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Indian Space Programme

Modern space science had its beginnings around 1946 when scientists started the deployment of instruments to the outer fringes of the earth's atmosphere using balloons and rockets to study radiations from outer space as well as geophysical phenomena. In spite of the professed scientific goals for the first earth satellite missions, the launch of SPUTNIK on 4 October 1957 by the then Soviet Union added a new dimension to the cold war between the US and the Soviet Union. The early scientific satellite missions of the US also had implicit goals of pursuing US interest in establishing the International legal principle that national sovereignty did not extend to the altitudes at which the satellite would orbit. Thus there was no obstacle in International law to the overflight of a reconnaissance satellite over Soviet territory. Against this backdrop, it is significant to note that the early inspiration for the Indian Space Programme came not from any military objectives, but from the interests of a large scientific community who have been actively engaged in research programmes related to geophysics and astrophysics.

More than four decades old, India's space programme started as a purely scientific endeavour, with the launching of sounding rockets from Thumba on the Arabian Sea coast 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 location.

India's space pioneer Vikram Sarabhai gave the country a vision that is extraordinary for its realism and pragmatism, unique for its deep insights into the socio-economic context of the country, extensive in the level of details and identification of different dimensions and remarkable for the display of his own conviction. The vision recognized that promotion of space research, besides contributing to societal benefits and enrichment also results in intangible benefits coming out of the need to develop high technologies for economic development and security. Establishing a synchronous satellite over the Indian Ocean to improve meteorological forecasting, critical to agricultural operations and identifying national plans using space technologies for resource survey were also visualized as important for India. The vision called for an exciting development of a synchronous direct television broadcasting satellite that could serve as the most powerful means of mass communication to reach a large segment of the population in an economically depressed region of the world. Early in the conceptualization of a satellite-based communication and broadcasting system, issues of system choice including the financial implications and the economic benefit were recognized as important. The establishment of strong linkages with key user agencies was central to this vision. Sarabhai's emphasis on self-reliance made it the life current of the Indian Space Programme and enabled the programme to overcome numerous challenges in the course of its journey towards operational applications of space. His vision was not merely restricted to technology and application, but also to the attendant needs of new organizational structures on one side, and the fundamental issue of the role of humans in space on the other. Development of this vision itself was spread over a decade from 1961. In retrospect, it is gratifying to note that such an elaborate and carefully formulated vision helped to grow the programme, in a directed manner over the next three decades.

The Indian Space Programme evolved through three major phases. The first phase related to initiation of activities with the objective of proof-of-concept evaluation (1960–1970), followed by the experimental phase of realizing end-to-end capability demonstration (1980s) and leading finally to the operational phase providing routine services (1990s and beyond). In the initiation phase, use of foreign space systems, configuring the ground system to suit the national needs and conditions, and working closely with potential user community, were the essence of the related efforts. This phase also witnessed the development of the first satellite launch vehicle SLV-3, with a capability of orbiting 40 kg class of satellites to low earth orbit.

In the second phase, i.e. experimental phase, a major exercise was undertaken to create an end-to-end capability in the design, development and in-orbit management of space systems, together with the associated ground systems needed for the users. Systems with limited capability, realized within stringent cost and time controls characterized this phase. Two experimental satellites Bhaskara-1 and Bhaskara-2 for remote sensing and the Ariane Passenger Payload Experiment (APPLE), for communications represent missions undertaken in this phase. This phase also witnessed the development of the Augmented Satellite Launch Vehicle (ASLV).

In the operational phase, major space infrastructures have been created over the last two decades. Such infrastructure broadly fall under two classes: one for communications, broadcasting and meteorology, through a multi-purpose satellite system (INSAT) and second, the space-based remote sensing constellation, the Indian Remote Sensing (IRS) satellite series. The details of these systems and their application are the subject matters of individual papers in this special section and are summarized below.

In the field of exploration, Agrawal *et al.* (**page 1767**) provide a brief overview of planetary studies and high energy astronomy. In a related paper, Jayaraman *et al.* (**page 1779**) have addressed several research programmes related to middle atmosphere, upper atmosphere and ionosphere. In the field of applications Bhaskaranarayana *et al.* (**page 1737**) describe not only the revolution that the country has experienced in communication capability but also in the provision of innovative services such as tele-education, tele-medicine, disaster warning, search and rescue and village resource centers. Similarly in the area of remote sensing, Navalgund *et al.* (**page 1747**) deal with applications in various fields such as groundwater exploration, wasteland mapping, forecasting agricultural produce, identification of potential fishing zones, weather and climate studies as well as environment impact assessment and monitoring. In the field of technology, Katti *et al.* (**page 1715**) discuss the different versions of the satellite configurations developed for applications in the area of remote sensing, communication and space science research. On the other side, the details of the current op-

erational launch vehicles PSLV and GSLV are dealt with by Gupta *et al.* (**page 1697**). Adimurthy *et al.* (**page 1791**) discuss unique features of conducting launch vehicle missions and satellite missions, and also the strategy that ISRO plans to adopt in accomplishing the mission to Moon. They also discuss the configuration of the ground-based control, tracking and data reception systems for satellites encompassing both hardware and software. Certain additional important dimensions of the Indian space endeavour covering organizational uniqueness of ISRO, the interface between space organization and user community, as well as the results of economics and cost–benefit analysis are discussed by Sridhara Murthi *et al.* (**page 1812**). Additional elements dealing with space policy framework both national and international, use of space as a common heritage for all humankind, as well as increasing influence of space activity in the commercial sector, are examined in the last paper by Sridhara Murthi *et al.* (**page 1823**).

Most of the articles also include sections on futuristic direction for India's Space Programme such as satellite-based navigation and global positioning, systems for disaster management, climate/weather watch systems, environmental monitoring, mobile communications, planetary exploration and research in space astronomy, manned missions, creation of habitats in space and so on. In materializing the above directions there is a need to evolve appropriate strategies by addressing the related options such as the use of global systems either through partnership or hiring, creating/sharing regional systems or setting up of national systems.

It is also appropriate at this juncture to mention about several policy initiatives taken by the space organization to enhance the role of industries in terms of greater integration of space systems, development of consortia approach, policy for long-term commitments and partnership in commercial activities.

Further, ISRO has also paid serious attention for cooperating with other developing countries and sharing with them the experience and expertise we have gained. A major highlight of this approach is the setting up of the Centre for Space Science and Technology Education for the Asia Pacific (CSSTE-AP) in Dehra Dun offering educational programmes to the countries of this region.

In the context of the strategy for the management of the future of India's Space Programme, in our considered view the social objectives will continue to be the main driver. This in turn implies consolidating and extending where applicable, the capabilities of the present remote sensing and communication space infrastructure besides sustaining the autonomy to access space through the development of cost-effective space transportation systems. The core programme for the foreseeable future will therefore continue to address applications such as timely, accurate and precise information about natural resources through remote sensing systems; education, health and remote area communications through communication systems; as well as enrichment through exploration missions of scientific nature. However one can envisage several issues of evolutionary nature that address efficient delivery of the related services. Among other things this could include increasing the outreach to the different beneficiaries, making the system more efficient and user friendly, as well as improving the related institutional frameworks or even creating new ones.

In the context of enhancing the space endeavour in the years to come, there is a need to address the related aspects that go beyond the core sector which as of now has substantial social component, that is limited in its strategic, commercial and international cooperation/collaboration elements. There is a need to examine models which would include additional dimensions to the space efforts with the attendant demands on increased financial and other resource inputs. One major step in this direction is to address private sector participation not only in the provision of downstream services but also in owning and operating satellite systems as well as providing launch vehicle services. This would need consortia of industries coming together to produce state-of-the-art, cost competitive satellites on one hand and manufacturing of launch vehicle and providing launch services on the other hand. Needless to emphasize there are the issues related to technology transfer from ISRO, use of ISRO infrastructure for testing and other related requirements of launch vehicle and satellite manufacture, use of launch pads and auxiliary services to provide launch services through private entrepreneurs besides the issues relating to confidentiality and national security. In this context a major initiative is needed from the private sector, while the government has to be prepared with the necessary policy framework as an enabler. Another dimension of increasing the level of space endeavour in the country is to increase bilateral and multi-lateral cooperation particularly for science missions. Further, the increased role of space systems in the strategic sector is yet to display its full potential. It is necessary to evolve a comprehensive policy and programme relating to national security with space systems playing an appropriate role.

Evolution and expansion of this strategy could see India playing an increasing role in manned space missions, creation of space habitats, lunar bases and planetary exploration; all within the ambit of a global partnership framework like the present model for International Space Station. Further, India could also play its effective role in global missions like that for disaster management, monitoring and understanding climatic/weather systems, and such emerging concepts. On the whole, one should recognize that India should continue to build a strong base in space technology, science and applications that will create the right type of credentials not only to realize its own autonomous national space systems infrastructure for development, strategic applications and commercialization, but also in an expanded role to bring to bear its preeminent position in space in the global context. It is both timely and appropriate for the country to embark on this next step in space.

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