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GUEST EDITORIAL

Social dimensions of India's space programme

The launch of a sounding rocket from Thumba Equatorial Rocket Launching station in 1963 heralded the advent of the space age for India. This modest beginning, with the goal of sounding the upper atmosphere and ionosphere above the geomagnetic equator, has, over the last 50 years evolved in several directions and dimensions. The capability to build state-of-the-art communication and remote sensing satellites, development of launch vehicles to enable placing these satellites in appropriate orbits, the creation of a large body of stakeholders in government, public and private sectors who use these space systems for meeting their own needs and conduct of science experiments in space are some of the major components of India's present space programme, carried out under Indian Space Research Organization (ISRO). Central to these efforts are the innovative ways in which India has used its space capabilities for societal benefits. In this editorial, we briefly examine with examples, some of the applications of space that have direct bearing on the socio-economic development of the country. In this context, the role of two of the major space systems established by ISRO, i.e. Indian National Satellite System (INSAT) and the Indian Remote Sensing Satellite (IRS) system is elucidated. It is also pertinent to note that to effectively utilize the space capabilities in the context of its applications, unique institutional mechanisms to link the stakeholders with ISRO have been established. The INSAT Coordination Committee (ICC) managed by ISRO oversees the definition, planning and utilization of the INSAT system and has representatives from the concerned government agencies like communications, broadcasting, information technology, and meteorology. Similarly, the National Natural Resource Management System (NNRMS) serviced by ISRO, plans the application of the space-based remote sensing and integrating it with the conventional approaches of different agencies dealing with natural resources management. This innovative framework for the use of space systems by several national, state and other agencies is unique to India, the likes of which does not exist anywhere else.

The INSAT series including the more recent GSAT is a multipurpose satellite system for telecommunication, television broadcasting, meteorology, disaster warning, as well as search and rescue operations. Further, it has also been reconfigured suitably for mobile and business communications and for regional navigation service (designated as IRNSS). These satellites, with an operational life of longer than 12 years, incorporate state-of-the-art technology for the satellite mainframe systems and their payloads. At present, 13 satellites in the class of INSAT/GSAT are in operation, providing services through a total of 235 transponders in S band, C and extended C bands, K_u band as well as UHF frequencies. Besides complementing and supplementing terrestrial communications, the INSAT/GSAT system, exploiting its unique capabilities in terms of coverage and outreach, supports diverse applications like television, direct to home (DTH) broadcasting, Digital Satellite News Gathering (DSNG) as well as a variety of other services that use Very Small Aperture Terminals (VSAT). Among the various initiatives pursued by ISRO towards societal benefits, some of the important ones include tele-education, telemedicine, disaster management and space-based navigation.

Telemedicine enables providing INSAT connectivity to link urban speciality hospitals to district and other rural hospitals. Through audio, video and data communication processes, the system enables diverse services such as tele-consultation, tele-diagnosis, critical-care monitoring, continuing medical education and even tele-surgery. Presently, the tele-medicine system encompasses cardiology, ophthalmology, diabetology, orthopaedics and the use of tele-clinics. Key considerations are access, rapid response, cost and time efficiency. As of now, more than 300 remote hospitals and 18 mobile units are connected to 60 super-speciality hospitals. Nearly 300,000 patients are treated annually using telemedicine services.

'EDUSAT' launched in 2004, is India's first thematic satellite dedicated exclusively for education. It provides a wide range of interactive educational delivery modes like one-way TV broadcast, video interactivity, computer-aided teaching and web-based tools. Among the varied objectives, some of the important ones include curriculum-based teaching, imparting effective teacher training, skill development and providing access to quality resource persons. The system provided connectivity to schools, colleges and other institutions of higher education and also supported non-formal education, including developmental communications. As of now, a total of 83 EDUSAT networks are implemented connecting to about 56,050 schools and colleges, covering 26 states and 3 union territories of the country.

Yet another application of satellite communication is Satellite Aided Search and Rescue (SAS&R), as a part of India's commitment to the International COSPAS-SARSAT programme for providing alerts and position location services for aircraft and ships in distress. Towards this, India has established two Local User Terminals (LUTs), one at Lucknow and the other at Bengaluru, with the Indian Mission Control Centre (INMCC) located in Bengaluru. During 2013, INMCC has provided search and rescue services for 14 distress incidents in Indian service areas and contributed to saving 94 human lives.

In the area of satellite navigation, India has realized a system called GPS-Aided Geo Augmented Navigation (designated as GAGAN). It uses a communication payload on-board INSAT with two channels operating in L1 and L2 bands allocated for navigation purposes. This payload provides Satellite Based Augmentation System (SBAS) service through which the accuracy of the positioning information obtained from Global Positioning System (GPS) satellites can be improved by a network of ground-based receivers and the same made available to the users in the country through geo-stationary satellites. Operationally, GAGAN will provide numerous benefits to the aviation sector in terms of fuel saving, flight safety, increased airspace capacity, efficiency, enhancement of reliability as well as coverage of ocean area for air traffic control. In addition, GAGAN can also be useful in sectors like navigation and safety enhancement in railways, roadways and ships; scientific research for atmospheric studies, geodynamics, natural resources and land management as well as location-based services, including mobiles and tourism. GAGAN is the first step towards ISRO's plans for establishing a full-fledged satellite navigation system.

The other major application of space technology is the use of earth observation satellites for resources survey. The spectral behaviour of reflected/scattered or emitted radiations from the earth's surface gives unique information, since different objects behave differently at different wavelengths. For example, the visible region of the electromagnetic spectrum yields information about plant pigments and turbidity levels of water bodies. The near-infrared region can provide information about structural variations in plant communities, whereas the short-wavelength infrared region is sensitive to the presence of various inorganic and organic molecules. Further, the thermal region is sensitive to kinetic temperature and emissivity of different earth-based objects; while the microwave region helps measure the dielectric constant, surface roughness and orientation of objects. Additionally, microwave sensing has the ability to penetrate through clouds and also enables day/night observations.

By exploiting the above spectral properties of the earth system, together with additional discrimination possible through the study of spatial and temporal characteristics, India has built a variety of earth observation satellites that carry sensors operating in the visible, near-infrared, middle infrared, thermal infrared, and microwave domains of the electromagnetic spectrum. Further, these sensors cover spatial resolutions ranging from 1 km from geo-synchronous altitudes to better than 1 m from Low Earth Orbits. Also, the satellites provide capabilities to look at dynamic phenomena at 30 min intervals for meteorological observations, two days in the case of oceanographic studies and five days for looking at vegetation cover in general and agriculture in particular. Observations from high-resolution cameras with submetre details provide information relating to urban settlements and for cartographic applications. Different agencies use these for retrieving and characterizing the biophysical parameters of terrestrial surface (water, soil, vegetation and man-made structures); atmosphere (aerosol, water vapour, cloud); and ocean (phytoplankton, salinity, ocean steady state). Additionally, repeat images of the same area over time can help monitor changes in vegetation, deforestation, flood progression and recession related to glaciers, etc.

To elucidate additional details, we present some examples. The exploration of potential groundwater sources uses hydro-geomorphological maps created out of satellite images involving geology, lithology, hydrology, geomorphology and soil. The perspective view possible of large-scale geological features like faults and lineaments from satellite altitudes enables deriving this information. Such maps have been used for the successful drilling of borewells with a success rate of 85–95% especially in hard-rock areas. As a part of the National Drinking Water Mission, groundwater prospecting and sustainability mapping has been completed for 19 states. Presently, it is in progress in 13 additional states and 5 union territories. In the case of oceanic sciences, optical, thermal and active microwave sensors have been providing data on phytoplankton, ocean temperature and wind speeds, which have been used for identification of potential fishing zones and also for ocean state forecast. Identification of potential fishing zones has enabled fishermen to improve the fish catch by 2–3 times and in some cases even as high as 5–8 times. Information on sea-surface state is a vital input for weather models and also for planning shipping routes. The satellite systems with optical and microwave sensors have enabled agriculture crop inventory, which has been operationalized at the Mahalanobis National Crop Forecast Centre (MNCFC), Ministry of Agriculture, New Delhi. The use of multidate satellite imageries to monitor the crop growth pattern and employing agrometric and econometric models, enables making such forecasts. MNCFC has carried out national crop production forecasts for 2013–14 covering eight crops, i.e. rice (*kharif* and *rabi*), wheat, rape-seed and mustard, potato, jute, sugarcane, cotton and sorghum. For many of these crops, the accuracy and precision of these predictions are consistent with the requirement of the Bureau of Economics and Statistics. Currently, operational capabilities have also been established for watershed monitoring, natural resources census, determination of land use/land cover, forest cover mensuration and change, and creating urban information system. Further, interesting applications related to snow and rainfall forecast in the Himalayan river basin, and inventory and monitoring of biosphere resources have also been carried out. Combined with other technologies like Geographic Information System, earth observation data have also been used as an important tool in urban and regional planning.

In the case of Disaster Management Support (DMS), ISRO uses the synergy between its communication, meteorological and remote sensing satellites to deliver timely and vital inputs and communication facilities during the different phases of the disaster cycle such as preparedness, response, recovery and mitigation. The National Remote Sensing Centre (NRSC) has set up a DMS-Decision Support Centre (DMS-DSC) which actively monitors natural disasters such as floods, cyclones, agricultural droughts, landslides, earthquakes and forest fires. This Centre has facilitated preparation of 140 flood maps for floods that occurred in 15 states in 2013. This included a major flash flood-related incident in Uttarakhand. Further, ISRO system also monitored the origins of cyclones in the Indian Ocean, including *Phailin*, *Helen*, *Lehar* and *Hudhud*. The cyclogenesis, track, intensity, landfall, rainfall and storm surge were also predicted by assimilating the satellite information with appropriate models. Further, operational capability exists for drought monitoring, which provides an early prediction for the onset of droughts and subsequent monitoring of their progress in different parts of the country. Space systems are also being used in other aspects of disaster management activities such as monitoring forest fires, assessment of landslides and studying earthquakes by monitoring the movement of the Indian plate tectonics along the Himalayan–Kutch faults. India is also part of the international cooperation framework in DMS, where we provide the services of IRS satellite data and other related information as a support to the international disaster events occurring elsewhere in the world on a reciprocal basis. For example, in recent times, a total of 102 datasets for 27 events were provided to the international agencies.

Keeping the focus on societal benefits, this editorial has not, so far, discussed the other important dimension of India's space endeavour – that of carrying out space exploration. India as an old civilization has always prided itself in its pursuit of science, astronomy and mathematics, all of which helped enrich the society from time immemorial. This characteristic still holds good in the case of the Indian space programme. Missions like the forthcoming ASTROSAT, the multi-wavelength space observatory operating in the visible, ultraviolet, soft and medium X-ray regions to study a variety of astrophysical phenomena and the successful accomplishment of Chandrayaan-1 and Mangalyaan emphasize the importance that ISRO attaches to promoting science. Even though one cannot immediately see the tangible benefits of such efforts, there are many intangible benefits to society that these missions can bring about. First, India's pre-eminent position as a knowledge-based society stands to be strengthened by space science exploration. Secondly, the excitement that follows every space science outcome ignites the young minds of this country and inspires them to take up science as a career. Thirdly, space science always puts high demands on technology and these technologies could be an important investment for sophisticating future application missions to bring increased benefits to society. Lastly, the successful conduct of planetary missions like Chandrayaan and Mangalyaan puts India in an exclusive club, and this in turn gives us the right credentials for international collaboration and cooperation on an equal partnership basis.

India's space programme is an excellent example of how high technology touches the grassroot levels of society with tangible socio-economic benefits.

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