Applications of space communication

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This paper presents an account of the evolution of satellite communications in India. Starting with the early experiments like Satellite Instructional Television Experiment (SITE) and Satellite Telecommunication Experiments Project (STEP), the paper goes on to describe the unique techniques developed both for space and ground segments keeping in mind the special needs of the country especially the applications in rural areas. The conventional SatCom applications cover telecommunication, broadcasting, disaster management and several other issues. Further unique and innovative applications such as training and developmental communication, launch of Edusat for exclusively educational purposes, telemedicine, as well as village resource centres are also described.

Keywords: Edusat, SITE, telemedicine, TDCC, village resource centres.

Early experiments

IN the early phase of the Indian space programme, it was recognized that satellite communication could provide vital connectivity between multiple locations for developmental applications. Based on the experience gained from the conduct of Krishi Darshan Experiment, which beamed educational programmes to 80 villages around Delhi in 1967, ISRO was fully convinced that the use of nationwide TV broadcast, the most powerful medium of mass communication, was essential for tackling the massive problem of illiteracy in India. In order to establish the immense potential of satellite technology for providing education, ISRO carried out the world's largest sociological experiment called the Satellite Instructional Television Experiment (SITE) in 1975–76, with the help of NASA's ATS-6 satellite. In the SITE experiment (Figure 1), specially tailored developmental video programmes, in respective local languages were broadcast for 6 hours on each day to 2400 specially selected remote villages in six states for a period of one year, for imparting education in health, hygiene, environment, better agricultural practices and family welfare. The uniqueness of SITE was that it became the first large-scale experiment to directly broadcast video programmes to village community reception TV centres. Extensive evaluation of both hardware and software components of the year-long SITE experiment, conducted by a number of independent teams, including those from outside the country, clearly demonstrated that SITE experiment had a very significant impact on rural population, thus firmly establishing the capability of satellite TV medium for rapidly transforming our rural society.

The SITE experiment was followed by a hardware-oriented experiment, called Satellite Telecommunication Experiments Project (STEP), conducted with the Franco-German satellite Symphony during 1978–79. STEP enabled ISRO to gain experience in conducting communication experiments with indigenously designed and fabricated ground hardware, thus paving the way for ISRO to embark on its own communication satellite programmes.

Development of communication satellites

During the decade of 1980s, ISRO also initiated a number of studies to conceptualize and arrive at an overall concept and design of a cost effective satellite system, suitable for meeting India's needs. In order to economize on cost, ISRO decided to employ a unique multi-purpose satellite system, combining communication, broadcasting with meteorological imaging on the same platform, unlike the conventional satellite system, which consisted of separate communication and meteorological satellites. With the growing pressure for establishing an operational communication and broadcasting satellite system, ISRO decided to procure the first generation INSAT-1 series of multi-purpose satellites from Ford Aerospace Communication Corporation (FACC). It may be noted, ISRO had just launched only its first experimental low earth-orbiting satellite Aryabhatta in 1975 and was yet to develop the capability to build complex operational satellites. Spacecraft technology has been discussed in details by V. R. Katti *et al.* (this issue).

However, in parallel, ISRO indigenously designed and fabricated an experimental three-axis stabilized, geostationary communication satellite APPLE (Ariane Passenger Payload Experiment) weighing 670 kg and carrying 2C-band transponders. The satellite was launched in June 1981, using the third Ariane launch mission. APPLE, in addition to enabling ISRO to gain experience in building, launching and on-orbit operation of a communication satellite, also provided a unique opportunity for broadcasting major national events and to carry out meaningful communication experiments for over 27 months. Large scale experiments on multiple access system, radio networking,

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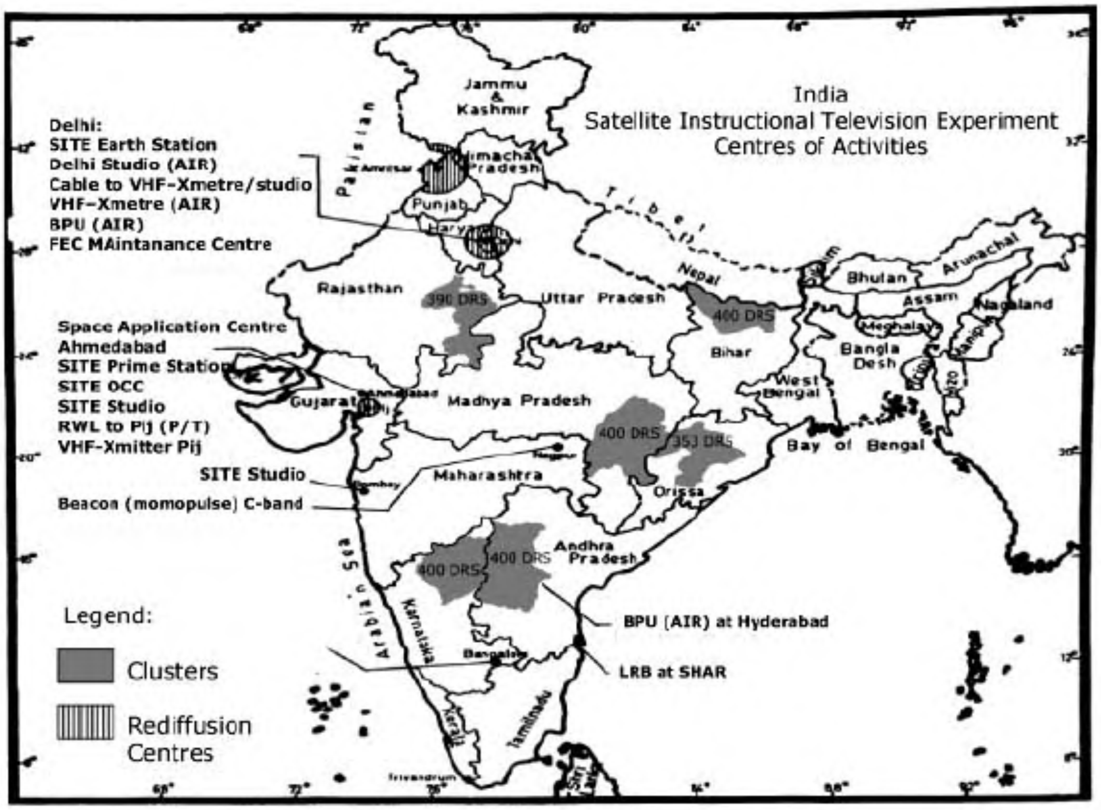

Figure 1. Satellite instructional television experiment.

computer-interconnect, random access and packet switching with a variety of multiple access protocols such as ALOHA, slotted Aloha and other protocols, based on fixed and demand assignment were carried out using APPLE. Spread spectrum multiple access system, data compression techniques and digital speech interpolation techniques were also experimented upon to gain experience in more efficient use of communication channels. Most importantly, APPLE experience enabled ISRO to indigenously undertake the design and fabrication of the second generation and subsequent INSATs (third and fourth generation) and GSATs, which were to follow the first generation INSAT's procured from FACC.

Impact of INSAT and GSAT

India, as of now, has one of the largest domestic communication satellite systems with a total of 199 communication transponders on ten satellites INSAT-2E, INSAT-3A, 3B, 3C, 3E, GSAT-2, Edusat (GSAT-3), INSAT-4A, 4B and Kalpana providing a variety of communication and meteorological services to the country. Twelve more transponders will soon be added to the tally with the commissioning of INSAT 4C-R, which was launched recently on September 02, 2007, after completion of in-orbit tests. Table 1 provides the details of all the communication satellites launched by India, beginning with APPLE. With over 10,070 two-way speech circuits covering about 492 routes and linking 704 earth stations of various sizes, the vast reach of the unique multipurpose INSAT and GSAT satellites has been advantageously used for providing nationwide radio networking, administrative, business and computer communication, VSAT networking and emergency communication services. More than 60,000 VSAT terminals including those installed by the National Informatics Centre (NICNET) are operating today to cater to the fast growing requirements of both public and private closed user groups.

The INSAT system has become the primary backbone of round-the-clock, regular, half-hourly meteorological imaging and continuous weather forecasting. The primary data from VHRR received by the Meteorological Department at Delhi, is processed along with the data from automated unattended data collection platforms located in inaccessible areas to derive products like cloud motion vectors, sea surface temperature, precipitation estimation, etc. The processed data along with cloud pictures are transmitted to about 40 Secondary Data Utilization Centres (SDUC) located in various parts of the country for further dissemination. During cyclones and other emergency situations, INSAT VHRR is capable of imaging

Table 1. Communication satellites of India

No.	Spacecraft	Launch date	Launched	Mass (kg)	Position	Major payloads	Status
1	APPLE	June 19, 1981	Ariane-1	670	GSO 102°E	2-C-Band	Mission completed
2	INSAT-1A*	April 10, 1982	Delta	1150	GSO 74°E	12-C, 1-S, VHRR, IR 8 km., 2.5 km	Failed after 5 months
3	INSAT-1B*	August 30, 1983	Space shuttle	1190	GSO 74°E	12-C, 1-S, VHRR, IR 8 km, 2.5 km	Mission completed
4	INSAT-1C*	July 21, 1988	Ariane-4	1190	GSO 93.5°E	12-C, 1-S, VHRR, IR 8 km, 2.5 km	Failed after 2.5 years
5	INSAT-1D*	June 12, 1990	Delta	1292	GSO 83°E	12-C, 1-S, VHRR, IR 8 km, 2.5 km	Mission completed
6	INSAT-2A	July 10, 1992	Ariane-4	1905	GSO 74°E	12-C, 6-Ext.C, 2-S, VHRR, DRT, SASR	Mission completed
7	INSAT-2B	July 23, 1993	Ariane-4	1932	GSO 93.5°E	12-C, 6-Ext.C, 2-S, VHRR, DRT, SASR	Mission completed
8	INSAT-2C	December 7, 1995	Ariane-4	2020	GSO 93.5°E	12-C, 6-Ext.C, 1-S, MSS, 3-Ku	Mission completed
9	INSAT-2D	June 4, 1997	Ariane-4	2070	GSO 74°E	12-C, 6-Ext.C, 1-S, MSS, 3-Ku	Failed after 4 months
10	INSAT-2E	April 3, 1999	Ariane-4	2550	GSO 83°E	12-C, 5-Ext.C, VHRR, CCD	In operation
11	INSAT-3B	March 22, 2000	Ariane-4	2070	GSO 83°E	12-Ext.C, 3-Ku, MSS	In operation
12	GSAT-1	April 18, 2001	GSLV-D1	1540	Inclined orbit	2-C, 2-S, 1-C steerable	Mission completed
13	INSAT-3C	January 24, 2002	Ariane-4	2650	GSO 74°E	24 -C, 6-Ext.C, 2-BSS, MSS	In operation
14	KALPANA-1	Sepember 12, 2002	PSLV-C4	1060	GSO	VHRR, DRT	In operation
15	INSAT-3A	April 4, 2003	Ariane-5	2950	GSO	12-C, 6-Ku, VHRR, CCD, DRT, SASR	In operation
16	GSAT-2	September 28, 2003	GSLV-D2	1540	GSO	4-C, 2-Ku, MSS	In operation
17	INSAT-3E	September 28, 2003	Ariane-5	2775	GSO	24 -C, 12-Ext.C	In operation
18	EDUSAT	September 20, 2004	GSLV-F1	1950	GSO 74°E	6-Ku, 6-Ext.C	In operation
19	INSAT-4A	December 22, 2005	Ariane-5	3086	GSO	12-Ku, 12-C	In operation
20	INSAT-4C	July 10, 2006	GSLV-F2	-	GSO	-	Mission (launch) failed
21	INSAT-4B	March 12, 2007	Ariane-5	3025	GSO	12-Ku, 12-C	In operation
22	INSAT-4CR	September 2, 2007	GSLV-F4	2130	GSO 74°E	12-Ku	To be declared operational soon

*Satellites procured from outside India, in this case from Ford Aerospace Communication Corporation, USA.

every 5 min in the sector scan mode. Beginning with the INSAT-2 series, a search and rescue payload was also added, which complements the efforts of COSPAS-SARSAT system and provide real time detection of 406 MHz distress alerts, within the Indian Ocean Region. At present INSAT-3A located at 93.5°E is providing the services with search and rescue payload on board. The payload picks up and relays alert signals originating from distress beacons of maritime, aviation and land users. Since its establishment in 1991, the satellites aided search and rescue programme has helped in saving more than 1600 lives.

The most dramatic impact of INSAT has been the rapid expansion of TV dissemination in India through the installation of about 1400 transmitters of Doordarshan, providing access to 95% of India's population through national as well as regional services utilizing about 60 channels of telecasting. Use of transportable earth stations and satellite news gathering vehicles now allow extensive real time coverage of important events anywhere in the country. Training and Development Communication Channels (TDCC) are being operated to feed over 6000 distant education/training classrooms spread across India. Recognizing the importance of the interactive communication system, a number of experiments were conducted for imparting developmental education to target audiences of different types, both in the rural and urban areas. Encouraged by the success of these, a few large scale experiments have been undertaken, typical example of which is the Jhabua Developmental Communication Programme (JDCP) in Madhya Pradesh that was implemented with more than 1500 receive terminals for imparting developmental education in the predominantly tribal areas.

As described in subsequent sections, rapid expansion of tele-education networks across the country covering more than 15 states as well as realization of telemedicine and Village Resource Centres (VRC) are a few more significant achievements attained through INSAT/GSAT system (Edusat).

Table 2. Early experiments helped in evolving new systems and technologies

Demonstration programme and studies	Operational system/evolution
Satellite Instructional Television Experiment (SITE)	Satellite TV
SITE and APPLE Utilisation Programme (AUP)	Radio Networking (RN), Disaster Warning System (DWS)
AUP (Spread Spectrum Multiple Access, SSMA)	Low Level Radar Network (LLRN)
Satellite Instructional Television Experiment (SITE) UHF band	Direct Reception System (DRS)–S Band
INTELSAT earth station for OCS at Arvi, Pune	Master Control Facility (MCF)
Joint studies with ESA and Geostar	Local User Terminals (LUTs) for Satellite Aided Search and Rescue (SAS&R)
Emergency Communications Terminal (ECT) and Small Communications Terminal (SCOT)	Extended C-band Low Noise Block Converter (LNBC) and MSS Type D terminals
Personal locator beacon	INSAT MSS Type C Reporting Terminal
Satellite-based Rural Telegraph Network	VSAT
DRS and talkback terminals in Jhabua Development Communications Project and Training and Development Communications Channel	ROT and SIT in EDUSAT
SNG	WLL-VSAT communications for disaster management

Technology developments

In the context of developing and utilizing the space communications, several state-of-the-art technologies were realized and adopted in designing and developing the onboard and ground satcom systems.

Technology for ground systems

From mid-1990s, the maturity of digital technology and availability of low cost, high-density memory and increase in processing power were reflected in the realization of smaller ground subsystems, with more user-friendly features like low power, increased capacity, etc. Digital modulation techniques and error correction were introduced, which in turn reduced the transmit power requirement, both from satellite and ground. Audio and video compression techniques reduced the bandwidth requirement per channel and helped in enhancing the capacity. Use of GPS time and frequency in communications systems improved the local oscillator (LO) stability and enhanced access protocols like open loop Time Division Multiple Access (TDMA). Complex network protocol could be realized using relatively cheaper network managers. In the radio frequency (RF) area, higher wattage and improved efficiency in solid state power amplifier (SSPA) became commercially available. Thus there was a migration of ground system technology towards enhanced features in almost all the old applications like Data Collection System (DCS) to Automatic Weather Station (AWS) by using advanced error coding and channel access techniques. This in turn helped increasing the number of transmitters per carrier from 300 to 1800; and converting Disaster Warning System (DWS) to Digital Cyclone Warning and Disaster System (DCWDS) by reducing the size and introducing digital modulation techniques, coupled with error coding and many other advanced features. Table 2 gives the evolution of operational systems and technologies from earlier experiment and demonstration.

Technology for payloads

In the space segment development, subsequent to APPLE, INSAT payload development was taken up. The experience obtained during APPLE payload development and the advance activities initiated in the R&D as well as the establishment of integrated payload test facility, communications systems laboratory and micro integrated circuits (MIC) fabrications facility at SAC, Ahmedabad contributed significantly towards achievement of indigenous communications payloads for INSAT satellites.

Communications payload, commonly known as transponders, is usually composed of receiver and transmitter subsystems. Different elements of transponders are antennas, receivers, frequency converters, multiplexers, filters and amplifiers. Electronic power conditioner (EPC) is an essential part of these subsystems to provide different current and voltage required by each subsystem. The challenge is to make these transponder subsystems efficient in terms of weight, size, power and performance.

Transponders in most of the satellite communications band, i.e. UHF, S, C, Ku and Ka have been realized. One of the major challenges was the realization of spacecraft antenna in all these bands. From the early days of single shell unshaped and fixed reflector, where simple elliptical coverage was used for India, the technology was improved to shaped and deployable reflectors, where coverage was effectively controlled to required area within and outside India. Dual-gridded reflectors were developed to improve the cross polarization performance so that satellites with different polarization could be collocated to enhance the capacity. More recently technology of multiple shaped beam coverage with good inter-beam cross-polarization has been realized to enhance the frequency reuse and hence, the system capacity.

Table 3. INSAT/GSAT spacecraft antenna

Reflector type	Band	Size
Single-shell shaped and un-shaped reflector, fixed and deployable	S, C and Ku	0.9–2 m
Dual gridded shaped reflector, deployable	C and Ku	2.0 and 2.2 m
Multi-beam 5 and 8 beams and sectored	Ku and Ka	1.2 m

Table 4. INSAT/GSAT payload subsystems

Subsystem	Band	Technology
Receivers and converters	S, C, Ku	MIC and
	Ku	MMIC
Input and output multiplexers	S, C, Ku	INVAR
	C, Ku	Dielectric loaded
Filters	S, C, Ku	SAW
Channel amplifiers	S, C, Ku	MIC
	Ku	MMIC
Power amplifier	S, C, Ku	TWTA 70 W
	C, Ku	SSPA up to 15 W

There was a constant endeavour to improve the payload mass, weight and DC power performance using newer technology. MIC and MMIC receivers and converters were realized for different communications bands. The earlier realized payload and noise figure of 3 dB has improved to 1.5 dB in later system.

The multiplexers are now realized with dielectric loading, thereby improving the weight and real estate. INVAR (also called FeNi, is an alloy of iron (64%) and nickel (36%) with some carbon and chromium) based multiplexer was realized to improve on thermal performance. Earlier, separate multiplexers were used for transmit and receive chains that forced the designers to use separate transmit and receive antenna. Realization of contiguous multiplexer has helped payloads working with single antenna for both transmit and receive. Realization of SAW filters has improved the weight performance.

In the amplifier area, high efficiency driver amplifiers, SSPA and linearized Travelling Wave Tube Amplifiers (TWTA) have been realized that helped in increasing the indigenous content in payload. Multi-collector TWTs are used to improve upon the efficiency of power amplifiers. Indigenous high efficiency electronic power conditioners (EPC) for high power amplifiers were realized in all the bands.

Some of the indigenously developed payload subsystems are summarized in Tables 3 and 4.

Ground and space technology usage: Present and future

Taking advantage of the technology trends in communications developed for other purposes, and to introduce them in innovative and societal applications, several R&D initiatives in technologies for both ground and space segments, are being taken. The present scenario of INSAT/GSAT space and ground segment utilization are briefly presented below:

Telecommunications: In the INSAT system, 15 main, 68 primary and 6 remote earth stations totalling to 89 earth stations are operating in the BSNL network providing 3840 IDR channels, 1582 MCPC channels and 27 SCPC channels. More than 60,000 VSATs are operating with 90 hubs in the government and private sectors.

Broadcasting: Doordarshan is providing about 60 channels for national, regional, DSNG and VSAT services through 11C band transponders in the INSAT system and 2C band transponders in PAS10. In Ku-band Direct to Home (DTH) service, they transmit 50 TV and 20 radio channels through INSAT, NSS-6 and PAS10 satellites. AIR is operating 40 RN channels in S-band, 53 RN channels in C-band and 12 of DSNG using INSAT S and C-band transponders. Doordarshan and AIR use satellite medium to transmit the signals to their 1406 and 213 terrestrial transmitters respectively for local re-broadcast. They cover 70% of Indian landmass and 95% of population. In addition, the DTH satellite broadcast covers almost 100% landmass, except down range islands. More than 8 million households in India are now receiving the DTH satellite TV and radio transmissions from national and private broadcasters.

Meteorology: IMD is providing VHRR imagery through Kalpana-1 satellite on a regular basis. About 22 pictures are taken in a day. Meteorological Data Distribution (MDD) service is uplinked from the Secunderabad earth station on round-the-clock basis. The Data Relay Transponder (DRT) is being used by the India Meteorological Department, Central Water Commission, Narmada Control Authority, Snow and Avalanche Study Establishment and Andhra Pradesh Government for almost two decades now. Over 300 AWS are using the Kalpana DRT for data collection from remote/unattended platforms.

Disaster management and search and rescue: The satellite-aided search and rescue is an important service, duly addressing the humanitarian element. ISRO has been a part of the international satellite-based search and rescue system COSPAS–SARSAT, since the early 1990s. This system uses six LEO and four GEO satellites, of which, one

GEO satellite is provided by India. ISRO, therefore, has a special status, among 40 member countries, as a geostationary space segment provider, in this system. The search and rescue payload, which was carried on the INSAT-3A satellite (Indian GEOSAR system had been using INSAT 2A and 2B since 1992 and then was switched over to INSAT-3A after completion of the life of these satellites), supports the 406 MHz position location beacons. These automatic-activating beacons are mounted on commercial fishing vessels and all passenger ships, and are designed to transmit, to a rescue coordination centre, a vessel identification and an accurate location of the vessel from anywhere in the world. Newest designs incorporate GPS receivers to transmit highly accurate positions of distress in the form of precise GPS latitude–longitude location. Two Local User Terminals (LUT), located at Bangalore and Lucknow are connected to the international search and rescue network and support 121.5, 243 and 406 MHz beacons. These LUTs are a part of the international maritime organization's Global Maritime Distress and Safety System (GMDSS) as also the International Civil Aviation Organization (ICAO). DG (Shipping), Government of India has issued regulation for all Indian registered ships to carry 406 MHz beacons. Currently more than 3460 numbers of 406 MHz beacons are registered with Indian Mission Control Centre (INMCC) at Bangalore (registered from August 6 to April 2007). The COSPAS–SARSAT will stop the satellite processing of 121.5 MHz signals from February 1, 2007 with the attendant increase in 406 MHz beacons.

A total of 224 numbers of 406 MHz alerts were received at INMCC during the year 2006 with a system availability of 99.5%. While 82% of these were undetermined, 16% were detected as non-distress and 2% as real calls. A total of 1611 lives have been saved in 53 incidents during 1991–2006 by Indian search and rescue system.

The India Meteorological Department also uses satellite medium to transmit cyclone warnings in the local language of the coastal area that may get affected due to impending cyclone. These cyclone warning dissemination signals are transmitted from Area Cyclone Warning Centers of IMD at Chennai, Mumbai and Kolkata earth stations.

Transponder growth: With the launch of INSAT-4B, the INSAT/GSAT capacity available in various bands has increased (Figure 2). Figure 3 shows the expected growth of the transponders over the next five years. Figure 2 is an estimate of number of transponders that anticipates the use of QPSK modulation on an average. Keeping in view the changing trend for use of higher order modulation techniques like 8-PSK, 16-QAM and higher compression techniques for transmission, new satellites will be designed to support these advanced transmission techniques which will help maximize the satellite throughput. Table 5 provides a glimpse of different technologies being implemented and the nature of probable applications in the near future.

In short, both ground and space technology in India has gone through a significant evolution, from initial learning days to present day maturity of high state-of-the-art standards. Many of the technologies are now indigenized and are being applied to practical applications. There is a continuous process of upgrading the knowledge base to try out newer techniques for broadening applications areas.

Developmental application programmes

Satellite communications technology offers the unique capability of being able to simultaneously reach out to very large numbers, spread over large distances even in the most remote corners of the country. It is a very strong tool to support developmental programmes meant for the common people. Pursuing this main objective, ISRO has been running several programmes, promoting tele-education, tele-medicine and other such themes for the benefit of the people residing in far-flung rural areas.

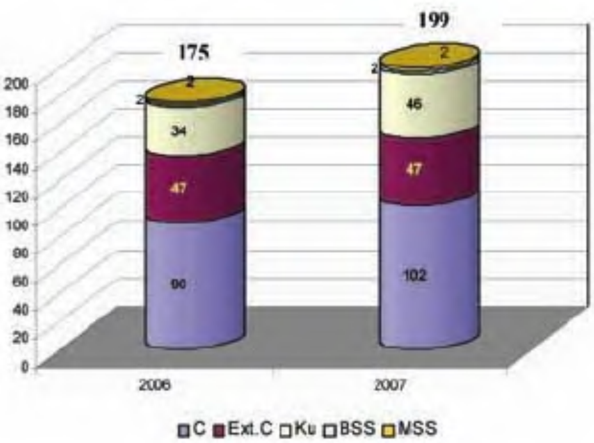

Figure 2. Existing transponders capacity in various bands.

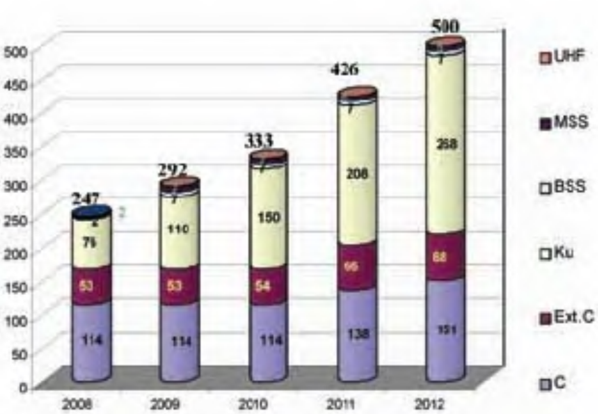

Figure 3. INSAT/GSAT expected growth in transponders.

Table 5. Technologies under implementation

System	Technique/technology area	Probable applications
GSAT-4	Satellite grid computing protocol development	DM SAR data handling, meteorology
GAGAN and IRNSS	Real time iono/tropo modelling, time sync/time transfer, atomic clock, integrated receiver, encryption, navigation software, etc.	Aircraft landing and other accurate satellite-based navigation, standard time and frequency applications
GSAT-4	Onboard processing, Ka-band propagation modelling, fade mitigation techniques	USAT
GSAT-6	Audio/video compression, handheld satellite terminals	Satellite-based mobile multimedia services
Disaster management	Distress alert terminal	Low cost alternative to PLB meant for fishermen

India was amongst the first few countries to explore the use of Satcom for carrying education and development-oriented information and services to the rural masses. The applications started with satellite TV broadcasting to schools and rural communities in the mid-seventies. With the growth of telephone networks, the broadcasting networks were adopted for one-way video two-way audio (return audio on phone) networks for training. Further development in V-SAT technologies led to applications like telemedicine, interactive networks for education, and Village Resource Centre, not to mention, a very large application of V-SAT technology in commercial applications.

Development TV

The theme of the development TV or community TV is to use a television, which is installed in a 'public' place, where people can gather and watch information-oriented TV programmes.

This was the first application of Satcom technology in India that was planned under SITE. As described earlier, Direct Reception System (DRS) community TV sets were installed under this programme, in public buildings in the villages – in most cases in the schools. About 150 battery-operated sets were also deployed in the villages, which did not have electricity. While many organizations played important roles in SITE, the overall 'system management' function was done by ISRO, which also had specific responsibility for all the hardware elements and for the production of science education programmes for children. The major responsibility for programme production was that of Doordarshan, the national TV broadcast organization. The Ministry of Education took specific responsibility for follow up or utilization of the school programmes and for the organization of a teacher-training programme. SITE established that the extension of communications infrastructure to remote areas is not only feasible, but that it can contribute concretely for promoting national development.

After the experience of SITE, use of Satcom for development communication is a regular feature of the National Television System (Doordarshan) using the INSAT-series of satellites. Doordarshan, at the national and regional level, produces and transmits many programmes meant for school and university students, women, children and youth, giving a large chunk of time for development and educational programmes.

A study conducted by DECU/ISRO to examine the impact of these development programmes indicated that a large majority of the viewers felt that television played an important role of providing information and knowledge about important activities, events and happenings. The study clearly brings out that the deprived sections of society are able to gain from television.

Satcom for training – TDCC

A need was felt to provide interactivity facility in the networks for educational and development information transfer. Initially the effort was made to use Satcom for two-way connectivity, but at that point of time (early eighties), the costs of interactive terminals were very high. At the same time, there was a sudden expansion of telephone facilities in India. It therefore became much more economical to use telephones for asking questions and clarifications. The trials with several state governments and educational institutes proved very successful and gave rise to the Training and Development Communication Channel (TDCC). This became a very important tool to meet the training requirements of the field staff/functionaries of various departments like agriculture, health, women and child welfare, forest department, etc. of the state governments. Besides, TDCC could also be utilized for imparting training under Panchayati Raj (self-governance and village level). The magnitude of the task was so large, that a tool like Satcom became a powerful means of meeting the requirements. As a result, ISRO helped several state governments like Karnataka, Gujarat, Madhya Pradesh and Orissa in setting up large networks and several other states like Rajasthan and West Bengal followed suit. So far, more than 6000 receiving centres have been set up across the country under TDCC programme and more than 10 lakh participants/functionaries of more than 60 departments of various state governments have been trained in these centres.

Educational communication

In view of the increased rate of enrolment, inadequate infrastructure and lack of qualified and trained teachers in the primary and secondary education sector in the rural and far-flung areas across the country, the need for educational communication is as acute as that of development communication. The educational sector therefore needs support through Satcom.

As a result of SITE, school broadcasts became a regular feature in early stages of INSAT. One Central Institute of Educational Technology (CIET) and several State Institutes of Educational Technology (SIETs) were set up for production of school-oriented TV programmes. The above experience led institutions of higher education to use Satcom for transmitting programmes for college level students. The first such institution was the University Grants Commission (UGC). It set up a number of production centres in several universities, and started a one-hour transmission under the 'country-wide classroom'. The activity has grown substantially, since then and is now running an independent channel called the Vyas Channel.

Another agency to take to satellite broadcasting for education on a fairly large scale was the Indira Gandhi National Open University (IGNOU). It has gradually built up the broadcasting activity to start an independent channel called Gyan Darshan. IGNOU in association with Indian Institute of Technology started transmitting programmes for engineering students and built this into an Eklavya Channel for a few hours, every day.

Therefore satellite-based educational broadcasting grew into a very substantial activity with all sectors of education, e.g. school, graduate and distance education using substantial hours of satellite time.

Interactive educational channels and Edusat utilization programme

The pilot use of one-way video, two-way audio for education was first tried out with UGC on the countrywide classroom, with a ten-day special broadcast on the national network. However the major operational use of this set up was started by IGNOU. A pilot effort was organized for IGNOU, after which it started a regular use of the channel for interaction with students as well as with faculty members, spread all over the country in the study centres. A very large network was created and was continuously used. This became an operational channel known as Gyan Darshan-2.

Edusat utilization programme: Looking at the communications needs of the education sector, ISRO proposed the launch of Edusat, a satellite dedicated to meet the needs of the education sector. The launch of this satellite has led to a revolution in the utilization of Satcom networks for education.

Edusat provides six Ext C-band national beam, one Ku-band national beam and five Ku-band regional beams, facilitating transmission of education in the regional languages. Depending on the requirement and location, the VSAT-networks operate in Ku or Ext C-band. Under the Edusat utilization programme – two types of satellite-based (Edusat satellite) VSAT networks, interactive networks consisting of Satellite Interactive Terminals (SITs) and receive-only networks using Receive-Only-Terminals (ROTs) – are being set up in various states across the country for promoting universal education. Generally, interactive networks are set up for imparting teacher's training and curriculum-based teaching to students of the arts and science colleges, polytechnics, and management and professional institutes. Similarly, the receive-only networks are being used for imparting curriculum-based education to primary and secondary schools students.

The Edusat utilization programme is being implemented in three phases, called pilot-phase, semi-operational phase and operational phase. In the pilot-phase, before the launch of Edusat, several engineering colleges of three universities in Maharashtra, Karnataka and Madhya Pradesh were connected through three independent networks using INSAT-3B Ku-band transponder.

In the semi-operational phase, which is being run currently and is likely to continue for another year or so, at least one network connecting minimum 50 interactive terminals is being set up in most of the states. ISRO is providing one hub and 10 interactive terminals free of cost to every state under this phase. It is expected that states/user would fund the remaining 40 or more terminals. Six primary schools-networks in the states of Kerala, Karnataka, Gujarat, AP, MP and Haryana have been set up and a total of around 27,000 ROTs are operating in various networks and this number is growing steadily. Haryana school-network is currently under expansion and while more than 10,000 ROTs have already been setup, another 1000 terminals are proposed by the end of 2007. Similarly, about 40 interactive networks consisting of nine national networks and other regional networks in Tamil Nadu, Karnataka, Kerala, Haryana, West Bengal, Rajasthan, Punjab, J&K, Lakshadweep, Gujarat, Jharkhand, Tripura, Nagaland, Maharashtra and MP have been established and they are functioning satisfactorily. Besides these, one special network for blind schools has been set up in the state of Gujarat. Another special network in Ext C-band connecting about 50 engineering institutes across the country has been established to impart teaching by distinguished professors/faculty from top 21 universities in USA, who would visit India to conduct 8-week courses in various subjects in engineering. More than 2500 interactive terminals have so far been set up as part of these networks. At present, under the Edusat implementation programme, two networks each in the North Eastern states, MP, Orissa and one each in Chhattisgarh, Maharashtra, Delhi and Andaman and Nicobar Islands are being set up and they will be established by October 2007. Under the operational phase of the Edusat utilization programme, the Edusat network will be expanded to cover the entire country.

The experience of Edusat indicates that creation of hardware infrastructure is a challenge that can be managed, but the issues of content generation are much more daunting. It also indicates that utilizing the system for conducting virtual classroom and taking live lecture is much easier, but creation of databases and building off-line usage is much more difficult and will take more effort and time.

Telemedicine programme

India is the seventh largest country in the world with almost 80% of the population residing in more than 600,000 villages. The government has created a huge infrastructure of more than 20,000 Primary Health Centres, 600 district hospitals and several state level hospitals and medical colleges. But this infrastructure is inadequate to provide proper medical care to the rural population. One major bottleneck is the nonavailability of specialist doctors in rural areas. More than 98% of the doctors practice in urban centres or big cities and towns. Hardly, 2 % of the doctors are available in rural areas.

The availability of speciality doctors in rural areas is not going to increase in the near future, and therefore, if the services of these doctors have to be made available to rural patients, there is no alternative, but to use Satcom and information technology to connect rural clinics to urban hospitals through telemedicine systems. Presently, the patients have to physically travel from rural to urban areas to get even minimal consultations from speciality doctors. To address these problems of the health sector, ISRO has decided to launch yet another developmental programme, called telemedicine programme in the country. The programme was started as a pilot exercise in five locations, but has rapidly expanded to cover about 200 remote hospitals and 40 speciality hospitals. This has been able to provide connectivity to the remotest locations in the country like the Andaman and Nicobar Islands, the Lakshwadeep Islands, the North-eastern Hilly regions, and the snow-covered mountainous regions of Jammu and Kashmir.

Telemedicine network configuration: The telemedicine networks, set up by ISRO, consist of patient-end nodes, doctor-end nodes, servers and VSAT-based communication systems. The software running in these systems plays an important role in interfacing the medical diagnostic instruments for acquiring medical images, for establishing connectivity between patient-end and doctor-end computers for data exchange and facilitating the video-conferencing to enable the doctor and patient to interact in real time. The patient diagnostic information is acquired and sent to doctor-end, along with his/her demographic data. At the doctor-end, a specialist can view all these and suggest the treatment. The doctor and the patient can interact in real time, through videoconferencing. A server is also located at the super-specialty hospital, which stores all the information of a patient, including his past illness, previous visits and medical images. When a specialist is giving tele-consultation, the patient information is accessed from the server.

A patient-end terminal, generally consists of a computer, videoconferencing camera, TV monitor, printer, one 1 kVA UPS, A3 size X-ray digitizer, 12 lead ECG and furniture for keeping indoor equipments. The patient-end terminal is connected to the VSAT terminal. Similarly, the terminal at doctor-end consists of a computer, videoconferencing camera, TV monitor and a 1 kVA UPS.

At present the telemedicine of ISRO has more than 240 installations, of which about 40 are super-specialty hospitals and eight are mobile van systems. Each super-specialty hospital is providing healthcare services to 5–6 remote hospitals.

While the telemedicine networks set up initially by ISRO use 3.8 m antenna and 2 W/5 W uplink power in extended C-band working on SCPC–DAMA technology using INSAT 3A, the new telemedicine networks, however, are given connectivity through Edusat satellite in Ext C-band with the antenna size reduced to 1.8 m/2 W.

Mobile telemedicine vans have also been deployed by ISRO for taking the telemedicine programme to the remote villages, where the permanent patient-end is not set up. These vans consist of one Ext C-band 1.8 m motorized antenna, which is mounted onto the top of the van (Figure 4). The antenna can be folded/stowed to most-stable position while on the move and can be repositioned to look at the satellite after the van is stationed at the place wherein the patient-end is to be set up. Stowing and deployment (folding and unfolding) of the antenna is motorized and there is also the provision for manual cranking.

Two types of configuration are possible for antenna positioning. The fully automated configuration takes care

Figure 4. Telemedicine mobile van.

of the antenna positioning on its own, once put in auto-position mode, by calculating the look angles of the satellite using GPS-based controller and flux gate compass. The manual configuration, however, needs an operator for moving the antenna to the required look angles using the antenna-control-unit and associated servo electronics. The angle encoder, inclinometer, magnetic compass, etc. required for positioning of the antenna are the integral part of the system. The system in both the modes is quite user-friendly and easy to operate. A canopy is also provided to cover the antenna to protect it while on move. Other indoor equipments mounted inside the van are same as of any patient-end of telemedicine configuration.

VRC programme

Satellite-based communication and remote sensing technologies have demonstrated their capabilities to provide services, related to education, healthcare, weather, land and water resources management, mitigation of impact of natural disasters, etc. To provide these space-based services directly to the rural areas, ISRO has initiated a programme to set up VRCs in association with NGOs and trusts and state and central agencies concerned. VRCs are envisaged as single window delivery mechanism for a variety of space-based products and services, such as tele-education; telemedicine; information on natural resources for planning and development at local level; interactive advisories on agriculture, fisheries, land and water resources management, livestock management, etc.; interactive vocational training towards alternative livelihood; e-governance; weather information, etc. VRCs also address a variety of social aspects locally, and can act as help lines.

Under the VRC programme, a number of village resource centres are being established in various villages, which will be connected, through satellite-based VSAT networks, to the blocks, district headquarters and state capitals. Remote sensing data/imageries received from IRS satellites are used to provide useful inputs about other resources required for the development of the villages and its population. For example, information about watersheds, wasteland, drinking water availability, weather information, soil mapping, etc. is provided to the villagers and administration to plan their line of action accordingly.

ISRO primarily provides satellite connectivity and bandwidth; telemedicine and tele-education facilities; and available/customized spatial information on natural resources, along with indigenously developed query system. The responsibilities of housing, managing and operating the VRCs, with all relevant contents rest with the associating agencies.

A total of about 250 VRCs have already been set up across the country and the programme, so far, has been a great success. ISRO is also currently in the process of identifying agencies (NGOs/Trusts, etc.) for setting-up VRCs in Madhya Pradesh, Rajasthan, Uttar Pradesh, Jharkhand, Bihar, Andhra Pradesh, Orissa, Chhattisgarh and Maharashtra states. It is proposed to set up about 500 VRCs by end 2007.

Conclusion

The Indian space programme has evolved over a period of four decades to reach its present level of maturity. Significant achievements have been attained in the development of both ground and onboard systems technologies. The indigenously developed INSAT and GSAT systems have brought a revolution in the communication field in the country and have been providing some unique services. The new ongoing application programmes such as tele-education, telemedicine, disaster warning, search and rescue, village resource centres, etc. are indeed fulfilling the objectives of ISRO, which is to bring the benefits of space technology to man and society.