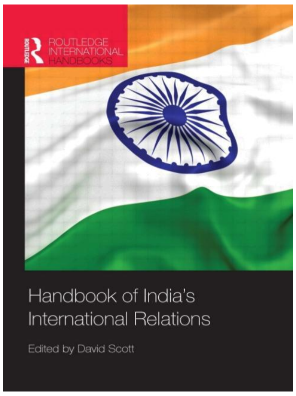

Handbook of India's International Relations

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India and outer space

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India and outer space

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Introduction

After the USSR and the USA heralded the dawn of the space age in 1957, almost all countries took it for granted at the outset that major space programmes were beyond their financial scope. Even the industrialized nations of Europe, with the possible exception of France, shared this outlook. The Indian Prime Minister, Jawaharlal Nehru, stated in early 1960 that although India was 'high up in the list of advanced countries' in the field of atomic energy, it could not go far in space exploration because of its want of resources.[1] Yet the appeal of space remained strong, and this chapter sets out to analyse the appeal and implementation of such drives for India.[2]

Setting up India's space programme

In India the appeal of space was largely confined to the scientific community engaged in the various branches of upper atmospheric and geophysical sciences. As early as 1956 the physicist Vikram Sarabhai, who had played an active role in shaping the international science programme International Geophysical Year (IGY) in 1957–58, had called for establishing a research base in 'rockets and missiles', and from 1958–59 was engaged with the problems of setting up an organized space programme in the country. With international co-operation in the peaceful uses of outer space emerging high on the agenda of the UN and with the National Aeronautic and Space Administration (NASA) of the USA making concrete proposals for co-operation in space research at the third meeting of the Committee on Space Research (COSPAR) in early 1960, policy-makers in India began to think seriously about the relevance of space research for a developing country like itself. Convinced that space research and space technology had practical applications with significant implications for agriculture, education, industry and other areas of scientific endeavour,[3] that 'the subject of peaceful uses of outer space is likely to be of increasing importance in the near future',[4] and that it was a field in which international co-operation on an extensive scale may be brought about, the Government of India in August 1961 entrusted the Department of Atomic Energy (DAE) with the responsibility of conducting space research and its peaceful applications. In early 1962 the DAE set up the Indian National Committee for

Space Research (INCOSPAR) to help formulate and execute policies for peaceful uses of outer space. With the appointment of Sarabhai as the chairman of this committee, Indian space plans began to take concrete shape.

INCOSPAR initially planned to set up a programme of meteorological rocket sounding in collaboration with NASA, but when international scientific unions such as COSPAR as well as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) came up with the proposals to accord UN sponsorship for international sounding rocket facilities in scientifically critical locations, India by virtue of its location on the geomagnetic equator offered to host such a facility. With the active support and assistance of the principal space powers, the USA and USSR, as well as France and the United Kingdom, India then established an international sounding rocket facility, the Thumba Equatorial Rocket Launching Station (TERLS), which became operational in November 1963 with the launching of a US *Nike Apache* rocket carrying a sodium vapour payload supplied by France.

Although India began its foray into space with a scientific research programme, from its inception the main thrust was on realizing the practical benefits of space research through self-reliant development of space technology. Homi J. Bhabha, the head of the DAE underscored this at a seminar organized by INCOSPAR in early 1963, when he said:

> Another and perhaps the most important reason for India going into space research was that there are many areas in which it is likely to yield results of great practical interest and importance in the near future, and we would once again be falling behind the advanced countries in practical technology if we were not to look ahead and prepare to take advantage of these new developments also […] If we do not do so now, we will have to depend later on buying know-how from other countries at much greater costs.[5]

In the latter half of the 1960s the basic infrastructure necessary for a broad-based space programme was put in place under the leadership of Vikram Sarabhai, who was appointed head of the DAE upon the untimely death of Bhabha in 1966. Sarabhai also broadly outlined the objectives of the space programme. While the broad goals of the programme were to enable the country to leap-frog to a higher level of social and economic development, the specific social and economic objectives of the space programme related to the use of orbiting satellites for communications, in respect of telecommunications and television, meteorological observation and forecasting, and remote sensing of natural and renewable earth resources.

As in other national endeavours, 'self-reliance' was the main thrust of the strategy employed in the accomplishment of India's space policy objectives. The accent on attaining self-reliance in space technologies was further reinforced by the difficulties in acquiring critical space technologies from the industrialized nations. In early 1965, when India, which had already signed an agreement with Sud Aviation of France for the licensed production of a *Centaure* sounding rocket, approached the USA for the *Scout* rocket technology, the USA saw it as a step in the direction of acquiring ballistic missile capability and refused to supply the rocket technology. For a country like India, which had been seeking to maximize its independence in the international system, the denial of rocket technology raised concerns over the dependence of a national programme on launch services provided by advanced space powers. As Sarabhai pointed out in August 1968, in his address to the UN Conference on the Exploration and Peaceful Uses of Outer Space:

> The political implications of a national system dependent on foreign agencies for launching a satellite are complex. They are not negative in the present day world only in the context

> of the coming together of the national interest of the launcher and the user nations. As long as there is no effective mutuality or interdependence between the two, many nations left with the ground segment would probably feel the need for some measure of redundant capability under complete national jurisdiction.[6]

The striking aspect here was his focus on the political national sovereignty considerations felt by India in relation to outside states. It was all part and parcel of India's wider concerns for 'strategic autonomy'.

In the latter half of the 1960s, therefore, the acquisition of indigenous capabilities in the entire spectrum of space technology, launch vehicles, satellites and supporting ground technology for space applications became a fundamental feature of the Indian space effort. The strategy that Sarabhai laid out for attaining self-reliance in space technology was one that combined strong domestic research and development (R&D) effort with import of technology from abroad. He stressed that leaders at the operative level of the programme must be committed and willing to stretch themselves to the fullest before asking for help from outside.[7] Guided by this principle, he developed the space programme with international collaboration by forging relationships with space organizations in the USA, France, the United Kingdom and the USSR.

The Space Science and Technology Centre (SSTC) that was established at Veli Hills in 1966–67 formed the core around which an extensive research and development infrastructure for designing, developing and constructing rockets and satellite payloads and instrumentation began to take shape. In the area of rocketry, with the basic infrastructure necessary for rocket construction becoming available from the licensed production of the *Centaure* sounding rocket, the DAE sought to acquire indigenous competence in the field by developing a series of one-stage and two-stage sounding rockets, called the *Rohini* series. Beginning with the *Rohini-75*, a small rocket weighing only 10 kg that was launched in November 1967, a number of sounding rockets, each with increasing diameter and payload capacity, were developed and launched. In the area of satellite communications India gained experience in building and operating ground satellite communication terminals from the Experimental Satellite Communication Station (ESCES) that was set up with funding from the UN Development Programme (UNDP). The DAE also organized experiments to demonstrate the development potential of television as well as remote sensing techniques, and conducted a series of system studies to define the overall system configuration for the satellite-based television broadcasting experiment that it proposed to conduct using NASA's *ATS-6* satellite. As a result of these activities, space research that was initiated by a small group of scientists expanded to include over 2,500 scientists from some 18 major institutions, universities and organizations by the end of the 1960s.

Institutionalized programme

Equipped with the basic capabilities to produce its own two-stage sounding rockets and sophisticated scientific payloads, in the early 1970s the DAE sought to acquire further capabilities to construct communication and remote-sensing satellites, as well as launch vehicles to orbit such satellites, by developing experimental satellites and launch vehicles. With space research and technology poised for a new phase of development, the Government of India considered it 'necessary to set up an organization, free from all non-essential restrictions or needlessly inelastic rules, which will have responsibility in the entire field of science and technology of outer space and their applications'.[8] Consequently, in June 1972 the Government set up a new policy-making body, the Space Commission, and handed over the subject of space research and its utilization (which had been held by the Department of Atomic Energy since

1961) to a newly created Department of Space (DOS). The DOS, directly under the charge of the Prime Minister, was made responsible for the execution of space activities in the country through the Indian Space Research Organization (ISRO), which had been set up in 1969. With this, the Indian space effort that began as an informal activity taken up by the DAE was transformed into an institutionalized programme with an assigned budget, time-bound goals, and specific projects in space applications and technology.

The newly established DOS initially focused on developing the necessary experience to enable the design, manufacturing and operational teams to make the best use of the technology available. To this end, it conducted a series of experimental missions in the fields of satellite technology, launch vehicles and space applications. In the area of satellite applications the DOS/ISRO gathered experience in running a satellite-based instructional television system by conducting a year-long experiment, the Satellite Instructional Television Experiment (SITE) during 1975–76. It used NASA's *ATS-6* geostationary satellite to beam educational television broadcasts directly to community systems in over 2,400 villages. The following year, the DOS initiated another preparatory experiment, the Satellite Telecommunications Experiment Project, using the Franco-German communications satellite *Symphonie*. This two-year (1977–79) experiment enabled the country to gather experience in operating and using a geostationary satellite for domestic telecommunications. ISRO also conducted experiments in remote sensing utilizing its own experimental satellites (*Bhaskara-I* and *Bhaskara-II*), which were launched by the USSR in 1979 and 1981. It built a station in Hyderabad to receive data from US *Landsat* earth resources satellites. This station later became the base of the Indian National Remote Sensing Agency (INRSA).

In the area of satellite technology ISRO built its first scientific satellite (*Aryabhata*), two experimental earth observation satellites (*Bhaskara-I* and *Bhaskara-II*) and an experimental communication satellite (*APPLE*—Ariane Passenger Payload Experiment) for launch aboard a test flight of the European Space Agency's *Ariane* launch vehicle in 1981. In building Indian capabilities in satellite technology, the USSR played a vital role. Both the *Aryabhata* and the *Bhaskara* satellites were developed by joint teams of Indian-Soviet scientists and engineers. An important feature of these experimental satellite projects was that they were not modelled after the early generation satellites of the space powers, but represented state-of-the-art technology.[9] The *APPLE* satellite, up-to-date in some of its features, incorporated the three-axis stabilization technology that was mastered by the USA and Europe only in the mid-1970s.

In the area of launch vehicles, in 1973 ISRO took up the development of a four-stage launch vehicle, the *SLV-3*. Between 1979 and 1983 ISRO conducted four experimental launches of the *SLV-3*, a small 23-metre solid-fuelled experimental rocket. Although the first launch of the *SLV-3* ended in failure, the second launch in 1980 succeeded in placing a small scientific satellite weighing 40 kg into near earth orbit. With this, India became a member of the select group of space-faring countries, joining the USSR, USA, France, People's Republic of China and the United Kingdom.

Since the early 1980s, which is generally described as the maximum spin-off stage of the Indian space programme, ISRO operationalized its space services, initially by utilizing the multifunctional Indian National Satellites (INSATs) constructed abroad, and later by developing its own INSAT and Indian Remote Sensing (IRS) satellites. ISRO also acquired indigenous capabilities to place its own remote sensing and communication satellites into sun-synchronous and geo-synchronous orbits, respectively. The INSAT system, which was established with the commissioning of the *INSAT-1B* satellite in 1983, initiated a major revolution in the communications sector. In 2010 a constellation of 11 indigenously built INSAT satellites with a total of about 211 transponders in the C, Extended C and Ku-bands provided services to not only sustain the communication revolution in telecommunications and television broadcasting, but also to play a vital role in weather forecasting, disaster warning, and search and rescue operations. The IRS satellite system, which became operational with the launch of *IRS-1A* in 1988, had 10 IRS satellites in operation in 2010, the largest civilian remote sensing satellite constellation in the world. The images provided by these satellites in a variety of spatial resolutions, spectral bands and swathes are being used for several vital applications covering agriculture, water resources, urban development, mineral prospecting, environment, forestry, drought and flood forecasting, ocean resources and disaster management.

In the 1990s India also acquired the capability to place its remote sensing satellites in sun-synchronous orbit. With the *SLV-3* establishing indigenous technologies relating to propulsion, aerodynamics staging, structural engineering, vehicle control and guidance, and mission management, in the early 1980s ISRO took up the development of the Polar Satellite Launch Vehicle (PSLV) to access the sun-synchronous orbit. The PSLV, a vehicle 10 times bigger than the *SLV-3*, incorporated complex technologies such as the strap-on motors and close-loop guidance system. Validating these technologies by constructing the Augmented Satellite Launch Vehicle (ASLV), ISRO carried out three developmental flights of the PSLV, beginning with its first launch in September 1993. With the first operational launch of the PSLV in September 1997 succeeding in putting a 1,250-kg remote sensing satellite, the *IRS-1D*, into sun-synchronous orbit, India's dependence on Russian launchers for orbiting its remote sensing satellites ended. With several improvements being made in subsequent versions of the PSLV, especially those involving thrust, efficiency and weight, the PSLV emerged as a workhorse for launching a variety of satellites into low earth- and sun-synchronous orbits, as well as unmanned lunar probes.[10] Its latest incarnation, the *PSLV-C15*, was successfully tested in July 2010 to launch an Algerian satellite, leading an Indian commentator to state that, 'this launch needs to be viewed beyond commercial interests […] with this launch it could be said that India has started using "space diplomacy" as a foreign tool'.[11]

The technological significance of PSLV also lies in the fact that it feeds directly into the first and second stages of the more powerful Geo-synchronous Satellite Launch Vehicle (GSLV) for launching communication satellites into higher orbits. The development of the GSLV with a cryogenic upper stage that was taken up in the late 1980s suffered a setback when Russia, coming under intense pressure from the Missile Technology Control Regime (MTCR), abrogated the 1991 deal to transfer cryogenic engine technology. The indigenous efforts to develop this engine began in 1996. In the meantime, ISRO used the cryogenic engines that were supplied by Russia without transferring technology, under the deal that was renegotiated with Russia in 1994. The first GSLV (*Mark 1*) was launched in 2001, putting an Indian satellite into orbit. Four more GSLV launches followed in 2003, 2004, 2006 (a failure) and 2007. In April 2010 the first flight of the *GSLV-D3 (Mark 2)*, incorporating the indigenously built cryogenic upper stage, ended in failure, pushing back ISRO's plan to attain complete self-reliance in orbiting its INSAT satellites, though a further launch attempt was envisaged for 2011.

Acquisition of technological capabilities

Although international co-operation played an important role in establishing the base for sounding rockets, satellite applications and satellite manufacture, the main thrust of Indian space policy has been on gaining indigenous competence in 'the essential components of space technology'.[12] This was prompted by the difficulties in acquiring critical space technologies from the industrialized nations. In the years after India conducted a Peaceful Nuclear Explosion (PNE) in 1974, its nuclear programme encountered problems due to stringent export control exercised by the industrialized nations. Anticipating similar problems with space technology, the DOS under the chairmanship of Satish Dhawan (1972–84), began to strategically plan and organize indigenous technology development.[13] Major initiatives to strengthen the domestic capabilities of industry and other national institutions were taken up. These included using existing capabilities as well as creating new capabilities in industry through technology transfer and technical assistance.

To begin with, the space programme had little or no industrial base to support it. In the 1960s much of the work was done in-house, including the development of equipment and hardware fabrication. In the 1970s, as a result of the expansion of activities associated with experiments in space technology and applications, ISRO made deliberate and sustained efforts to promote the participation of domestic industry in the space effort by instituting technology transfer. However, only a few industries accepted major responsibilities or committed themselves to the space projects. Throughout the 1970s industry's collaboration with the space programme was largely confined to the establishment of ground-based facilities, although it took up some fabrication work related to satellites and the *SLV-3*. With the projects taken up by ISRO in the 1980s (satellite services and development of operational satellites and launch vehicles) requiring gigantic facilities and new technologies, large industrial back-up became a necessity. However, the industry was reluctant to take up ISRO projects or absorb the know-how for products and processes generated by the space programme. Studies conducted by ISRO's research centres in the early 1980s identified the factors limiting the industry's participation in space projects as follows: the low volume and less repetitive jobs of ISRO; the rigorous quality and time standards set by the space establishment; and hesitation of industry to experiment with new materials and processes.[14] In an effort to lower the costs of the programme and share the burden of hardware and technical work with industry, DOS/ISRO adopted a range of policies such as aggressive promotion of technology transfers from ISRO laboratories and offering consultancy services to industry,[15] discouraging the Government from adopting liberal import policies,[16] and designing space products and services not only to meet domestic requirements but also international market requirements.[17]

As a result, by the end of the 1980s Indian industries emerged as sub-contractors for various ISRO projects. In the process ISRO's budget spent through the Indian industrial sector rose from 1% in the 1970s to over 60% by the 1990s. By summer 2010 over 500 industries were contributing a range of products and services to the Indian space effort.[18] With most of the fabrication work on rockets and hardware and about 20%–30% of fabrication work on satellites subcontracted to industry, ISRO emerged mainly as a research and development organization with end-to-end capability, from conceptualizing to realizing the space system—satellites, launch vehicles and associated ground systems.[19]

The expansion phase

Having acquired the capability to design and develop its own satellites and launch vehicles, and established the space systems (INSAT and IRS) that had become an important part of the country's developmental infrastructure, since the 1990s India has sought to commercialize space technologies and services as well as strengthen space sciences by taking up planetary missions. As has been seen, in the 1980s the DOS/ISRO began designing its products to meet the domestic and international market to stimulate the participation of Indian industry in the space endeavour. The forced indigenization efforts since the 1980s, as a result of the restrictions on technologies and components imposed by the MTCR and the escalation of the cost of space projects, have strengthened the urge to commercialize. In the 1990s India entered the international market to offer its products and services by establishing Antrix Corporation Limited as a commercial wing of the ISRO in 1992. Antrix initially began its earnings by providing services and data, but with the PSLV launcher proving its reliability and cost efficiency, Antrix began offering launch services for accessing low and polar orbits. Since 1999, when Antrix first launched a third-party satellite (the 100-kg South Korean satellite *Kistsat-3* and 45-kg German *DLR Tubsat*) along with ISRO's own, it has launched over 22 small and large foreign satellites, the heaviest one so far being the 350-kg Italian satellite *Agile* in 2007.[20] It has also begun to supply satellite subsystems and has established an alliance with Europe's leading satellite manufacturer, EADS Astrium, to jointly manufacture communication satellites using the INSAT Bus for selling in global markets.

Although India has been carrying out research in the fields of astronomy, atmospheric sciences and long-term climate research using sounding rockets, balloons and scientific satellites, in the early years of the new millennium the DOS/ISRO embarked on an ambitious planetary exploration, the flagship mission of which was *Chandrayaan*. This development was widely seen as a departure from the DOS's original vision of an application-driven programme, even if the mission 'can provide impetus to science in India, a challenge to technology and, possibly, a new dimension to international cooperation'.[21] The *Chandrayaan* mission, launched in October 2008, consisted of a lunar orbiter and an impactor. In addition to five indigenous instruments, the mission included six scientific payloads from NASA, the European Space Agency and Bulgaria. The mission was instrumental in the ISRO-NASA joint discovery of water molecules on the moon's surface, unattained by any of the previous missions of such nature. The follow-on mission, *Chandrayaan-2*, proposed to be launched in 2013, is being jointly developed with Russia. It will have an Indian orbiter and Russian lander and rover, and opportunities for scientific instruments from other countries. Meanwhile, the ISRO is also exploring the possibility of setting up an intermediate base on the moon so that it can help the space agency to explore other planets such as Mars and Jupiter from that platform.

Indian space programme: the security dimension

Space technology and its applications have enabled India to develop more autonomy in international relations and acquire greater control over its economy, as well as capacity for autonomous development. Equally important, they are providing a number of technology-related strategic choices to deal with the national security challenges facing the country, in which 'space security' has become a concern for India.[22]

Despite its civilian thrust, the Indian space programme had to contend with a significant military push. The diffusion of nuclear and advanced conventional weaponry in the country's immediate neighbourhood, particularly Pakistan and China with which India has had adverse relations, contributed to these pushes and pulls.[23] The first major push came in the mid-1960s when, in response to the nuclear explosion conducted by China in October 1964, the Indian Government revised its nuclear policy and reserved the option to go nuclear. In such a context, the nascent space programme gained wider support, as space activity came to be seen as an important element in the technological base for not only economic security but also military security.[24]

The continuing nuclear testing by China and advances made by that country in rocketry kept alive the debate on India's nuclear option and strengthened the advocates of military use of space technologies. In the 1970s the military potential of the civilian space programme came into sharper focus during the debate on the country's nuclear posture. That debate was sparked-off by the launch of a satellite by China in April 1970, a development which was widely seen in

India as evidence of the growing nuclear muscle of China. The demand for the nuclear deterrent capability vis-à-vis China was revived and gained widespread support. At a symposium in New Delhi called to review China's success in space in May 1970, scientists, defence experts, economists, political analysts and members of parliament decided by an overwhelming majority that the Government should revise its nuclear policy and produce the bomb immediately. When the Government of India outlined to the public the profile of a 10-year nuclear energy *and* space development programme in July 1970, which included among other things the development of an experimental satellite launch vehicle, the 'bomb-for-security' lobby saw it as a firm step towards nuclear weaponry. Although a separate missile development programme, the *Devils Programme*, was initiated in the defence sector in 1970–71, it was the space programme that had already established a modest infrastructure in rocketry, which continued to attract the attention of the 'bomb-for-security' lobby.

In this context, those who wanted the immediate or early establishment of nuclear deterrence vis-à-vis China called for accelerating the space launch vehicle project, the *SLV-3*, so that it could be developed into an Intermediate Range Ballistic Missile (IRBM) with the addition of an improved guidance system. Others who wanted a balanced development of rocketry called for close co-ordination between the missile development efforts in the defence sector and the civilian space programme, and between the DOS and defence ministry.

In the early 1980s, taking advantage of the growing technological capabilities within the country, the Government of India decided to establish design and production capabilities for guided missiles within the country to meet the perceived immediate and future needs of the armed forces of the country. That decision was strengthened by the belief that achieving self-reliance in critical technologies and weapon systems in a selective manner would not only meet the country's military security requirements but also reinforce and strengthen the country's capabilities in 'dual-use' technologies and, therefore, its development of high technology. The Integrated Guided Missile Development Programme (IGMDP) set up under the aegis of the Defence Research and Development Organization (DRDO), the primary source of all defence R&D within the country, was charged with the task of developing a variety of missiles. Utilizing the missile R&D base that was already present in the DRDO, and deriving sustenance and strength from the industrial and technological infrastructure established by the civilian space programme, the IGMDP achieved quick results. Within a short span of seven years the IGMDP developed a variety of guided missiles and established the country's capability for indigenous production of long-range ballistic missiles. Several of these missiles, including the nuclear-capable *Prithvi* and *Agni* missiles, have already been inducted into the armed forces since the 1990s, even as efforts are on to develop ballistic missiles with a longer range.

Conclusions

Since the late 1990s a new dimension to the military use of space technology has emerged on the security horizon. This arose as a result of the increasing use of space assets to complement and support military functions on the one hand, and the development of ballistic missile defence systems on the other. With the USA demonstrating the effectiveness of space assets for aiding military operations in the first Gulf War in 1991, the military functions of space assets are becoming increasingly attractive to space powers. At the same time, the incentive to deny the benefits of space assets to their adversary has also become strong among some space powers. The USA, Russia and China have proven capability to destroy space assets; several others have the capacity to disable these space assets through a range of technologies. In this scenario, the demand for military use of space technologies has gained ground. The Indian Air Force (IAF), which has been seeking to establish an Aerospace Command to leverage space technologies, received support from the Parliamentary Standing Committee on Defence in 2004. In early 2007, soon after China carried out a test in which it used a missile to destroy an old satellite in orbit, the IAF chief announced that India would build an Aerospace Defence Command (ADC) aimed at preventing possible attacks from space. Military analysts say that the Indian project will probably replicate the North American Aerospace Defence Command (NORAD), set up by the USA and Canada, which detects and tracks man-made objects in space.

Even as the IAF is pressing for the military use of space, the anti-satellite (ASAT) test by China in January 2007 added a new dimension to space security—the possibility of the weaponization of space. While there are concerns over the safety and security of the space assets that the country has so painstakingly built,[25] there is no consensus on how best to deal with the issue. On the one hand, the Minister of External Affairs, Pranab Mukherjee, warned that the international community was 'treading a thin line between current defence related uses of space and its actual weaponization', and called on 'all States to redouble efforts to strengthen the international legal regime for the peaceful use of outer space'.[26] At the same conference, Aerospace Power in Tomorrow's World, the Minister of State for Defence Production, Rao Inderjit Singh, said that the 21st century would belong to aerospace power and urged the creation of a 'vibrant' aerospace industry in India to create the necessary synergy: 'a robust civil programme can be used to transform the IAF into a dominant space power'.[27] On the other hand, the Minister of Defence, A.K. Antony, expressed concern about the emergence of anti-satellite weapons, a new class of heavy lift-off boosters and an improved array of military space devices in the neighbourhood, and wondered how long India could 'remain committed to the policy of non weaponization of the outer space'.[28] Meanwhile, the *Space Security Report* of the IDSA-Pugwash Society Working Group on Space Security noted with concern that 'India is one of the few countries where space capabilities have been developed primarily for developmental and societal progress with almost no dedicated capacity to meet the needs of the military or security establishment', and warned that this could 'prove to be a major vulnerability'.[29] Which of these approaches will eventually come to prevail in the near future will depend on how India defines its core security interests and advances in the field of space research. It will equally depend on how the other space powers, with their different levels of development of space and levels of assets, arrive at a consensus on space security.

Notes

1 Nehru cited in the *New York Times*, 6 January 1960.

2 See S. Reddy, 'India's Forays into Space. The Evolution of Its Space Programme', *International Studies*, Vol. 45, No. 3, 2008; K. Murthi and H. Madhusudan, 'Strategic Considerations in Indian Space Programme—Towards Maximising Socio-economic Benefits', *Acta Astronautica*, Vol. 63, No. 1–4, 2008; P. Bagla, 'India in Space: No Dream is Too Big for Us', *Economic Times*, 18 July 2010.

3 S. Dhawan, 'Manned Flight', *Seminar*, No. 5, November 1960. See also D. Kothari and A. Nagarajan, 'Exploration Prospects', *Seminar*, No. 5, November 1960.

4 Government of India (Department of Atomic Energy), *Annual Report 1960–61*, Mumbai (Bombay): Department of Atomic Energy, 1961, p.20.

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7 K. Chowdhary (ed.), *Science Policy and National Development: Vikram Sarabhai*, Delhi: Macmillan, 1974, p.30.

8 Cited in M. Rajan, *Indian Spaceflights*, Delhi: Publications Division, 1985, p.134.

9 The *Aryabhata* was as sophisticated as many satellites that were being flown by other countries at that time. Incorporating more than 12,000 active and passive electronic components in addition to 20,000 solar cells, *Aryabhata* was also the heaviest first launch ever attempted by any country. U. Rao, 'An

Overview of the Aryabhata Project', in U. Rao and K. Kasturirangan (eds), *The Aryabhata Project*, Bangalore: Indian Academy of Sciences, 1979.

10 A modified version of the PSLV, with stretched strap-on boosters, was used in October 2008 in the *Chandrayaan* mission to the moon, which included an orbiter and an impactor.

11 A. Lele, 'Successful Launch of PSLV-C15', *IDSA Comment*, 16 July 2010. In addition, it carried two Indian satellites, one Canadian satellite and one Swiss satellite.

12 S. Dhawan, 'Application of Space Technology in India', in *Prof. S. Dhawan's Articles, Papers and Lectures*, Bangalore: ISRO, 1997, p.134.

13 A. Baskaran, 'From Science to Commerce: The Evolution of Space Development Policy and Technology Accumulation in India', *Technology and Society*, Vol. 27, 2005, p.166.

14 'Indian Industry's Space Trek', *Business Standard* (New Delhi), 12 January 1986.

15 Under the Technology Consultancy Scheme initiated in 1982, ISRO began transferring product and process technologies covering a wide range of categories. Of the 150 technologies transferred, around 62% cater to spin-off applications and around 32% to the space applications market.

16 For instance, in January 1982 the DOS drew the attention of the Scientific Advisory Committee to the Cabinet to the impact of technology import policies on generation and utilization of domestic science and technological capabilities, and called for checking technology dumping by foreign countries, L. Sharma, 'Indigenous Efforts Get Raw Deal', *Times of India*, 26 January 1982.

17 S. Dhawan, the Chairman of the Space Commission, for instance, urged the industry to take part in evolving space technologies by pointing to the growing interest of many developing countries in remote sensing technologies and the opportunities for export of know-how, S. Dhawan, 'The 18th Sriram Memorial Lecture', in *Prof. S. Dhawan's Articles, Papers and Lectures*, op. cit., p.129.

18 U. Sankar, *The Economics of India's Space Programme – An Exploratory Analysis*, New Delhi: Oxford University Press, 2007.

19 M. Nair, 'Empowering the Bottom of the Pyramid from the Sky: A Case for Satellite-based Services', *IIMB Management Review*, Vol. 17, No. 13, 2005.

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21 DOS/ISRO Chairman, K. Kasturirangan, quoted in P. Chakravarty, 'India Craves the Moon to Crown its Space Odyssey', *Space Daily*, 12 March 2000, www.spacedaily.com.

22 K. Singh, 'India's Endeavour to Attain Space Security Asset', *Articles*, No. 3071, 15 March 2010, www.ipcs.org.

23 O. Marwah, 'Indian Nuclear and Space Programmes: Intent and Policy', *International Security*, Vol. 2, No. 2, 1997.

24 For instance, *Science and Culture*, an influential journal in science policy circles, observed that 'even without a bomb but with well-developed indigenous rockets and missile technology, electronics and radar technology, we can to some extent claim a feeling of adequacy in future situations that may arise', in 'China Joins Atomic Club: What Should India Do?', *Science and Culture*, Vol. 30, No.10, October 1964.

25 At a modest estimate, the value of India's space assets, in space and on the ground, is about Rs.100,000 crores or US $25,000m.; see K. Kasturirangan, 'The Emerging World Space Order', in A. Lele and G. Singh (eds), *Space Security and Cooperation*, New Delhi: Academic Foundation, 2009, p.33.

26 P. Mukherjee, 'Address by EAM at the Inaugural Session of the International Seminar on "Aerospace Power in Tomorrow's World"', 4 February 2007, meaindia.nic.in.

27 Singh cited in 'Preserve Outer Space from Weapons: India', *INS News*, 4 February 2007, news.boloji.com.

28 R. Rao, 'Will India Prepare for Space War?', *Article* (IPCS), No. 3038, 7 January 2010.

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