for national communication program. ISRO had very interesting way of working in the sense that first take whatever data is available from abroad or whatever systems are available, use it, learn from it, then define our own system; then go for the indigenously developed system and if you can't launch it from our side, doesn't matter, get it launched from somewhere till you develop the launch capability. INSAT program had meteorological payloads delivered from the Remote Sensing group. We are very good in the applications. The best part in this is the cross interaction within the groups of ISRO, within the group of SAC and the team effort that is put up by all teams from various centers. I became the group director of data product system sometime in 1985, and then IRS systems were established for data processing purposes at NRSA and then I was shifted to Hyderabad as director. We could develop necessary hardware and software for advanced image processing system. I was asked to go back to SAC in 1995 as a deputy director for Remote Sensing Area. Subsequently I became director of Space Application Centre in 1998. It was a very challenging time, but everyone co-operated and many things were achieved only through their co-operation

Achievements & Milestone

In fact microwave remote sensing was dormant for sometime, except that they were developing airborne sensor. Soon we proposed a microwave radiometer in the Oceansat I, and that was conceived and it was implemented and successfully flown. And then came Radarsat program which was initiated at that time. Similarly Cartosat I, II programs were also initiated at that time. So I was instrumental to a large extent to ensure that these were properly coordinated and development takes place properly. Application programmes in meteorology and oceanography was strengthened. As far as the other aspects are concerned we created a lot of infrastructure at that time. Like a compact antenna testing, then the clean room for microwave system development, clean room for optical system development. These were all done during my time. But particularly there was one disturbing thing which was people coming late. We tried to solve it but that could not be easily done. But finally it was solved.

Technological Challenges & Social Issues

There is no doubt that space technology can create change in the lives of the people. For example the disaster warning system has been developed, which gave advanced warning like cyclone, that helped to save lot of lives and live stocks.

DECU as Relevant Part Of ISRO

I really do not have much insight into DECU operations. During SITE time whatever was done, was very relevant and advanced. New concepts like watershed development thru remote sensing can also be included in the DECU's program. So as I see the DECU is doing whatever best it can. If there is a quality problem then these have to be improved because today everybody is used to watching quality television programs.

Chandrayaan

I think it's a remarkable achievement. And the kind of prestige it has given to the nation, and I am sure the Indians look forward to their own future space stations in moon like any other country. Therefore it is very essential to have programme like this, there is nothing wrong in thinking big for future.

Key Strength & Uniqueness of SAC

I think uniqueness is that it is just like a university. You have subjects covered from Zoology, Botany to Computer Science, electronics, to engineering, to various kind of things. But at the same time this is very advanced work. It is very interesting to know that SAC is a place where you have applications, you have technology development, you have infrastructure to do high level of research, and more than that you have human resources which are very well equipped.

Dreams of Dr. Sarabhai

I think it has been very largely achieved. Everything we did is totally development oriented. I don't think that we have failed him.

Another Opportunity as Director, SAC

I think the foundation is laid out now what we have to do is to aim for higher and higher quality, and new advanced work for space probes and so on. That is the area of work. But as far as the activity of SAC is concerned, everyone has given their best for what was is going on and that's how it's built up. There is no serious deviation from the activities that we are carrying out last 10-15 years. So ultimately one can think of putting energy in commercialization aspect of our technology developed. That is one possible area I think.

Message for Young Generation of SAC

ISRO is not a paymaster as compared to others but the kind of facilities ISRO has in terms of technical, medical and housing are nowhere available. It's very comfortable for anybody to live a very peaceful, and also very fruitful life. No family tension in terms of your work. We should do very good work. It satisfies you, it also gives a very good feeling for the family that you are doing very important national prestige kind of work. And another advice is that work as a team because each element is critical to success of ISRO. And also ensure that there nobody is condemned that he is useless, he is not given work. Put them in some place where they do at least something-after all you are going to keep them, so let them do whatever best they can do and encourage them.

Recount your journey from the day you joined ISRO

Immediately after completion of my Ph.D from IISc, Bangalore I joined Microwave Antenna Engineering Group in Ahmedabad and started working on the design and development activities. I worked there for several years. Later in 1972, we moved to SAC campus & our division was renamed as Microwave Division & did work in microwave technology & Antenna-Engineering. I took over as Head MCSD (Microwave Components and Subsystems Division) in 1985, I became Group Director of first spacecraft payload group and major task was to develop communications-payload for INSAT-2 involving new design, developments, fabrications & test facilities. We later on established other facilities like hybrid Micro-wave Integration Circuit, component-Testing, Mechanical Engineering Fabrication, PCB facilities, etc.,



Journey as Director, SAC

In 1996 I moved to ISAC in Electronics Division Area, then later on I worked as Director, INSAT program office and then in 2002, I was back as Director, SAC, Thus SAC is memorable part of my life.

Challenges

Number of projects in ISRO are increasing & in-spite of technological advancements, new facilities, there are new challenges and I am sure that today's generation of excellent engineers & scientists are capable of taking this forward for all our future activities like HSP & planetary missions. Chandrayaan-1 (RS-payloads) was one such project where leadership by SAC in many new state-of-art technologies was successfully demonstrated.

About Chandrayaan-1

The Question on Relevance of Space Programme, and Chandrayan has been debated many times. Now people are convinced in this country that these technologies are very essential for the development of nation. Chandrayan-1 has been a challenging programme.

About Remote-Sensing

I think, in Remote Sensing Technology, we have almost reached state-of-art technology comparable to any other country. Excellent payloads in optical to microwave technology have been demonstrated successfully. Many things have been done in the area of remote sensing applications and I think we are covering most of the applications in this field. Probably we are in the forefront in adopting the Remote Sensing Applications. Remote Sensing applications has benefited National Development to a great extent.

Compare with other contemporaries

In the area of Satellite Technology we are very much comparable to any other country. In fact we have supplied two state of art satellites to Europe and they have purchased it on a commercial basis and we have all the state of art facilities for building the satellites. Facilities at ISAC Bangalore, for Satellite Integration and Testing probably is one of the biggest in the world and it has all the facilities under one roof. We are at par with any other country but still there are couple of new things which we will have to accomplish in future and I am sure the work towards this will go on.

Message for younger Generation

I am very happy to say that the younger generation of today is excellent and coming-up with meeting all challenges to grow as leaders but they have to really work hard in terms of developing new areas in technology, applications, facilities and evolve Technical Management of world standards and be on the top.

About SAC leadership

SAC and DECU have major role to play not only in developing state-of-art technology but also operationalising these applications with the involvement of various people in the country and with current direction SAC can accomplish this with the help of various other organizations.

About another opportunity

I would like to work as an engineer if I get an opportunity which however seems bleak but not really as Director, SAC.



Dr. R.R. Navalgund [2005 Onwards]

I joined the Space Applications Centre on August 17, 1977 after completing my PhD at TIFR, Bombay. I had an opportunity for doing post-doctoral fellowship in the USA but my professor advised joining space research as it was a growing area. In addition, I was also influenced by an open letter written by Prof. Yash Pal to young scientists urging

them to give something back to the society.

In my first year at SAC, I was not very comfortable with the nature of work in the group to which I was assigned. May be the environment was not purely academic. But soon I settled down and was at home with a lot of exciting things happening, like, satellite for earth observation, activities related to defining future remote sensing satellites through joint/continuing working group (JWG) of IRS. Right from the beginning, I was made to feel important as I was given responsibility of leading and coordinating activities and guiding youngsters. Later I also planned an experiment for the Challenger Shuttle mission. Then IRS programme itself became extremely important and when IRS-A was launched on March 17, 1988 (coinciding with my birth-date), I said to myself that I am destined to be a remote sensing scientist.

My remote sensing career took an interesting turn when, sometime in 2001, Dr. Kasturirangan asked me to go to NRSA (now NRSC), Hyderabad as its Director. I did not ask him why; but just joined there instead. I helped initiate R&D activities there as well as strived towards increasing revenue from services. I was also instrumental in setting up a Decision Support Centre related to disaster monitoring and mitigation. Needless to say that I had a very exciting time there, newer and different kind of experience; dealing with a large number of users, user interfaces which helped in broadening my horizon that probably trained me enough to come back to SAC in this capacity.

SAC is a very liberal centre having a large number of diverse and vibrant activities both in SATCOM and Remote Sensing from building payloads to data processing, applications, capacity-building (like CSSTE-AP in academics), etc. And I love being at SAC.

Future Projects of SAC

SAC is matured in development of communication and earth observation payloads. What we need is a quantum jump like Advanced Communication Satellites (ACS) providing higher band width, power and flexibility (inclusive technology of rural population). Similarly, in navigational satellites, India has decided to set up its own Indian Regional Navigation Satellites System (IRNSS) which eventually I hope should target becoming Global Navigation Satellite System with a large number of application services resulting in synergy of communication and navigation technologies.

In RS, emphasis would be on measurement of climate quality parameters using optical and microwave payloads pertaining to land, atmosphere and ocean. This includes measurement of green house gases, polar ice, sea level rise, etc. Understanding the interaction between earth, ocean and atmosphere is important and is likely to lead to study of climate changes and their impact on natural resources.

Interplanetary Missions and Human Spaceflight Programme

Instruments once used for gazing stars and planets are now sent in space for looking at the earth itself in remote sensing. We shall also have scientific exploration missions to our nearby planetary bodies like Mars, Venus and our own satellite - Moon. I think, SAC should also get into the area of planetary sciences as it already has the ability of building sophisticated instruments, data processing and understanding science issues. It will provide ample opportunities to the younger generation of scientists at SAC.

Human Spaceflight is an important programme of ISRO wherein SAC would be providing continuous, uninterrupted (24X7) communication services between the crew (astronauts) and the ground as well as sensors development for measuring health parameters of the environment of astronauts. The third area in which SAC is interested would be doing certain experiments in space (microgravity) through the astronauts.

Should a country like India spend money on Chandrayaan like projects?

Today India is one of the robust economies in the world. There are various reasons why India would be taking up such missions. We have the technological maturity to do these exercises. We should not be left behind in such space exploration related activities. It is important not only for understanding scientific issues of the planet's origin but to discover precious resources like Helium-3. Now we are one of the six major space faring nations, so we should be in the space exploration and Chandrayaan is only the first step towards that and we should also go to the Mars may be, in a few years time.

Relevance of Software System Groups (SSG) or DECU since times of Prof. Sarabhai

The people who develop technology should also endeavour demonstrating its use. It is relevant; DECU must be given autonomy to carry out newer kind of experiments as per today's requirements. In fact, sometime back, I was asked whether DECU can now be part of SAC and I said, "No, DECU should remain independent so that it can follow its own agenda of activities of social relevance independently."

Strength and Uniqueness of SAC

Firstly there is diversity of academic backgrounds/disciplines of scientist and engineers. You have people of agriculture, forestry, botany, anthropology and social sciences. Secondly, the founding Directors of SAC, particularly Prof. Yash Pal brought in and inculcated a sense of liberal mindset which is extremely important for growth of ideas and initiatives. Thirdly, attracting a very large number of young scientists and engineers from different regions of the country provides a synergy of cultures. I have seen other ISRO centres and let me tell you, SAC is unique in many ways.

How far or near are we to the goal set by Prof. Sarabhai?

To a large extent, we have realised the goals set by Prof. Sarabhai in communication, earth observation or meteorology. There is a continuous need for newer, relevant applications to be taken up.

Message

I say you enjoy your life and enjoy whatever work you do. I would say excel in whatever you do. That is important.



Shri Kiran Karnik [1983 - 1993]

Early Days of Space Programme and Evolution of DECU

I came here (to Ahmedabad) in 1970 and we started off sitting in PRL in one and half rooms as part of what was then INCOSPAR (Indian National Committee for Space Research). Dr Vikram Sarabhai was there and his vision was our driving force. He was a fantastic leader, a visionary who led through motivation and got everybody on board. In the early years, we were charting out the vision of what ISRO would be. The focus was on using space technology for rural development, in particular, and the exciting challenge was how to use the latest technology of high-power satellites, which were then just coming up, for the purpose. When ATS-6 was launched, the Americans were very happy with our goals, because they had a great satellite with nothing much to do in the US and here was India ready to demonstrate what such a satellite could do. What followed was a lot of hardware development, a lot of programme development and management of a complex, multi-organization, global project. And the story started from there. It was SITE and the societal concerns of the space programme that were the seeds which ultimately led to the creation of DECU.

DECU: A relevant part of ISRO

I think this (the relevance of DECU) is a very good question and I don't think we have an easy answer at that. The fact is that in a largely technological organization, you have people who are totally different – “long haired” and “*jholawala*” types! What are these people doing in this technology campus? We were able to prove that this group of strange people were doing useful (and different) things, and what they did took ISRO on a certain track. Some even said that DECU is the conscience-keeper of ISRO.

But, yes; it is a challenge. In any organization when you have a group, and that too a comparatively small group and one which is very different, then the problems of integration, what role they play, where do they fit in etc always crops up. Frankly, I don't think that after 25 years or more these questions have vanished, but I think there is a much deeper understanding within ISRO – and particularly within the leadership in ISRO – about the kind of role, the importance of the role, of what DECU does.

DECU's team of programme-producers, social scientists and management professionals is truly unique. No space organization anywhere in the world has such a group. Its role of looking at economic viability and social desirability (facets beyond technological feasibility) of space applications has been vitally important in keeping ISRO's focus on relevance and national need.

Why Chandrayaan-1

Chandrayaan is a great achievement. It is a different kettle of fish: it is more science (rather than applications) and there are positive spin offs that are huge, but this question (about relevance) will be asked, especially when one talks of things like sending a man into the space. Some people (frankly, I too) have questions as to what is the value of manned space missions versus Chandrayaan and unmanned probes, which can do things without the huge additional cost – and the dangers

involved - in manned space missions. But there are a lot of spin offs, there are positives, there are things that are intangible; for example, motivation for young people, the country's image and standing.

Outreach

The ISRO tradition has been to fight shy of publicity: we don't like to speak about ourselves, we don't speak of what we are doing, and we don't like to speak of our people who have done such outstanding work – individuals or groups. I think we should open the doors maybe a little bit more – not too much, because it is good to be humble, it's great to continue to do good work for its own sake and not for any fame or publicity. But there is a need to be more aggressive in the media and I think it will help. You'll always have the questions anyway!

Again as Director, DECU

I would enjoy being back here again. It's always been a great place. I enjoyed my years here phenomenally. We had a great team of people (as I am sure you have today too), and I think DECU is a very unique sort of place in an extra-ordinary organization (ISRO). To those who are here today, I say: I envy you in many ways; you are all lucky, indeed, to be here!

Key Strengths of DECU

I think the key strengths really are two or three. The first, of course, is the expertise and experience of the people who have been through this and grown with it and seen what it is. The second is the passion of the people. Today, you can do anything you want provided you are good at it and you can be good only if you are passionate about it. So, I think that is one of the key elements of DECU. The third is the fact that you are embedded in an organization that is respected, and is very flexible. Despite being a government organization, it is able to do a lot of things and this gives considerable freedom and flexibility to DECU.

Far or Near to the Goal of Dr. Sarabhai

Dr. Sarabhai had set specific goals and we are on the track to achieving some of them: indigenous satellites and indigenous launch vehicles; using technology in general, and television in particular, for development; utilizing space technology for rural development. Much of this has now been achieved. I think we need that kind of clear vision. Think about this – he envisaged this and painted this very broad picture as long back as the 1960s. Now, we need something else, looking ahead at the next 20-25 years. To my mind, this is a task for the young people; to come up with new ideas and a vision.

Message

I would urge the team to stay focused on the goal of transforming this country, and to use every possible tool for that. Television cameras, satellites, launch vehicles: they are all means. We need to use them as methods to do something to meet the basic development goals for our country. That is what DECU was about and is about. And I would like the young people to keep that sharply focused in whatever they are doing, and continue to take forward the great work that has been done.



I joined ISRO in April 1971 and had the opportunity to work with people like Dr Sarabhai, Prof Chitnis, Mr. Karnik, Prof. Yashpal etc. My first task was to select the villages for SITE where community sets would be installed. These were finalized based on the Backwardness criteria of the Planning Commission and the criteria of continuity of service jointly defined by our partners AIR. Districts of Six states e.g. Rajasthan, Bihar, Orissa, Madhya Pradesh, Andhra Pradesh, Karnataka, were selected and secondary data of 24000 villages was processed to get a list of 6000 villages which had to be physically visited to collect primary data on availability of Electricity- Room- Clear view for Antenna etc.. to decide which villages would be suitable for installation of DRS.

Achievements as Director DECU.

The Major projects that I have been associated with are as follows:

Kheda Communications Project

This was a great experiment in design of Development oriented communications. We developed the Research based Team mode of production which was a very scientific approach to design audience sensitive communications material. We also developed the Participatory Mode of communication in which the audience itself participated in decision making of the programs as script writers, performers etc.. Production of series like Tamara TV Maate Tame Lakho,—Hun Havae Lakhun Chun—and Exploitation series was sequential of growth in this direction. The work done in KCP remains unparalleled in the field of Development communications.

Training and Development Communications Channel (TDCC)

This was a “One- way –Video, Two- way –Audio” Network established for Training. This network was found to be most useful by the State Governments to impart training to large number of field workers. It was successfully established and operationalised in states like Gujarat, Karnataka, Orissa, and MP. Besides several educational agencies like IGNOU, NCERT, UGC used it for training.

Jhabua Development Communications Project

This was a unique project in use of Satcom in Tribal areas. It had both Broadcast and two way interactive elements.

Tele Medicine

This activity was initiated in ISRO by DECU. It expanded very rapidly to provide Telemedicine connectivity to place like Andaman Nicobar Islands, Leh, NE Regions and Lakshdweep. This then expanded to several major Hospital networks like Apollo, Arvind Eye Hospital, Shankar Netralaya etc.

EDUSAT

This was a satellite dedicated to education. DECU was involved from conception of the spacecraft

to the implementation and utilisation of the Networks. Networks were established for a large number of universities, States and Educational agencies.

Should DECU be a part of ISRO?

DECU's role is to assist the user in covering the "Last Mile" in Applications. This is very crucial for successful applications. However this puts DECU closer to the user. DECU has to work "End to End" and has therefore reach out to users with lot of assistance, training and updates in new applications. It would therefore appear that DECU is working more for the user than ISRO. But all this is aimed at better utilization of Space technology.

It would have been better to establish DECU as a service and training organization for user agencies. It could draw support from both ISRO and user agencies. I am sure if Dr Sarabhai had survived, DECU (at that time AVID) would have been spun off as an autonomous agency.

Science Channel

DECU worked for Science program production since SITE. More than 200 programs were produced during SITE. A studio was set up in Bombay for this purpose. A credo was defined that "Science is everywhere" and programs were produced with this basic philosophy using team mode and research based including development of briefs and pretesting of scripts and pilot programs. Subsequently programs on Scientific temper were produced for the Kheda audiences including programs on Solar Eclipse, the coming down of Space Lab etc.. Finally production of a series of programs with Vigyan Prasara was undertaken. These programs received very high viewer ratings. It was realized that there is great scope for starting a Science Channel. This concept was defined in detail. It is observed that a large number of Scientific Departments including CSIR, DST, Dept of Non-Conventional energy sources, Dept of Ocean Development etc.. are all keen to have a channel to communicate to the people. It is essential that DECU/ISRO take a lead and bring together all concerned govt. agencies to establish such a channel. If necessary a PPP model could be adopted as several private channels are also interested in this. The operational and commercial aspects could be looked after by the Private partner and the content could be looked after by the Scientific Depts. under the leadership of DECU/ISRO.

Key Strengths of DECU

DECU has a unique combination of Social Scientists, Communicators, Producers and Engineers/Technologists working as a team. This can help in making technology relevant to the users.

DECU's future

DECU can have a bright future only if it maintains its proximity to the user agencies. It has to bring in the user point of view and make the technology appropriate for the users. It must continuously upgrade the applications and provide more and more services to the user agencies. It should therefore move in a direction where it is jointly supported by ISRO and the user agencies.

Message for younger generation

You are working on the frontiers of Technology and its applications. Be sensitive to real social needs and persist with conviction for applications. Success and credit is not easy to come by but if you persist enough things will happen. All the best to you.



Dr M Y S Prasad [2006 – 2008]

I consider DECU is the bridge between ISRO & society and it is very important organization, which had translated Dr. Vikram Sarabhai's vision into actions.

Milestone / Achievements during his tenure:

First major thing done is the films / documentation on very complex technical areas in which we are working, for which the content as well as the context is not readily available to the private channels. I am very happy to say that something like 8 to 9 very good technical films were made by DECU like “Golden Catch” on SRG and Disaster Management communication system for ISRO and PSLV's success etc. “Life Line to GSO” was one of the best films done by DECU. The second thing was on the education & telemedicine networks. The whole of North East India, educational networks were set up by DECU's teams using Edusat. Third area initiated is the content generation in Science, Mathematics & English for class 10 as per CBSE. Something like 75 programmes were done in a very short time. And the fourth thing I did during this time was getting all approvals for modernization of DECU's studios.

Leadership:

I was (concurrently) holding the position of deputy director in SAC which is again in the hardcore area. So I had to everyday switch between hardcore technology work to the TV programming, educational networks, health network settings, the customer relations, applications problems, software... In a system like DECU, there are two important things. One is content, second one is the format. Both must be of high quality because ISRO is high quality and you can not bring out from DECU anything less than ISRO's standard. That was the target I put it and I am very happy that DECU met that standard and continues to hold it.

Challenging to make DECU as a part of ISRO

DECU still continues to be relevant because today still 600 million people of India are below poverty line. They need information, they need the content, they need the content which will change their life style which will help them to acquire higher qualification, higher knowledge and more vocational knowledge. DECU has to change, according to what changes are going on outside. ISRO should do much better quality programmes that is the first aim. Second aim is ISRO's content should be either high tech systems like what we deal with or highly relevant social objectives

What more DECU can do to increase the production value

We have invested about 6 to 8 crores in a procuring the latest equipment and upgrading our studios, non linear editing systems and the all those things. I don't fully agree that the investment need to be very high. More than investment whatever equipments we buy, and whatever systems we procure we must be efficiently used.

CHANDRAYAAN

In a democratic country like India you can't stop people asking questions but only answer them properly. Investment in science and knowledge is at the highest level, but with a large gestation period. You may not see the results of it today, you may get results after 20-25 years, so from that angle, I think investment done in Chandrayan, will be very very relevant & highly essential at this stage. We have launch capabilities, operations & applications, the only thing missing in the large canvas is the science investment. So that way Chandrayan was a significant investment, conscious investment of ISRO, in the science programme. Third aspect of it is that going to moon has got a strategic angle to it - to prove to the world that moon belongs to the whole humanity and it does not belong to only a few countries.

Development related programmes are out of fashion

To some extent its true because it depends upon whom you look at it. People do not learn things only from the TV but they have other means. But their will be and there are people in the country, who have only TV as a high-tech instrument in their whole life for them definitely whatever good content you give that will be useful. If our content is correct and if our format is attractive, audience will go on increasing.

What DECU should do to become more proactive and make its presence felt

First thing I feel is we should involve more young people into DECU that's because any organization after 30-40 years of its existence will face aging problem. So we must continuously take people and then train them, see the rich heritage of the past is transferred, knowledge is transferred before the experienced people retire or exit from the scene. Secondly, as ISRO has to exist within the Indian context, DECU has to exist within Indian context and ISRO context. DECU should contribute in a relevant way with an attractive format and with a good content.

DTH channel viable option?

Earlier I proposed that ISRO should have an ISRO TV channel, like NASA TV channel but then now I feel we must take one hour dedicated daily programme at a prime time from doordarshan, and we should get ready for that.

Again as director DECU

I will take it as my privilege to work with such a dedicated experienced team which had got roots both in ISRO and in society.

Dr. K.S. Dasgupta [2008 - 2010]

Recount your journey as Director DECU highlighting major achievements and milestones during your tenure.

DECU is like eyes and ears of ISRO so I keep telling in every occasion "If DECU doesn't exist then our societal link will get disturbed and a communication satellite without a societal application has no meaning". I recall some of the science programs we made for others were very world class; the program for Dr Abdul Kalam's was well accepted internationally. Even educational programs were well accepted not only by Gujarat Higher Secondary Board but also by Meghalaya and other northeast places. Science Mission Programs are also done on cryogenics and Chandrayan. For disaster management and impacts studies need of social researchers is also well accepted.



DECU a relevant part of ISRO?

For some time there was a discussion about DECU's existence but I have a feeling that "taste of food is in eating". Production quality at DECU has made people understand the need that Tele-education without DECU cannot work, it is very very important.

SITE and JDCP were landmark experiments. With EDUSAT came a certain thrust of new activities at DECU. We cannot make a satellite and then try to search for user. We have to find an application, application should write the mission and that mission should give an input to satellite community. DECU and SAC should jointly make one very good research study to find out the communication need in the context where the terrestrial studies are also there and where we can position ourselves and such that we can get scenario of the wireless and the wired communication.

What should DECU do to become proactive or is a DTH channel an option for DECU?

I feel that one channel is definitely required but how to initiate, how to co-ordinate is a big issue. One can think about it. ISRO channel could be a good possibility but again there are certain ifs and buts, because if it is a channel how to keep the program and the whole system running, it should not become like Doordarshan. DECU basically is supposed to spread the application of satellite communication into the masses. That way our emphasis is different.

I strongly feel that if education has to survive, there should be an education channel and I feel that over all monitoring of education channel should be DECU's responsibility

I feel DECU has enough scope for outreach because whenever a new mission comes, lot of odd questions come. Those odd questions come intentionally sometimes, sometimes unintentionally, but we should be geared for FAQs. We should have given some sort of a pre-impact on Chandrayan. DECU should think ahead of time, see what are the due future missions, make some capsules, create an enthusiasm and orient people's mind. Even we can come out with some of the new plans and program which will help to create the seed. Actually according to me, putting seed is the responsibility of DECU.

Television in educational part cannot be ignored. Lot of colleges / institutes / universities are coming, so if a program which is running at some institute like IISc or IIT is beamed through the satellite to different places, then quality of higher education can be upgraded at faculty-scarce places. Entertainment will be there on television but if education and entertainment are fused together, then Physics, Mathematics or any other subject can be made interesting to the students. You have to be very innovative in making the program then only programs will attract people. Not only program quality but lot of efforts is required on program content and research to make it international level.

Sir if you get another chance of becoming Director DECU what would you do more and how differently?

DECU should become a link between the society and ISRO. I don't want DECU to produce a lot of volume but produce quality, intellectual capability and professional approach that people respect. HSP is coming in a big way, make a good documentary on HSP mission and create awareness. A lot of questions will be raised again as were at the time of Chandrayan, but can be answered with coverage of technological complexities, astronauts and people trained, infrastructure getting set etc.

Sir can you tell us the strengths or the uniqueness Of DECU?

DECU is handling educational programs in one end, handles science program on the other end. There is social related program for awareness etc. with very few limited resources. So, this sort of variety according to me is the strength of DECU.

How far or near is DECU in fulfilling Dr Sarabhai's goal ?

Migration from SITE to EDUSAT is quite a challenging thing and perhaps if Dr. Sarabhai would have been there, he would have been very thrilled. But we have to reach every nook and corner of the country and tell the real need of the society. Dr. Sarabhai had given a mandate, DECU should give a mandate to ISRO that we want this particular satellite, this particular mission or a program or a project which will cater to this sector of the society and this is the impact which we will get.

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