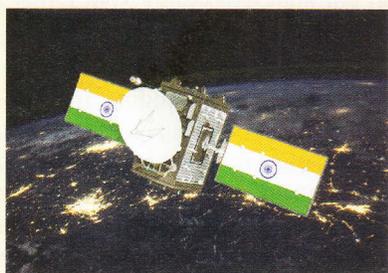


India as a Space Power

Dr K Sivan and ISRO Team



With its humble origins in 1960s, the Indian Space programme, over the span of six decades, has grown from strength to strength. Administered by the Department of Space (DOS) and primarily executed by its R&D arm- the Indian Space Research Organization (ISRO), the country today is widely recognised as a global space power having developed end-to-end capabilities cutting across various domains viz. space transportation systems, space infrastructure, and space applications such as Earth Observation, Communication, Navigation, Meteorology, Space Science, and the like.

The beginnings of the Indian Space Programme resonated strongly with its founding father Dr Vikram Sarabhai's vision, that we must be 'second to none in the application of advanced technologies for the benefit of society.' It was with the formation of the Indian National Committee for Space Research (INCOSPAR) in 1962, followed by the first sounding rocket launch from Thumba Equatorial Rocket Launching Station (TERLS) in 1963 that the space programme formally took off.

Dr Sarabhai, the architect of the Indian Space Programme, initiated the creation of dedicated clusters. So, while Trivandrum became the hub for sounding rockets, solid propellants, etc., with the setting up of Space Science & Technology Centre [SSTC, present-day VSSC (Vikram Sarabhai Space Centre)], the cornerstone for payload development and related electronics was at Ahmedabad in the form of Experimental Satellite Communication Earth Station [ESCES, present-day SAC (Space Applications Centre)]. The Indian Space Research Organization (ISRO) was formed in 1969, superseding INCOSPAR. Today, with a total workforce of over 18,000, ISRO's establishments are functioning in many parts of the country with each concentrating on a specific specialised domain. The country's public as well as private sector industries are playing a crucial role in our Space Programme. Besides, various academic institutions have also contributed to the Indian space endeavour.

With the establishment of the Space Commission and the Department of Space (DOS) in 1972, ISRO was brought under DOS and the structured space programme was now poised to soar under the leadership of Dr Satish Dhawan. The 70s were the learning phase during which several experimental satellites were built, including India's first satellite *Aryabhata*, which was launched on 19 April 1975, from a launch centre in the former Soviet Union. *Aryabhata* laid a firm foundation for the later immensely successful Indian Satellite Programme. *Bhaskara-I* and *II*, the two experimental earth observation satellites, provided the rich experience and the confidence to build complex operational remote sensing satellites. Today, India is world leader in the satellite-based remote sensing area.

Additionally, APPLE- Ariane Passenger PayLoad Experiment, India's first experimental communication satellite, although launched by the European Ariane rocket, reached its final geosynchronous orbital home in June 1981, with the help of a rocket motor developed in India. *Aryabhata*, the two *Bhaskaras*, as well as APPLE were launched free-of-cost, which reflects India's successful international space cooperation policy. In the recent past, India has not only flown foreign scientific instruments on-board Indian spacecraft but has also launched them.

Two further significant satellite communication experiments that deserve a mention here for their ingenuity and spirit of cooperation are SITE- Satellite Instructional Television Experiment (1975-76) and STEP- Satellite Telecommunication Experimental Project (1977-79), comprehensively

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establishing the usage of satellites for communication and broadcasting and providing hands-on experience for the same, paving the way for INSAT (Indian National SATellite) series of satellites.

In the space transportation domain, it was the commissioning of the Satellite Launch Vehicle-3 (SLV-3) project in the early 1970s, the first indigenous experimental satellite launch vehicle, that served as the beginning of an enduring partnership between ISRO and Indian industries. An all solid, four-stage launch vehicle, the SLV-3 was designed for placing satellites weighing 40 kg in Low Earth Orbit. The SLV-3 had its successful launch on 18 July 1980, thrusting India into the select league of six countries with the capability to launch satellites on their own.

On the heels of SLV-3, was commissioned the ASLV- Augmented Satellite Launch Vehicle project in the early 1980s, the next step of evolution in launch vehicle technology. The two launch vehicles, SLV-3 and ASLV, validated the critical launch vehicle technologies and gave ISRO the confidence to reach the next level with the Polar Satellite Launch

Vehicle (PSLV) project, commissioned in mid-1980s.

During the same period, INSAT-1B, India's first multipurpose operational satellite was launched in 1983, demonstrating its ability to bring about a rapid and major revolution in India's telecommunications, television broadcasting, and weather-forecasting domains. India's ability to design, build, and maintain a complex remote sensing satellite was demonstrated in 1988 when IRS-1A, the first operational satellite built in India, started imaging the earth. The images sent by that satellite circling the Earth from its 900 km high polar orbit were utilised in various diverse fields such as agriculture, groundwater prospecting, mineral survey, forestry, etc.

During the 1990s, ISRO began building INSAT-2 series of multipurpose satellites indigenously. At the same time, systematic usage of imagery from our remote sensing satellites for tasks like crop yield estimation, groundwater and mineral prospecting, forest survey, urban sprawl monitoring, and wasteland classification and fisheries development began. The optimal usage of onboard capabilities of INSAT and remote sensing satellites was coordinated using inter-ministerial mechanisms such as INSAT Coordination Committee (ICC) and National Natural Resources Management System (NNRMS).

Today, India has a fleet of advanced remote sensing satellites equipped with high resolution and multispectral cameras dedicated to the themes of cartography, resource survey, and ocean and atmospheric applications. The INSAT system with over 300 transponders in the C-band, Extended C-band, Ku-band, Ka/Ku band, and S-band provides services to telecommunications, television broadcasting, radio networking, satellite newsgathering, societal applications, weather forecasting, disaster warning, and Search and Rescue operations. High Throughput Satellites (HTS) such as GSAT-11, GSAT-29, and GSAT-19 are supporting the Digital India campaign by boosting the broadband connectivity to the rural and inaccessible Gram Panchayats in the country. The transponders on these satellites will bridge the digital divide of users including those in Jammu & Kashmir and the North-Eastern regions of India.

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The space transportation domain, with the successful advent of the Polar Satellite Launch Vehicle (PSLV) in 1994, witnessed a quantum jump in the indigenous launch capabilities. The vehicle has proven to be a workhorse of ISRO, logging over 50 successful missions, launching national as well as foreign satellites. On 15 February 2017, PSLV created a world record by successfully placing 104 satellites in orbit during a single launch. Well, as numbers go, it was undoubtedly a record at the time, but the real

significance of the achievement is the immense confidence reposed by foreign countries in the capability of the Launch Vehicle.

With the solid and liquid propulsion technologies perfected through SLV-3, ASLV, and PSLV, the nation embarked upon a highly challenging quest to master the complex cryogenic technology. The commissioning of the Geosynchronous Satellite Launch Vehicle (GSLV) in the 1990s was a step in this direction. The launch vehicle was designed with three stages (including the cryogenic upper stage), with four liquid strap-ons. Cryogenic technology involves the storage of liquid hydrogen & liquid oxygen at very low temperatures. Materials used to operate at these very low temperatures, chilling processes, and interplay of engine parameters make the development of the cryogenic stage a very challenging and complex task. With the successful qualification of the indigenously developed Cryogenic Upper Stage (CUS) in the GSLV-D5 flight on 5 January 2014, ISRO demonstrated its mastery of cryogenic rocket propulsion. Including the one in January 2014, the vehicle has had six successful flights over the past decade.

The next-generation launch vehicle of ISRO, with a capability for putting 4T payload in GTO, came in the form of GSLV-Mk III designed with two solid strap-ons, a core liquid booster, and a cryogenic upper stage. LVM3-X/ CARE Mission, the first experimental suborbital flight of GSLV Mk III, was on 18 December 2014 and launched the Crew Module Atmospheric Re-entry Experiment (CARE). The CARE module began its return journey and a little later, re-entered the earth's atmosphere. It

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was successfully recovered over the Bay of Bengal about 20 minutes after its launch. Subsequently, after two successful developmental flights and with the injection of Chandrayaan-2 into Earth Parking Orbit in July 2019, GSLV Mk III successfully entered into its operational phase.

Indian Space Programme has always focused on the development and utilisation of space technologies

to achieve the overall development of the country. Despite its emphasis on applications, ISRO has pursued many space science projects to perform meaningful exploration of space. India's first satellite Aryabhata was a scientific satellite. After Aryabhata, ISRO entered into the realm of science missions again with a unique mission- the Space Capsule Recovery Experiment-1 (SRE-1). Launched by PSLV in January 2007, SRE-1 with its scientific experiments, orbited the Earth for 12 days and was successfully deorbited and recovered over the Bay of Bengal. This proved several technologies necessary for reusable launch vehicles and human spaceflight.

The space science missions of India- Chandrayaan-1, Mars Orbiter Mission, AstroSat, and Chandrayaan-2- have caught the attention of millions of Indians as well as the outside world.

Launched by PSLV on 22 October 2008, the 1380 kg Chandrayaan-1 spacecraft was successfully navigated to the Moon in three weeks and was put into an orbit around the moon. On 14 November 2008, when a TV set sized 'Moon Impact Probe' separated from Chandrayaan-1 spacecraft and successfully impacted the surface of the moon, India became the fourth country to send a probe to



the lunar surface after the United States, the Soviet Union, and Japan. Later, when Chandrayaan-1 conclusively discovered water molecules on the lunar surface, it was widely hailed as a path-breaking discovery.

Uplifted by the success of Chandrayaan-1, ISRO embarked on the Mars Orbiter Mission, for demonstrating India's capability to build, launch, and navigate an unmanned spacecraft to Mars. Launched by PSLV on 5 November 2013, the 1340 kg Mars Orbiter Spacecraft encountered Mars on 24 September 2014. With this, ISRO has become the fourth space agency to successfully send a spacecraft to Mars orbit.

AstroSat, launched by PSLV in September 2015, is the first dedicated Indian astronomy mission aimed at studying celestial sources in X-ray, optical, and UV spectral bands simultaneously. AstroSat recently made a major breakthrough by discovering one of the earliest galaxies in extreme-Ultraviolet light.

The Chandrayaan-2 Mission- India's second mission to the moon was successfully launched on 22 July 2019. Chandrayaan-2 Orbiter spacecraft was placed in its intended orbit. The eight instruments onboard the Orbiter are continuously providing useful science data which will enrich our understanding of the moon's evolution and mapping of the minerals and water molecules in Polar regions.

ISRO has also successfully established and operationalised Navigation with Indian Constellation (NavIC) which provides highly accurate Position, Navigation, and Time information to users in India and its surroundings. The Global Standards body- 3rd Generation Partnership Project (3GPP), which develops protocols for mobile telephony, has approved NavIC and major mobile chipset manufacturers have incorporated NavIC in their releases. Further, through GPS Aided GEO Augmented Navigation (GAGAN), ISRO is providing Satellite-based Navigation services with accuracy and integrity required for civil aviation applications and to provide better Air Traffic Management over Indian Airspace.

In the recent past, the "Gaganyaan Programme" approved by the Government of India in 2018 marks a point of inflexion in the Indian space journey, marking its entry into the new age of human space exploration. The Human Space Flight Centre (HSFC) was constituted in ISRO in January 2019, for implementing the vision on the human space flight programme.

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HSFC is entrusted to implement the Gaganyaan Programme and to act as the lead centre for sustained and affordable human spaceflight activities. The Gaganyaan project has the stated objective of demonstrating human space flight capability to Low-Earth Orbit (LEO) for a defined duration and safe recovery after the mission.

ISRO successfully proved a crucial technology element of Human spaceflight in July 2018- The Pad Abort Test (PAT), which is the first in the series of tests to qualify the Crew Escape System (CES). The Pad Abort Test flight

was a demonstration of the capability of CES to evacuate the Crew in case of a contingency at the launch pad.

Towards capacity building in human resources and to meet the growing demands of the Indian Space Programme, the Indian Institute of Space Science and Technology (IIST), a deemed university, was established at Thiruvananthapuram in 2007. The institute offers Bachelor's Degree in Space Technology with specialisation in Aerospace Engineering and Electronics & Communication and a Masters Programme in the areas of Space Technology.

Further, amidst the Covid-19 pandemic, the landmark space reforms initiated by the Government of India in June 2020 mark a significant step forward in the evolution of the Indian Space ecosystem. The creation of the Indian National Space Promotion and Authorization Center (IN-SPACe) to promote, handhold, and authorise Non-Government Private Entities (NGPEs) to undertake space activities shall unleash the next wave of advancements in the sector. This will enhance the diffusion of space technology and boost the space economy within the country.

Empowering the department PSU- NewSpace India Limited (NSIL) to 'own' the operational launch vehicles and space assets of ISRO, opens up a new chapter in the management of space activities in the country. Further, the present supply-based model was changed to a demand-driven model, wherein NSIL shall act as an aggregator of user requirements and simultaneously obtain commitments.

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With these structural adjustments, ISRO shall focus on advancing the R&D endeavours such as heavier and more efficient satellites, advanced space missions such as Chandrayaan-3, Aditya-L1, and Mission to Venus to further explore the solar system and of course, the Gaganyaan Programme. The future of space activities in the country looks very promising indeed and shall cement India's position as a 21st-century space power. □