SPACE: THE INDIAN ODYSSEY

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India's first indigenous satellite, the Aryabhatta, entered orbit in April 1975 launched aboard a Soviet rocket. It took another five years for the nation to achieve its first indigenous space launch. The four stage solid-fuel Satellite Launch Vehicle-3 (SLV-3) blasted off from the Indian launch site, Sriharikota, in July 1980, successfully placing the Rohini-1 satellite into a Low Earth Orbit (LEO), enabling the nation to become the seventh in the world's select group of countries with the capability of indigenous space launchers that could launch and place satellites in orbit. This was at a time when India had already acquired nuclear capability in 1974 but the space programme was conceived and executed with a purely peaceful orientation. India has displayed tremendous acuity and maturity, and in its ventures in space, the new dimension, it took the path for peaceful purposes for the benefit of its people, with no content that offered any military utility.

This essay chronicles the motives behind the Indian space programme and traces its evolution to the contemporary times.

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The Indian Space Programme

100th Milestone in India's Space Chapter

In a landmark achievement in its ongoing space programme, India on September 9, 2012, launched its 100th mission into space. The Indian Space Research Organisation (ISRO) launched a commercial payload aboard its space workhorse, the PSLV–C21. Two satellites were successfully placed in orbit, the French 712 kg optical remote sensing satellite, SPOT 6, and a 15 kg Japanese micro-satellite, the Proiteres. With this launch, ISRO has successfully launched 62 satellites, including 28 foreign ones, aboard 38 rockets.

The foundation of the space venture in the country was laid based on the forward thinking policies enunciated by Pandit Nehru. The Indian Astronautical Society was formed in 1957, with the aim to encourage domestic research on space topics. It took another 18 years to launch the first indigenous satellite, in 1975, and then another five years to achieve an indigenous space launch. There has been no looking back since then in the success story of the Indian space venture.

THE MOTIVES BEHIND THE SPACE PROGRAMME

Pandit Nehru was not only an advocate of the Non-Aligned Movement (NAM) but also one of the founding fathers of the movement in 1961. His vision of non-alignment was to avoid dependency on either of the two power blocs and seeking to occupy the middle ground, he sought to avoid being drawn into a possible third World War.[1] India applied a self-imposed moratorium on developing ballistic missiles as a means of delivery of long range munitions. Dr. Vikram Sarabhai, the father of the Indian space programme, piloted the space programme towards applications that could functionally benefit the Indian masses in terms of education and health care, and bolster the nation's economy, for which three areas were selected and energised for development: communications, weather/climatology and

1. Percival Spear, *India: A Modern History* (Ann Arbor, Michigan: University of Michigan, 1961), p.444.

remote sensing.[2]

India's Space Launch Vehicles (SLVs), unlike those of the other global space players, did not emerge from ballistic missiles but originated from civilian rockets. Over the decades of execution of the Indian space programme, the earlier vision of Dr. Vikram Sarabhai of space-based applications was engineered for social needs that encompassed capability-building in areas as far and wide as telemedicine, education, weather forecasting, remote sensing, agriculture, telecommunications, disaster management, environment monitoring and Direct-To-Home (DTH) television, aimed towards social upliftment and poverty eradication through a constellation of 20 in-orbit and operational satellites as of September 2012.

Backed by a relatively modest[3] annual budget of around US$ 1.5 billion for the year 2012-13, the Indian space programme offers additional dividends by gaining tremendously in the realm of self-reliance. Over the years, the motive has undergone a paradigm shift by way of broadening into a vision that appears to have naturally gravitated from societal development to a stance that also views space as an arena for global prestige.[4] Commencing in 1999, the Indian space initiative entered another exclusive field, that of providing low cost launch services. Commerce is not necessarily the only motivator as such partnerships with global players offer tremendous foreign policy spin-offs in India's favour.

The year 2008 saw another glorious chapter being added to the Indian space-success narrative. Chandrayaan-1, launched in October 2008, was the country's first unmanned lunar probe and made a controlled landing on the lunar surface, making the country the fourth in the world to have its flag planted on the Moon.[5] It was this mission that made the world aware that

2. Rajeev Lochan, "Some Reflections on Collective Security in Space," in John M. Logsdon and James Moltz, eds., *Collective Security in Space: Asian Perspectives* (Washington, D.C.: George Washington University, Space Policy Institute, 2008), p.33.
3. A modest budget for space is a relative term as it is 7.5 percent of NASA's budget, a quarter of the European Space Agency's and a mere 0.34 per cent of the Indian government's expenditure. "Winning is a Matter of Belief: ISRO Chief," *The Hindu*, September 9, 2012, accessed at http://www.thehindu.com/todays-paper/tp-features/tp-downtown/winning-is-a-matter-of-belief-isro-chief/article3875930.ece, on September 26, 2012.
4. Bharath Gopalalswamy, "Indian Space Policy: Aiming Higher," *Space News*, July 21, 2008, P. 23.
5. "Tricolour's 4th National Flag on Moon," *The Economic Times*, November 15, 2008.

water exists on the Moon. The mission carried the most international lunar payloads ever, a result of the combined efforts of the USA, Bulgaria and 17 countries within the European Space Agency (ESA). With plans afoot for Chandrayaan-II and Mangalyaan to the Moon and to Mars respectively, India's motive would need to be beyond the scope of just acquiring 'international prestige'.

A HISTORICAL PERSPECTIVE

The launch of the Sputnik-1 by the Soviets in October 1957 was an event that galvanised Dr. Sarabhai into looking at the potential of satellite applications for socio-economic development and brought to the government's attention the need to build an indigenous satellite. The government saw reason and the Indian National Committee for Space Research (INCOSPAR) was set up in 1962, with Sarabhai as its first Chairman. Building rockets was the obvious first step in any space venture and that led to setting up the Thumba Equatorial Rocket Launching Station (TERLS) near Thiruvananthapuram. Sarabhai spearheaded the establishment of the Indian Space Research Organisation (ISRO) in 1969.

The very first cooperative venture in the realm of rockets came about with partnering the Soviets in launching their scientific sounding rockets from TERLS. It was largely due to India's non-aligned stance that it held the middle ground, with the USA and USSR both playing a part in the early steps in rocketry. Indian scientists underwent training on sounding rockets at the National Aeronautics and Space Administration's (NASA's) launch facility in Virginia. The first rocket launched from TERLS in November 1963 was based on the design of the US Nike-Apache.[6] This enabled Indians to gain expertise in modern rocketry that eventually led to indigenous capability in SLV.[7]

The first purely indigenous rocket, the 10-kg solid-fuelled Rohini-75 (75 indicating the diameter, in millimetres), was launched in November 1967 from TERLS. Over time, the rockets became bigger,[8] went higher, carried

6. B. N. Suresh, "History of Indian Launchers," *Acta Astronautica 63*, 2008, p. 429.
7. James Clay Moltz, *Asia's Space Race* (New York: Columbia University Press, 2012), p. 114.
8. In a span of five years, the rocket launch weight went from 60 kg to over two tons. http://www.bhaskarastro. org/earlyhistory.htm, accessed on October 1, 2012.

better technology payloads and, most importantly, with an enormous amount of hands-on experience, boosted confidence in testing advanced sub-systems and evaluating more powerful propellants. TERLS was limited to launching rockets of a diameter of only up to 0.56 m from its three launch pads, which was obviously inadequate to realise the dream of launching bigger and heavier SLVs. A launch site at Sriharikota Range (SHAR), an island off the east coast of Andhra Pradesh, was selected and made operational in October 1971.

To provide focus to the space programme, ISRO was placed under a newly created Department of Space (DOS) in 1972, with a strategic plan to place a 40 kg satellite into LEO. ISRO continued on the course charted by Sarabhai, that of 'leap-frogging' the process of development by acquiring advanced technologies and then developing them to suit domestic requirements.[9]

SPACE LAUNCH VEHICLE TAKES FLIGHT

Development of the four-stage, solid-fuelled SLV-3 commenced in 1973 under the Project Director, Dr. A. P. J. Abdul Kalam, with plans of a 17-ton launch mass, 13 tons of which was fuel. The SLV-3 had 44 main systems totalling 10,000 components, 85 per cent of which were indigenous. Forty-six organisations in the public and private sectors were involved in the project. The SLV-3's first successful launch was on July 18, 1980; it orbited the 40 kg remote sensing satellite Rohini, heralding India's entry into to a select group of launch-capable space-faring nations, the seventh in the world to do so.

Launching heavier satellites would need larger rockets. A low cost 'augmented' version of the SLV (ASLV) was the next step: a 23-m tall, five-stage, solid fuelled rocket designed to place a 150-kg satellite into a circular orbit, launching two 'stretched' Rohini satellite series, or SROSS, in the period 1992-94.

While the SLV-3 and the ASLV were designed as experimental launch

9. V.S. Mani, "Space Policy and Law in India and Its Relevance to the Pacific Rim," *Journal of Space Law* 35, no. 2, Winter 2009, pp. 618-619.

The Technology Experimental Satellite (TES) launched in October 2001 provides imagery of one metre resolution, making the country the only one other than the USA to possess such capability.

programmes, it was the Polar SLV or PSLV that conferred on India the rites of passage into the 'big launcher league'. To place in orbit larger satellites of one ton class that was envisaged for the series of Indian Remote Sensing (IRS) satellites, the need was to exploit the advantages of power and control that liquid-fuelled rockets offered. The 44-m tall and 275-ton PSLV was almost ten times bigger and heavier than the ASLV and had a combination of alternate solid-liquid stages in its four stages with strap-on boosters. The first successful launch of the PSLV was in October 1994 that placed the 870-kg IRS P2 satellite into an 825-km orbit. This feat allowed the country to break away from its reliance on Russian launchers for orbiting the IRS series of satellites and, in addition, made the domestic launch services commercially available to foreign partners. PSLVs till date have an enviable track record of 21 consecutive successes in 22 launches[10] and continue to launch and orbit satellites in LEO. The most notable amongst them remain the series of IRS satellites that have enabled the nation to have the *largest constellation of remote sensing satellites in the world*, with some of the newer ones providing sub-metre resolution. Other notable and successfully orbited payloads and missions launched aboard the PSLVs include the first commercial launch in May 1999 that orbited three satellites, including one each of Korea and Germany; the Technology Experimental Satellite (TES) launched in October 2001 that provides imagery of one metre resolution, making the country the only one other than the USA to possess such capability;[11] Metsat (later renamed Kalpana), the first indigenous meteorological satellite, in September 2002; SRE-1, the space capsule recovery experiment that was de-orbited and recovered after 12 days, in January 2007; mission PSLV C-9 that placed 10

10. ISRO, "Launch Vehicles'", accessed at http://www.isro.org/Launchvehicles/launchvehicles.aspx, on October 6, 2012.
11. "India's Spy Satellite Boost", *BBC News*, November 27, 2001, accessed at http://news.bbc.co.uk/2/ hi/south_asia/1679321.stm, on October 15, 2012.

satellites into orbit simultaneously in April 2008 and made the nation the first in the world to do so; Chandrayaan-1, the unmanned lunar probe in October 2008; and RISAT-1, the first indigenous all-weather radar imaging satellite weighing 1,858 kg, in April 2012.

To gainfully exploit the complete spectrum of space applications, one essential segment was of having dedicated satellites operating at the Geo-Stationary Orbit (GEO) — satellites that would orbit once every 24 hours and would appear to be permanently 'parked' 36,000 km over a geographical point in the Indian subcontinent. Launching two-ton satellites into GEO required yet another quantum leap in launch technology. For economic reasons and more, importantly, the nationalistic desire for self-reliance, it was in 1987 that India felt the need for indigenous launchers for orbiting its two-ton satellites in GEO, a need that gave birth to the Geo-Stationary Space Launch Vehicle (GSLV) programme. The design of the 49 m tall, 414-ton, three-stage GSLV caters for the already proven solid-fuelled first stage of the PSLV as its first stage. The second stage is the same proven Vikas engine that formed the second stage of the PSLV that sent Chandrayaan-1 to the Moon. The development and operationalising of the third stage, the liquid-fuelled cryogenic engine, turned out to be an altogether different story, both technologically and politically.

In 1991, the USSR and India entered into an agreement wherein India would buy cryogenic engines and related production technology. Having apprehensions that such technology would violate the provisions of the Missile Technology Control Regime (MTCR) by being used for developing long range ballistic missiles, the USA applied sanctions on this deal in 1992. The reason for such apprehensions was not necessarily violation of the MTCR, as cryogenic fuel takes a long time to prepare on the ground and has no utility for military rockets that need to be launched at shorter notice, but was rather, commercial.[12] Prior to the deal with the Soviets, India had approached Japan for its LE-5 cryogenic engine, which did not fructify. Getting wind of this, the American General Dynamics Corporation offered

12. Prof. U.R. Rao, former ISRO Chairman, *Space India*, October 1993-March 1994, accessed at http://www.frontlineonnet.com/fl2710/stories/20100521271010100.htm, on October 8, 2012.

the cryogenic engine and its technology transfer. India did not express an interest as the cost was found to be prohibitive. Some are also of the view that the American intervention in the USSR-India deal was to keep India out of the commercial space launcher market. Post the break-up of the Soviet Union, the need for hard cash made Russia initially reject the US request for sanctions. The American financial aid package to Russia in 1993,[13] however, turned the tide and Russia held up the Indian deal, agreeing only to the sale of seven of the completed cryogenic engine, the KVD-1.

The first successful launch of a GSLV fitted with the Russian cryogenic engine placed an educational satellite, the 1.5-ton G-SAT 1, in a near-GEO in April 2001. Of the balance six Russian rockets, five were expended in GSLV launches between 2003 and 2010. The nation's first indigenous cryogenic engine fitted GSLV, the GSLV Mark, II, launched in April 2010, crashed into the sea five minutes into its flight. With only one KVD-1 engine in its hand, it is now for ISRO to draw lessons from the failure of the first indigenous cryogenic engine and face up to the challenge of bearing fruit for the ambition of self-reliance. While the saga of Indian space launchers has been creditable, the space launcher industry, at the very least, should aim to catch up with the domestic satellite industry whose progress and reach have been even more remarkable.

SPACE-BASED APPLICATIONS FOR THE SOCIETY

In the 1960s, when satellite-based applications were still in the experimental stages even in the USA and USSR, Dr. Sarabhai was quick to understand the implications of such applications in support of, and to supplement, ground-based systems. While charting the course for developing indigenous satellites, Sarabhai realised the need to tap into existing space assets by initially banking on foreign satellites for proving applications, building the requisite ground support infrastructure and then innovating to indigenise.

13. The financial aid package was essentially US$ 400 million that the USA paid to Russia for seven American flights to the Mir space station, the very exact amount that the Russians lost in the Indian cryogenic deal. Brian Harvey, Henk H. F. Smid and Theo Pirard, *Emerging Space Powers: The New Space Programs of Asia, the Middle East, and South America* (Chichester, UK: Praxis Publishing Ltd., 2010), p. 224.

Partnership with the US in the 1970s led India to capitalise on available American satellites in two fields: rural education and remote sensing. India experienced first-hand, space-based applications that emerged from both the distinctly different orbits: education and communications from the ATS-6 satellite in GEO, and remote sensing from the Landsat satellite in LEO. Dr. Sarabhai presented a plan on the Indian National Satellite System (INSAT) in 1970 that involved procuring the first set of satellites from foreign partners and building the subsequent series domestically.[14] Within the domestic satellite programme, ISRO commenced its work in essentially two fields. The first was in the field of remote sensing, the Indian Remote Sensing (IRS) satellite system and the other in the realm of geo-synchronous satellites, by way of the INSAT system for communications, TV broadcasting and meteorological services. INSAT aimed at another first in the world: to harness the advantages of communications (in GEO) and Earth observation (in LEO) from a common satellite platform in GEO, an approach more complex but 40 per cent cheaper in the long run.[15]

SAGA OF THE INDIGENOUS SATELLITES

The country's first indigenous satellite, the Aryabhatta, a 360-kg scientific satellite for study of the Earth's atmosphere was launched aboard a Soviet Cosmos 3M rocket in 1975 on a 594-km circular orbit but lasted only five years.[16] The first step towards remote sensing was the satellite Bhaskara-I launched in June 1979 from the Soviet Union that provided one kilometre resolution photographs. It sent ten pictures a day and provided valuable information on snow melting in the Himalayas, river flooding in north India, desertification in Rajasthan, rainfall in the coastal belts and mineral resources in Gujarat. Bhaskara-II, launched in 1981, returned the most useful data in its ten years life, providing information on agriculture, vegetation and weather, and in assisting in making maps of Bengal.

14. "History of Indian Space Programme," accessed at http://www.bhaskarastro.org/earlyhistory.htm#a10, on October 10, 2012.
15. Harvey, et al., n. 13, pp. 184-185.
16. n. 14.

Come the time to test the indigenous space launch capability, as the SLV programme had progressed on course, it was obvious that the first step to orbit the satellite would be small and tentative. The first indigenously launched satellite, the Rohini that was launched from SHAR in July 1980 was a mere 35 kg mass, though equipped with a TV camera of one kilometre resolution. Upbeat and assured with this success, Rohini-2's launch in May 1981 was covered live on TV and radio. Rohini-3, launched two years later, performed even better by beaming back 5,000 images, picking out water, vegetation, snow and clouds.

THE IRS SYSTEM TAKES SHAPE

The indigenous satellite-building capability stood proven with the successes achieved in the experimental satellites of the Bhaskara and Rohini class. IRS satellites were designed to be of one ton weight, revisit or cross the same point on the Earth every 21 days to carry out systemic mapping of the Earth's surface. The first IRS, IRS-1A was ready but the SLV/PSLV was not. IRS-1A was launched in March 1988 on a Russian rocket. The 975-kg satellite was put in a 904-km polar sun-synchronous orbit of 22 days revisit, providing a resolution of 36.25 m. It operated for over eight years,[17] returning 400,000 images that enabled comprehensive mapping of forests, salt land, water and wasteland. IRS-1B, specifically designed to forecast crop yields of tea and coffee, was launched in August 1991, again from the Soviet Union.[18]

The first in the series of IRS satellites to be launched by an indigenous PSLV was the 804-kg IRS-P2 (P for Polar) in October 1994. The satellite-capability envelope thereafter was raised and the country moved to its second generation IRS satellites. India orbited the 1,250-kg IRS-1C in December 1995 aboard the Russian Molniya rocket and the satellite's operation was unique in two ways. Its panchromatic camera with a six-metre resolution provided a significant boost in the accuracy of remote

17. ISRO, "Earth Observation Satellites," accessed at http://www.isro.org/satellites/irs-1a.aspx on, October 15, 2012.
18. Harvey, et al., n. 13, pp. 174-175.

sensing, making it the most advanced remote sensing satellite in the world at that time.[19] Such an output enabled digital mapping of the whole country on a 1:125,000 scale and coupled with the output from the infrared-band sensor, fed in to the early years of mapping of the domestic Geographical Information System (GIS). The other ground breaking activity linked to the IRS-1C was India's entry as an exporter at the global level. India permitted a franchise to EOSAT, an American company, to sell this imagery to the global market, while the Japanese space agency, NASDA, bought the IRS data for its own remote sensing centre.

The PSLV programme stabilised, grew from strength to strength and the days of dependency on foreign launchers for the IRS satellites were over.

The PSLV programme stabilised, grew from strength to strength and the days of dependency on foreign launchers for the IRS satellites were over. The all encompassing IRS series gave way to a variety of satellites that are designed and operated exclusively for individual facets of remote sensing, with the satellites being named as per their area of application. The OceanSat (IRS-P4) launched in May 1999 carried payloads exclusively for oceanographic studies and had instruments that could see up to 200 m depth. The Technological Experimental Satellite (TES) launched in October 2001 to experiment with, and validate, new technologies in spacecraft and payloads, provides a one metre resolution that made the country the only one other than the USA to possess such capability at the time, raising apprehensions in some who saw implications of such a capability in matters military.[20] Metsat, in September 2002, later renamed Kalpana, orbiting in GEO, was specifically for meteorological purposes. It carried out hourly scans in the visible, infrared and water vapour bands, collected data from weather stations across the country and relayed them to the meteorological centre at New Delhi. The Cartosat series of satellites operate for digital mapping, town planning, and road and canal building. The highly agile

19. Ibid., p 175.
20. n. 11.

and steerable Cartosat 2B launched in July 2010 provides a resolution better than one metre.[21] The technological graph gained a notch with the launch of a radar imaging satellite, the RISAT-2 in 2009. This was the country's first observation satellite with an all-weather radar imaging application for disaster monitoring. It has applications in the field of radar-based tracking of ships, a special need that arose in November 2008 during the Mumbai blasts, necessitating an outright buy from Israel within five months.[22] The state-of-the-art RISAT-1 took this application further. Launched in April 2012, the 1,858-kg indigenous satellite, the heaviest launched by PSLV into LEO, carries a microwave synthetic aperture radar operating in C band, that enables day and night imaging operations in all weather conditions.

With over a dozen satellites currently in operation, the IRS system is the largest civilian remote sensing satellite constellation in the world, providing imageries in a variety of spatial resolutions, spectral bands and swaths.[23] Resolution available today is that of less than one metre. The data is used for wide-ranging applications covering agriculture, water resources, urban development, mineral prospecting, environment, forestry, drought and flood forecasting, ocean resources, conservation of wildlife and disaster management, activities across a broad spectrum that are contributing immensely to India's economic, environmental and social development.

THE INSAT IS IN PLACE

Dr Sarabhai's presentation in 1970 on the envisaged INSAT system operating in GEO, found favour with the powers-that-were and approval of the programme was accorded in 1977. GEO slots were registered two years later with the International Telecommunication Union (ITU) for orbiting INSAT satellites in GEO. The INSAT programme involved the Ministry of Telecommunications, All India Radio, and Departments of Space and of

21. ISRO, "Cartosat-2B," accessed at http://www.isro.org/satellites/cartosat-2b.aspx, on October 15, 2012.
22. "Why RISAT-2 Came Before RISAT-1," May 3, 2012, accessed at http://www.strategypage.com/htmw/ htspace/20120503.aspx, on October 18, 2012.
23. n. 17.

Meteorology. With the rather unique aim of providing applications in the dual role, that of communications and weather systems, an agreement was finalised with the US in 1978 to build the first of the INSAT-1 satellites[24] and with NASA for launching them. Events unfolded thereafter in a manner that allowed India to collaborate with the European Space Agency (ESA) too in the field of space launch. The first four flights of ESA's Ariane launcher were development flights and ESA offered free space to ISRO—free, as these were test flights and there was an inbuilt element of failure. The Indian response was prompt. The 630-kg[25] satellite, Ariane Plane Passenger Payload Experiment (APPLE), built by HAL, took 36 months to design, build, test and ship to Kourou, French Guyana, from where it was launched aboard Ariane V3, the third flight, in July 1981. This was the period when the indigenous satellites Aryabhatta, Bhaskar and Rohini had already been launched. Most welcome was the Indian hands-on experience and confidence in the GEO-based space relay platform that would pave the way for the indigenous INSAT-2 series of satellites.

Four of the US built INSAT-1s were launched in the period 1982 to 1990, by the USA and Ariane. The indigenous INSATs commenced with the second-generation INSAT-2 series of satellites that, however, still required foreign launchers. Five satellites in this series of two-ton class of satellites were launched in the period 1992-99 all aboard ESA's Ariane rocket. INSAT-2A and 2B were near identical 1,906-kg multi-purpose satellites that provided communications (C, extended C and S bands), meteorology and satellite-based search and rescue services. INSAT-2C and 2D satellites were purely for communications and, in addition, had transponders in Ku band. INSAT-2C provided coverage to remote parts of the northeast, Andaman and Nicobar Islands and as a yet another first, with enlarged C band transponders, reached out to countries beyond the subcontinent. The higher frequency Ku band enabled higher-density traffic, while transmission began being received by small rooftop antennae. The last in this series, the multi-purpose INSAT-2E weighed 2.55 tons and besides the standard fare

24. n. 14.
25. Harvey, et al., n. 13, pp. 184-189.

in payload, carried for the first time, a high-resolution sensor for the water vapour band and a Charged Coupled Device (CCD) camera that provided one kilometre spatial resolution. It collected and retransmitted data from 100 weather stations in remote areas. The performance of this satellite was such that a European consortium, INTELSAT, leased 11 transponders for 10 years at a cost Euro 188 million. With the INSAT-2 system in place, 90 per cent of the population was covered by space-based TV, while 700 TV and almost 200 radio stations used signals retransmitted from the INSAT series. By the turn of the century, the INSAT system was extensive enough to provide video teleconferencing and education for farmers and rural development workers through 4,700 voice circuits via 430 Earth stations and 1,200 terminals. Fishermen in the coastal areas were being guided to fishing grounds by the space platforms. The ground stations for INSAT-based search and rescue applications set up at Bangalore and Lucknow not only served distress calls to the mainland but acted as relay stations for countries as far as Indonesia to the east and Tanzania to the west.[26]

The INSAT-3 series of satellites were driven by increased domestic demand for communication channels. Four of them launched in the period 2000-03, all on Ariane, with the aim of placing more transponders in space as also to step into the GEO slot and fulfil the role carried out by the ageing INSAT-1 and 2 series of satellites. INSAT-3E is purely a communications satellite, while the other three are multi-purpose satellites launched to augment the services being provided by the preceding INSAT satellites. The fifth in this series, the INSAT-3D, planned for launch in 2012-13 will be purely a weather satellite.

The need for the INSAT-4 series of satellites arose essentially to build upon the services that were already in use, primarily in the rapidly growing fields of telemedicine and DTH TV. Four INSAT-4 satellites were launched between 2005 and 2007, of which one satellite failed to reach its orbit. The INSAT-4A enabled ISRO to connect 33 specialised hospitals to 132 remote, rural or district hospitals in its telemedicine network in 2006,[27] while the

26. Ibid., pp. 190-195.
27. Ibid., p. 196.

figure today stands at 80 hospitals connected to 306 remote/rural hospitals and 16 mobile telemedicine units.[28]

WIDENING THE SPECTRUM OF SPACE APPLICATIONS

Sqn Ldr Rakesh Sharma, a fighter pilot in the Indian Air Force became the first Indian and the 139th human to reach space, aboard the Soyuz T-11 in April 1984, for a week-long stay on the Salyut space station. Though remarkable, this could have been considered a singular feat but for the fact it gave birth to the idea of an indigenous manned space flight in the years to come. True enough, the Space Recovery Experiment (SRE) was launched in 2007 aboard the PSLV and the spacecraft safely deorbited and returned to Earth 12 days later. This was the natural first step to prove the desired capability of safely recovering space travellers back.

While the INSAT series of satellites provide services in communications, weather and Earth observation, it was in the field of rural development that a new range of geo-synchronous satellites was conceived. The Department of Space and the Ministry of Rural Development partnered in 2000 to introduce the GRAMSAT (*Gram* is Hindi for village) programme aimed to transmit TV, CD-quality sound, data and internet over the communications network connecting state capitals to districts and rural blocks. The terrestrial grids were planned to be connected via communications satellites. Thus, was born the GSAT series of satellites that were based on the INSAT-2 design with six powerful transponders on a national beam for educational TV and two spot beams to transmit sound in four different languages.[29] Commencing with the launch of the GSAT-1 aboard the GSLV in 2001, a total of six GSATs were launched, including the last one, the GSAT-10, aboard Ariane, in September 2012. This constellation of satellites has, equally importantly, also augmented the communications services of the INSATs, by adding transponders in space. Indian geo-stationary satellites, that is, the complete series of INSATs and the GSATs, occupy GEO slots of 55, 74, 83 and 93.5

28. ISRO, "Telemedicine," accessed at http://www.isro.org/scripts/telemedicine.aspx, on October 17, 2012.
29. Harvey, et al., n. 13, p. 220.

degrees east longitude,[30] some of which have three or more satellites parked together, including a few obsolete ones.

In the field of satellites, ISRO announced on October 8, 2012, that it plans for 58 space missions in the next five years to place 33 satellites in orbit.

To encourage study of space sciences among students of the domestic universities, ISRO has invited partnerships for building satellites and then launched them on home-grown PSLVs.

THE YEARS AHEAD

In the ever changing global geo-political milieu, the nationalistic focus on self-reliance is not likely to be lost sight of. Towards this end, the immediate aim would need to be in the launch sector, by achieving success in the critical cryogenic technology that has so far eluded the indigenous GSLV-Mk II and then following it up with its technological successor, the GSLV-Mk III that would place a five-ton satellite in GEO — a programme that has already been approved by the government in 2002. This three-stage GSLV will be mightier and more powerful, with a launch weight of 630 tons, 200 more than the GSLV. Self-reliance in this core capability, besides the issues of pride and cost savings, would offer tremendous benefits by way of geo-political spin-offs.

In the field of satellites, ISRO announced on October 8, 2012, that it plans for 58 space missions in the next five years to place 33 satellites in orbit.[31] Besides just the numbers of satellites, it would be more prudent to look at the applications that are planned to be fielded. The INSAT and GSAT series to be launched in the years to come, would continue to add transponders in space to meet the burgeoning need of domestic communications as well cater to those of foreign partners. Equally important are service-based systems that are planned for the mid-term. One of the notable among them is the GPS Aided Geo-Augmented Navigation (GAGAN) system, a satellite-based

30. Committee on the Peaceful Uses of Outer Space, "Actual Situation in the Geostationary Orbit," 49th Session, Vienna, February 6-17, 2012, accessed at http://www.unoosa.org/pdf/limited / c1/AC105_C1_2012_CRP25E.pdf, on October 17, 2012.
31. "ISRO to Launch 58 Space Missions by 2017," October 8, 2012, accessed at http://www.satellitetoday.com/st/headlines/39643.html?hq_e=el&hq_m=2537808&hq_l=22&hq_v=7c49e30760, on October 25, 2012.

regional navigation service that is being fielded by the Airports Authority of India (AAI) and ISRO that aims to provide air traffic management and navigation over the Indian air space, making India the fourth in the world to do so. GSATs-8 and -10, with GAGAN payloads, are already in their GEO slots and provide better than seven-metre accuracy[32] while the third satellite to complete the constellation, the GSAT-9, is planned for launch in 2013-14. To be operational in 2014, GAGAN, with its enhanced accuracy, will not only make the skies and landings safer by providing by a three-dimensional approach operation but also enable less safety-spacing between two aircraft allowing three times more aircraft to fly. Better air space management is estimated to cut airline fuel costs by 20 per cent[33] providing for cheaper air travel. Even though designed primarily for civil aviation applications, GAGAN is scalable enough to provide far-ranging enhanced end-user services like agriculture, land mapping, emergency response, natural resources, mining and vehicle tracking.[34]

In yet another giant leap towards self-reliance, the Indian Regional Navigational Satellite System (IRNSS) is being fielded by ISRO. Approved in 2006, the project envisages a constellation of seven navigation satellites, three in geo-stationary and four in geo-synchronous orbits, providing 10 m accuracy over the mainland[35]. The first satellite of the IRNSS constellation, the IRNSS-1, is planned to be launched aboard the PSLV in 2013, while the full constellation is planned to be operational in 2014.[36] The project includes complete indigenous content in the space and ground segments as well as in the end-user receivers.

32. ISRO, "Future Programme," accessed at http://www.isro.org/scripts/futureprogramme.aspx, on October 26, 2012.
33. "Air Navigation System GAGAN to Help Jet Airways, Indian Airlines, Others to cut Fuel Cost by up to 20%," *The Economic Tim*es, October 8, 2012, accessed at http://articles.economictimes.indiatimes.com/2012-10-08/news/34323085_1_indian-skies-air-navigation-airlines-end, on October 26, 2012.
34. A.S. Ganeshan, ISRO, "GAGAN is Expected to Replace the GPS Receivers and Provide Data Integrity," February 2012, http://mycoordinates.org/gagan-is-expected-to-replace-the-gps-receivers-and-provide-data-integrity/, on October 26,2012.
35. A. Bhaskaranarayana, ISRO, "Indian IRNSS and GAGAN," presentation to COSPAR meeting at Montreal, July 15, 2008, accessed at http://www.oosa.unvienna.org/pdf/icg/2008/expert/2-3.pdf, on October 29, 2012.
36. n. 32.

The Space Vision 2025 strategy enunciates the use of a two-stage Reusable Launch Vehicle (RLV), called Avatar.

In its mid- and long-term visions, ISRO sees itself performing a stellar role in three fields. The first aims at lowering the cost of orbiting a satellite, which currently costs US$ 6,000-7,000 per kg on a PSLV/GSLV. The Space Vision 2025 strategy enunciates the use of a two-stage Reusable Launch Vehicle (RLV), called Avatar[37]. The first stage would be designed to shoot the payload to twelve times the speed of sound, separate and fly back to the launch pad, while the second stage continues onwards to orbit the satellite.[38] Avatar would weigh 25 tons and eventually bring down the cost of orbiting a one-ton satellite to US$ 67 per kg.[39] The second field for focus would be manned space flights. Buoyed by the success of the space Capsule Recovery Experiment-1 (SRE-1), the next step would be a two or three-man crew in a fully autonomous orbital vehicle on a 300-km LEO.[40] As per an agreement with Russia in 2008, an Indian cosmonaut will receive training on a Russian Soyuz flight in 2013, followed by an Indian-only three-man crew aboard a capsule launched by GSLV in 2015.[41]

The third sector involves active participation in the space sciences that centre around missions to the Moon and Mars, including manned ones. In the realm of exploring space beyond the Earth, Chandrayaan-1's remarkable success has bolstered ISRO's confidence in planning for Chandrayaan-2 to the Moon in 2013. Mangalyaan, a mission to Mars, that aims to place a scientific payload in orbit around the red planet, is also slated for end 2013.[42]

37. ISRO, "Space Vision India 2025," accessed at http://www.isro.org/vision.aspx, on October 29, 2012.
38. P. V. Manoranjan Rao and P. Radhakrishnan, *A Brief History of Rocketry in ISRO* (Hyderabad: Universities Press (India) Private Limited, 2012), pp. 318-319.
39. Susmita Mohanty, "Indian Space Programme," June 2008, accessed at http://www.earth2orbit.com/ pdf/ISRO.PDF, on October 29, 2012.
40. ISRO, "Future Programmes," accessed at http://www.isro.org/scripts/futureprogramme.aspx, on October 29, 2012.
41. K. S. Jayaraman, "India Plans First Manned Mission with Assistance from Russian Space Agency," *Space News*, February 2, 2009, p. 11.
42. Press Trust of India, "Manmohan Formally Announces India's Mars Mission," *The Hindu*, August 15, 2012, accessed at http://www.thehindu.com/sci-tech/science/article3775271.ece, on October 31, 2012.

CONCLUSION

At the global geo-strategic level, it would be prudent for India to focus on two growth areas that will impact its stand in the international arena in the years to come. First and foremost is the field of international relations, where the need emphasises a larger and an all-encompassing Indian presence in the global field of partnerships and collaborations. This could be realised by a two-pronged strategy. The first should aim at joint ventures with countries that have modest budgets but relatively larger space ambitions. Such countries should be proffered the entire range of services that Antrix, the marketing arm of ISRO, currently engages in, with a view to project and expand the country's "soft power". The second prong should aim at bilateral and multilateral partnerships with nations that have already established themselves as major players in space, with the aim of sharing emerging technologies and trends for mutual benefit and energising cooperative ventures in space sciences and in space exploration missions beyond the Earth.

The second growth area for the indigenous space industry lies within the national realm, that of safeguarding the country's space interests. Ranking sixth in the world in terms of space budget and technological capabilities, India can ill afford to ignore the practical aspects of ensuring the security of its space infrastructure, especially of its space-based assets. It would serve the Indian interest well to remain actively engaged in the international fora on discussions and negotiations on space security, with a view to remain abreast of the dynamic and ever-evolving power balance. This essay concludes with the thought that it would well serve India's growth narrative to have a comprehensive space security policy in place, from which should evolve key drivers that should chart the course for a national space security framework.