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India in Space:
Factors Shaping the Indian Trajectory

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By launching its space probe to the Moon, Chandrayaan-1, on 22 October 2008, India joined the United States (U.S.), Japan, Europe, Russia, and China in this accomplishment. The principal goal of the probe was to conduct mapping of the lunar surface, and among the scientific payloads it carried two were from the United States and three from the European Space Agency (ESA). This was a unique mission as it was an attempt to map high-resolution, 3-D topography of entire Moon, get mineral composition of surface, and investigate the availability of water and Helium-3. Chandrayaan-1 operated until August 2009, coming to an abrupt end after 312 days, as opposed to the intended two years. Despite the setback, Chandrayaan-1 did achieve 95 percent of its planned objectives, and made the significant discovery of water ice molecules on the lunar surface.[1]

Chandrayaan-1 is a historic milestone for the Indian space program, aimed at laying the groundwork for further space expeditions. It was a landmark project for the Indian Space Research Organization (ISRO), which had launched dozens of satellites since its founding in 1969, but had never before sent an object beyond Earth's orbit. The Indian government has already approved the follow-on Chandrayaan-2 mission, a collaborative venture with Russia. The data relayed by Chandrayaan-1 about the nature of Moon's surface, will pave the way for the soft landing of the rover that Chandrayaan-2 is scheduled to take to the lunar surface.

For India, the lunar probe is yet another testament to the progress it has made in the last few years as an economic and technological power. The mission is a sign of India's growing strategic ambition, and an indication of the importance it gives to space exploration. The superpowers had dominated space for much of the space age, and now emerging powers, such as China and India, are joining them. Space accomplishments translate into greater technological standing and strategic clout, as well as an index of high-technology capability. Moreover, space is an important element of power projection and the lunar

...India intends to use space for planetary research and for economic purposes.

[1]See Chandrayaan, Lunar Mission by Indian Space Research Organization, see http://www.chandrayaan-i.com/index.php/chandrayaan-1.html (accessed April 2010). Chandrayan-1 was placed into lunar orbit at an altitude of 100 kilometers. Though it did not complete its two years in orbit, it provided a large volume of data from its sensors, such as terrain mapping camera, hyper-spectral imager, and moon mineralogy mapper. The moon mineralogy mapper confirmed the existence of water ice on the Moon, and analysis of the data acquired detected more than 40 water ice-filled craters in the lunar north pole.

mission is part of an effort to assert Indian prowess in space.

This paper examines the drivers of the Indian space program. Factors at the structural, domestic, and individual levels shaped the trajectory of the Indian space program. Their relative importance vis-à-vis each other influence Indian aspirations in the realm of space for both civil and military use.

Evolution of the Indian Space Program

The Indian space program started with launching of sounding rockets in 1963. At that time, the purpose was to focus on scientific investigations of the upper atmospheric and ionospheric phenomena above the geomagnetic equator. India's first sounding rocket was launched with the help of the National Aeronautics and Space Administration (NASA), which provided a Nike-Apache rocket along with other hardware and training aids. It took more than a decade's time after this launch to put the first Indian satellite in Earth orbit. Aryabhatta was India's first satellite, named after an Indian mathematician of the 5th century of the Common Era. It was launched with the help of the former Soviet Union on 19 April 1975 from Kapustin Yar, a Russian rocket launch and development site.[2] Since then, India demonstrated that it could send an indigenous satellite to orbit by using an indigenous rocket. This was the launch of satellite, Rohini 1, with the Satellite Launch Vehicle (SLV) from its own launch site located at Sriharikota on 18 July 1980.

India's space program started under the aegis of Department of Atomic Energy in 1962 with creation of Indian National Committee for Space Research (INCOSPAR). The mandate to the committee was to oversee all aspects of space research in the country. Work began on the establishment of the Thumba Equatorial Rocket Launching Station (TERLS) in 1962. India's former Prime Minister Indira Gandhi dedicated TERLS to the United Nations (UN) on 2 February 1968. On that occasion, INCOSPAR Chairman, Vikram Sarabhai, articulated India's goal in space. He stated that India's program is civilian, with a focus on the application of space technology as a tool for socioeconomic development of the country. The basic aim of India's space program was described as a program capable of using space technologies in the vital areas of development, such as communications, meteorology, and natural resource management.[3]

ISRO was formed under the Department of Atomic Energy in 1969, and was subsequently brought under the Department of Space in 1972. A Space Commission was also established in 1972, which reports directly to the Prime Minister. The Department of Space along with ISRO operates four independent projects: (1) the Indian National Satellite Space Segment Project; (2) the National Natural Resource Management System (NNRMS); (3) the National Remote Sensing Agency (NRSA); and (4) the Physical Research Laboratory (PRL). The Department of Space sponsors research in various academic and research institutions under a program called RESPOND, the sponsored research. This program allows ISRO to interact with various educational institutes and outsource research efforts.[4]

[2]The Soviet Union and India negotiated in August 1971 an agreement, signed on 10 May 1972, in regard to a joint effort to launch a satellite.

[3]U. Sankar, *The Economics of India's Space Programme* (New Delhi: Oxford University Press, 2007), pp.1-2.

[4]India Space Program Research, India Department of Space, Science Advancement, http://www.indianchild.com/india_space_research.htm, http://indianspacestation.com/index.php?view=article&catid=35:articles&id=106:respond-program-by-isro&format=pdf (both accessed April 2010).

Presently, ISRO has various operating divisions throughout the country. These divisions deal with space systems, propulsion, communications, telemetry and tracking, research, space launch, and other facets of the space program. The major achievements of the space program have been in the area of the domestic design, production, and launching of remote sensing and communications satellites. Over the years, ISRO established a strong infrastructure for remote sensing and communications satellite systems with launcher autonomy. In 1992, ISRO established its commercial outlet, the Antrix Corporation.[5] This organization markets space and telecommunications products of ISRO.

Initially, the Indian space program focused on experimental, low-capability projects that allowed Indian scientists to gain experience in the construction and operation of satellites and launch vehicles. ISRO built the Bhaskara Earth observation satellites, a communication satellite, the APPLE satellite, and conducted four test flights of the SLV-III satellite launch vehicle between 1979 and 1983.[6] The Bhaskara satellites were launched with help from the former Soviet Union. Even though only two of the four test flights of SLV were successful, this program was followed by a more advanced program, the Augmented Satellite Launch Vehicle (ASLV).

Indian armed forces understand the relevance of space technologies to address 21st century security threats.

From the mid-1980s, India focused on more capable, mission specific systems. ISRO started designing and developing the Polar Orbiting Satellite Launch Vehicle (PSLV), and its successor, the Geosynchronous Satellite Launch Vehicle (GSLV). These launch vehicles were required to launch the indigenously developed Indian Remote Sensing (IRS) satellite, and a meteorology and telecommunications Indian National Satellite (INSAT). PSLV commenced its operational launches in 1997, and since then, it has been a reliable launch vehicle with ten consecutive successful flights through April 2007.[7] On 2 September 2007, India successfully launched an INSAT geostationary satellite with the GSLV. This launch proved India's capabilities to put satellites weighing 2,500 kilograms (kg) into geostationary Earth orbit (GEO). The first two stages of GSLV I and II are derived from PSLV.

ISRO is developing as well a more advanced GSLV version, GSLV III, which is an entirely new launch vehicle that is not derived from PSLV or previous GSLVs. In April 2002, the Indian government approved $520 million U.S. dollars for development of GSLV III with the capability to launch 4,500 kg satellite to geo-synchronous transfer orbit (GTO) with growth potential towards 5,000 kg payload capability.[8] However, ISRO's GSLV program suffered a setback in April 2010 with the failure of GSLV D3. This launch vehicle was carrying a communication satellite called GSAT-4 with a mass of 2,220 kg. The main feature of this mission was the employment of the first Indian made cryogenic engine. The failure of the cryogenic engine underlined that India will have to wait for a number of years to realize its dream of sending 5,000 kg of various satellites to space.[9]

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[5]Antrix is a Sanskrit word meaning Space.

[6]Dinshaw Mistry, "India's Emerging Space Program", *Pacific Affairs* 71:2 (Summer, 1998): 153.

[7]Ibid. Also, see "ISRO Does an Italian Job," *Hindustan Times*, 23 April 2007.

[8]See ISRO, http://www.isro.org/Launchvehicles/GSLVMARKIII/mark3.aspx (accessed April 2010).

[9]"India's ambitious quest to achieve total independence in cryogenic technology for launching satellite launch vehicles

The Indian space program has followed the path in space envisaged by Sarabhai in the 1970s of socioeconomic applications for the country. Investments have revolved around remote sensing and multi-purpose application satellites, and related launching technologies. Yet today, India is looking beyond Sarabhai's vision of harnessing space just for economic and social development. India's lunar probe, Chandrayaan, and ISRO's proposal to undertake human lunar missions are examples of how India seeks to expand upon its national space endeavors.[10] Of note, is that during the 1970s, Sarabhai argued that India does not have the fantasy of competing with the economically advanced nations in the exploration of the Moon, the planets, or to engage in human spaceflight.

In addition to Chandrayaan, India has formulated a road map to send a human mission to the Moon by 2020. This added dimension of undertaking human space missions needs to be viewed not as a policy shift per say, but as a natural progression in developing space capabilities. India also plans to send satellites to study Mars. With the successful launch and mission of Chandrayaan, India, for the first time, has entered into an arena of deep space exploration. ISRO managed to keep the cost factor very low for this effort. It looks certain that this mission is not a "one-off mission," and Indian investments in this area are likely to increase in the near future. As stated earlier, the Indian government approved a second robotic lunar mission, Chandrayaan-2, at a cost of around $100 million U.S. dollars.[11] ISRO is planning to put its first Indian astronaut into orbit by 2014-2016, depending on whether the government approves ISRO's budget needed for this effort (see Table 1 below).

At the end of the first decade of the 21st century, India's satellite program is headed towards following a multi-pronged strategy. In addition to social causes, India intends to use space for planetary research and for economic purposes. To conduct all these activities, focus areas for Indian space efforts include: remote sensing, meteorology, communication, education, navigation, and astronomy and planetary missions.

Military Space Program

Sarabhai had articulated in the early 1970s that India's space program is civilian in nature. Also, the development of the Indian civil space program was not born out of military programs, like ballistic missile programs. Rather, civil space efforts focused on satellite development and establishing satellite launch capabilities for civil purposes.[12]

However, satellite technology, being inherently dual-use in nature, has applicability for military purposes. For example, a one meter (m) resolution Technology Experiment Satellite (TES) was launched by ISRO in 2001. It was stated by the then ISRO Chairman, K. Kasturirangan, that the satellite was meant for "civilian use consistent with

suffered a setback with the indigenous cryogenic engine in a Geosynchronous Satellite Launch Vehicle (GSLV-D3) failing to ignite and the vehicle tumbling into the sea." See *The Hindu*, 15 April 2010, http://beta.thehindu.com/news/national/article398070.ece?homepage=true (accessed April 2010).

[10] K.S. Jayaraman, "India's Space Agency Proposes Manned Spaceflight Programme," *Space News*, 10 November 2006.

[11] P. Sunderrajan, "Cabinet clears Chandrayaan-2," *The Hindu*, 19 September 2008.

[12] For an overview of recent trends in Indian Missile Capability, see Harsh V. Pant and Bharath Gopalaswami, "India's Emerging Missile Capability: The Science and Politics of Agni-III," *Comparative Strategy* 27:4 (August-September 2008): 376-387.

our security concerns."[13] Such high resolution imagery has obvious military utility. In the recent past, India also launched Cartosat 1, Cartosat 2, and Cartosat 2A high resolution satellites with 2.5 m, 1 m, and 0.8 m resolutions respectively. These satellites are for cartographic purposes, as well as for urban and rural development. Such satellites offer India the capability of intelligence-gathering, keeping an "eye on the region surrounding the country.

Geographically, India's location at the base of continental Asia astride the Indian Ocean places it at a vantage point in relation to maritime trade. India has a strong stake in the security and stability of these waters since a large percent of Asian oil and gas supplies is shipped through the Indian Ocean.[14] Presently, the security of such supplies depends on multilateral initiatives that have been sanctioned by the UN. Indian navy and cost-guard play a role within the ambit of the UN *Law of the Sea Convention*. The use of space could clearly help India in this role.

Indian armed forces understand the relevance of space technologies to address 21st century security threats. The Indian Air Force (IAF) is planning to integrate space-based applications into conventional strategies and operations. The IAF is already using space for telecommunications, reconnaissance, navigation, targeting, and other operations. The IAF is adopting a focused and fast-tracked approach to harness space effectively to provide synergy with all facets of its operational roles.[15] For the last few years, the IAF has been advocating and preparing for the establishment of a tri-service aerospace command to protect both the territorial and space assets of India. Today, India understands that many modern day defense options rely heavily on space-based sensors, and for better coordination and timely dissemination of surveillance, reconnaissance, and tracking information.[16]

India has no policy towards weaponization of space, yet Indian armed forces require the assistance of the space assets to undertake various operations, in air, land, and sea. Keeping in view such military space requirements, particularly with the backdrop of the anti-satellite test conducted by China during January 2007, India has established a "Space Cell" under the command of the Integrated Defence Services (IDS) Headquarters. IDS acts as a single organization for integration among the armed forces, the Department of Space, and ISRO. India maintains that such a body is required due to "offensive counter space systems and an improved array of military space systems emerging in India's neighborhood."[17]

Drivers of Indian Space Program

Following below is a discussion of the main drivers that have influenced the trajectory of India's space program. They can be broadly

[13] See Joe Katzman, "India's Emerging Military Satellite System," 10 August 2005, http://www.windsofchange.net/archives/007318.php (accessed April 2010).

[14] From the lecture delivered by Shri M.M. Pallaum Raju, Minister of State for Defence, Government of India. See "P.C. Lal Memorial Lecture," organized by the Air Force Association, 19 March 2007, New Delhi, India.

[15] D.C. Kumaria, "Leveraging Space Capabilities for India's Defence", *Air Power Journal* 1:2 (October-December 2006): 86-87.

[16] From the lecture delivered by Shri M.M. Pallaum Raju, Minister of State for Defence, Government of India. See "P.C. Lal Memorial Lecture," organized by the Air Force Association, 19 March 2007, New Delhi, India.

[17] See "Now, space cell to keep an eye on China's plans," *The Times of India,* 11June 2008, http://timesofindia.indiatimes.com/India/File_Now_space_cell_to_keep_an_eye_on_Chinas_plans/articleshow/3118491.cms (accessed April 2010).

examined under three levels: (1) structural, (2) domestic, and (3) individual. At the structural level, the changing global balance of power and growing competition among spacefaring states is analyzed' at the domestic level, the economic and political factors, as well as the technological development and bureaucratic momentum shaping Indian space policy, are examined; and at the individual level, the role of key personalities in shaping the Indian space priorities is assessed.

International Structural Factors

With the recent rise in India's economic and political power, India is more ambitious in defining its priorities in space than it has ever been in the past. India's space policy is responding not only to India's own attempt at emerging as a major global actor, but also to the space efforts of other powers. With other powers, such as China and Japan, deciding to explore the lunar surface with humans, India has also joined the "bandwagon." India has a technologically sophisticated space program, which is now addressing the challenges of human spaceflight and exploration. Towards this end, India is cooperating with a number of states and U.S.-Indian space cooperation is beginning to grow substantially.

India has only recently started the military dimension of its space program, and as the space race among major powers gains momentum, it will become pivotal for Indian military planners. With China viewing conflict in space as an integrated part of military operations, India is gradually coming to terms with the possibility of the weaponization of space.[18] For long, the Indian government has resisted the demand of its military to establish an aerospace command by arguing that it did not want to trigger greater militarization of space or the possibility of arms race in space among regional powers. But gradually, India is realizing that whether it likes it or not, the military use of space is pervasive among world powers, and there is little India can do to stop it. Also, by supporting the already deployed U.S. missile defense system, India seems to have casted its vote towards the militarization, and perhaps weaponization, of space with the missile defense system being a first step towards an anti-satellite capability.

India has a two-tiered missile defense system, the Prithvi Air Defence (PAD) missile for high altitude interception, and the Advanced Air Defence (AAD) Missile for lower altitude interception. Several successful tests for this system have already been conducted, and these systems will become operational in two to three years. Also, according to the Defence Research and Development Organisation, Indian defense scientists are readying a weapons system to neutralize enemy satellites operating in low-Earth orbit (LEO).

India's space policy is responding not only to India's own attempt at emerging as a major global actor, but also to the space efforts of other powers.

It was the Chinese test of an anti-satellite weapon (ASAT) in 2007 that led the Indian establishment to take more seriously the military uses of space. China successfully used a ground-based missile to hit and destroy

[18]For a detailed account of writings discussing China's views of war in space as an integrated part of military operations, see Kevin Pollpeter, "The Chinese Vision of Space Military Operations" in *China's Revolution in Doctrinal Affairs: Emerging Trends in the Operational Art of the Chinese People's Liberation Army*, James Mulvenon and David M. Finkelstein, eds. (CNA Corporation, December 2005).

one of its weather satellites. In effect, China demonstrated an effective ASAT capability comparable to the United States technology from the mid 1980s and Russian systems from about the same time. The test reinforced China's status as a military space power; equal to the United States and Russia, but more significantly key U.S. space systems are now at risk in any future conflict with China.[19]

As a consequence, suggestions are now being made that the United States should start investing in offensive counter-space capabilities.[20] The Bush Administration tacitly asserted the United States right to space weapons and has continued to oppose the emergence of treaties or other measures restricting them. For the United States, any arms control regime in outer space would constrain its military options, and it wants to retain its military operational flexibility.

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In early 2008, the United States Navy's missile interceptor successfully struck a dying spy satellite of the United States in LEO over the Pacific Ocean. With this missile strike, the United States categorically signaled that its missile defenses can be used to counter strategic ASATs. An interceptor designed for missile defense was used for the first time to attack a satellite, and as such, showcased how the emerging missile defense arsenal could be reprogrammed to counter an unexpected threat, which in this case was deadly rocket fuel aboard a dead satellite. This will no doubt strengthen the hands of the supporters of the missile defense system in which the United States has already made significant investments. This test was as a major success for the United States Missile Defense Agency, in so far as it amounted to an unprecedented use of components of the military's missile defense system designed to shoot down hostile ballistic missiles in flight, not satellites.

It is instructive that this strike by the United States came days after China and Russia proposed a global treaty banning weapons in space in the UN Conference on Disarmament, as well as rising Russian opposition to the United States placement of missile defense interceptors in Eastern Europe. The United States has opposed this treaty effort arguing that the proposed draft is largely directed at U.S. military technology, as it allows China and Russia to fire ground-based missiles into space or use satellites as weapons. There is also reluctance on the part of China and Russia on clearly defining a space weapon as they too want to keep their options flexible.

The Europeans are presenting their own challenge to U.S. supremacy in space. The first satellite in the European Union's (EU's) Galileo satellite navigation program was launched in 2005 rivaling the United States Global Positioning System (GPS). The Galileo project is a $4 billion U.S. dollar enterprise whereupon Europe hopes to end its reliance on the GPS system. Apart from demonstrating Europe's technological prowess, Galileo's launch also signaled European desire to enhance its own space capabilities, rather than depend on the United States. Not surprisingly, the United States military had been extremely critical of Galileo, calling it unnecessary and a potential security threat during wartime as its signals might interfere with next-generation GPS signals intended for use by the United

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[19] Ashley Tellis, "Punching the U. S. Military's "Soft Ribs": China's Anti-satellite Weapon Test in Strategic Perspective," *Carnegie Endowment, Policy Brief* 51, June 2007.

[20] Ashley Tellis, "China's Military Space Strategy," *Survival* (Autumn 2007): 41-72.

States military. Though this dispute was later resolved when the EU and the United States agreed to make Galileo compatible with GPS, it underlined the unease with which the United States views any attempt to challenge its supremacy in space.

American plans to militarize space have come into sharp relief in recent years. In 2004, the United States Air Force issued a *Counter Space Operations* document that discussed both defensive and offensive counter space operations.[21] Prior to this, in the 1996 Clinton Administration's National Space Policy for example, a more pacific use of space was emphasized, including satellite support for military operations, arms control, and non-proliferation pacts. Regardless, space capabilities provide vital support to American power projection. The United States military has invested enormous sums in the research, development, and procurement of satellites for intelligence-gathering, communications, and navigation, and that investment is widely regarded to great benefits for U.S. warfighting.

The unilateral withdrawal of the United States from the Anti-Ballistic Missile (ABM) Treaty in 2002 and its pursuit of an open-ended ballistic missile defense program already point towards future U.S. plans to address the challenges of space as a new battlefield. In fact, a commission headed by the former U.S. Secretary of Defense, Donald Rumsfeld, had recommended in 2001 that the military should "ensure that the President will have the option to deploy weapons in space."[22] It is towards this end that the Pentagon launched the XSS-11 orbital micro-satellite, which is designed to disturb other states' military reconnaissance and communication satellites.

Despite financial, technological, and diplomatic hurdles, U.S. efforts to gain space superiority will continue, and the rest of the world will have to find ways and means to respond to this challenge. It is in this broader global context that India, as a major space power, is trying to re-define its priorities in space.

Since inception of its space program, India has been supported by the United States, erstwhile Russia and the European countries, in various areas, from providing launching facilities, to helping with technology transfer, and to sending astronauts to space. At the same time, the United States imposed sanctions on the Indian space program from 1987 to 2004 because of subsequent change in U.S. policies due to India's nuclear and missile posture.[23]

Since 2004, the Indian space program is receiving support from all major space powers. The United States is likely to play the

[21] *Counter Space Operations*, Air Force Doctrine Document 2-2.1, 2 August 2004, http://www.dtic.mil/doctrine/jel/service_pubs/afdd2_2_1.pdf (accessed April 2010).

[22] The report of the Rumsfeld Commission to Assess the Ballistic Missile Threat to the United States, http://www.fas.org/irp/threat/missile/rumsfeld/toc.htm (accessed April 2010).

[23] The United States and India began space cooperation in the 1960s with sounding rockets, which expanded to transfer of technology for launch vehicle development and sharing of satellite data. However, concerns about the global proliferation of ballistic missiles led the United States to establish the Missile Technology Control Regime (MTCR) in 1987 to coordinate national export licensing measures on missiles and related technology, including technology for space launch vehicles that might contribute to the development of military systems. MTCR targeted emerging missile programs, including those of India, and led to restrictions on U.S. technology transfers to India's space launch vehicle programs. In 1992, U.S.-India space relations further deteriorated when the United States objected to an agreement between the Russia and India for the sale to India of cryogenic rocket engines and the technology to produce them. In 1998, the Indian nuclear tests led the Clinton Administration to impose sanctions, restrictive export licensing requirements, on ISRO and other Indian entities involved in space and missile programs. Since January 2004, U.S.-India space cooperation was re-established to facilitate greater commercial space cooperation, and cooperation in space exploration and the launching of satellites.

policy of using India to balance China in the region, and India is likely to exploit the situation.[24] Already, India has collaborated with the United States for its first Moon mission, and the Manmohan Singh-Bush joint statement agreement of 18 July 2005 indicates that in the arena of space India-U.S. collaborations are likely to strengthen.[25]

India's has worked and is working with various members of ESA on a host of space issues. India is also engaging Russia on various space ventures, and the joint collaboration reached by both states on Chandrayaan-2 is a case in point. India is not collaborating with China in space; however, China has given certain encouraging signals to India towards collaboration. Wu Ji, identified as Director of the Center for Space Science and Applied Research, Chinese Academy of Sciences, mentioned the possibility of space cooperation during his visit to India in 2006, while accompanying Chinese President Hu Jintao.[26] Today, both states understand that collaboration could allow them to take advantage of existing capacity on both sides. Given the rivalry that animates Sino-Indian ties, and absent any near-term cooperation, India intends to match Chinese advances in space.

[24]On the changing regional balance of power in the Asia-Pacific, see Harsh V. Pant, "The Emerging Balance of Power in the Asia-Pacific," *The Royal United Services Institute Journal* 152:3 (June 2007).
[25]See Joint Statement Between President George W. Bush and Prime Minister Manmohan Singh, 18 July 2005, http://georgewbush-whitehouse.archives.gov/news/releases/2005/07/20050718-6.html (accessed April 2010). For high-technology and space, it was declared that the two countries will: provide for joint research and training; build closer ties in space exploration, satellite navigation, and launch, and in the commercial space arena through mechanisms, such as the United States-India Working Group on Civil Space Cooperation; and build on the strengthened nonproliferation commitments between the two states to remove Indian organizations from export control restrictions.
[26]Bruce Einhorn, "Chindia - Cooperation in the Space Race?" *Business Week*, 21 November 2006.

Domestic Factors

ISRO has not faced problems in securing resources, and has tended to receive steady governmental support. This is one area where a "bottom-up" approach has been found in regard to the growth of the space program. It is ISRO that normally decides what projects to undertake and how to proceed. The government has so far been supportive of most of ISRO's plans. The value of ISRO's overall assets today is approximately $25 billion U.S. dollars.[27] ISRO spends 85 percent of its $1 billion U.S. dollar annual budget on development-related missions, and the remaining 15 percent on advanced research and development (R&D), and on missions, such as Chandrayaan. Table 1 highlights the distribution of funds.

Table 1. Distribution of Funds for the Indian Space Program.
Source: ISRO, http://www.isro.org (accessed April 2010).

Rupees in Crores [one Indian Rupee in Crores equals $0.224 million U.S. dollars as of April 2010].

	ACTUALS 2006-2007	REVISED ESTIMATES 2007-2008	BUDGET ESTIMATES 2008-2009
Space Technology	1668.37	2017.00	2611.52
Space Applications	284.46	299.77	375.28
Space Sciences	228.36	321.60	268.37
INSAT, Operational	376.77	573.57	404.81
Administration	430.70	78.15	414.09
Total	**2988.66**	**3290.09**	**4074.07**

A major limitation, which India's space program is likely to face, is the availability of a trained workforce. This becomes evident from the fact that many young scientists recruited by ISRO are leaving jobs because of the much higher remuneration offered by

[27]K. Kasturirangan, "The Emerging World Space Order" in *Space Security and Global Cooperation*, Ajey Lele and Gunjan Singh, eds. (Academic Foundation: New Delhi, India 2009), p. 33.

private companies. ISRO is not able to attract the best people from the Indian universities, and in the year 2006, more than 50 percent of newly inducted scientists left ISRO.[28] Also, a major part of the existing aging workforce is likely to retire in years to come. ISRO expects to address this shortfall by outsourcing research and undertaking major recruitment drives to replenish the workforce. In order to find a long-term solution to this problem, ISRO has established an institute at Thiruvanandapuram, India for workforce training. However, these efforts will not address workforce issues completely. This is mainly because many India students are attracted to Information Technology as a profession for more than a decade, and the trend is likely to continue. Rocket scientists have limited options of joining government jobs, which do not offer attractive pay salaries.

Apart from human resources, ISRO is not expected to face any major resources problems, like non-availability of materials required for hardware production.[29] Though at present, India is not capable of integrated circuitry manufacturing. Yet, it is expected that India will overcome this deficiency, which in turn will benefit the space sector.

Political Changes

Since independence, India's science and technology policies have more or less remained unchanged irrespective of the political ideology of the government in power. It needs to be emphasized that actually it is not the political party, but the political leadership that plays a significant role towards giving support to new technologies. The history of various political parties in power shows that the programs of national importance, which have security implications, do not get entangled in party politics. India's nuclear test in 1998, Pokhran II, exemplifies this.

For the Indian space program, scientists and ISRO officials have largely shaped the trajectory and have been able to muster the requisite support from the government. The benefits of India's space program are well demonstrated, and in view of this, it is unlikely that any major changes would take place in policies and budgetary support depending on the political party in power. However, some degree of dependence on the United States still exists and is likely to exist, and as such, the emergence of political tensions between India and the United States would have an effect on the Indian space program.[30]

ISRO has not faced problems in securing resources, and has tended to receive steady governmental support.

Other political issues facing the national space program include bureaucratic and programmatic factors. Successes in the space sector tend to be short-lived, and at times, failures are more highlighted. ISRO's recent failure in regard to its commercial venture, the W2M satellite, could have some negative impact on its international reputation when it was trying to develop a niche for itself in the communications satellite field. Any more failures could bring in the bureaucratic cautiousness in this area.

[28]In 2006, ISRO hired 354 new scientists, but 187 trained ones left the organization by 2007. See "ISRO bleeds as scientists leave," *The Times of India*, 6 September 2007, http://timesofindia.indiatimes.com/India/ISRO_bleeds_as_scientists_leave/articleshow/2341361.cms (accessed April 2010).
[29]Personal correspondence with ISRO scientists.

[30]It has not been clearly articulated by ISRO for obvious reasons; however, personal correspondence with ISRO scientists second this concern.

India's space program is placed directly under the Prime Minister, and thus, is relatively free of bureaucratic delays despite programmatic issues that may arise. A broad look at the development of science and technology within the country in general, and the programs of major technological organizations, like Defence Research and Development Organisation (DRDO) and ISRO, during last decade shows that political, bureaucratic, and financial support for projects are not problems.

A major limitation, which India's space program is likely to face, is the availability of a trained workforce.

This observation is further reinforced by the facts that the technocrat community within India has established itself, and ISRO is a success story, which has brought prestige and foreign exchange to the country. Also, given indigenous capabilities for satellite and launch vehicle development, ISRO is unlikely to acquire any large-scale technology from other states, and hence, bureaucratic constraints, which usually exist in regard to technology transfer, are not an issue at play.

Technological Factors

Within next 20 years, technologies, like biotechnology, nanotechnology, and robotics and cognitive technology, are expected to revolutionalize the space sector. These technologies are expected to bring light weight materials to the space sector, which will largely impact the structural design of satellites and components. In addition, computing capabilities will increase in years to come, and power sources will be carrying more capacity with reduced mass.

These technological factors could be viewed at two levels: indigenous development and transfer of technology. After the success of the India-U.S. nuclear deal, it is unlikely that transfer of technology could become a major issue in years to come.[31] Apart from the United States, India is expected to have good relations in space with states like France, United Kingdom, Israel, and Russia. Current trends indicate that India's future programs could constitute various joint projects, either at bilateral or multilateral levels. Many spacefaring nations are likely to prefer joint projects in years to come because of the cost factor and gestation period required for indigenous development of technology. On the other hand, technologies, which could have direct or indirect military relevance, are not shared in cooperative programs and projects. Such technologies would demand indigenous development.

Individual Level Factors

Science and technology leadership in India is driven by various key individuals. Vasant Sathe played a key role during the 1980s to bring color television to India; Rajiv Gandhi was instrumental for the information technology revolution; and Sam Pitrotoda for the revolution in communications. More specific to space, Homi Bhaba, Vikaram

[31] The United States Congress, on 1 October 2008, gave final approval to an agreement facilitating nuclear cooperation between the United States and India. The deal is seen as a watershed in U.S.-India relations and introduces a new aspect to international nonproliferation efforts. First introduced in the joint statement released by President Bush and Indian Prime Minister Manmohan Singh on 18 July 2005, the deal lifts a three-decade U.S. moratorium on nuclear trade with India. It provides U.S. assistance to India's civilian nuclear energy program, and expands U.S.-India cooperation in energy and satellite technology. For details on US-India civilian nuclear energy cooperation agreement, see Harsh V. Pant, "The US-India Nuclear Pact: Policy, Process and Great Power Politics," *Asian Security* 5:3 (September 2009):273-295.

Sahrabhai, APJ Abdul Kalam, K. Kasturirangan, and Madhavan Nair played key roles towards providing science and technology leadership.

Bhaba is regarded as a visionary in the field of science in modern India. He did pioneering work towards peaceful development of atomic energy. Bhabha established the Atomic Energy Commission of India in 1948. His other areas of interest include research on cosmic rays and quantum theory. Apart from being a scientist, he was an able administrator and played a significant role towards developing a world class automatic energy research center in India. Bhaba was succeeded in 1966 by Vikram Sarabhai as the Chairman of the Atomic Energy Commission. Known as father of Indian space program, Sarabhai was the first Chairman of INCOSPAR, which was created after Sputnik was launched into the space in 1957. Sarabhai established the first launching site in the country, TERLS.

...the Indian space program is civilian in nature, and India is yet to articulate a strategic approach. This will make it difficult to reconcile civilian and military priorities in space.

India's 11th President, A.P.J. Abdul Kalam, who assumed office on 25 July 2002, is a scientist. Before assuming the office of the President, he had held various scientific positions, and is often referred to as the "Missile Man of India" – he was the Project Director of India's first indigenous SLV. He has a unique distinction of working both on India's missile program and on India's satellite program. Kalam also spearheaded the campaign of motivating children and young scientists to involve themselves in undertaking various scientific challenges. In many ways, Kalam succeeded in motivating an entire generation to look constructively towards issues of science and technology.

Kasturirangan, presently a Member of Parliament, steered India's space program for over nine years as Chairman of ISRO. He led various space programs successfully, including PSLV and in conceiving India's Moon mission. Kasturirangan largely succeeded in placing India as a preeminent spacefaring nation. His successor, who recently retired, Madhavan Nair, played a significant role in developing ISRO's future roadmap with plans for deep space missions and proposals to put an Indian on the Moon within a decade's time.

Conclusions

India's lunar mission is a statement of the nation becoming more ambitious in defining its priorities in space, and in the coming years, the civilian aspects of the Indian space program can be expected to gather further momentum. The military aspects will also get greater attention of the government, in light of competition among spacefaring nations. Also, greater cooperation in space will emerge with the United States, Europe, and Japan, though with respect to China, the relationship will remain inherently competitive.

India's efforts in space will continue to be hampered by an absence of a coherent national space policy. This is the case because the Indian space program is civilian in nature, and India is yet to articulate a strategic approach. This will make it difficult to reconcile civilian and military priorities in space. The current roadmap of ISRO demonstrates firm resolve to move in a particular direction, yet India is taking only tentative steps in so far as the military dimension of its space policy is concerned.

Konstantin Tsiolkovsky, the “father of space travel” wrote in 1911: “Earth is the cradle of humanity, but humanity cannot stay in the cradle forever.” The world is on the threshold of a new age of space exploration, as well as militarization of space, and possible weaponization of space. India, with its achievements in its own space program, is in a unique position to be a major player in the drama of space. The trajectory of India’s space efforts demonstrate that India is getting ready to use its space capabilities for not just expanded civil and commercial use, but also for force multiplication and power projection.