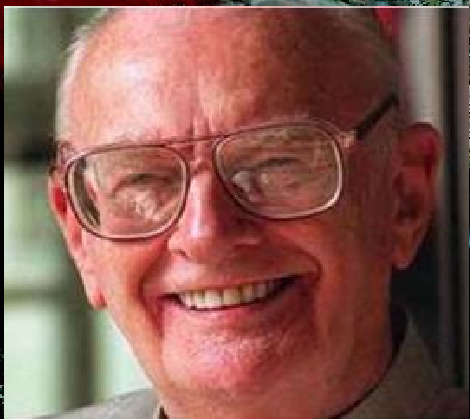
First Sir Arthur C Clarke Memorial Lecture

Space Odyssey – A Down to Earth Perspective

K Kasturirangan



Arthur C Clarke :
The Godfather of the Communications Satellite

Cover page: This image of South India and Sri Lanka was taken by the Advanced Wide Field Scanner (AWiFS) onboard IRSP6 of Indian Remote Sensing Satellite Series.

Space Odyssey - A Down to Earth Perspective

by

Krishnaswamy Kasturirangan

Hon. Prof. Tissa Vitharana, Hon'ble Minister of Science and Technology, Prof. K.K. Y.W. Perera, Chairman, CCIMT, Eng. Sanath Panawennage, Director & CEO, ACCIMT and distinguished guests. It is a great pleasure to be in this wonderful country of Sri Lanka. I am highly privileged and greatly honoured by this invitation of Sri Lankan government to deliver the inaugural Sir Arthur C Clarke memorial lecture. I would like to thank Arthur C. Clarke Institute of Modern Technologies for giving me this opportunity to speak in front of this august gathering. It is with profound regret and sorrow that we had to accept the sad demise of Sir Arthur C. Clarke on 19th March, 2008.

Sri Lanka, an island nation, has a wide range of geographic features and is rich in natural beauty. The island has an abundance of natural resources, diverse fauna and flora, mountains, rivers and beautiful beaches. Large parts of Sri Lanka are covered in tropical forests, with hundreds of rivers flowing through them, often cascading in awesome waterfalls. The country has gorgeous rolling hills and tea plantations. The entire island is teeming with bird life and animals - elephants and leopards. This natural beauty of Sri Lanka attracted Sir Arthur C. Clarke to this country. Clarke lived in Sri Lanka from 1956 until his death in 2008. He emigrated there when it was still called Ceylon, **first in Unawatuna on the south coast, and then in Colombo**. During his stay in Sri Lanka, he wrote several fiction and nonfiction books and articles about the Indian Ocean. A quote from Clarke in the View from Serendip, 1977 is appropriate in this context.

> "The island of Ceylon is a small universe; it contains as many variations of culture, scenery, and climate as some countries a dozen times its size. What you get from it depends on what you bring; if you never stray from your hotel bar or the dusty streets of week, and it would serve you right. But if you are interested in people, history, nature, and art-the things that really matter-you may find, as I have, that a lifetime is not enough."

This island nation as characterized by Sir Arthur C. Clarke is indeed a God's own country and its people accordingly are highly gifted. We are indeed fortunate to be the neighbour of such a country with people who are well known for their warm heartedness, generosity and friendly disposition.

I chose to speak on the theme of SPACE for a number of reasons. Firstly, Sir Arthur C Clarke has dealt with this subject in several of his writings kindling the imagination of everyone irrespective of age; secondly, it is a new dimension of human endeavour hardly half a century old, but with a high promise for the future of humanity; thirdly, it is exciting, and promotes the spirit of exploration and adventure; fourthly, the vantage point of space has already demonstrated its ability to enhance the quality of life on the earth if used properly, and last but not the least, I have spent nearly all my professional life in facing the challenges and excitements of a space endeavour.

1.0 Background

Science fictions bring science and technology to get close to common people without the complication of theory and complex concepts. These fictions are man's technological imaginations and are based on scientific facts and incidents that may happen in the future. Science fictions written by those great writers like Sir Arthur C. Clarke were really helpful in the progress of science and technology. Sir Arthur C. Clarke's visions of space travel and communication sparked the imagination of readers and scientists alike all over the world. Sir Patrick Moore in his obituary paid his tributes by rightly describing him as "a great science fiction writer, a very good scientist, a great prophet and a very dear friend."

Apart from his literary endeavors, Arthur C. Clarke is remembered as the inventor of communication satellite. He described this concept in a paper titled *Extra-Terrestrial Relays - Can Rocket Stations Give Worldwide Radio Coverage?,* published in *Wireless World* in October 1945. The geostationary orbit is now sometimes known as the Clarke Orbit or the Clarke Belt in his honour. The essay was reprinted in Ascent to Orbit, a collection of his technical writings that he brought out after receiving the Marconi Award in 1982 for his contributions to communications technology. Sir Clarke's professional writing career spanned over several decades.

In the 1950s, Clarke got interested in undersea exploration. He was an avid **scuba diver** and a member of the Underwater Explorers Club. Living in Sri Lanka afforded him the opportunity to visit the ocean year-round. It also inspired the locale for his novel *The Fountains of Paradise,* in which he described the concept of a space elevator. This, he believed, ultimately will be his legacy, more so than geostationary satellites, once the space elevators are ready, it will make the space shuttles obsolete.

A **Space elevator** is a proposed structure designed to transport material from a celestial body's surface into space. Many variants have been proposed, all of which involve traveling along a fixed structure instead of using rocket powered space launch. The concept most often refers to a structure that reaches from the surface of the Earth to geostationary orbit (GSO) and a counter mass beyond. This structure would be held in tension between the Earth and the counterweight in space like a guitar string held taut due to the operation of centrifugal forces. Space elevators have also sometimes been referred to as ***beanstalks, space bridges, space lifts, space ladders, skyhooks, orbital towers, or orbital elevators***.

Current (2009) technology is not capable of manufacturing practical engineering materials that are sufficiently strong and light to build an Earth based space elevator. However, a recent breakthrough at Cambridge University may make such materials possible in the very near future. Recent conceptualizations for a space elevator are notable in their plans to use carbon nano tube based materials as the tensile element in the tether design, since the measured strength of microscopic carbon nano tubes appears great enough to make this theoretically possible. Current technology could produce elevators for locations in the solar system with a weaker gravitational field, such as Mars.

The creative instinct of Sir Arthur C. Clarke is evident from these three laws which he formulated:

(i) When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong.

(ii) The only way of discovering the limits of the possible is to venture a little way past them into the impossible.

(iii) Any sufficiently advanced technology is indistinguishable from magic.

Due to a severe attack of polio in 1962, Clarke became completely paralyzed. As his farewell to the sea he wrote *Dolphin Island*. After recovering Clarke started his cooperation with the director Stanley Kubrick. Later he accompanied his friend Like Wilson on an underwater adventure six miles off the coast of Sri Lanka, which was depicted in the *Treasure of the Great Reef* (1964). The Kubrick/ Clarke vision from 1968 of computers and space programs at the turn of the century did not come true. In an interview Clarke acknowledged: "We science-fiction writers never attempt to predict. In fact, it's the exact opposite. As my friend Ray Bradbury said, 'We do this not to predict the future but to prevent it.' "(Newsweek, December 2000 - February 2001, special edition). In 1975, Indian government presented him with a satellite dish, with which he was able to receive programs broadcast from experimental satellite ATS-6. In 1980, he was Vikram Sarabhai Professor at Physical Research Laboratory in Ahmedabad, India. In his 1999 revision of *Profiles of the Future*, published in London by Indigo, Clarke added his Fourth Law: "For every expert there is an equal and opposite expert." For the last two decades of his life, Clarke suffered from post-polio syndrome. He died in Colombo, Sri Lanka, on March 19, 2008.

1.1 Satellite Communication: An Evolution

As the inventor of Communication Satellite, Arthur Clarke ushered a new era in communications, transforming the very basis of our civilization. The Satellite technology has made tremendous progress since the launch of the pioneering communication satellite (ECHO) in 1960. The growth and development of geosynchronous satellites during the first quarter-century have provided the world with international and long distance fixed satellite services (FSS) that have helped, in large measure, to create the Marshall McLuhan vision of the global electronic village. It has even been said that satellites have become the greatest force for the “super-tribalization” of the human species - even more important than television. Starting with the global viewing of the moon landing in July 1969, communication satellites have changed the world.

During this epoch, the satellite industry has been at the forefront of change and innovation. Year in and year out, with satellites growing in size and sophistication, this remarkable new industry grew quickly and vibrantly. The record of achievements by international industrial firms is remarkable and currently has reached a revenue level of $85-90 billion. This technology has gone through various development cycles and created a great international business opportunity. In fact, we can classify the growth of communication Geo-satellite in four generations.

The **first generation** Communication GEO-satellites developed during the year 1972-1979 had nominal satellite life time of 3-7 years with launch mass of around 200-1700 Kg having a primary power requirement of 200-1000 Watt. The average satellite cost of the first generation satellites was approximately $60 Million. The **second generation** communication GEO-satellites during the year 1980-1989 had nominal life time of 7-12 years with launch mass of 250-2500 Kg having primary power requirement around 250-1500 Watt. The average satellite cost was around $ 70 Million. The **third generation** communication GEO-satellites during the year 1992-2002 had nominal life of 9-17 years with launch mass of 1000-1700 Kg having primary power of 500-1500 watt. The average cost of these satellites was around $98 Million. The **fourth generation** communication GEO-satellites is expected to have nominal life of 12-20 years with launch mass of 1700-6000 Kg having primary power requirement of 750-8000 watt. The average cost of these satellites will be around $100 Million. One can make following important observations by studying the need of communication GEO satellites in terms of satellite life, power and mass from first generation to fourth generation:

(i) Life of the satellite is progressively increasing which implies there is an increasing demand for reliable space qualified components/ subsystems. In other words, an intensive research is on towards design and development of reliable, low power space qualified components/ subsystems.

(ii) There is a steady increase in satellite mass and power. This in turn demands high power launch vehicle and high power bus of satellite. Hence, it calls for an intensive R&D in the area of launch vehicle design and generation of high efficiency solar power.

1.2 Indian Space Program - A Historical Perspective

India's Space programme has crossed 40 years since its inception. It started as a purely scientific endeavour, with the launching of sounding rockets from Thumba on the Arabian Sea coast near the town of Thiruvananthapuram at the southern tip of India. Being on the **geomagnetic equator,** this location provided the opportunity to conduct interesting studies of the upper atmosphere and ionosphere whose physical and dynamic characteristics are considerably influenced by the geomagnetic equator. The sounding rockets that were flown from here in the early 1960s also provided a unique opportunity to observe astronomical objects of interest, particularly in the X-ray domain, in view of large part of the southern sky being visible from this location.

The development of satellites and launch vehicles were driven by the priority needs of applications for development; science objectives alone could not justify such large scale investment. However, it was recognized that such capabilities, once developed, could provide opportunities for front ranking research in space science. This rather unique approach, viz., to develop scientific capabilities without making science as the prime reason for resource investment gave the Indian Space Programme a distinct character.

1.3 Organizational Setup

The space activities in the country were initiated with the setting up of the Indian National Committee for Space Research (INCOSPAR) in 1962. In the same year, the work on the Thumba Equatorial Rocket Launching Station (TERLS), near Thiruvananthapuram, was also started. The Indian Space Programme was institutionalised in November 1969 with the formation of the Indian Space Research Organisation (ISRO). 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.

The Space Commission, a unique set up with some of the key decision makers of the country serving it, formulates the policies and programs of the space endeavour. It also oversees the implementation of the Indian Space Programme and ensures its relevance for the development and application of space science and technology for the socio-economic benefit of the country. DOS implements these programmes, through mainly, different Centres of the Indian Space Research Organisation (ISRO), Physical Research Laboratory (PRL), National Atmospheric Research Laboratory (NARL), and North-Eastern-Space Applications Centre (NE-SAC). The Antrix Corporation, established in 1992 as a Government-owned Company, markets the space products and services.

The establishment of the space systems and their applications are coordinated by the national level committees, namely, INSAT Coordination Committee (ICC), Planning Committee of National Natural Resources Management System (PC-NNRMS) and Advisory Committee on Space Sciences (ADCOS). The representatives of the major users of space systems at the National level, serve as members in these committees.

1.4 Indian Space Programme - Current scenario

In the context of generation and utilization of information, Sir Arthur C. Clarke, had the following to say:

> “Nevertheless, it is vital to remember that information - n the sense of raw data is not knowledge; that knowledge is not wisdom; and that wisdom is not foresight. But information is the first essential step to all of these.” (from’ Is Life After Television’ in Greetings, Carbon-Based Bipeds! 1999).

Many of the space endeavours across the world, ultimately generate and transmit data/ information for a variety of end use, with the help of sophisticated technologies and systems and in a variety of environments. The Indian space programme today is a large integrated program, which is self-reliant, and applications driven, maintaining vital links with the user community and committed to excellence in scientific endeavours.

The program developed capabilities to produce world-class satellites and launch vehicles and to apply them in diverse areas relevant to national development. India has established two operational space systems. The Indian National Satellite (INSAT) system, currently made up of nine state-of-the-art satellites in orbit, is one of the largest domestic satellite communication systems in the world. Presently, India is having 2nd, 3rd and

4th generation family of INSAT of satellites with 220 transponders covering frequency spectrum from S, C, Ext-C and Ku bands to provide communication networks across the country.

The Indian Remote Sensing satellite (IRS) system, presently with a constellation of seven satellites, comprises some of the best satellites in the world for generating information on natural resources. Indian Remote Sensing Satellite IRS-1A, launched in March 1988, was the first operational satellite. IRS-1B was launched in August 1991. The data from these satellites were used for national level mapping. IRS-1C/ 1D made a quantum jump in the capability for urban mapping and vegetation dynamics studies. Data from IRS-P4 provided greater impetus to physical and biological oceanographic studies. Launch of IRS-P6, one of the world’s most sophisticated EO satellites, provided data that could be used to map various themes at national level to village level, especially, pertaining to agriculture. Cartosat-1 provided along track stereo images, which has opened a wide range of photogrammetric based applications. Panchromatic data at 1m spatial resolution provided by Cartosat-2A is being used for various cartographic applications. IRS satellite system is the world’s largest constellation of remote sensing satellites in operation today, and provides a suite of resolution ranging from 1 km from GEO stationary satellite to sub metre from remote sensing satellites.

Space launch vehicles developed by India are aimed towards providing autonomous launch capability to orbit these classes of satellites. India’s Polar Satellite Launch Vehicle (PSLV) is well proven through many successive successful flights and it provides the capability to orbit remote sensing satellites of the 1.4 tonne class in polar sun synchronous orbits. The Geo-synchronous Satellite Launch Vehicle (GSLV), capable of launching 2 to 2.5 tonne class of INSAT satellites, has been operationalised with three successful flights in a row, making India one of the six countries in the world to possess capabilities for geo-stationary satellite launch.

Both IRS and INSAT satellites have benefited the country in various areas of national development. INSAT satellites are the main stay for the Television broadcasting and provide connectivity to more than 1100 TV transmitters. They also network radio stations, provide rural area communications, business communications and Tele-education and Tele-medicine services. They are also used to relay cyclone warnings, gather meteorological data, assist weather forecasting for emergency communication support during disasters and providing search and rescue support. The imageries and data from the IRS satellites are used for vital applications such as locating zones of groundwater availability in habitations having no access to drinking water, monitoring agricultural crops, providing advisories to coastal fishermen on potential zones for fishing, planning water-shed development, wasteland management programs and disaster management support.

Front-ranking scientific investigations are being carried out in the fields of astronomy, atmospheric sciences and long-term climatic research using satellites, balloons, sounding rockets and ground instruments. India has also embarked on an ambitious planetary exploration programme, the flagship mission of which is Chandrayaan-1. This mission launched on October 22, 2008 has successfully placed a satellite around the Moon for physical and chemical mapping of the lunar surface.

India piloted a Satellite Communication Policy in 1997 paving the way for use of INSAT capacity by private users and for private ownership of communications satellite assets. Further, a comprehensive Remote Sensing Data Policy on acquisition and distribution of remote sensing data to civilian users is also in place. Remote sensing data from satellites have been accepted as legal evidence in most States of the country for purposes such as environment impact assessment for site clearances, forest encroachment and infrastructure development.

In a nutshell, these multifaceted contributions from the Indian Space Programme, which has been developed and run with modest budget provides a unique example of what a developing country can achieve with its resources.

1.5 Evolving Strategies

The evolution of the Indian space program over the past four decades represents a systematic and phased approach to build knowledge, technological capacity and an organizational system to ensure effective application of sophisticated technologies to national development

Beyond the first decade of vision and initiation, the evolution of the space program can be broadly categorized under three distinct phases. The first phase related to proof-of-concept demonstration, the second dealt with the realisation of end-to-end systems at an experimental level that then led to the current operational phase.

1.6 India’s Space Vision for the future

Every country needs a vision which stirs the imagination and motivates all segments of society to greater effort. It is an essential step in building a societal consensus on a broad national development strategy, which encompasses, inter-alia, the roles and responsibilities of different agencies in the economy, government, industries, academia and even citizens.

Currently, India, among the developing countries, is ranked among the ten fast growing economies. India's GDP growth, according to our Planning Commission, would be more than 10% towards 2025. Still, the challenge is to bridge the divide between the haves and have-nots and of dealing with poverty and inequity. Among the 1027 million population about 350 million are still illiterates. This is one of the major societal dimensions calling for urgent and effective response. In other words, the colossal nature of the problem would need supplementing and complementing support by new and innovative approaches. There are also issues of quality education at higher and professional levels. The second aspect is the Health divide. If one looks at the distribution of medical specialists between urban, semi-urban and rural areas, nearly 98% are in the urban areas with hardly 2% in the rural areas. Ensuring health equity to the rural population will be yet another challenge. Another alarming development is the depleting natural resource base with the increasing population. When we talk of the natural resources, the question is one of efficient land and water management, empowering people for sustainable development, provision of better civic amenities and infrastructure and the ability to generate employment.

A vision for development needs to encompass the integration of economic and technical developments with the social realities and cultural ethos. Further, India's progress in the next 25 years will be influenced by several other dimensions of national endeavour, into which the vision for space has to dove-tail. The space vision for India as envisaged encompasses:

- **A Societal Vision,** to apply space to enhance the quality of Indian society and its people;
- **A Scientific Vision,** to kindle the spirit of enquiry through space exploration and expanding the horizons of knowledge.
- **A Technological Vision,** where space could enable a multi-dimensional technology capability in the country, including contributions from developing a cost-effective space transportation system of the future.
- **A Commercial Vision,** where the enterprise of Indian Space could attain global dimension and become a profitable business endeavour, and
- **A Strategic Vision,** where space could support the strategic requirements of the nation in the areas of foreign policy and global economics.

2.0 Translation of Arthur Clarke's Dream: An Indian Experience

Sir Arthur Clarke propagated three things about science and technology - stimulate creative use of communication technologies and social resources to improve health, education, and the quality of life for people everywhere; integration of science and technology with literature and film to enhance recognition of our increasingly complex and interconnected world and deepen public understanding of science and technology and their impact on humanity.

In 1975, Satellite Instructional Television Experiment - SITE was carried out in six States of India with the use of Applications Technology Satellite - ATS-6 of NASA. This was a new star of India; though it was invisible to the naked eye; its influence was greater than that of any zodiacal signs. India was the first country to receive the benefits of space directly at home, in villages. Sir Arthur C. Clarke mentioned this as the next step in the evolution of communications satellite. Sir Arthur C. Clarke further added, those who live in west and had exposure to all the communications gadgets and quite often who suffer from the scourge of information pollution may not be able to imagine a situation that is exactly the opposite of it - information scarcity. Those who live in East, with their day-to-day life problems are the best to appreciate the cheap and high quality communications, which could improve their standard of living and social inequalities.

Dr. Vikram Sarabhai, who also believed in a similar ideology, promoted use of space technology for the cause of societal development. Dr. Sarabhai had the vision that "we don't have the fantasy of competing with the economically advanced nations in the exploration of the moon or the planets or manned space flights; but we are convinced that if we are to play a meaningful role nationally and in the community of nations, we must be second to none in the applications of advanced technologies to the real problems of man and society, which we find in our country". He further believed that the process of education is basically related to an information dissemination/transfer process. For rapid and sustained growth of developing countries, the urgent need to disseminate information to the masses is obvious.

In this backdrop, ISRO undertook several projects that only focused on development of humanity through sophisticated satellite-based communication. In this section, the projects i.e. from 'SITE to Edusat' in terms of the objectives, the actual implementation of the project, the impact or the findings and the lessons learnt so far are discussed. While the overall objectives of the project have been achieved and the development is measurable, there is still a large scope for improvement - in hardware, software and the content - in using satellite communication for socially relevant causes.

2.1 A journey from SITE to EDUSAT

Amongst the developing countries, India, by virtue of its cultural plurality and linguistic uniqueness has always attracted the attention of many nations of the world. Despite some visible progress in the field of science & technology, IT industry etc., there remain many socially relevant issues to be addressed like school education, gender equality, adult literacy etc. This clearly shows the disparity in human development. In this context, satellite communication, though may not be the panacea, but certainly has provrd to be of a great help in creating homogeneity among the heterogeneous groups.

In using space communication for development, the experiments like Satellite Instructional Television Experiment (SITE), Kheda Communications Project (KCP) and Jhabua Development Communications Project (JDCP) have been the pilots. This was followed up further with the Training and Development Communication Channel (TDCC) and Edusat Utrilisation Programme, which are being continued as key developmental programmes. It is worthwhile to share the experiences of carrying out these projects.

SITE was conducted in 2330 villages scattered in six States and 20 districts of India, known as a cluster for a period of one year, beginning August 01, 1975. The TV sets, augmented with 10 feet parabolic antennae and front-end converters, were placed in isolated villages in parts of six States of India. The programmes under SITE were classified into two broad categories viz., Educational, which was meant for the school children in the age group of 5-12 years; and the Instructional programmes which was meant for adult audience, primarily designed for neo-literates and illiterates. The pre-recorded TV programmes were transmitted using ATS-6 satellite from Ahmedabad and Delhi Earth Station (DES). The villagers who participated in the SITE experiment did not have any prior exposure to television viewing.

KCP was conceived originally as an experiment within the year long SITE; while SITE ended in a stipulated period of one year, KCP continued. The Kheda district, located near the head-quarter of SITE transmission facility at Ahmedabad, which was also a content-production centre staffed with production personnel and researchers, served as an ideal setting for testing the effectiveness of television as a “participatory interaction communication channel” for rural development. The KCP was thus different from the SITE, in the sense that interaction, frequent feedback, and audience participation in programme production was possible because of physical proximity.

Both the projects were based on the premise that television communication can thus facilitate rural development. From both the experiments, it was learnt that television as a media had greater impact on the viewers and proving to be an effective medium for instructional programmes in rural India. The involvement of the people with the medium and the credibility of the medium greatly increase when the medium deals with the issues of immediate concern to the audience. One of the major lessons of SITE was that the planning of software (content) rather than hardware required more time. Hence, in such efforts, the planning for software aspects must start years prior to planning the hardware aspects.

During SITE and KCP, people in the community had very little knowledge about handling the television. There were many managerial issues to be addressed. It was found necessary to broadcast recent, relevant and appropriate content without disturbing the social milieu of the region. By then, as television became a proven media, there was not much hassle in dealing with the hardware i.e., technological aspect of the media.

In experiments like SITE and KCP, it became clear that broadcast has the potential for rural development. However, certain limitations in terms of immediate interaction, coordinating ground support concurrently with broadcast, etc., were encountered. Realizing that immediate interaction is an essential feature for educational and training purposes, teleconferencing as a viable solution was pursued. The use of one-way video and two-way audio teleconferencing network for education and training were experimented with. Initially, around 24 experiments were carried out using one-way video and two-way audio channels during 1992-95 by Development & Educational Communication Unit (DECU/ ISRO) in collaboration with different user agencies. This network, known as **TDCC,** became a popular feature since 1995 using INSAT spacecraft.

The experiences of SITE and KCP as a model of locale based narrowcasting having people-centric development communication approach was replicated in Jhabua Development Communication Project (JDCP), adding one more component of Interactive Training Programme (ITP). JDCP had two elements: Broadcast and Interactive Training Programmes. As a part of broadcast, development oriented programmes consisting of two hours every evening five days a week (from Monday to Friday) were transmitted. Simultaneously, it conducted ITP in the afternoon for village, block and district level functionaries.

In TDCC and JDCP, the Interactive Training Programme (ITP) was one of the main elements apart from evening broadcast in Jhabua. In ITP, the technology was simple and training of personnel from different departments, NGOs etc., was the only objective of the system. Thus, the two-way audio and one-way video was the ideal concept. The sharing of information was now no more restricted to few villages or one region, rather it aimed at the State as a whole.

ISRO's **Telemedicine** network is one of the unique ventures of its kind in the field of healthcare. It started in the year 2001-2002 with a small demonstration at Narayana Hrudayalaya, Bangalore. The first ISRO telemedicine network was established in the year 2000 consisting of 5 nodes with Bangalore and Kolkata as super specialist end hospitals, and Chamarajanagar, Saragur and Tripura as patient end hospitals. At present, we have 315 nodes consisting of 271 remote/district/ medical college/ mobile hospitals connected to 44 super speciality hospitals in different cities through ISRO's satellites. This has paved way for planning a national level adoption by Government of India of this innovative concept.

Telemedicine system consists of customized medical software integrated with computer hardware, along with medical diagnostic instruments connected to the commercial VSAT (Very Small Aperture Terminal) at each location. The network has three elements, viz., (i) The Patient End, (ii) The Speciality End and (iii) The Communication link. From our experiences, we have realized that in the long run, sustaining the services will require commitment of specialist doctors on a continuing basis for reaching the un-reached. Also, integration of the space based networks with other non-space based systems, through interoperable mechanisms would make it more effective.

Having gained adequate experience in broadcast and also to keeping pace with the developments in the field of communication, we thought of migrating from television broadcast to IP based communication. Further, we had also gained experience in carrying out development and educational projects for the niche user. With these two things in mind, we thought of covering the entire country, and also use computers instead of television broadcast for communication.

With this in the backdrop **Edusat** (GSAT-3) was launched in 2004. This is a satellite dedicated to supplementing the education efforts in the country. Edusat has been envisaged to support both formal and informal education through low cost ground systems. Edusat provides an Extended C Band national beam, Ku-band national beam as well as five Ku band regional beams to cater to all the regions of the country. Since the aim was to strengthen the education efforts by augmenting curriculum based teaching, effective teachers training and community participation by increasing access to education and access to new technology, the objectives have been laid down accordingly.

2.2 Village Resource Centre (VRC)

Towards providing a host of space-enabled services directly to the rural areas, ISRO has embarked on the unique initiative of setting up VRCs in partnership with the reputed NGOs and others. VRCs are envisaged as the single window delivery mechanism for a variety of space-enabled services and deliverables such as telemedicine; tele-education; information on natural resources for planning and development at local level; interactive advisories on agriculture, fisheries, and land & water resources management; livestock management; interactive vocational training towards skill improvement, alternate livelihood; e-governance services; weather information, etc. Over 450 VRCs have been setup, and many more are in the pipeline.

3.0 Earth Observation Programme: An Indian Experience

A constellation of remote sensing satellites in operation today provides data on various spatial, temporal and spectral resolutions and swath. This has enabled India to be in the forefront of utilization of satellite based information for natural resources inventory and management. Further, with proper institutional mechanism in place operational applications of satellite data in various sectors of natural resources management viz., land, water, agriculture, atmosphere, ocean, forestry, etc., have been realised

Satellite Observations over land, oceans, atmosphere, and during natural and human-induced hazards have become crucial for protecting the global environment, reducing disaster losses, and achieving sustainable development. Remote Sensing using space borne sensors is a tool, par excellence, for obtaining repetitive (with a range from minutes to days) and synoptic (with global coverage) observations. Improved spatial, spectral and temporal resolution data from the forthcoming satellites would further provide ample thrust to application projects towards optimal management of natural resources. A few examples of applications using EO satellites are briefly described below to illustrate our experience.

3.1 Weather and Climate

The INSAT system provides round-the-clock surveillance of weather systems including severe weather conditions around the Indian region. Deriving the operational parameters for weather forecasting, collecting and transmitting of meteorological, hydrological and oceanographic data from remote, inaccessible areas through data collection platforms; timely dissemination of warning of impending disasters such as cyclones through cyclone warning systems; and dissemination of the products and services through the operational agencies are the prime functions of the INSAT systems.

3.2 Natural Resources and Environment

India is endowed with well-diversified natural resources. However, with the ever-increasing population and its demand, there has been constant erosion of natural resources, calling for a scientific means of managing the same on a sustainable basis. Information generated through satellite remote sensing is being utilized for inventory and monitoring of natural resources. Several national missions in the key areas of socio-economic development have been carried out in the country under the aegis of the National Natural Resources Management System (NNRMS) with the active involvement of the user agencies.

Drinking Water Inventory: Under the National Drinking Water Mission of the Ministry of Rural Development, remote sensing technology has been used for the preparation of hydro-geomorphological maps showing the groundwater prospects for the entire country at 1:250,000 scale, and subsequently at 1:50,000 scale in phases. With such remote sensing derived information, the success rate has gone up from the earlier 40-45% to around 90% in most of the States.

Crop Production Forecast: Timely availability of reliable information on agricultural output and other related aspects are significant for planning and policymaking. In India, the projects such as Crop Acreage and Production Estimation (CAPE) and ‘Forecasting Agricultural output using Space, Agro-meteorology and Land-based observations (FASAL)’ are carried out using data from IRS satellites with >95% accuracy. The challenge lies in the coming years in forecasting the crop acreage and production in a multi-crop and mixed crop situation, with requisite accuracy, coverage and timeliness.

Potential Fishery Zone (PFZ) Advisories: In India, the Potential Fishery Zone (PFZ) advisories generated using the chlorophyll and the Sea-Surface Temperature (SST) obtained from satellite remote sensing data are operationally disseminated to the coastal area. The fishermen use the advisory to improve their fish catch with minimal effort.

Land reclamation: Mapping of wastelands over the entire country has been accomplished using remote sensing data for effective reclamation purposes. These maps are used in conjunction with the village and watershed level information. The district level wasteland information is being made available on the web to enable the concerned district authorities carry out reclamation activities.

Biodiversity Characterization: With the aim of protecting the vast biological diversity, India has taken many steps to strengthen the measures of biodiversity conservation and sustainable use. Satellite remote sensing has been effectively used in the biodiversity characterization at landscape level to create geospatial database on vegetation cover types, disturbance regimes and biological richness. In India biennial forest mapping is being carried out regularly using IRS data to assess the forest cover of the country.

Disaster Management: India is one of the most disaster prone countries in the world with increasing vulnerability to cyclones, floods, landslides, droughts and earthquakes. INSAT and IRS satellite systems provide disaster management support for the early warning, risk information, impact and damage assessment, preparedness and emergency communication. Today, satellite-based information is used in the country for various disasters such as floods, cyclones, agricultural drought, forest fires, earthquakes, etc. A Decision Support Center (DSC) has been established as a single window service provider to deliver the space services for disaster management. INSAT Mobile Satellite Services (MSS) terminals are being put to use during emergencies for providing necessary connectivity.

4.0 A framework for Cooperation between Sri Lanka and India - Some thoughts.

We are aware of the extensive efforts in Sri Lanka of utilizing the different capabilities of space systems. In particular, Sri Lanka has been actively using remote sensing and GIS tools for geo-informatics. There is also an important research and development programme towards sustainable exploitation of fisheries resource. Further, various institutes in Sri Lanka are working on town and country planning, geomatics and advanced electronics. Sri Lanka has also been an active partner in the management of the Center for Space Science & Technology and Applications of the Asia and the Pacific located in India, responsible for capacity building in the area of space for countries of Asia pacific. Thus, there is scope for sharing the experiences of both the countries in the areas of mutual interest. Some of the possibilities in this context are:

(i) As discussed, India has a comprehensive space infrastructure consisting of indigenously developed Remote Sensing and Communication satellites. The data from the Indian Remote Sensing (IRS) satellites could be of value for several of the applications undertaken in Sri Lanka for the various development needs. Further, one could also explore the possibility of using the satellite communication/ connectivity for related applications in Sri Lanka, say, in areas like telemedicine and distance education.

(ii) Considering that both the countries have experience in the applications of remote sensing for a variety of themes, it would be of interest to share the information with respect to the approaches and methodologies. Mutual visits as well as conduct of joint seminars and workshops could be a way to understand share others' knowledge that could also result in improving and enhancing our mutual capabilities for the benefit of both.

(iii) India has a large array of ground based instruments like Mesospheric Stratospheric Tropospheric Radar; instruments for ionospheric measurements and such other facilities. The atmospheric science community of Sri Lanka could possibly be associated with these capabilities in terms of collecting observational data for specific scientific objectives and in collaboration with their Indian counterparts.

(iv) Similar possibility could also be explored by the astronomy science community of both the countries in having mutual arrangements of visits to the respective institutions and laboratories. India has ground based astronomical observation capabilities in visible, infrared, radio and gamma ray domains of spectrum. One could explore interest among the Sri Lankan scientists for carrying out observations with these facilities.

(v) India's scientific space missions could be another area where one could explore the interest of Sri Lanka, particularly for utilizing the data for investigating interesting scientific problems. Possible examples could include data from planetary missions, astronomy missions and atmospheric missions.

These are some of the very preliminary thoughts that come to my mind in the context of strengthening the collaborative links between the scientists and professionals of the two countries for mutual benefit. There is need for an umbrella agreement between the two countries, under which, specific programmes can be identified for further follow up. These could be done by the concerned Governmental agencies of both the countries responsible for the conduct of various scientific activities.

Concluding Remarks:

Our tryst with space has taught us, in a humble way, that the enterprise is essentially a people's enterprise and that it demands the best of our qualities that it has got to do with totality of all things and demands a quest for “excellence”, and excellence alone. We need to take this agenda and make it a reality. The space community in general must always orient its activities towards the mainstream of the developmental march and must rise to the challenge posed by the nation, and stand up to the rigors of achieving excellence.

The space as a vantage point promises several new applications that could benefit the people of our respective countries in the context of improving the quality of their life. In this connection, the immense advantages of collaboration between our countries are beyond doubt. The work already accomplished in our countries in using the Space for national development covering resource management, telemedicine, tele-education and several other applications could be the basis for laying the foundations of a future cooperation. The Governments of our two countries should embark on a serious dialogue with respect to reaching agreements for collaboration and cooperation and also facilitate working out a detailed road map. Personally I am extremely happy to share my own thoughts with all of you in this context.

I carry with me the nostalgic memories of my stay including the hospitality that you so generously extended during my stay. I would like to thank the Government and the people of Sri Lanka for the same. I am sure that this Institute of Modern Technology named after one of the great visionaries of modern times, on whom you bestowed the most prestigious title of your country “Sri Lankabhimanya” will continue to serve as a fountainhead of new ideas and play its own important role in transforming your country in particular and world in general as we enter the 21st century. I wish peace, prosperity and happiness for the people of your great nation.

Thank you.

Acknowledgement: I would like to thank Dr. V.S.Hegde, Dr. K.S.Dasgupta and Dr. S. Bandyopadhyay for their assistance in the preparation of this talk.