Recognising the potential of space as a catalyst for development, the Indian Space Research Organisation (ISRO) devised its space programme with the objective of “Harnessing space technology for national development, while pursuing space science research and planetary exploration” since its inception and this has remained the fundamental tenet around which the Indian Space Programme has evolved.

The ISRO Satellite Centre has rolled out 100 satellites capable of providing services in various application domains like communication, meteorology, remote sensing, navigation and space science explorations. These satellites are continuing to serve the key sectors of the Indian economy such as socio-economic security, sustainable development, disaster risk reduction, and governance at large.

Communication Satellites
Satellite links are the primary means of connectivity to remote and far-flung regions of the country – they are the backup links for terrestrial connectivity in the mainland too. Communication satellites play a vital role in today’s digital era focusing on the utilisation of satellite communication throughout the country. The technology has matured substantially over the past three decades and is being used on commercial basis for a large number of applications.

Today, we have 15 operational communication satellites in orbit supporting 285 transponders in C, Ext C, Ku, Ka/Ku and S-band for diverse applications like Television, DTH Broadcasting, Radio Networking, and Mobile Satellite Services to exploit the unique capabilities in terms of coverage.
and outreach. The prominent users of the transponders are BSNL, Doordarshan, DTH and TV operators, All India Radio, Government users, Public Sector units, Private VSAT operators, banking and financial institutions.

Communication satellites have been a major catalyst for the expansion of television coverage in India. Satellite television now covers 100% area and 100% population. All of the Satellite TV channels are digitalised. DTH services are becoming popular with the introduction of premium services like HDTV services, On-demand movie services, etc. High power Ku-band transponders are used to support DTH television service with the smallest dish antenna all over India. The free-to-air DTH service “DD Free Dish of Doordarshan offers 59 TV channels.

More than 1404 Satellite Earth Stations of different size are operating in the satellite network of BSNL, government users, closed user group, commercial users and broadcasters and are being utilised for telecommunications/broadcasting applications. About 2,74,000 VSATs are being used in star/mesh connectivity of various sizes and capabilities.

Telecom services, GSM connectivity, ATM/Banking connectivity through about 19000 IPSTAR VSATs, about 5000 Digital Satellite Phone Terminal (DSPTs) Networks of Bombay Stock Exchange and a number of other captive government networks are also working with Indian satellites.

Tele Education projects through EDUSAT were exclusively meant for educational services to cater to a wide range of interactive educational delivery modes like one-way TV broadcast, video conferencing, computer conferencing, web-based instructions, etc. EDUSAT had manifold objectives – to supplement the curriculum-based teaching, imparting effective teacher training, providing access to quality resource persons and new technologies, thus taking education to every nook and corner of India.

It also provided connectivity to schools, colleges and higher levels of education and also supported non-formal education including development communication. About 15 million students got benefited through the EDUSAT programme.

Mobile Satellite Services with voice communication provide communication links especially during disasters when other means of communication are broken down. It can be used from any location in India for emergency communication. Transmit and receive frequencies of the terminal in S-Band could be made between any satellite and local phones.

Radio networking through satellites provides reliable high-fidelity programme channels for national as well as regional networking. At present, 419 All India Radio (AIR) stations and about 607 radio transmitters have been equipped with receive terminals, and 21 radio channels of AIR are broadcast through DTH platform of Doordarshan.

As a part of Satellite Aided Search and Rescue programme, India is a member of the international COSPAS-SARSAT programme for providing distress alert and position location service through satellite system which provides coverage to a large part of the Indian Ocean region rendering distress alert
services to Bangladesh, Bhutan, Maldives, Nepal, Seychelles, Sri Lanka and Tanzania.

Navigation – NAVIC and GAGAN Applications
ISRO has also entered into satellite-based navigation applications through GAGAN & IRNSS. GAGAN will redefine navigation over the Indian airspace, IRNSS will provide independent and self-reliant satellite-based navigation services over the Indian region.

ISRO and Airports Authority of India have implemented the GPS Aided Geo Augmented Navigation (GAGAN) project as a Satellite Based Augmentation System (SBAS) for the Indian airspace. The objective of GAGAN to establish, deploy and certify satellite-based augmentation system for safety-of-life civil aviation applications in India has been successfully completed. The system is inter-operable with other international SBAS systems and has expansion capability for seamless navigation services across the region.

GAGAN provides the additional accuracy, availability, and integrity necessary for all phases of flight, from en route through approach for all qualified airports within the GAGAN service volume. Besides these, they will also provide benefits beyond aviation to many other user segments such as intelligent transportation, maritime, highways, railways, surveying, geodesy, security agencies, telecom industry, personal users of position location applications, etc.

IRNSS, the Indian Regional Navigation Satellite System named as NavIC, is an ISRO initiative to design and develop an independent satellite-based navigation system to provide positioning, navigation and timing services for users over the Indian region. The system is designed with a constellation of seven spacecraft and a vast network of ground systems operating all the seven satellites. IRNSS-1A to IRNSS-1G are fully operational designed to provide a position accuracy of better than 10 metres for navigation services.

Using the first generation NavIC Receivers, tracking applications were demonstrated in the areas of road transport, railways, shipping, etc. NavIC capabilities have also been demonstrated for time synchronisation applications in power system operations.

A fishermen App has been developed using the messaging capability of NavIC. A compact NavIC device communicates to the fishermen’s smart phone via Bluetooth the message information to the App. This App provides position information for navigating to the potential fishing zone, alert messages on rough sea and weather status and warning messages on approaching international water boundaries.

Ruggedised hybrid (NavIC & GPS/GAGAN) receivers have also been developed and tested on PSLV & GSLV launch vehicles for determining trajectories and the performance was found to be satisfactory.

Remote Sensing Applications
Earth observation satellites are application-oriented focusing towards providing continuity of services in areas like land and water resource observation, ocean and atmosphere, cartography & large-scale mapping, and microwave imaging. Today 15 satellites are in the orbit catering to a wide variety of applications like flood mapping, landslide inventory mapping, agriculture assessment, underground water assessment, urban planning, forest mapping, etc.

India is one of the most flood-prone countries in the world. Floods occur in almost all river basins in India. Both optical and microwave satellite data are being used and information is disseminated to the concerned Central/State agencies. Satellite-based imageries due to their synoptic coverage are the best tools for assessment of the extent of flood-affected areas and the damage to the infrastructure facilitating the decision makers to plan for relief operations.

The major natural disaster that affects the coastal regions of India is cyclone. With 7500 kilometres of coastline it is exposed to nearly 10% of the world’s tropical cyclones. Using appropriate models and satellite data, ISRO is supporting the efforts of the India Meteorological Department to predict the tropical cyclone track, intensity and landfall. After the formation of cyclone, its future tracks are regularly monitored and predicted using a mathematical model. These track predictions are regularly posted on the departmental web portal. Such cyclogenesis predictions are being carried out for all the global cyclones and uploaded to the portal.

With more than 70 percent of India’s population relying directly or indirectly on agriculture, the impact of agricultural drought on human life and other living beings is
critical. In India, around 68% of the country is prone to drought in varying degrees. Coarse resolution satellite data, which covers larger areas, is used to monitor the prevalence, severity level and persistence of agricultural drought at state/district/sub district level during kharif season (June to November).

The operational methodology developed by ISRO over the years is now institutionalised by setting up a Forecasting Centre under the Ministry of Agriculture. Currently, ISRO is concentrating on upgrading the methodology for monitoring the drought and efforts are on to develop early warning systems for agricultural drought.

Similarly, active forest fires are detected from the satellite images and the information is uploaded daily to the Indian Forest Fire Response and Assessment System website.

Remote sensing data have been proved to be useful for landslide inventory mapping both at local and regional level. These maps can be combined with other terrain maps like slope, slope aspect, slope morphology, rock weathering and slope-bedding dip relationship in GIS environment to map the vulnerable areas for landslides. ISRO has prepared Landslide Hazard Zonation maps (LHZ) along tourist and pilgrim routes of Uttarakhand and Himachal Pradesh, Himalayas and in Shillong-Silchar-Aizawl sector.

Similarly, Remote Sensing Satellite data gives synoptic overview of the area affected by an earthquake. These data can be used to create a very large scale base information of the terrain for carrying out disaster assessment and for relief measures.

The Decision Support Centre established at the National Remote Sensing Centre (NRSC) of ISRO is engaged in monitoring natural disasters. The information generated from aero-space systems is disseminated in near real time for aiding in decision making.

Water is a crucial input required to enhance agricultural production, as most of the small farmers living in arid and semi-arid regions are deprived of irrigation facilities. Over the years, spatial analysis of temporal satellite data has been facilitating the performance evaluation of irrigation commands, reservoir capacity surveys, assessing gaps in potential irrigation and utilization, ground water information, water Resource Information System, etc.

Remote Sensing data has also been of significant help in understanding the loss of forest cover, resource depletion, assessment of trees outside forest and planning for sustainable use of forests. Significant information on glaciers (retreat/advance) in the sub-basins of Himalaya has been generated using satellite images at the behest of the Ministry of Environment, Forest & Climate Change.

High resolution satellite data and aerial data have been used to generate urban maps containing information such as landuse, geology, soil, settlement locations for 152 cities/towns in the country. The data helps in preparation of Master Plan/Development Plan, Transportation Plan, Urban Site Suitability Analysis, Urban Environmental Planning, etc.

The prediction of weather in tropical regions, like India, is a major challenge due to the complex and dynamic nature of the weather system. The day to day changes of weather elements such as rainfall, temperature, wind speed and humidity are important meteorological parameters to be monitored on a continuous basis. The meteorological satellites provide a synoptic measurement of weather parameters at frequent intervals. The satellite images on cloud cover and various parameters such as winds, rainfall, sea surface temperature, etc., have become an integral part of weather forecasting.

Remote sensing satellite images also play a vital role in crop assessment, fibre crop information system, Antarctic ice studies, hydrological studies, snow and glacier studies, air quality monitoring from space, monitoring of integrated watershed management programme, National Land use/Land cover mapping, Empowering Panchayat Raj Institutions Spatially, etc.

Space Sciences and Planetary Research

Besides the operational satellite missions catering to varied applications, ISRO has also been pursuing space science missions. Chandrayaan-1, Mars Orbiter Mission and Astrosat missions were realised and launched successfully with various scientific objectives.

Chandrayaan-1 Mission was India’s first mission to moon that provide significant scientific data about the Moon and pioneered in the discovery of water molecules on the lunar surface and water ice at the lunar poles.

Space science research activities at par with international scenario are continuously being pursued at premier research laboratories of ISRO/DOS, namely, Physical Research Laboratory (PRL), National Atmospheric Research Laboratory (NARL), Space Physics Laboratory (SPL) at VSSC, and Space Astronomy Group at ISAC.

The landmark Mars Orbiter Mission (MOM) has completed three years in the Mars orbit and is still providing appreciable data. Based on the scientific analysis of data received from the Mars Orbiter spacecraft, 25 scientific papers have been published and submitted for publication in international journals.
been published so far in peer-reviewed journals. The Mars Colour Camera, one of the scientific payloads onboard MOM, has produced more than 900 images so far. The MENCA (Mars Exospheric Neutral Composition Analyser) has discovered the presence of superthermal Argon atoms. The discovery has important implications in the context of understanding the energy disposition in the Martian upper atmosphere and in understanding the Martian atmospheric escape rates.

AstroSat India’s multi wavelength space astronomy mission completed two years in orbit and is being operated as an Observatory in which observing time is allotted based on the proposals received from interested researchers and scientists in the country through ISRO’s announcements of Opportunity (AO). Ultraviolet Imaging Telescope (UVIT) imaged hot stars, evolved stars, planetary nebulae, star clusters, star-forming galaxies, active galactic nuclei, cluster of galaxies and star formation history in the distant universe. Soft X-ray Telescope (SXT) has observed a variety of objects ranging from nearby active stars, X-ray binaries, supernova remnants to many types of distant active galaxies and clusters of galaxies.

Future Perspective

Looking towards the future, ISRO is poised to build and launch 18-20 satellites every year to meet the burgeoning demands of space-based services in the country. In doing so, the Centre has evoked greater private sector participation in satellite building activities to enhance its throughput. Capacity building in the private sector is the need of the hour to enable private players to deliver “launch on demand” satellites.

ISRO is also focusing on building advanced satellite technologies catering to newer applications that would aid development of the nation. In the Communication sector, the focus is towards packaging 80-100 transponders in a satellite that will meet the requirements of various users from private and Government sectors. In future, satellite transponders with high bandwidth specifically in Ka, Q, V and even optical bands will primarily be used in governance function.

The future advanced technology communication satellite missions shall provide the required space infrastructure platform for high-speed internet connectivity, bandwidth on demand, broadband connectivity using multiple spot beams, and broadband VSAT connectivity with higher data rates.

Similarly, in the navigation sector the focus is more towards providing enhanced accurate navigation services across all the modes of transportation like Railways, Roadways, Maritime, Surveys besides the aviation sector. Navigation services are also planned to facilitate fishermen with timely information and alerts near International border crossing in the Ocean/sea. Once our indigenously developed Navigation Chipset is ready, it will enable IRNSS based services to be used by each and every citizen of this country.

In the Earth observation front, the major focus is on building high-resolution sub-meter resolution imaging, hyper spectral imaging, all weather condition microwave imaging capability, 3D Modelling imaging, Geo imaging capabilities for natural resource management and meteorological applications. In the meteorological domain, the focus is more towards providing timely and accurate weather predictions with advanced onboard instruments to avoid damages and losses occurring due to natural calamities in the country.

The future challenges of India’s Space Science programme include demonstration of soft landing capabilities on the Moon to carry out in-situ chemical analysis of the lunar surface with an indigenous rover in Chandrayaan-2, space docking experiments, XPosat Mission to observe cosmic objects, Aditya Mission to study and understand Solar chromosphere and corona dynamics, Mars Orbiter Mission-2 with enhanced scope to understand the Mars planet, mission to Venus for deeper understanding of Venus planet, and Large Scale Telescope for Space Astronomical studies.

Having gained mastery over spacecraft and launch vehicle technologies, ISRO is poised to leap-frog into the next step with plans on the anvil for the Human Space programme (HSP) which is beset with challenges galore.

Padma Shri Dr. M. Annadurai is currently Director, ISRO Satellite Centre (ISAC), Bangalore. Dr. Annadurai has managed eight INSAT Missions, as Mission Director. He also contributed in the first satellite dedicated to tele-education, Edusat, as its Associate Project Director. Dr. Annadurai has made significant contribution to India’s first Lunar Mission, Chandrayaan-1 as its Project Director. He also realised the launch of the most prestigious Mars Orbiter Mission in record time and successful insertion in the Martian orbit. He has also overseen two student satellite projects.

Apart from the innumerable awards he has been bestowed with, he is also Fellow of the International Academy of Astronautics. Dr. M. Annadurai’s life and works are mentioned in the 10th Standard Science Text book of Tamil Nadu State.