# Space the Next Frontier: Opportunities and Challenges for India

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**Abstract**

*Use of space has fast spread to countries across the globe with enormous implications for security since each state seeks to develop offensive as well as defensive capabilities in space to pursue its security and other interests. India, too, was quick to recognise the potential of space exploration in the development of the country. With a modest start in year 1967 involving launch of first indigenously built sounding rocket from Thumba, the Indian space program has come a long way. The Indian space program has been a civilian one since its inception. With the growing dependence of the armed forces on space-based assets the military applications of this technology cannot be ignored. With each passing day the reliance on space assets is increasing manifold. It is important not only to launch more satellites to meet the growing demand of civilian use but also to meet its military applications. While it is essential to have adequate space assets to meet the ever-increasing requirements of communications, it is prudent to develop an effective anti-satellite weapon system as deterrence against any threat to these space assets. The article argues that if India is to maintain itself as a credible military power into the 21st century, it must exploit this medium.*

*"Expand on both sides as it is a Quote and not part of Abstract is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the moon or the planets or manned space-flight. But we are*

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*convinced that if we are to play a meaningful role nationally, and in the comity of nations, we must be second to none in the application of advanced technologies to the real problems of man and society."*

*Dr Vikram Sarabhai*

**Introduction**

Mankind has always been fascinated by what lies above them. The quest to explore this sphere has led to various inventions and discoveries over the decades. Space as a medium for exploration has enthralled many and has been articulated in fantastic fictional as well as ancient mythological stories. From the invention of the hot air balloon, man has come a long way and now there are even arguments that the next war will not be fought on ground but in space.

The space age and practical astronautics commenced with the launching of Sputnik-1 by the Soviet Union in October 1957, and the subsequent formation of the National Aeronautics and Space Administration (NASA) in the US in 1958. During the next two decades, more than 1600 spacecraft of all varieties were launched, mostly in earth orbit. By 1986 several thousand objects, mostly spent upper stages of space-launch vehicles, and inert spacecraft were circling the earth, and operational spacecraft numbered about 300. Manned and unmanned space probes have provided a great new source of scientific data on the nature and origin of the solar system and the universe. Moreover, many practical benefits have been derived from earth-orbiting satellites, including improved global communications, weather forecasting, navigational aids, reconnaissance of the earth's surface for the location of mineral resources, and for military purposes.

Military use of space started with the launch of an American reconnaissance satellite in 1960. Since then, the benefits from the space-based support operations were realised quickly and these operations were extended to surveillance, navigation, communication, and weather monitoring. Use of space has fast spread to countries across the globe with enormous implications for security since each state seeks to develop offensive as well as defensive capabilities in space to pursue its security and other interests.

India, too, was quick to recognise the potential of space exploration in the development of the country. To India's credit, she has concentrated her efforts on civilian applications of space technology to make economic and social improvements. With a modest start in year 1967 involving launch of first indigenously built sounding rocket from Thumba, the Indian space program has come a long way. In the past four decades, India has launched about 100 satellites for various scientific and technological applications like communication, meteorological observation, telemedicine, tele-education, disaster warning, radio networking, search and rescue operations, remote sensing, and scientific studies of the space. The Indian space program has been a civilian one since its inception. With the growing dependence of the armed forces on space-based assets, the military applications of this technology cannot be ignored. If India must maintain herself as a credible military power into the 21st century, it must exploit this medium.

## Growth Trajectory of Indian Space Technologies

India launched its first indigenously built satellite, *Aryabhatta,* on 19 April 1975 on board a Soviet Cosmos 3-M rocket. This was followed by *Bhaskara-1* in June 1979 and *Bhaskara-2* in November 1981. India then launched indigenous experimental satellites, Rohini-2 and Rohini-3 after initial failures. In late 1980s, India developed two main satellite systems, Indian Remote Sensing (IRS) system and Indian National Satellite System (INSAT), and two launch vehicles, the Polar Satellite Launch Vehicle (PSLV) and Geosynchronous Satellite Launch Vehicle (GSLV). On the way, Indian Space Research Organisation (ISRO) faced many failures, but it learnt quickly and came out stronger post every failure. Since its first launch in 1975, ISRO has sent more than 100 satellites into orbit including a few on behalf of foreign customers.

**Indian Remote Sensing System.** Indian scientists, like Sarabhai and Professor PR Pisharoty, realised the potential of remote sensing in India. India is affected by natural disasters on a regular basis and the lack of forewarning in 60s and 70s caused innumerable losses of life along with adverse effect on the economy. This prompted Indian scientists to develop means for remote sensing and earth observation satellites to provide early warning of the impeding disasters. Starting with IRS-1A in March

1988, a series of IRS satellites have been launched. Presently there are almost 30 remote sensing satellites in operation, making the IRS system the largest civilian remote sensing satellite constellation in the world. The data from these satellites is utilised for several applications including land use/cover mapping for agro-climate zone planning, wasteland mapping, forest cover mapping, wetland mapping, crop acreage and production estimation, coastal zone regulation mapping, natural resources information system, etc.

**Indian National Satellite System (INSAT).** The first generation INSAT series of satellites was constructed in early 80s with the help of Ford, a US company, since India lacked indigenous capability in construction of heavy satellites. The first of the INSAT series satellites was launched on 30 August 1983. During the next two and half decades, India launched 24 satellites. Presently there are 11 active satellites with 175 transponders on board, making the INSAT system one of the largest domestic satellite communication systems in Asia-Pacific Region. The services provided by these satellites include telecommunications, weather forecasting, disaster warning, distant education, telemedicine facilities, and Search and Rescue operations.

**Satellite Launch Vehicle (SLV).** Indian scientists gained experience while working on the Nike-Apache and Centaur rockets supplied by the US and France respectively. This experience was used to develop the indigenous Rohini series of rockets in the mid-1960s. Later, under the aegis of Dr APJ Abdul Kalam, India developed the first indigenous launch vehicle named Satellite Launch Vehicle (SLV). Three of the Rohini series of satellites were launched with the help of SLV during the period 1979-83. Having tasted success with the SLV in launching small satellites, ISRO commenced development of Augmented Satellite Launch Vehicle (ASLV) and PSLV. The initial two flights of ASLV were failures while the later two flights successfully launched the *Rohini Satellite Series* in the year 1992 and 1994. PSLV, in the meanwhile, was first launched unsuccessfully in 1993. However, in the very next year PSLV was successfully launched on 15 October 1994, placing the IRS-P2 in a sun-synchronous polar orbit. Since then, PSLV has launched 52 satellites / space crafts (25 Indian and 27 foreign Satellites) into a variety of orbits including the launch of Chandrayaan-1 on 22 October 2008.

**Geosynchronous Satellite Launch Vehicle (GSLV).** While the PSLV programme was still under way, India started working on development of a bigger launch vehicle capable of putting more than two-ton INSAT satellites into Geosynchronous Transfer Orbit (GTO). The aim was to overcome dependence on the European Ariane space vehicles for launching INSAT series of satellites. However, cryogenic engines were essential for this project and India lacked this technology. Initially, India got into an agreement with Russia for supply of two such engines with transfer of technology arrangements. However, US threatened to impose economic sanctions against the two space agencies on the grounds that cryogenic technology could be used to launch intercontinental ballistic missiles (ICBMs). Thus, seven readymade cryogenic engines were supplied by Russia without the transfer of technology. The first of these engines was used to place GSAT-1 into a GTO aboard its indigenously developed GSLV on its maiden flight on 18 April 2001. With this, India joined select nations having capability to launch two-ton class satellites into the GTO. Till date, India has had four successful flights of GSLV placing in orbit GSAT-1, GSAT-2, EDUSAT and INSAT-4CR. With the successful test of the S200 solid fuel booster early this year, the third most powerful in the world, payload capability for a GTO will be enhanced to four tonnes and ten tonnes for a near-earth orbit at an altitude of about 300 km.

## Satellite Technologies

India's foray into the domain of space began with satellites. While India's launch vehicle technologies were still evolving, Indian scientists had begun launching experimental devices, restricted to studying aspects like earth's atmosphere, weather prediction and studying magnetic fields. Efforts came to fruition in 1975 with *Aryabhatta,* the first Indian satellite, launched in April that year aboard a Russian rocket. Designed to conduct experiments in X-ray astronomy, aeronomy and solar physics, Aryabhatta gave ISRO valuable insight and experience in building and operating a satellite. This was followed up with *Bhaskara* I and II satellites launched in June 1979 and November 1981, respectively. Both satellites were India's first low orbit Earth Observation Satellites and carried TV and microwave cameras as part of payload to collect data on telemetry, oceanography, and hydrology.

Since these early achievements, ISRO has evolved technologically and created an extensive satellite development program. Today, ISRO develops indigenous satellites for following disciplines:

- Communication Satellites.
- Earth Observation Satellites.
- Experimental Satellites.
- Navigation Satellites.
- Small Satellites.
- Space Science and Exploration Satellites.

**Threat to India's Space Assets**

An initial assessment reveals that space assets today face multifarious threats which can broadly be classified as below:

- Attack on space based assets include:
  - Dazzling or blinding of satellite sensors.
  - Hit-to-kill anti-satellite weapons.
  - Pellet cloud attacks on low orbit satellites.
  - Attack by micro-satellites used as space mines.
  - High-altitude Nuclear Detonations (HAND).
  - Space Debris.
- Attack on Earth based assets include:
  - Physical attacks on satellite ground stations.
  - Electronic warfare (EW) such as jamming communications, and command and control systems/links and cybernetic attack.
  - Natural threats like space weather and debris from asteroids and comets.

For a closer analysis, we can classify and study the threats to space-based systems as follows:

- Threats to ground based assets.
- Threats due to Directed Energy Weapons (DEW).
- Threats due to Kinetic Attack Weapons.
- Cyber Threats.

**Utilisation of Existing Technologies for Space Warfare**

For India to safeguard its space assets in short term and long term, it is prudent to assess what capabilities are in existence, in any form, which can aid the development process. These are elucidated below:

- **Space Situational Awareness.** In 2015, India operationalised an indigenous Multi-Object Tracking Radar at Satish Dhawan Space Centre, Sriharikota, which can track 10 different objects at a range of 1000 km simultaneously. Concurrently, ISRO Telemetry, Tracking and Command Network (ISTRAC), Bengaluru, has a network of ground stations at Bengaluru, Lucknow, Sriharikota, Port Blair, Trivandrum, Mauritius, Brunei, and Biak (Indonesia). India is also planning to build a station in Vietnam. Since 2009, India has operationalised Swordfish radar as part of ballistic missile defence system to track incoming enemy missiles. This radar has the required fundamentals to track space-based objects also with some modifications.
- **Protection from Space Debris.** Presently, India relies on data compiled by NASA to ascertain threats to its orbital assets. Since changing the course of debris is difficult, the best possible immediate solution is to track potentially threatening debris and change the course of the functional hardware. Future solutions can include more accurate tracking of debris and measures to lower their orbit for eventual burn out in the atmosphere. Closer association with Inter Agency Space Debris Coordination Committee (IADC) and developing satellite bodies which can withstand minor impacts are some of the other steps which can be taken.

- **ASAT Capability.** On 27 March 2019, India tested an anti-satellite weapon during an operation code named 'Mission Shakti'. The target of the launch was a satellite in low earth orbit which was hit with a kinetic kill vehicle. The test put India on an equal footing to US, Russia and China, the countries with such capability in the world till date. The test potentially enables India to claim the right to be involved in the formation of future international norms and guidelines with regards to militarisation of outer space.

- **Resource Redundancy.** Creating redundancy in assets is financially constraining for a developing country like India. While some redundancy in critical resources like imaging and navigation can be created, this capability cannot be applied across the spectrum of Indian resources. Redundancy in non-critical assets can, therefore, be created by sharing resources of other nations through partnerships and also by becoming economically sound.

- **Quick Responsive Launch.** Solid fuel-based rocket technology is the prerequisite for this capability. India has already demonstrated indigenous achievements in this respect through the PSLV and Agni-V launches. Hence, the fundamental technological requirements exist. However, the financial aspect of keeping a credible number of such platforms ready for launch, and their security, takes a toll in its full implementation.

- **Application of Small Satellites Technology.** In June 2017, NASA launched a satellite made by an Indian student. The most important facet of this launch was the fact that it was the world's lightest satellite ever launched, fully 3-D printed, weighing 64 grams and sized 3.8 cm cube. Designed to measure radiation levels, it fell into the sea after a few days. This adequately proves that the necessary technologies for manufacturing small satellites are present in India. However, more research needs to be carried out in placing appropriate tools on these platforms. International restrictions on conduct of orbital tests to prevent space debris do constrict the research and development to some extent but using simulation tools and computers, these can be carried out. Hence, India needs to make considerable effort to actualise this tool.

- **Ground Based Weapons.** India too has embarked on various projects to develop DEW by Defence Research and Development Organisation (DRDO), Centre for High Energy Systems and Sciences (CHESS), and Laser Science and Technology Centre (LASTEC). As per reports, DRDO and CHESS conducted a test in Karnataka using 1 KW laser to hit a target 250 m away. Hence, the technologies are still distant which can be used to target or neutralise an adversary's orbital satellites using DEW.

- **Cyber Attacks.** Indian efforts in this sector are restricted to few nodal agencies. It is not clearly known about the efficacy of their capabilities; however, it can be safely assumed that in a global environment where everything from power stations to financial sectors are interlinked, carrying out a cyber-attack to shut power to ground based command stations, intercept ground to satellite communications to gain control of orbiting satellites is not impossible. India must, therefore, incorporate this aspect in the overall cyber doctrine and exploit it as a low risk and cost-effective tool.

- **Attack on Ground Based Infrastructure.** India today possesses adequate capabilities to identify and target enemy's ground-based space infrastructure. Use of ballistic and guided missiles and sabotage action are just some of the means available today. India further needs to enhance its intelligence acquisition capabilities in form of espionage and satellite imaging to accurately locate such infrastructure and engage them.

**Path India Should Follow**

As India grows economically, it is equally important to develop its military might commensurately. With each passing day, the reliance on space assets is increasing manifold. It is important not only to launch more satellites to meet the growing demand of civilian use but also to meet its military applications. While it is essential to have adequate space assets to meet the ever-increasing requirements of communications, it is prudent to develop an effective anti-satellite weapon system as deterrence against any threat to these space assets.

Presently, India should continue to launch satellites primarily for civilian use but with limited military capabilities. Gradually, the focus should be shifted to its military applications by launching full-fledged military satellites. By 2025 AD, India should have adequate military satellites in space to develop indigenous regional positioning system, in contrast to global positioning system, to assist weapon guidance systems and precise navigation.

At the same time, India should collaborate with other developed nations to develop advanced space technologies, as it may not be economically feasible for India to pursue a high-level space programme alone. Moreover, it may not be prudent to spend already meagre resources just to develop obsolete technologies while the developed nations are already acquiring new technologies. However, over dependence on any other nation to promote space programme may not be prudent. Above all, an important and new principle of war, that of 'Space Superiority' has been accepted by the superpowers while the developing space powers have introduced the 11$^{th}$ principle of war – the 'Principle of Cooperation in Space'.

Though India could continue to work for the demilitarisation of space by taking active participation in various international treaties and agreements, it should not ignore the ineffectiveness of these treaties so far. ASAT systems have become necessary and the concepts which are being kept in view while designing such systems should be of interest to the emerging space powers like India as they would be thinking in the same terms within the next decade. Also, tactical space weapons such as ASAT are of great significance. India should design ASAT systems to attack the strategic space systems which, although not weapons themselves, are vitally important in animating and informing the weapons of mass destruction which await their commands on earth. Further, space is considered a strategic area which is vital for military, commercial and scientific programmes. India as an emerging space power certainly would like free entry without any restrictions whatsoever, quite apart from its ventures in space.

With the growing advancements in anti-satellite system, including particle beams, radio frequency weapons and orbital interceptors as well as signal jammers and other electronic warfare devices, India should step up its technological research and application of spacecraft survivability measures. Most of the satellites in space today harbour few self-protection features, a situation that should change with the design of next-generation spacecraft that will be called on to operate during crisis situations and warfare.

Today, the value of the global space industry is estimated to be $350 billion and is likely to exceed $550 billion by 2025. Despite ISRO's impressive capabilities, India's share is estimated at $7 billion (just 2% of the global market) covering broadband and Direct-to-Home television (accounting for two-thirds of the share), satellite imagery and navigation. Already, over a third of transponders used for Indian services are leased from foreign satellites and this proportion will rise as the demand grows. India must look into this aspect and has to collaborate with partners to increase its share in the global space market.

Developments in Artificial Intelligence (AI) and big data analytics have led to the emergence of 'New Space'. New Space entrepreneurship has emerged in India with many start-ups which seek value in exploring end-to-end services in the Business-to-Business and Business-to-Consumer segments using New Space. However, these start-ups are yet to take off in the absence of regulatory clarity. Hence, they need an enabling ecosystem, a culture of accelerators, incubators, venture capitalists, and mentors that exist in cities like Bengaluru which is where most New Space start-ups have mushroomed. India has to transform these start-ups into full-fledged industries to accelerate India's dominance in space.

Another revolution underway is the small satellite revolution. Globally, 17,000 small satellites are expected to be launched between now and 2030. ISRO is developing a small satellite launch vehicle (SSLV) expected to be ready in 2021. It is a prime candidate, along with the proven PSLV, to be farmed out to the private sector. In this context, The Assembly, Integration and Testing (AIT) role, which is restricted to ISRO, must now be outsourced.

India should have a time-bound space programme and should try to develop both offensive and defensive weapons with their supporting command and control networks to form an integrated system for the conduct of nuclear war. However, looking at the present capability, it is a distant dream both, economically and technologically. To offset this limitation, India should try to acquire these technologies from other space powers by entering into technology transfer agreements through continued diplomatic efforts.

With the Ministry of Defence now setting up a Defence Space Agency and a Defence Space Research Organisation, ISRO should now actively embrace an exclusively civilian identity. With increasing competition, complexity and demand for space-related activities, there is a growing realisation that national legislation is needed to ensure overall growth of the space sector. A 'New Space' law for India should aim at facilitating growth of India's share of the global space economy to 10% in the coming decade.

## Conclusion

Each new frontier that man has discovered has become a new battleground. Land, sea, air and even cyberspace are apt examples of this fact. Space too has not been spared by this transformation. As nations discovered increasing uses of space, there emerged a need to secure unrestricted access to space. Satellite based communication, studies of weather and ground, and navigation have become enmeshed in individual lives as also in the story of national growth and security. This enforces a need on nations to protect its own space access and deny the same to an adversary, if required. However, maintaining the diminishing balance between an offensive and a defensive posture in space is the challenge facing India. Unlike China, which unabashedly carries out ASAT tests, India has to play by international norms and rules.

However, this adherence to international norms and rules must not be seen or interpreted as a handicap. In the larger perspective, as India rapidly grows into a space faring superpower, it must act with responsibility. An important factor which does limit India's unrestricted exploitation of space is economics. Being a developing country with limited financial resources, the authorities must balance between the immediate advantages of investing in infrastructure and social development and the long-term benefits of space technology. But India's peace-oriented approach to space is vehemently challenged by its neighbourhood. China, and Pakistan assisted by China, are serious concerns to India's security objectives. Sharing the space technology with Pakistan, China has created adequate doubts in the minds of Indian authorities about its intentions to use space as another dimension for conflict manifestation. This forces India to prepare itself to fight for its access to space and use of space-based platforms.

The most suitable way ahead then appears to be rapidly advancing space technologies used by ISRO in aspects discussed above and creating infrastructure to transform these capabilities for military use at short notice. As India cannot carry out actual tests of its space warfare capabilities in space due to fear of debris, the vast computational resources like supercomputers can be used to simulate such weapons with high precision. India must strive to forge ahead in space technologies and compete with the best in the world in this business. Missions like *Mangalyan, Chandryan* I and II should become the pinnacles of India's technological prowess and establish deterrence in the minds of any potential adversary about the scope of India's space-based warfare capabilities. In a symbiotic relationship, the milestones achieved by ISRO can be amalgamated into the missile development program to develop increasingly reliable, accurate and lethal missiles, and a quick and responsive missile defence system.

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