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India And China Space Programs: From Genesis Of Space Technologies To Major Space Programs And What That Means For The Internati

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INDIA AND CHINA SPACE PROGRAMS: FROM GENESIS OF SPACE TECHNOLOGIES TO MAJOR SPACE PROGRAMS AND WHAT THAT MEANS FOR THE INTERNATIONAL COMMUNITY

by

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ABSTRACT

The Indian and Chinese space programs have evolved into technologically advanced vehicles of national prestige and international competition for developed nations. The programs continue to evolve with impetus that India and China will have the same space capabilities as the United States with in the coming years. This will present new challenges to the international community in spheres civilian, to space and military applications and their residual benefits.

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CHAPTER ONE: INTRODUCTION

Why do humans endeavor to understand the heavens, stars and space? Is it the innate curiosity within human nature to try to explain the unexplained or that humans like challenges? Whatever the motivations are, it has led the human race to build technology to seek understanding of the heavens through space programs. Traditionally, advanced space programs have been the bastion of a few, U.S., Russia, Japan and Europe. However, in recent years two space programs have garnered much attention, India and China; each with a potential to rival the advanced space programs in the future. Nevertheless, the Indian and Chinese programs require special examination. These two developing nations, future superpowers, have not let any power or dissuasion deter them from their path of joining the ranks of advanced technological nations.

Along with Japan which also has a technologically advanced space program, the three Asian tigers will reshape the international order in the future. India and China, two neighbors, two ancient civilizations, two ambitious nations and two nations both victims of colonialism, striving to relinquish the last vestiges of their colonial pasts towards their own manifest destines; that of becoming great powers in the new millennium. One way to achieve power status is through success in space technology and application. Therefore, India's and China's space programs are of special importance for comparison. Thus, this paper will examine the genesis of their space programs, their motivations, their progress till now, their applications, their domestic and global importance, and their future. Chapter two will discuss the genesis and the motivations behind the Indian and Chinese space programs.

CHAPTER TWO: GENESIS AND MOTIVATIONS OF THE SPACE PROGRAM

The Indian and Chinese space programs have reached new heights in their respective endeavors. Each program started with different motivations and goals that have shaped them overtime. The Indian space program's initial motivations were using space for social and economic upliftment of the people. Meanwhile China's space program initial motivations were to build military ballistic missiles and garner international prestige. It is my thesis that domestic and international geopolitical motivations have played critical roles in shaping the Indian and Chinese space programs. The thesis can also be seen through the prism of international relations theories of liberalism and realism.

The realist approach considers the nation-state as the primary actor in international politics, self-interest, as defined by power are the main motivating factors for state actions, the distribution of balance of power (primarily military power) is the critical concern a state must address at any moment in time and quality of state-to-state relations (not domestic politics in another nation) drives the interplay between nations. Meanwhile, the liberal approach considers the nation-state one of many players in foreign policy, values rather than interests shape foreign policy, distribution of power is one of many concerns, socio-economic issues are equally as important as military ones and global circumstances, not state-to-state relations dominate foreign policy (McCormick, 1992, p. 118-119). In the context of liberalism and realism, the thesis is reflects of both theories, domestic motivations would reflect liberalism and geopolitical motivations would reflect realism.

Indian Space Program

The future of India's space program seems bright but its start was an arduous one. Coming out of the costly struggle for independence, India struggled to regain a sense of self, purpose and its place in the world. Prime Minister Jawaharlal Nehru foresaw scientific development as an essential component of India's destiny, the independent space program as one important part. Unlike the space programs of Russia and the United States, India's desire for reaching the stars was not born out of an existing military ballistic missile program, but from a desire for practical socioeconomic benefits (Indian space programme: accomplishments and perspective, n.d., para. 1- 2). This quest for self-sufficiency allows India to pursue programs of socio-economic development within the community of space faring nations.

The objectives and motivations of the Indian space program have been shaped by revealing economic philosophies and political necessities. The civilian space program policies were the by-product of the politics of Nehruvian socialism in which the state directed policies to cure the ills of society. Thus, the program initiated to uplift the personal economics of the common Indian. The beginnings of India's space policy focused only on socio-economic space applications until the 1990's, when the prospects of commercialization of New Delhi's space assets saw the program diversify. In the new century, India diversified its program further with space exploration activities. The Chandrayan-1 lunar mission in 2009 was the first successful manifestation of its space odyssey, with manned spaceflight being the next one. Nevertheless, even as the space program has advanced and diversified, it still had at its core, the enhancing of space applications for the Indian public's empowerment. Herein, the space program was first conceived as a significant factor in the broader national policy of sustainable planned socioeconomic development. India's political and scientific establishment has traditionally focused on the use of science and technology for speedy economic development. The vision of India's space pioneers was the realization of the potential space technology held for a developing nation such as India to leapfrog over traditional stages of development and make a rapid transition to an industrial economy. Hence, satellite communications, meteorology, educational programs, natural resource management and survey were, and continue to be main areas of focus for the Indian space program (Mistry, 1998, p. 5).

In 1962, Dr. Vikram Sarabhai, father and founder of the Indian space program chose Thumba near Trivandrum in Kerala on the southern tip of India to build the initial space complex (Harvey, 2000, p. 127). He envisioned the use of space technologies for the social and economic betterment of India and her people. He foresaw satellites as tools of development by providing communications, remote sensing, meteorology and television broadcasting. Sarabhai wanted to uplift the economy of the nation and its poor, overall to bridge the widening gap between India and developed nations. He reasoned that developing countries must leapfrog to advanced technology, as they did not have the luxury of slow incremental gain to seek parity with developed countries. Also, development of such technologies must be for societal benefit, not prestige. Herein, under Sarabhai's stewardship, the space program imbibed two main objectives for societal benefits:

- Management and surveying of the nation's natural resources
- Speedy development of education and mass communication capabilities (Harvey, 2000, p. 130).

The space capabilities were to be unambiguous in their purpose according to Vikram Sarabhai:

"*There are some who question the relevance of space activities in a developing nation. To us, there 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 flights. But we are convinced that if we are to play a meaningful role nationally and in the community of nations, we must be second to none in the application of advanced technologies to the real problems of man and society, which we find in our country. The application of sophisticated technologies and methods of analysis of our problems is not to be confused with embarking on grandiose schemes whose primary impact is for show rather than for progress measured in hard economic and social terms*" (Harvey, 2000, p. 129- 30). Additionally, the Indian space program has been a product of strong political motivations. Though initially, the space program wasn't a prestige project but with each successful launch, the space program became a great source of pride. Political and public support has never wavered for the program because it accrues international prestige for India. Additionally, the support by politicians enhances their and their party image. Particularly, after the Chandrayan-1 mission, the support of Indian Space Research Organization's (ISRO) endeavors increased manifold. The international recognition India received after the lunar mission was unlike previous accolades of other missions; it was unique, as if India's space program 'had arrived.' The global reaction will be interesting once the program achieves human spaceflight. The ISRO has built strong relationships internationally through cooperation agreements with nations and their agencies, as well as international organizations. The international cooperation permits India to contribute to civilian efforts and lay the seeds of future influence. Also, cooperation gives ISRO the ability to access advance space technology, deficient indigenously.

Moreover, active global involvement by the ISRO makes easier for it to offer its space assets for space commercialization efforts. Even though, India has kept its civilian program separate from the defense establishment and has a strong record of this delineation, it was not able to escape the MTCR regime. The US has imposed sanctions against India, ISRO and other nations and/or entities helping the ISRO gain space technology. The most prominent of these sanctions by the US under the MTCR was the arm-twisting of Russia in April 1992 and July 1993 into not selling cryogenic engines and technology know-how to India, a deal which had been already finalized. The sanctions regime has had the opposite effect on India's space program, in some respects it has slowed its progress in certain areas but it has also emboldened the ISRO scientists to formulate the technology indigenously. Herein, it has enhanced indigenous capabilities, sanctions being 'blessing in disguise' for the ISRO in some instances. The indigenous cryogenic engine, a technology denied under the sanctions regime, is ready for integration with the Geosynchronous Launch Vehicle (GSLV) in late 2009.

The program is meant to be a symbol of India's achievement in science and technology among the non-aligned group of nations. Also, the space program caters to a domestic constituency, from which extends a sense of pride that a developing country can achieve what is meant to be the preserve of the technologically advanced nations, a sense of prestige. From its inception guided by political motivations, India space policy has been the pursuit of self-reliance in all spheres of indigenous space technology without having to rely on foreign technical assistance that could make the Indian space program hostage to the benevolence and potential pressures from other nations (Mistry, 1998, p.5). In 1971 Sarabhai passed away, a great loss for the space program. Prime Minister Indira Gandhi appointed Satish Dhawan as Sarabhai's successor to the ISRO in 1972. Chairman Dhawan molded the neophyte space program, providing important management and organizational framework. Under his guidance, the ISRO and other space-related departments were transformed into energetic and sustainable reservoirs of scientific and technological progress. These space-related organizations implemented effective project management methods to assess, ruminate, master, monitor and nurture ongoing projects. Project management coordinated across diverse centers within ISRO, in industry and academic institutions. Dhawan encouraged team building and sought to spawn collective decision-making frameworks.

Chinese Space Program

China's space program has grown from weakness to strength since its inception in 1956 and with the establishment of the Fifth Research Academy of the Ministry of National Defense. Unlike India's space program, China's motivation for space efforts originally evolved from the Communist leadership's compulsion to obtain nuclear missiles, which could also be used as launchers to put satellites into orbit. The perceived military threat from the world superpowers, intense nationalism coupled with a desire for world prestige fueled China's space ambitions. The domestic politics dictated a strong military space program that would allow China leverage in case of conflict with a superior force, an opportunity to present punitive retaliation in a hostile theatre. The power and prestige, domestic and international offered by the space program to the Chinese Communist Party (CCP) was important in solidifying its position among the people. The program inflamed the nationalistic flames, unifying the public in common cause, thus strengthening the party's position further. Also, in the coming years, the socio-economic benefits provided by civilian aspects of the program not only helped the people but the communist regime as well. In the international arena, the military space program gave strategic space, allowing China to pursue its geostrategic politics. It is well documented, China's continued covert proliferation of nuclear and missile technology against the norms of the international nonproliferation regime (China's Non-Proliferation Words vs. China's Nuclear Proliferation Deeds, n.d.). In order to keep its enemies occupied, it has proliferated nuclear and missile technology to North Korea and Pakistan, the two most prominent examples; North Korea keeps Japan, South Korea and the US occupied with its hostile actions, while Pakistan keeps India busy with its sabre-rattling. According to Paula DeSutter , Assistant Secretary of State for Verification and Compliance in July 2003, "*At the highest levels, the Chinese government has claimed that it opposes missile proliferation…. Unfortunately, the reality has been quite different*" (Zaborsky, 2004, para. 4).

Additionally, in case of any breakout of hostilities with Taiwan, the space program has afforded Beijing's military enough time to bring to a conclusive end, Taiwan's disputed status, in Beijing's favor. As China has been an illicit proliferator under the constructs of sanctions regime, it has been on the receiving end as well. In 1993, Clinton Administration imposed sanctions on 11 Chinese military industrial companies, including China Great Wall Industry Corporation (CGWIC), after determining that China had provided M-11 missile related equipment to Pakistan (Kan, 1998, para. 19). Also, like India, Beijing has strong relationships with nations, their space related entities, businesses and international organizations as to make positive contributions to the arena, find opportunities in space commerce for its products, access space technology and knowledge and seek to influence through soft power. The space program is interrelated with the national military missiles program and the domestic economy. But like

India, China lacked the financial resources, technical expertise and infrastructure to endeavor upon a sophisticated space program. Also, China faced an additional challenge of political stability, the stability of Mao Zedong's communist regime. Mao's communist regime would not falter in the face of apparent challenges and initially gave full support to anyone who could start the space effort in the right direction. With Mao's support and blessing, Tsien Hsue Shen would be the man to give impetus to the space program.

As in the Indian Space Program, Vikram Sarabhai was instrumental to its success; so was Tsien Hsue Shen to the initial development of the Chinese Space Program. Tsien Hsue Shen in Chinese means 'study to be wise,' and he lived up to his father's aspirations. His studious nature reflected in his strong academic record growing up. He was awarded a scholarship to study in America in 1935. His stay in the US was productive, as he taught at universities, worked on rocket technology projects for the US military, and co-founded the Jet Propulsion Laboratory. His return to his motherland in 1956 coincides with the genesis of China's modern space program. Within the Fifth Research Academy, the first Rocket Research Institute was created with Tsien as its first director (Harvey, 2004, p. 22). However, irrespective of government support and theoretical knowledge of the scientists, the fact remained that China didn't have the technological hardware to build a rocket (Harvey, 2004, p. 22). Hence, China sought assistance from its communist friend, the Soviet Union. The Soviets provided some technical assistance and older rockets, but never current technology. The relationship with the Soviet Union suffered from a doctrinal split in 1960, leaving China again on its own to develop the program. Undeterred, isolated and friendless, China marched on the path towards military rocket development which would lay the foundation for its space program. However, its space program would never truly be a civilian space program, as it was and remains under military control.

CHAPTER THREE: DEVELOPMENT OF THE SPACE PROGRAM – HISTORICAL PERSPECTIVE

Space Program

Roots

India

India's knowledge of astronomy can be traced to the *Rig Veda*, which dates to 2000 B.C. The ancient religious Vedic text of the Aryans includes passages praising the comets, stars and sun. The Indian ancients identified nine grahas (planets) that decide a person's destiny. The Indian astronomers using primitive tools were profound in their ability to predict cosmological occurrences, such as eclipses. They were ahead of their peers in discerning that the sun was a star and that it was the center of our solar system. Aryabhatta, a fifth century Indian astronomer preceded Copernicus by a thousand years with his heliocentric theory of gravity. Also, he was an early proposer that the earth was a sphere. His seminal work *Aryabhattiya,* translated into Latin in the thirteenth century was used by Europeans to calculate square and cube roots, areas of triangles, and volumes of spheres. In the seventh century, Indian astronomer Brahmagupta calculated the circumference of Earth as 5,000 yojanas at 7.2 kilometers per yojana; which is 36,000 kilometers, a close approximation to the actual 40,000 kilometers (Indian Astronomy, n.d. para. 1-10). Even though Chinese invented rockets, its first practical military use occurred in 1792, when Tipu Sultan (Sultan of Mysore, in South India) effectively used rockets fired from iron canister against the British colonial forces. However, it was not until Indian independence in

1947 when the end of colonialism unshackled Indians again to seek science endeavors, uninhibited (History of the Indian Space Program–1, n.d., para. 1-2).

China

As an ancient civilization like India, China has a proud history of astronomy and rocketry. The Chinese invented gunpowder in the 3rd century. Gunpowder technology and its use slowly spread to the west over the next thousand years. In 970, Feng Jishen used gunpowder to propel arrows through the skies. During the reign of the Ming Dynasty (1368-1644) evolution in Chinese rocketry took a giant leap. Over 39 types of rocket weapons were used during the Ming Dynasty. The ascendance of the Manchu Dynasty in 1644 led to interruption of rocket development for 300 years (Harvey, 2004, p. 15-17).

Laying the Foundation

India

The unshackled endeavors for space were pursued by Dr. Vikram Sarabhai, father and founder of the Indian space program in 1969. He was authorized by the Prime Minister Jawaharlal Nehru to lay the foundations of a space program in the country. Sarabhai saw the program benefitting the socio-economic spheres of an entire Indian people. Herein, the Indian space program was resolute in purpose of helping social and economic upliftment. In 1971, Sarabhai died and the mantle was passed to Satish Dhawan, as Chairman of the Indian Space Research Organization. Under his dynamic leadership, the new space program was transformed into a dynamic and sustainable incubator of scientific and technological progress. Within a few years, under his management, Indian space program achieved extraordinary growth (Harvey, 2000, p. 130-33).

China

After a year at Massachusetts Institute of Technology, Tsien Hsue Shen transferred to the California Institute of Technology (CalTech), where he received his doctorate in 1939. At CalTech he started devoting time in discovering the theory and application of rocketry. By 1942, he was working on rocket projects for the military on how to use rockets to propel aircrafts and ballistic missiles. He co-founded the Jet Propulsion Laboratory, a subsequent reservoir of cutting edge space and military technology innovation. The surrender of Germany gave the US and Soviet Union opportunities to scavenge advanced German rocket technology and appropriate it to their respective nations. In 1945, Tsien was a member of US surveying teams that scoured Germany military sites for rocket knowledge. Upon his return to the U.S. he published a book of wartime technical writing called *Jet Propulsion.* Through the mid 1940s he continued his research and teaching at M.I.T and CalTech. However, in 1951 at the apex of the McCarthy inquisitions, he was accused of being a communist. Tsien was stripped of his security clearance and placed under house arrest. His research papers were confiscated but he continued to work under home confinement. He was finally released in 1955, along with 93 other scientists from the US to Communist China in an exchange for 76 Americans prisoners of war of the Korean conflict.

The dawn of 1956 saw a new proposal from Chairman Mao Zedong for the fast expansion of science and technology that would enable China to quickly catch up with the West. A Scientific Planning Commission by Prime Minister Zhou Enlai was set up in response to Mao’s call. Tsien submitted a report to the Central Commission in February 1956 titled, *Opinion on establishing China’s national defense aeronautics industry*. After further consultations with other scientists, the commission drew up long-range plans essential for scientific and technological development, 1956-67. The plan outlined 57 priority tasks to make China self-sufficient in jet, rocket, computer and atomic energy technology. On October 8, 1956, the Communist Party's Central Commission established the Fifth Research Academy of the Ministry of National Defense to start the space endeavor. This is acknowledged as the Chinese space program's official birthday. Under the Communist Party's vice-premier Nie Rongzhen the China Rocket Research Institute was established, with Tsien as it director.

China mimicked Russia's protocols for naming the classified space, military and nuclear efforts under generic titles such as the Russian space industry's heading body the Ministry of General Machine Building. The Fifth Academy's title was in the Russian tradition of subterfuge. Even though, experts like Tsien Hsue Shen, Guo Yonghuai, Xu Guozhi and other scientists possessed theoretical knowledge, it soon became apparent that China didn't possess the capabilities to build a basic rocket from scratch. So, negotiations began with the Soviet Union to acquire the necessary technology to build the rockets at home. In July 1957, the Soviet Union agreed under the *New Defense Technical Accord 1957-87* to supply China technical documents, missile models, designs and Soviet specialists. The Soviets supplied several R-2 rockets to the Fifth Academy, which the Chinese attempted to reverse engineer. However, they didn't have the materials, the resources and the know how to assemble a complete rocket, even a rudimentary one such as the R-2. The Chinese lacked the expertise in areas of tooling, machining, welding, pressing and punching. Their rocket production facilities were archaic (Harvey, 2004, p.22- 27). Herein, independent of the development of the R-2, a parallel sounding rocket program began in 1959.

The sounding rocket program after several tests launched the operational Shijiedu or T-7 on September 1960. The rocket weighed 1,138 kg, carrying a payload of 25 kg reached the height of 60 km. It carried equipment that measured temperature, atmospheric pressure, density, wind speed and direction. While, the sounding rocket program progressed, China came closer to realizing success of its military program with the launch of a Chinese copy of the Russian R-2 on November 5, 1960 (Harvey, 2004, p. 30-34). The launch site was northeast of Jiuquan in the Gobi desert, 994 miles from Beijing. The Chinese named the R-2 Dong Feng 1 or 'east wind' (Harvey, 2004, p. 31-33).

Applications :The Beginning

India

The precursor to the growth of a space program was the establishment of the ISRO in August 1969 and the Space Commission, the policy-making body in June 1972. The Space Commission operated under the auspices of the Department of Space (DOS), under the Prime Ministers office. These structures provided a stronger foundation to build the space program in the realm of research, activities, coordination and training. The Indians built their first earth station, the Experimental Satellite Communication Earth Station (ESCES) in 1967 in Ahmedabad. This station made a step forward by making contact with the American Application Technology Satellite. In addition, five years later a fully operational earth station was inaugurated at Arvi. The main reason for the impetus of India's space program was to advance development in several spheres of Indian society. Herein, Vikram Sarabhai and P.R. Pisharoty (father of Indian remote sensing) appreciated the application of remote sensing satellites data for the ordinary Indians' benefit. In those years, India lost $1.3 billion to pests, $220 million to floods, and $430 million to droughts. However, remote sensing capabilities could help Indians avoid many such losses, as well as in terms of human loss, human suffering and other financials. The mapping and surveying of India's terrain by remote sensing satellites could prove invaluable in economic and human terms for the nation. India sought earth resource data from countries that could provide it.

American satellites could provide earth resource data from its Landsat satellites. India in 1978, initiated the construction of a station to receive earth resource data at Hyderabad, Andhra Pradesh. This station became the foundation of the Indian National Remote Sensing Agency that would analyze remote sensing data. Additionally, the American Technology Satellite 6 (ATS-6) launched in 1975 performed pioneering work, such as broadcast medical advice and teleconferencing. In an experiment called Satellite Instructional Television Experiment, NASA broadcast over two thousand hours of ATS programs through Indian stations for almost a year, between August 1975 and July 1976. The programs were relayed to over 2400 rural villages and covered multiple educational topics such as health, hygiene, agriculture, literacy, family planning and rural development. This first hand familiarity coupled with the immense potential of remote sensing data resonated deep within the Indian scientific community (Harvey, 2000, p. 130-33).

China

The Chinese chose the Gobi desert as a launch site for its military and space programs due to its remote location and secrecy. Any launch site in a coastal area would have been vulnerable in the incident of a conflict, had large population densities and any launch activities could have been monitored easily by foreign powers. Unknown to the Chinese, by March 1962, the US through satellite and U-2 plane reconnaissance activities had a good idea of China's military space activities. The reconnaissance photographs clearly detailed the Jiuquan launch center. They showed three launch pads, as well as two Surface to Air Missile (SAM) sites. Also, the support infrastructure could be clearly delineated including, accommodations, airfield and communications systems and servicing facilities. By June of 1967, the CIA had a detailed knowledge of the activities at the center. As the early development of the Chinese space program was led by American-trained Tsien Hsue-Shen, he continued in his efforts to advance the program to new heights (Harvey, 2004, p. 31-33).

Satellite Endeavor: the Start

India

Aryabhata

The Indians and the Soviets had strong relations, which also migrated to the realm of space cooperation. India signed its first space agreement in 1962 with the USSR. Also, a key space agreement was signed between the two nations in 1972 that paved the way for an Indian satellite launch aboard a Soviet rocket and the Soviet use of an Indian port for launching their sounding rockets. The first Indian satellite, the Aryabhata was named after the fifth century mathematician and astronomer, weighed 360 kg (794 lbs), and launched on a Soviet *Cosmos 3M* rocket on April 19, 1975. The satellite would study solar flares and their emitted neutron and gamma radiation, stellar x-rays, and radiation in Earth's ionosphere. Unfortunately, the satellite mission was abandoned after five days when the transformer failed (Harvey, 2000, p. 134).

Bhaskhara

India's second satellite Bhaskhara, was launched on June 7, 1979 in an orbit of 519-541 km, 50.67deg, 95.16 mins. The satellite named after seventh century Indian astronomer weighed

442 kg, was a 26-sided polyhedron, 1.119 m tall, 1.55 in diameter, with a surface area of 6.5 m^2. The successful launch on the Soviet rocket Cosmos 3M from Kapustin Yar placed into orbit India's first experimental remote sensing satellite. It carried television and microwave cameras. The satellite would study changes in water and vegetation, obtain wind velocity, surface temperature, moisture content information of India's surrounding oceans, collect data from India's eight meteorological stations and relay them to a central receiver station in Ahmedabad, and also identify X-rays. However, Bhaskhara was a limited operational success due to the camera system not working properly.

Bhaskhara 2

The second experimental remote sensing satellite was launched on November 20, 1981 from Kapustin Yar near the banks of the river Volga aboard the Cosmos 3M. This satellite was similar to Bhaskhara 1 and provided the Indians their first opportunity in operating a remote sensing satellite system for its complete lifespan. The cameras of Bhaskhara 2 enhanced knowledge of water vapor, sea winds, and rainfall rates. The satellite burned up in the atmosphere in November 1991 (Harvey, 2000, p. 135).

Rohini Series

The ISRO initiated the Rohini series with a launch of the Rohini Technology Payload (RTP) on August 10, 1979 aboard the Indian Satellite Launch Vehicle (SLV 3). The RTP was the only one in a series of four satellites to be unsuccessful in placement of orbit. These satellites were mainly technology demonstrators in nature used to test indigenous solar cells were launched on the experimental launch vehicle SLV.

Satellite Endeavor: the Progress

Remote Sensing

The next stage in development of the Indian Satellite program was the Indian Remote Sensing Satellite (IRS), part of the Indian Remote Sensing Satellite System. The IRS was in the one-ton class of satellites with upto three linear imaging self-scanning sensors, one 70 mm, and two 35 mm meant to carry out of systematic survey's of Earth's surface for the use of geologists, hydrologists and agriculturalists. The satellites crossed the same point of the Earth every 21 days (Harvey, 2000, p. 137-40). The launch of Cartosat-2A on April 28, 2008 culminated in the thirteenth Indian Remote Sensing series satellite being placed in orbit. Cartosat-2A data will help urban and rural infrastructural development and management (Cartosat-2A, n.d., para. 1-2). The remote sensing system is critical to the national management system for natural resources in India. This system is called the National Natural Resources Management System (NNRMS), which is under the auspices of the Department of Space. NNRMS collects ground and satellite data for mapping waste land, fighting drought, water resource management, approximating crop yield, mineral development, forestry management, flood prevention, and costal and fisheries development. The nation's multi-dimensional development program uses 45% data from IRS for planning input (Harvey, 2000, p. 141).

Communication and Weather

The socio-economic mission of the space establishment was carried forward with the National Satellite System (INSAT) series of satellites. The satellite series was envisaged to be placed in 24-hr geosynchronous orbit. The total cost for the initial project in 1976 was $559 million, a joint project between the Indian Meteorological Department, Department of Space, All-India Radio, and Department of Telecommunications (Harvey, 2000, p. 146). INSAT series is composed of 21 satellites out of which 11 are in service, thus making India possessor of one of the largest domestic communication satellite systems (Programmes, n.d.).

The INSAT series would provide weather and communication capability to India. India became the first country to combine these two purposes in one satellite with the launch of the Ford Aerospace built INSAT-1 aboard the NASA shuttle in 1981(Harvey, 2000, p. 147-48). The subsequent launches of the INSAT series led to a wide expansion of benefits for the Indian populace. Today over 90 percent of the Indian population receives television; it was 30 percent before the initial INSAT launch. Indian satellites have provided weather information to prevent disaster and provide disaster relief, training for farmers, video conferencing and have enhanced the overall communications capabilities from rural areas to cities.

China

Dong Fang Hong 1

The Dong Fang Hong-1 (Red East 1) was China's first space satellite, launched on April 24, 1970 aboard the Long March 1 (CZ-1). Its main objectives were to perform satellite technology experiments and atmospheric readings. The 173kg (381 lbs) satellite continually broadcast 'The East Is Red' music at 20.009 Hz. The launch of the satellite made China a member of space faring nations to independently launch a satellite into space (Chinese Satellites, n.d., para. 1).

Shi Jian 1

One year later after Don Fang Hong 1 satellite's success, China launched its second satellite, San Jian 1 into orbit. Once the propaganda value of launching a satellite into orbit had been achieved with the first launch, China could concentrate on satellites with more scientific value. The 72 polyhedron San Jian, slightly heavier than its predecessor at 221 kg was placed into an orbit of 267 by 1,830km, 69.9 degrees, period 106.15 min on March 3, 1971 (Harvey, 2004, p. 60-61). The satellite carried three scientific instruments, a 3mm S-ray detector, 11 mm cosmic ray detector, and a magnetometer. San Jian had a successful 3,028 day mission in space.

Communications

The next big event in China's satellite program was the development of communication satellites in the 1980s. China now moved ahead with ambitious plans to place satellites into geosynchronous orbit 36,000 km over the Earth. There were many reasons China wanted to develop satellite-based communications. Communication satellites offered the country's vast geography advanced communications quickly. The satellites would save time and funds by foregoing establishment of complex systems of relays for television transmission and land lines for telephone communication (Harvey, 2004, p. 96).

The first launch of China's communication satellite, Shiyan Weixing took place on January 29, 1984 aboard the Long March 3 rocket. Due to the failure of the rocket's third stage, the satellite wasn't able to reach the desired geosynchronous orbit (Harvey, 2004, p. 103). Subsequent launches of the Dong Fang Hong series of communication satellites would prove to be extremely successful. The increasingly sophisticated satellites expanded TV transmission and telephony to cover all of China.

Navigation Satellites

In 2000, China launched the first of its navigation satellites, Beidou. The nation put into place a long baseline triangular navigation system that would help provide navigational fixes for road and transport, ships, and possibly aircraft (Harvey, 2004, p. 157-58). Additionally, in 2003 China signed an agreement with the European Space Agency and the European Union to participate in the Galileo program.

The Launchers

India

After a few launches of the Satellite Launch Vehicle (SLV), India's first launcher, a rocket with limited carrying capacity was proceeded with the upgraded version Augmented Satellite Launch Vehicle (ASLV). After 12 years of service, in 1999 the ASLV an intermediate rocket able to place 150 kg payloads into 150-300 km orbits was decommissioned. A new larger launcher the Polar Satellite Launch Vehicle (PSLV) was set to take its place.

PSLV: Joining the Big League

From the modest beginning with sounding rockets of the 1960's India has established the capability to launch remote sensing satellites using Polar Satellite Launch Vehicle (PSLV). The PSLV has given India the ability to place upto 1000- 1200 kg payloads into sun-synchronous polar orbits. The PSLV was given the task to launch the Indian Remote Sensing Satellite (IRS) series. This launcher enabled India to be counted among the select club of Russia, US, China, Europe and Japan, able to build large launchers. The PSLV was the third largest *solid* fueled rocket in the world, after the NASA space shuttle and the Titan. Unlike other rockets, the PSLV was a mixture of solid and liquid fuel. The second and fourth stage of the five-stage rocket used storable liquid propellants unsymmetrical dimethyl methyl hydrazine (UDMH) and nitrogen tetroxide. India hoped to offer the PSLV's services in the world launcher market and with it recover its $122 million development costs.

`The initial PSLV launch on 20 September 1993 was unable to place the valuable IRS payload into proper orbit due to software error. Nevertheless, the next launch on 15 October 1994 successfully placed the 870 kg IRS-P2 remote sensing satellite into 825 km polar orbit (Harvey, 2000, p. 154-58). Thus far, the PSLV has had 13 consecutively successful flights (Programmes, n.d.). The PSLV enabled India to place large resource satellites into polar orbit for the continued socio-economic benefit of the Indian populace.

GSLV: Joining the Big Leagues

India began in the 1980s to develop a launch vehicle able to place 2 to 2.5 ton payload into synchronous geostationary orbit (200 km by 36,000 km). The Geo-synchronous Satellite Launch Vehicle (GSLV) is a three-stage vehicle that assumes solid and liquid stages of PSLV and Russian cryogenic engines in the upper stage. The first flight of GSLV-D1 on 18, April 2001 from Sriharikota Island launch site in the southern state of Andhra Pradesh successfully placed a 1.5-ton experimental satellite GSAT-1 into 180 x 32,155 km geo-synchronous transfer orbit (GTO).(Indian space programme: accomplishments and perspective, n.d., para. 14). The GSLV has had four successful flights out of five missions since inception, the last one being GSLV-F04 placing communication satellite INSAT-4CR satellite into orbit on September 2, 2007 (Programmes, n.d.).

China

China has been able to reach new heights from the era of "fire arrows" and gunpowder rockets developed for ancient warfare to modern rocket technology for its space program, again borne out of military development.

Dong Feng 1 – Joining the space race

The Chinese scientists took on the challenge of copying a Russian R-2 rocket. Even though China lacked the infrastructure and resources to build basic rockets, they tried to get the R-2 into production. At one point, substantial momentum was building to discontinue the efforts at duplicating the R-2 as it was thought too advanced a task for a developing nation. However, Mao Zedong and Zhou Enlai insisted that rocket development continue (Harvey, 2004, p. 24-28). As the 30 year Chinese-Soviet accord eroded in August 1960, the Chinese had sufficiently mastered the construction of the R-2 to launch the first 'Made in China' rocket on November 5, 1960; China had officially joined the space race.

Dong Feng series

The successful launches of the R-2 rockets didn't prepare the Chinese for the extensive time and effort required to realize further development of the Dong Feng. The military imperatives were the genesis of China's space program; as such these imperatives continually trumped civilian aspects of the space program. For these reasons, China's first indigenously designed and manufactured rocket, the Dong Feng 2 had the capability of hitting arch nemesis Japan 932 miles away (Harvey, 2004, p. 37). Eventually, incremental advancements in rockets culminated into China's long-range rocket, the Dong Feng 5. The development of the Dong Feng 5 provided China significant progress in propulsion, rocket engine steering devices, guidance systems and strengthened light materials. The rocket allowed the Chinese to achieve an intercontinental ballistic missile capability, with the USA within its reach. The work performed on the Dong Feng series contributed to the development of the Long March 1 rocket, used to launch China's first Earth satellite.

Long March Ahead

The space program needed a new rocket to launch China's first Earth satellite. The design of the new rocket Chang Zheng or Long March 1 began in earnest in November 1967 at the Chinese Academy of Launcher Technology (Harvey, 2004, p. 52). This family of rockets is divided into four series with the fifth under development. The Long March 1 was basically a three stage version of the Dong Feng 4 (DF-4) missile. However, a small third stage solid rocket motor was added to the DF-4 to place satellites into orbit. This initial liquid fuelled launcher propelled China's first two satellites into orbit, the Dong Fang Hong in 1970 and the Shi Jian in 1971. The Long March series of launchers have served China's space program well with an excellent reliability record (Harvey, 2004, p. 211).

Feng Bao

The Project 701 was a new launcher; the Feng Bao (storm) designed in Shanghai unlike the Beijing designed Long March. The rocket was principally based on the Dong Feng 5 missile. The first flight of the Feng Bao occurred on August 10, 1972 (Harvey, 2004, p. 71-73). But the rocket only lasted a decade in service from 1971 to 1981 (Harvey, 2004, p. 209).

Space Centers

India

Over the years, the Department of Space (DOS) has laid strong research and development and technology foundation with the requisite manpower and infrastructure for implementing the space program. A detailed space center list and description can be found in Appendix A.

China

A critical component of a space program is the support infrastructure. Over the years China has developed support launch centers that are fairly large and comprehensive. All the launch sites were developed with the foresight of not only establishing its capability to support indigenous space efforts, but provide services to other nations as well. China operates four modern launch sites. Located in the Gobi desert, the Jiuquan launch site has two launch pads for the Long March-2 rocket for placing payload into low-earth orbit and medium-orbit with orbital inclinations of 57^{o} to 70^{o}. The work horse Long March 3 is launched from the Xixhang site for geostationary missions. The Taiyuam site is used for sun-synchronous meteorological and earth resource missions (Patterson, 1995, p. 5). The fourth, minor site on the island of Hainan is used for launching sounding rockets. Additionally, there is launch site at Harbin, Manchuria solely used for military use (Harvey, 2004, p. 195). Mission control is undertaken from China Satellite Launch and Tracking Control Center near Xian that contains Telemetry & Control as well. The tracking stations are spread out domestically, overseas and on a fleet of tracking ships. With these launch complexes and supporting facilities, China has successfully positioned itself to meet modern space launch requirements and commercial space enterprise.

Space Business: Commercial Space Activities

India

Unlike, the Russian and Western space programs, the commercial space activities in India have evolved from a different course. The Indian program has its genesis as implemented by the ISRO as a wholly civilian program, with the goal of using modern space technology towards hastening the country's socio-economic development. From the early stages of the space program, ISRO had been responsible for the requisite design, expansion, manufacturing, assembly and testing of space systems. Due to the dearth of private sector and industrial space technology base in the earlier stages of the space program, the ISRO remedied this in the mid1970s, with the technology transfer program to Indian industries.

This laid the seeds in the private sector, the establishment of necessary process expertise and facilities to undertake manufacture of diverse services and products for national space projects. In a matter of time, the private industry started providing the ISRO centers with an assortment of electrical modules and subsystems, diverse materials, test equipment, components, software and hardware including the propellants, structures for satellites and launch vehicle systems, and ground systems.

A significant portion of ISRO's manufacturing activities were successfully farmed out to the industry as part of the technology transfer program. The program had critical residual benefits in the form of several space technology spin-offs and in instilling culture and practices associated with dependability, reliability and quality assurance. Another important component of industry partnership was the involvement of user agencies in the government from the start of space applications development and subsequent validation. User's representatives were incorporated in the management hierarchical structures to provide user viewpoints for future mission planning. To further expand the scope of marketing Indian space services and products of the ISRO in the international arena and to also foster the participation of the nascent industries in space commercialization, the Government of India in 1992 formed the Antrix Corporation, a commercial arm under the auspices of the Department of Science.

Over time Antrix has developed into a one stop shop for international clientele, catering to diverse needs ranging from small space components, IRS satellite imagery, to deliverance of sophisticated satellite systems into orbit. Structured as a private limited company, Antrix's alliance with the American firm Space Imaging Inc. has cornered 20% of the global market for remote sensing data. Over 20 ground stations, spanning USA, China, Germany, Kazakhstan, Russia, UAE, Algeria, Saudi Arabia, Thailand, Myanmar and so on directly access data from IRS satellites. Furthermore, the recent establishment of an alliance between Antrix and EADS Astrium, the European satellite manufacturer to jointly market and manufacture commercial communication satellites in the international market will further offer India opportunities to enhance its commercial space portfolio. The past remains true in terms of the space launch market being the reserve of the Americans and Europeans. Entry into this lucrative arena of commercial space offers considerable challenges due to restrictions placed by major space powers like the US. The launch industry is also subject to stiff competition and overcapacity.

Antrix has made preliminary forays into the launch market by providing low-cost launch services for petite satellite systems in piggyback mode. ISRO has successfully launched satellites for Argentina, Germany, Korea, Belgium and Indonesia in this mode by PSLV. In 2007, the PSLV performed a full-fledged commercial launch of Italian scientific satellite AGILE by placing it into a near equatorial orbit. The launch capacity of the Indian space program is growing with new more powerful launchers under development, such as the GSLV III, with an indigenous cryogenic upper stage engine. This will propel India into the ambit of a select few nations with the ability to launch heavy satellites into geosynchronous orbit. However, many challenges remain for the nation as global space commerce will be driven by low cost accessibility to space, geopolitical developments, international political and security imperatives, and technological advancements (Murthi, Sankar, & Madhusudhan, 2007, 1815-1817).

China

After the several successful launches of the Long March 3 rocket, China broadcast its intention to join the commercial space launch business. In 1985, astronautics minister Li Xue made the formal announcement to offer the Long March series to the West for placing commercial comsats into geosynchronous orbit. Little interest was shown by the Western companies until 1986, when within a span of a few months, America's two leading rockets exploded (Titan and Delta) and the *Challenger* space shuttle was lost. Additionally, Europe lost an Ariane 2 rocket due to technical difficulties. Many of the companies that had relied on America and Europe for commercial space transport for their satellites were left with no alternatives but to use Russia's Proton or China's Long March (Harvey, 2004, p. 115).

Majority of the communications satellites requiring launch services are built in the U.S. or include U.S. components, hence require U.S. export licenses for satellites to be launched from China. The United States played the critical role in the evolution of the Chinese commercial space launch business. In 1988, President Ronald Reagan approved the first export licenses for three satellites to be launched from China, only if China met certain conditions. The conditions entailed China sign three international treaties regarding, among other things, negotiating a fair trade agreement with the U.S. pertaining to commercial launch services; liability protection against satellite damage from space launches and agreement on satellite technology protection while the satellites were in China.

The Chinese met all conditions by January 1989. During this time all export license requests were under the purview of the State Department. However, the occurrence of the Tiananmen Square uprising in June 1989 led to President George Bush suspending the export licenses for the three satellites. Ultimately, the suspension was lifted and the satellites were successfully launched by China. This incident underscored the immense dependence of China's commercial space endeavor on the West, particularly America and America's near monopoly on the commercial launch business. Chinese space launch services business was hostage to the whims of US political-military power, examples of which were common throughout the 1990s, when export licenses were granted, suspended and reinstated based on the political situation. In 1997, serious allegations surfaced that China was benefitting its militarily space efforts by obtaining useful information by launching American satellites. The charges emanated from U.S. investigations into launch failures involving its commercial satellites where, Loral and Hughes, two U.S. companies possibly helped China in understanding the cause of the launch accidents and how to rectify them. In 1999, the State Department stopped granting further export licenses for commercial launches onboard Chinese rockets (Smith, 2003, p. 4-5).

Nevertheless, an easing of tension between the U.S. and China and a commitment by China not to assist some nation in the development of ballistic missiles led to the State Department lifting of restrictions on Chinese launchers. However, the export regime made lifting of the ban an academic exercise (Harvey, 2004, p. 129). The Chinese commercial satellite launch services have had small successes but have not yielded the penetration of the global market as had been aspired to. China continues to launch satellites for a small sparse foreign clientele; on May 14, 2007 for the first time China launched a home grown commercial satellite for a foreign buyer, Nigeria (Atkins, 2007, para 1-5).

Historical Objectives

India

Since its beginnings, India's space program has as its core focus, space applications. Even though national prestige was not the initial motivation for starting the program but has become overtime part of the program's awareness. As the leader of the Non-Aligned Movement (NAM), New Delhi's unique socio-economic space program enhanced its prestige among the member developing nations, symbolizing high technology achievements. For the domestic constituency, the program has retained considerable popularity; each successful space launch raises morale. In addition to political domestic and international prestige, another politically guided goal of New Delhi's space policy was the achievement of indigenous development, enabling the nation to explore and use outer space with its own space assets, without having to depend on external assistance that could compromise the autonomy of the space program. Following the war with Pakistan in 1971, the government upgraded the space program in mid-1972. The ISRO was removed from the Atomic Energy Commission and placed under the auspices of the DOS.

The increased activity within the ISRO coincided with the beginnings of working on India's nuclear delivery, the ground tests of the SLV-3 in 1974-75 combined with its nuclear tests signaled New Delhi's political intentions that India was ready to indigenously build a nuclear delivery system for it nuclear defense. The significant spin-off from the civilian space program to the military occurred in the mid 1980s, when it emerged that the SLV-3's first stage was used in the Agni ballistic missile. Currently, the missile program is handled by the Defence Research and Development Laboratory (DRDL), and thus future missile spin-offs are unlikely to come from the ISRO's launch vehicles. As the Indian economy liberalized in the 1990s, the goals of the ISRO expanded to include space commercial efforts. In 1992, the Antrix Corporation was established to offer ISRO's space services on the international market.

As in domestic politics, prestige played an important role in the space program; the commercialization of space assets enhanced the prestige further internationally. India's space program has historically been active building relationships globally. The bilateral and multi-level cooperation with nations, space agencies and other international organizations derives India's space program many benefits. In 2006, India and Russia reached an agreement that allowed India to be a partner in Russia's Glonass satellite navigation system (Joseph, 2006, para. 1). ISRO has a commercial partnership with EADS-Astrium of Europe to build and launch satellites for international customers. The Indian space diplomacy has allowed it to enhance trust, contribute to international space science and technology, access space tech, gain access to international markets for conducting space commerce and garner political influence for national interests.

National interests may lead the international community to question India's intentions for its space program. It is true that India's launch vehicles and satellites have military and strategic applications but with the exception of the SLV-3 episode, they have no current military purpose. The launch vehicles and satellites can perform military functions but it is not practical. The PSLV and GSLV can be converted to ballistic missiles and the IRS and INSAT can offer rudimentary defense reconnaissance and communications capability. However, during fueling the launch vehicles with liquid fuel will make them open targets, the resource satellites can't provide high enough resolutions and day/night cloud penetration capability, and the communication satellite frequencies can be easily jammed; herein, these dual-use civilian space assets can provide limited, if any tangible assistance during a military conflict (Mistry, 1998, p. 5-6). India's program has reached an advance level of sophistication, earning accolades for the recent lunar Chandrayan- 1 mission. It brought the ISRO and India immense domestic and international prestige. There is a Chandrayan-2 robotic moon lander mission and manned mission in the works, leading to the possibility that India places less emphasis on historical socio-economic space projects.

China

Chairman Mao was a man on a mission, to gear China to once again be a strong power, able to develop independent of arm-twisting by world powers. In that spirit, the cold war environment provided domestic political compulsion a ready environment to seek international prestige and territorial defense. Beijing's space policy has been guided by military compulsions, which it sees as critical to regaining its lost sense of historical greatness, its 'manifest destiny.' The military space program has been in modern times, a fast track to achieving Beijing's 'Mandate of Heaven.' Unlike, India's space program that placed emphasis on civilian space applications from inception, China's space policy expanded from its core military focus, later to provide socio-economic services to its people. Additionally, the program expanded to leverage space commerce to showcase China’s space services offerings and enhance its international prominence.

The seeking of international prestige has been more prominently associated with the Chinese space program than the Indians. For China, the mythical ‘Celestial Kingdom’ being reduced to the 'sick man of Asia' by the acts of imperialism, the recovery from this is part of its national narrative since Mao’s rise. The attainment of space power status represents for the Chinese a modern ‘Celestial’ state. National and international prestige is not only essential for the recovery from historical offenses, but enhancing future standing (Delios, 2005, p. 4). International cooperation with other nations, space agencies and international organizations has been part of China’s space program from its inception. This cooperation has led Beijing to access technology to advance its space program. In the 1990’s, China received illicit aid from Loral, Hughes Aerospace and Lockheed-Martin that helped improve China’s launch capabilities. The technical assistance provided by Loral and Hughes corrected the guidance system of the Chinese Long March rockets, a launch system used by the military’s civilian front organizations, the China National Space Administration (CNSA) and commercial division China's Great Wall Industry Corp (CGWIC). The satellite-launch data provided by the American space firms was also applicable to the guidance systems of intercontinental ballistic missiles (Chapman, 1998, para. 7-9). Eleven Chinese entities were sanctioned and the American firms fined due to the technical transaction.

The main objectives of China’s space cooperation efforts have been to use the civilian face of the CNSA to access technology that can help its defense efforts in the space arena and elsewhere, develop space commercial opportunities and to serve geostrategic aims through nuclear and missile technology proliferation. China has manufactured and launched satellites for Venezuela and Nigeria, as part of its recent space commercial efforts. For its geostrategic objectives of keeping Japan and South Korea in constant flux, it proliferated nuclear and missile technology to North Korea, as well as to Pakistan to keep India continually on the edge. Also, the space program has afforded Beijing enough strategic space to buy time in case of conflict with Taiwan, to have a decisive solution in its favor. China's historical involvement in illicit proliferation continues unabated even though it and its entities have suffered sanctions under the MTCR regime. Also, the nation and its space entities have received sanctions on dual-use technology imports The sanctions have not arrested the progress of the space program, possibly delaying it for a period of time, but never stopping its advancement. The Chinese have had three successful human spaceflights, Shenzhou V – VII and a Chang'e 1, lunar mission, enhancing the program's prestige substantially.

CHAPTER FOUR: COMPARISON OF INDIAN AND CHINESE SPACE PROGRAM

Indian Space Program

The Indian program was meant to have a social impact, the uplifting of the Indian people. The program was also meant to help the nation leapfrog to advanced technologies and be used for two main purposes:

- Enhancement of education and mass communications, particularly for rural people.
- Appraisal and administration of the nation's natural resources

The mission and passion of Dr. Sarabhai continues to be part of the space program. However, while the program and its scientists are committed to projects that benefit the Indian people, they are exploring new horizons. One of the new horizons India is exploring is the moon, the surface of the moon. The Chandrayaan-1 spacecraft was launched on October 22, 2008 aboard the PSLV launcher. Chandrayaan-1 carries aboard it 11 scientific payloads, five from India and six from abroad, including NASA, the European Space Agency and Bulgaria. The scientific payloads will map the minerals and chemicals on the moon, as well as prepare a 3-diemensional map of the total lunar surface. The lunar mission will also offer clues on the early origin of the moon (Subramanian, 2008, para 13).

Reaching the moon has been a dream of Madhavan Nair, chairman of India's space program, which is using $1 billion per year on its space efforts, compared to an estimated $2.5 billion annually by China. The successor of the $100 million Chandrayaan-I mission, the Chandrayaan-II, a cooperative effort with Russia, is anticipated to land a rover on the moon by

2012. The ISRO'S future plans include putting a man on the moon by 2020, followed by robotic missions to a nearby asteroid, Mars and the sun, a schedule more ambitious than China's (Hennock, Kushner, & Overdorf, 2008, 2).

China's Space Program

China is concurrently considered a developing country and a world power. Many things remain a mystery about many spheres of China due to censorship and on many occasions much available public information is carefully orchestrated by the communist party. The same can be applied to China's space program; many aspects about it remain shrouded in mystery. However, the reasons for the birth of China's space program remain clear. Soon after the founding of the PRC, the Chinese space program was initiated. Like the United States and the Soviet Union, China's space program had at its genesis a military foundation and attainment of national prestige. The program had a military outlook and nuclear deterrence a critical component.

Overtime, China has developed the status of a top-tier space program third in class after the U.S. and Russia. The recent success of its astronauts' first spacewalk, have fueled China's ambitions. The nation has embarked on advancement projects of developing a space station, manned moon mission by 2020 - 2025, building a space shuttle, and more. The space programs for both nations have grown to be power prestige fares. As India's program has grown strength to strength, so has the regional rivalry between the two country's space endeavors, the aim, to become the undisputed Asian space power.

The Beginning

India: Upliftment and Development

India’s first Prime Minister, Jawaharlal Nehru envisioned a post-independent India using “*planned development of an industrial society to eliminate poverty, provide social justice, create a self-reliant economy and assure national independence and security in world politics.”* He wanted an India that was free of imperial western commercial exploitation, an industrialized India, politically independent and economically self-reliant. Nehru realized that to make India self-reliant, it would have to leapfrog in technology quickly, without having the luxury of progress over hundreds of years in development to have technological parity with the West. Technologies were the ‘temples of modern India,’ as Nehru referred to it; modern technology would uplift the Indian people from the ills that define third world status, hunger, poverty and the like, towards a path of self-reliance to guarantee the expansion of an independent industrial base that would then lead to national socio-economic development.

Out of Nehru’s clarion call of independence and socio-economic development, the Indian space program discovered its roots, beginning in 1962 the program had a muscular sense of its importance in national development. Scientist Vikram Sarabhai, answered the prime minister’s call of secular socio-economic national upliftment. Sarabhai was convinced that the space program, if it were to *“…to play a meaningful role nationally, and in the community of nations, [it] must be second to none in the application of advanced technologies to the real problems of man and society*” (Raja, 2006, p. 2).

China: Military and Prestige

Shrouded in secrecy, since its inception, the world outside the corridors of civilian-military intelligence agencies that keep tabs on the military activities of China, one gets its information on the Chinese space program from what the communist regime releases, the think tanks ponder, the academia publishes, the journalists investigate and the other world governments release publicly. What is known publicly about China’s space ambitions is that the program is an integral component of the military, an outgrowth of Chairman Mao Zedong’s desire for the People's Republic of China (PRC) to become a become a nuclear power. Hence, China's space program was prompted in the 1950s by a choice to acquire nuclear weapons. The political compulsions behind this decision were driven by the twin imperatives of territorial defense and national prestige.

China’s great leader, CCP Secretary General Deng Xiaoping, who was later to play a critical role in China’s history as the man to introduce market-driven reforms and open China to the world, addressed the nuclear matter succinctly. "*The Soviet Union has the atom bomb. Where does the significance lie?*" he asked in 1957. "*It lies in the fact that the imperialists are afraid of it. Are the imperialists afraid of us? I think not . . . The United States stations its troops on Taiwan because we have no atom bombs or guided missiles*" (Dellios, 2005, para 3). Even though, the Chinese leadership painted the West with the imperialist brush, they didn’t however; hide their own imperial intentions of military prowess, power politics and prestige by returning China to its mythical destiny as the ‘Middle Kingdom.’

The Budget

India’s Space Costs

In the last four decades, the ISRO has developed competence in communications, remote sensing, broadcasting, meteorology, launch technologies and space science research. This space program has made significant contributions to several areas of national development. Due to direct and residual benefits of the space program upon improving the quality of life across India, the program continues to receive strong and unflinching political and public support. The national program has always strived to be as transparent as is possible, unlike China’s opaque space program. India’s space budget is available to the public for observation and scrutiny. While the true costs of China’s civilian space program may be difficult to delineate from the military cost overlaps, the ISRO budgeting faces no such quandaries. The ISRO prides itself as a thoroughbred civilian entity and goes to pains to delineate boundaries with the DRDO.

Space is viewed as a catalytic investment, the ISRO awards funding and contracts to a great number of Indian industries that provide software and hardware to it. ISRO also offers support to companies that supply value-added services using satellites and additional space infrastructure. Hence, as the space program has expanded consistently, so has India's space budget over the years. However, recently there have been certain dramatic increases, the primary drivers of budget increases include:

- Overall development of the Chandrayaan-1 lunar mission
- Development of GPS Aided GEO Augmented Navigation (GAGAN), India’s navigation system

- Comprehensive development and launch of new INSAT satellites onboard Ariane-5
- Evolution of the next generation of INSAT satellites, 4 metric ton class
- Design, evolution, flight of new earth observation satellites onboard the PSLV
- Development and production of the new cryogenic upper stage Geostationary Satellite Launch Vehicle GSLV Mk 3
- Testing and development of the Space Capsule Recovery Experiment (SRE) atmospheric re-entry demonstrator capsule

The ISRO budget has grown close to $1 Billion. It is quite amazing how much the Indians have been able to accomplish on a shoestring budget (Mohanty, 2008, p. 17).

China's Space Cost

As China's space program excels into new frontiers, questions keep arising about the cost of the nation's space program. The opaque space program has always been and will be an extension of the PRC military apparatus. Even though officially, the military and civilian space program separated as part of reorganization effort of the Industry of National Defense (COSTIND) and State Commission for Science. According to Sun Laiyan, administrator of China National Space Administration, the development of China's space industry is an annual ￥2 billion, approximately $240 million (China, n.d. para 2). However, realistically, it is into the billions of dollars, most estimates place the range at $1.5 - $2 billion (Cheng, n.d., slide 6). The Chinese manned space program costs through the first manned space flight on October 15, 2003 have officially been registered at $2.5 billion, of which $1 billion went to infrastructure (Wade, n.d., para 28). By comparison the U.S. space program has an estimated annual cost of $17 billion.

The Technology

India

The space programs of India and China are beacons for developing nations, in what they have been able to accomplish as developing economies and in the face of Western technology sanctions, restrictions and embargoes. The two space programs may belong to the same continent but they developed from two separate focuses, one a military program, the other civilian. India's space efforts started about a decade and half later than China but have caught up quickly. Over the last four decades in the arena of space development, India has established capability in space applications (remote sensing, meteorology, and telecommunications), launch systems and ground operations.

Historically, unlike China, India has focused exclusively on space applications. The pronounced weight on space applications efforts are the major components of the Indian space program, while newer emphasis is being seen on prestige projects, such as space exploration and human spaceflight. According to Vincent G. Sabathier and G. Ryan Faith, space industry experts at the Center for Strategic and International Studies, "*In technological terms, the Indian space program is roughly comparable to China's program, except in human spaceflight and exploration*" (Critical Questions: India's Space Program with Vincent G. Sabathier and G. Ryan Faith, 2008, para 5).

China

The Chinese are a few years ahead of the Indians in human spaceflight capabilities and accompanying infrastructure. China has thus far, achieved status as a world class space program, along with India. China aspires to be compared to the US, when comparisons are made between space powers, such as ‘US versus Chinese space programs,’ this is a matter of national pride for them. But beyond the propaganda value, domestic and international, the Chinese space program is more comparable to India’s. The only opportunity for India to play catch up with China’s space program lies in manned space flight. Since 2003, China has launched three successful manned space missions with the latest one culminating in Zhai Zhigang becoming the first Chinese to "set foot" in the outer space for 20 minutes on September 27, 2008 (Backgrounder: Major breakthroughs in China's manned space program, 2008, para 7). It is not a question of whether India has the technological capability of pursuing a manned space program but the desire to do so.

India is not as demonstrably ambitious as it northern neighbor in terms of international prestige. From India's space program’s inception, four decades ago, a manned mission has not been undertaken. Instead main emphasis has been to use the space infrastructure on building satellites and rockets that have socio-economic applications, especially for the benefit of the rural areas. The Chinese can learn from this more pragmatic approach and publicize space applications more heavily, in view of continued exploding social unrest in the poorer interior provinces. Herein, China’s grand nationalist projects should be promoted with as much fanfare as their practical space projects, like bridging the economic gap between the coast and interior. This would also place more weight behind China’s continuous pronouncements about its space program’s peaceful intentions (Dellios, 2005, para 25-27). So while China is marginally ahead of India in the human spaceflight endeavors; India plans to bridge this technological gap with the first planned manned space flight by 2015.

Commercial Aspects

China and India both offer international consumers commercial space services. China provides space services through its China great Wall Industry Corporation (CGWIC), the commercial platform of China Aerospace Science and Technology Corporation (CASC) and India through Antrix Corporation Limited, the commercial arm of Department of Space (DOS).

Antrix

Antrix was incorporated in September 1992 to promote commercial products and services from the Indian space program. The impressive array of achievements of the program over forty years provides Antrix a strong foundation to market space products and services to global customers. The company's goal is to achieve considerable market penetration in the global space market; hence Antrix has made significant investment in efforts towards marketing space products and services, especially remote sensing data and services. The international marketing of Indian Remote Sensing (IRS) Satellite data products is performed via Space Imaging, USA. The stable partnership has expanded over the years, which has lead to a growing network of global ground stations that receive/process IRS data, as many as ten ground stations to receive IRS data around the globe.

As per ISRO's Annual Report 2007-2008, "*Concerted efforts put in over the last one year have resulted in penetration of IRS data, particularly, Resourcesat-1, Cartosat-1 and Cartosat-2 data into new territories. Significant inroads have been made into new markets in Australia, Africa and Korea for IRS data access and sales. The Agreement with Australia has paved the way for a significant entry for down linking of IRS data into the Australian continent* *and the southern hemisphere for the first time. Contribution of IRS data to the Eagle Vision programs has increased appreciably, thus drastically increasing the IRS data presence in the US"* (Annual Report 2007-2008, 2008). Recently, Antrix entered an agreement that is expected to lead to increased IRS distribution over the African region. Antrix has major presence in the USA (10 stations) and Russia (4 stations). Even China receives Cartosat-1 data from the archive station at Svalbard in the Arctic Ocean. Major inroads have been made in offering INSAT transponder capacity for TV broadcasting applications encompassing, especially Direct-To-Home (DTH) services, the leading market driver for transponder capacity.

In 2006, EADS Astrium of Europe and Antrix signed contracts to market communication satellites for the international market. The alliance aims to offer the combined expertise of both companies in communications satellites to the market segment of around 4kW of payload power and with a launch mass of 2 to 3 tons. The combined European payloads and Indian platforms provide cost-effective and flexible solutions to telecommunications operators. The first triumph of this alliance was the awarding of the W2M satellite contract by Eutelsat Communications. Antrix has used its PSLV to provide launches to numerous foreign clients, the most recent being the record setting multiple launch of 10 satellites in one shot, two of them Indian, including the primary payload CARTOSAT-2A; the remaining were pico- and nano-satellites from nations such as Canada, Denmark, Germany, Japan and the Netherlands. Also, Antrix has reached an agreement with Europe's Arianespace to explore launch opportunities for small satellites using the PSLV. The company aims to capture between 5 to 10% of the international launch market in the coming years. Antrix's revenues have consistently grown since its inception, quite impressive by global space services standards. This is due to the cost-effective services of

India’s space program, for example, Antrix is able to offer competitive prices for launch services, sometimes at a third of the cost of other international players. The company’s revenue for the financial year 2006-07 was approximately $154 Million from launch services, leasing transponders and sale of remote-sensing images. The profit was roughly $24 Million post-tax (Mohanty, 2008, p. 22-23).

China Great Wall Industry Corporation (CGWIC)

The China Great Wall Industry Corporation (CGWIC) was established in 1980, as the global commercial space services arm of China Aerospace Science and Technology Corporation (CASC). CGWIC is the singular commercial organization sanctioned by the Chinese government to offer global commercial satellites, launch services and conduct international space technology cooperation. The CGWIC uses the work horse Long March launch vehicle for the international commercial launch services market (CGWIC Overview, n.d., para. 1). The commercial viability was considerably helped with the illegal assistance of Loral Space & Communications Ltd. In 1996, Loral aided a Chinese investigation of the February 1996 crash of a Chinese Long March missile carrying a Loral satellite. A 1999 congressional investigation determined that Loral gave China invaluable information that helped it improve its missiles (McMillan, 2002, para 1-8). Since Loral’s help, the Long March hasn’t experienced any launch failures. The company has used the Long March to perform twenty-four commercial launch missions for thirty satellites and six piggyback payloads.

In 2004, CGWIC signed numerous contracts for communications satellite in-orbit delivery with global customers based on the newly developed DFH-4 platform, a new milestone for China’s satellite export business. Through its commercial initiative, CGWIC has formed close ties with satellite manufacturers and satellite operators across the globe (CGWIC Overview, n.d, para. 2). While the CGWIC develops its primary space services business, as the main economic cooperation and international trade conduit for China’s aerospace industry, it has developed import and export capabilities in various areas. According to the company, annual gross value of import and export is around $400 million. While the main import focus is on aerospace related technologies, exports are mainly of electronic and mechanical products, as well as furniture, ferrous metal, various machinery and chemical materials. The export business spans the major regions of Asia, Africa, Europe, North America, South America, Australia and Pacific islands, included are almost sixty countries. Since its inception, CGWIC's gross value of import and export has hit $7.2 billion (CGWIC Import-Export, n.d., para. 1-2).

A lot has been made of the daring initiatives taken by China's space program, but it has not been able to translate it into a profitable success in the commercial space arena. This failure is most glaring in China’s inability to crack the Southeast Asian satellite communications market. CGWIC has yet to secure a true commercial satellite transaction and is heavily dependent on government-to-government exchanges for the inadequate amount of satellite business it has conducted. Compare this to Antrix, which runs more like an independent private entity. As China came out of a prolonged period of inactivity of commercial satellite launches in 2005, questions of the nation’s technological aptitude re-emerged a year later with the well-publicized loss of Sinosat-2 due to a malfunctioning solar panel (Brown, 2008, para. 3).

In November 2008, the space program's reputation took another knock when a Chinese built satellite for Nigeria had major failure in geosynchronous orbit. The satellite designated NigComSat-1based on the Chinese DFH-4 satellite bus launched on May 2007 was meant to have a 15 year life span but only lasted 18 months in space (Nigerian satellite fails in space, 2008, para. 1-5). At a cost of approximately $450 million to the Nigerian exchequer, this is a costly loss for a developing nation and it seems there was no insurance protection provided to the satellite. The DFH-4 bus is meant to form a foundation for new Chinese civil and military communications satellites, as well as international sales. Out of the four DFH-4 satellites launched so far, two have failed, the first being Sinosat-2 due to onboard failed electrical systems (Nigerian Sat Fails, 2008, para. 1-2).

While China's space business is still at its infancy, the failure of the Chinese made Nigerian satellite places further hurdles on the viability of its products. Other obstacles for China's ambitious space business include China's satellite industry being an extension of the military apparatus, more established rivals in the international industry, mixture of unfavorable political factors and a disinclination of customers to spend on China's low-cost satellites, given the low number of "birds" it has in operation. Even with ambitious goals, China will have to be patient in order to build a reputation as a qualified and established commercial satellite supplier. Reputation and experience are necessary credentials before low price becomes the decisive factor (Brown, 2008, para. 4). Herein, the Indian commercial space endeavors have been successful, initially targeting the niche 600 kg payload launch market, a less competitive arena as the traditional space powers concentrate on the more lucrative bigger payloads. So far India has offered launch services at above or at market rates. ISRO's first purely commercial launch on

April 23, 2007 included placing Italian satellite Agile in equatorial orbit well above market rate at $11 million. The agency has launched foreign satellites before, light weight or micro-satellites piggybacked on the PSLV, with the primary load being an Indian satellite. However, the Agile launch was the first time a foreign satellite was the primary load.

The second commercial launch of an Israeli spy satellite TecSAR ON January 21, 2008 under a commercial contract was also at higher than market rates, according to some sources the cost was above $6 million for the 300 kg payload. Presently, ISRO gets 75% of their business from foreign customers (ISRO joins big league in space, 2008, para 1-19). The launch of the W2M satellite for Eutelsat Communications co-developed by EADS Astrium of Europe and Antrix failed due to an anomaly affecting the satellite's power subsystem six weeks after launch on December 20, 2008 (ISRO-built satellite fails in space, 2009, para. 1-4). This is a minor bump for the ISRO on its path towards developing more robust satellite services. The ISRO has proven its satellite manufacture, launch and operational capabilities in the past, which have only been enhanced by the recent successful Chandrayan-1 technically complex unmanned lunar exploration mission.

Additionally, as a constitutional republic, India faces no political reservation in the international community that would impede its getting contracts for its space services; India is broadly admired and seen as a force of good in the world order. According to Michael Griffin, NASA Administrator, *"Indian Space Organization is good, and more important than the facilities it is the quality of the engineers and scientists and the technicians. They have a great capability*" (ISRO joins big league in space, 2008, para. 16).

The outsourcing of satellite production capability is in the works by the ISRO (except for remote sensing satellites), both for domestic and foreign consumption. In the next few years ISRO will start training manpower of some Indian private companies that currently supply components for ISRO missions. The agency will provide comprehensive training at its facilities. According to ISRO director, *"…we want the private industry to take over production of commercial satellites from us, leaving ISRO free to focus on R&D and pursue new technologies*" (Madhumathi, 2006, para. 5). India and China have both new launchers in development, the GSLV Mark III and Long March 5, that are near completion and more than double their payload carrying capability. Both will be able to offer more competitive launch solutions than the big three, USA, Europe and Russia. It will be a slow process but Indian and Chinese programs are ambitious, have the modern technical expertise and the infrastructure to take on the majors in commercial space services.

Space Applications

India

As envisioned by Vikram Sarabhai, India has continued on the path of using space infrastructure for the socio-economic benefit of the people of India. The space infrastructure of communication and earth observation satellites combined with the ground infrastructure offer value-added services to the people for:

"fisheries, forestry, mining, soil conservation, water resources management, agriculture, environmental studies, oceanography, urban planning, public health, infrastructure development, utilities management, rural development, tele-education & training, disaster warning and mitigation, satellite-aided search and rescue etc."

The following offer a brief description of the main space applications that are helping the Indian people uplift themselves:

Telemedicine: India can offer world-class health infrastructure to its population in the metros and big cities, but the standards are yet to reach the majority of the population in rural areas. Telemedicine offers people in remote areas access to specialist doctors in a city with the capability to diagnose and treat illnesses from the comfort of their own hospitals. The Department of Science (DOS) telemedicine initiative was launched in 2001 and now the network encompasses large parts of India.

The telemedicine systems given by the DOS include hardware and communication equipment, software, as well as satellite bandwidth. Hospitals and state governments use their funds for part of their manpower, infrastructure and maintenance. There are also clinic-on-wheels with satellites that provide medical treatment to people for who a trip to the city hospital could be life-threatening. These care mobile units offer medical diagnosis in general medicine, diabetology, ophthalmology, cardiology, women, infant and children healthcare. The telemedicine network connects over 278 rural districts with top doctors in the cities. Additionally, 235 remote/rural/semi-urban hospitals connect to 43 specialty hospitals via 10 mobile telemedicine units.

Tele-education: Obtaining education has always been in the forefront for Indians, to that end, the DOS has implemented many tele-education initiatives over the years. Recently, the

EDUSAT initiative was launched in 2004, with India's first "thematic satellite" EDUSAT dedicated solely for educational purposes. EDUSAT can deliver educational content via the following modes: video conferencing, computer conferencing, web-based instructions, one-way TV broadcast and interactive TV. The specially configured satellite helps create "interactive classrooms" by employing multi-media multi-centric system. The DOS has leveraged its space satellites as to service more than 2600 interactive classrooms and 27000 receive only classrooms totaling close to 30000 tele-education classrooms.

Tele-communications: Television visited majority of Indians late, before 1980 average Indians had virtually no TV. The state owned Doordarshan was the only channel available in limited areas where lay scattered terrestrial transmitters. In 1982 India launched the INSAT satellite program which over time gave the nation increased meteorological and television coverage, over 20 communications satellites blanket India. Every type of local and foreign channels permeate the neighborhoods, even rural villagers can be part of the MTV generation.

Remote sensing: The biggest pride of the Indian space program remains the network of remote sensing satellites. The network has produced immeasurable benefits from producing major breakthroughs in search and rescue, uncovering archaeological ruins, detecting climatic shifts, managing fisheries and forests and detecting water in the most barren regions of the planet. Today, India is only matched by the U.S. with comparable remote sensing capabilities (Mohanty, 2008, p. 18-19).

China

Remote sensing: The use of domestic and foreign remote-sensing satellites started in the early 1970s, which led to development and enhancements of satellite remote-sensing application technology for agriculture, forestry, meteorology, mining, oceanography, seismology, surveying, urban planning and water conservancy. The sphere of remote sensing applications and technologies are enlarging, a national satellite remote-sensing application system has taken shape. Most notably China has strengthened the infrastructure facilities to support remote sensing momentum by establishing the National Remote-Sensing Center, National Satellite Meteorology Center, National Satellite Oceanic Application Center, China Resources Satellite Application Center and China Remote-Sensing Satellite Ground Station, as well as remote-sensing satellite application and certification institutes applicable to cities, provinces and relevant state departments. The remote sensing data is playing a critical role in environmental protection and ecological construction, nationwide land resources surveys, as well as in major national projects, such as the Three Gorges Project, the South-North Water Diversion Project and the Project to Transmit Natural Gas from West to East.

Tele-communications: Satellite telecommunications and broadcasting technologies are developing rapidly, their application is becoming more extensive and an application industry in this field has taken initial shape. By the end of 2005, China had more than 80 domestic and international broadcasting and telecommunications Earth stations, and 34 satellite broadcasting and TV link stations. There are more than 50,000 Very Small Aperture Terminals (VSAT) and some 100 satellite specialized communication networks. The advent and application of satellite, radio and sister TV broadcasting services has improved the coverage and quality of the programs across China, chiefly in the rural countryside. Satellite telecommunications and broadcasting technologies play the critical irreplaceable role of uplifting rural villages through access to telephones, broadcasting and TV, technology that provides access to the modern world. An up-and-coming satellite telemedicine and tele-education broadband network has been established. China has developed a maritime satellite communication network that covers the entire globe.

Satellite Navigation: China has employed domestic and foreign navigation and positioning satellites to service and expand the national market for navigation and positioning services, which are doubling every two years. The nation is making great strides in development, application and services of satellite navigation and positioning technologies. The technologies are being used in transportation, project surveys, earthquake monitoring, basic surveying and mapping, meteorological exploration, resources investigation, oceanic surveys and so forth (China's Space Activities in 2006, 2006, p. 4-5).

So far, China has been advancing its space applications capabilities to provide benefits to its population. However, it is playing catch up to India in this realm, as New Delhi’s space program’s main focus from the beginning has been to use space technology for the benefit of the people. In this arena, India is unique among the space faring nations.

International Cooperation

India

The Indian space program has always welcomed building relationships in the international sphere. ISRO has great interest in mutually beneficial exchanges, as well as great interest in offering services and expertise to developing countries in the applications of space technology. India has Formal Memoranda of Understanding (MOU) or Agreements with Australia, Brazil, Brunei Darussalam, Canada, China, EUMETSAT, European Space Agency (ESA), France, Germany, Hungary, Indonesia, Israel, Italy, Japan, Mauritius, Mongolia, Myanmar, the Netherlands, Norway, Peru, Russia, Sweden, Thailand, U.K., Ukraine, U.S.A and Venezuela.

Major recent agreements signed are: 1) Memorandum of Understanding on Joint Activities in the Field of Human Spaceflight Program with Russia, 2) Implementing Arrangement for cooperation between India and Brazil regarding augmentation of a Brazilian earth station for receiving and processing data from IRS Satellites 3) Agreement between the ISRO and Japan Aerospace Exploration Agency regarding cooperation in space X-ray observations, 4) Agreement of cooperation between the ISRO and the Russian Federal Space Agency (RKA) for Joint Moon Exploration.

The successful Indian lunar mission Chandrayaan-1 of 2009 carried Indian instruments, as well as hosting two instruments from the U.S. and four from Europe. The future Chandrayaan-2 mission will be jointly developed with Russia and contain an orbiter, lander/rover and scientific instruments from developing nations.

Megha Tropiques, an Indo-French joint satellite mission to study of the tropical atmosphere and climate related to aspects such as monsoons, cyclones, etc., is progressing well. The MADRAS satellite will carry jointly developed ISRO-CNES instrument and two additional instruments SCARAB and SAPHIR will be given by CNES. ISRO will launch and operate the satellite, collect and distribute the data. The cooperation will also entail validating and calibrating the instruments and analyzing the data. Additionally, ISRO and CNES have begun a joint satellite mission called SARAL for which CNES will supply an onboard relay instrument for the global ARGOS data collection system and a radar altimeter instrument called ALTIKA. ISRO will offer the satellite bus, launch and operations.

The ISRO will carry aboard its OCEANSAT-2 an atmospheric sounder called ROSA from Italy as a component of the main payloads (ISRO Annual Report 2007-2008, 2008). ISRO and the Israel Space Agency (ISA) cooperation continues to blossom since India launched ISA's most technologically advanced spy satellite, TECSAR on January 21, 2008 into polar orbit (Clark, 2008, para 1-3). The cooperation continues with the development of technical and scientific interfaces for flying an ultraviolet astronomy telescope from Israel called TAUVEX aboard the ISRO's GSAT-4 experimental geostationary satellite. ISRO and the Canadian Space Agency (CSA) are developing an Ultraviolet Imaging Telescope (UVIT) planned on ISRO's astronomy satellite ASTROSAT. India and Russia have reached varying agreements relating to cooperation in the development and use of GLONASS, the Russian version of the US GPS navigation satellite network. ISRO and the RKA have agreed to develop an experimental satellite called YOUTHSAT, university students from India and Russia will be involved in developing scientific instruments and analyzing the data (ISRO Annual Report 2007-2008, 2008). ISRO also contributed an X-ray astronomy instrument for the Russian satellite called CORONAS-PHOTON launched on January 30, 2009 (Koronas-Foton, n.d., para. 1).

India continues to play an active role in multiple international bodies such as the International Astronautical Federation (IAF), the United Nations Committee on the Peaceful Uses of Outer Space (UN-COPUOS), United Nations Economic and Social Commission for Asia and the Pacific (UN-ESCAP), the Committee on Space Research (COSPAR), the Inter Agency Debris Coordination Committee (IADC), the International Space University (ISU), the international COSPAS-SARSAT system for search and rescue operations, the Committee on Earth Observation Satellites (CEOS), the Space Frequency Coordination Group (SFCG), the Coordinating Group on Meteorological Satellites (CGMS), the International Global Observing Strategy (IGOS), the International Society for Photogrammetry and Remote Sensing (ISPRS), the Asian Association for Remote Sensing (AARS), etc. As a partner in the International Charter for Space and Major Disasters along with CNES, ESA, the Canadian Space Agency (CSA) and NOAA, ISRO is working with the additional partners in planning to provide satellite data for the natural disaster management.

Sharing of Experience in Space (SHARES) is a system ISRO has developed that provides training in different applications of space technology to scientists from other developing nations. Under the auspices of the scheme, selected candidates will be given living expenses and allowances by the DOS, while the international travel costs will be borne by the sponsoring nation. The UN Office for Outer Space Affairs (UN OOSA) has been established in India, an initiative which offers ten month post graduate diploma courses in Satellite Communication (every alternate year starting in July), Remote Sensing and Geographical Information Systems (every year starting in October), Space and Atmospheric Studies (every alternate year starting in July) and Satellite Meteorology and Global Climate (every alternate year starting in July). Following the coursework, candidates can carry out research in their respective country for one year leading to an award of a Master's Degree from the Andhra University (ISRO Annual Report 2007-2008, 2008).

China

China has signed bilateral cooperation agreements on the use of outer space for peaceful means and space project cooperation agreements with Argentina, Brazil, Canada, France, Malaysia, Pakistan, Russia, Ukraine, the ESA and the European Commission. Also China has established joint commission schemes or space cooperation subcommittees with Brazil, France, Russia and Ukraine. Space cooperation memorandums have been signed with space organizations of India and Britain, as well exchanges with space-related bodies of Algeria, Chile, Germany, Italy, Japan, Peru and the United States have been exercised. China has enhanced collaboration with Brazil on the Earth resources satellite program. The successful launch of the Sino-Brazilian Earth Resources Satellite 02 in October 2003 has led to further signing of supplementary protocols on the joint research and manufacturing of satellites 02B, 03 and 04. Further cooperation is envisioned in expanding data application of Sino-Brazilian Earth resources satellites regionwide and globally.

Under the auspices of Sino-French Joint Commission on Space Cooperation, China and France have developed wide-ranging space cooperation and exchanges in Earth science, life science, space science, satellite application and satellite TT&C. The historic space cooperation between China and Russia continues to produce results. Within the framework of the Space Cooperation Sub-Committee of the Committee for the Regular Sino-Russian Premiers' Meeting, many exchanges have come to fruition, the latest being in the sphere of manned spaceflight. China’s manned space program infrastructure has benefitted immensely from Russian technological help. China has space exchanges and cooperation with Ukraine under the auspices of the Sino-Ukrainian Joint Commission on Space Cooperation. China and the ESA have cooperated in the “Dragon Program,” related to Earth observation satellites. Thus far, they have conducted remote-sensing application projects in the fields of agriculture, disasters, forestry, meteorology, oceanography and water conservancy (China's Space Activities in 2006, 2006, p. 9-10). China, along with six other nations is an active participant in the European Union’s civilian Galileo satellite navigation project.

On December 16, 2008, the representatives of China, Bangladesh, Indonesia, Iran, Mongolia, Pakistan, Peru and Thailand formally inaugurated the Asia-Pacific Space Cooperation Organization (APSCO), an organization headquartered in Beijing. The organization aims to promote multilateral cooperation in space science and technology amongst its members. Member nations will cooperate in research and development, space technology application and training of space experts (Asia-Pacific Space Cooperation Organization starts operation, 2008, para. 1-3). Additionally, China continues to support the Asia-Pacific Region Multilateral Cooperation in Small Multi-Mission Satellites Project. Beginning in 2007, China started working with Bangladesh, Pakistan, Iran, the Republic of Korea, Mongolia and Thailand on research, manufacture and application of small multi-mission satellites.

China actively encourages, supports and participates in the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS). China has acceded to the "*Agreement on the Rescue and Return of Astronauts, and on the Return of Objects Launched into Outer Space, Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies*, *Convention on the Registration of Objects Launched into Outer Space and Convention on International Liability for Damage Caused by Space Objects*." China has also acceded to a disaster mitigation mechanism encompassing space organizations from various nations in the light of the Charter on Cooperation to Achieve the Coordinated Use of Space Facilities in the Event of Natural or Technological Disasters. China has participated in programs promoting the use of space for sustainable development in Asia and the Pacific organized and implemented by the UN Economic and Social Commission for Asia and the Pacific (China's Space Activities in 2006, 2006, p. 10).

China and India place deep importance on bilateral and multilateral relations with space agencies and space related bodies with the purpose of defining international constructs for exploitation and utilization of outer space for peaceful purposes, aspiring to new scientific and technological challenges, reforming and refining space policies and building and strengthening ties between nations.

Manned Space Program

India

The ISRO has set its sights on setting up a manned spaceflight program. This is a relatively recent development for the Indians, truly making the space program a robust one. In February 2009, the Government of India authorized $2.5 billion to launch its first astronauts into space by 2015. The decision was arrived at after the highly successful launch in October 2008 of India's first unmanned lunar mission, *Chandrayaan-1*, which is now orbiting the Moon and mapping its terrain in 3-D. The lunar mission has catapulted India into an elite club, with members United States, Russia, Japan and China, as the only nations capable of independently reaching the Moon (Page, 2009, para. 1-4).

Also, the ISRO and the RKA have decided to work together to share critical equipments for the Indian manned lunar mission. India and Russia signed a MoU to promote joint activities in the arena of human space flight program. Under the MoU, both nations will jointly build spacecraft for the Indian manned mission, based on the Soyuz capsule. As per the MoU, an Vimanaut (an Indian astronaut) will fly to space aboard a Russian spacecraft within the next five years, eleven years after China and ahead of ISRO's maiden human space flight to the Moon by 2020, four years before China's target mission date (ISRO, Russian Space Agency join hands for Indian Man Mission, 2008, para. 1-2).

China

China sent its first taikonaut (Chinese astronaut) Yang Liwei into space in 2003 aboard Shenzhou-5. In 2005, a two-man mission carrying Nie Haisheng and Fei Junlong to space, a tour lasting five days. In September 2008, a trio of Shenzhou-7 taikonauts, Liu Boming, Jing Haipeng and Zhai Zhigang orbited the earth for three days with Zhai becoming the first Chinese to "set foot" in outer space. His spacewalk lasted about 20 minutes and is believed to help pave the way for the country's next space mission-- the launch of a space lab or space station (Backgrounder: Major breakthroughs in China's manned space program , 2008, para, 6-7). China is planning a manned moon mission between 2020 and 2025.

Traditionally, India has focused almost entirely on space applications, an exploration and human spaceflight being relatively new. According to the Center for Strategic and International Studies, the Indian space program is almost equivalent to China's program, except in manned spaceflight and exploration (Critical Questions: India's Space Program with Vincent G. Sabathier and G. Ryan Faith, 2008, para. 5)**.** Both nations have ambitious human spaceflight programs, yet to be fully realized.

Space Policy

India

Space policy is irrevocably part of national politics, an extension of it; it cannot be viewed in isolation. The national mood, domestic-international politics, social mores, national security, moment in time, history and more play critical roles in the establishment of a national space program. Nehru's vision that space science and technology could be used to spur development was unique in the Sputnik era. This policy was novel in its concept, especially in the Cold War arena, when the superpowers (and later China) propagated national space programs out of the military prism. The Indian National Committee for Space Research (INCOSPAR) was established in 1962 to counsel the government on space policy and cultivate international cooperation. The official birth of India's space program came in 1972 with the establishment of the Space Commission, which was entrusted with the role of reviewing "*the development and application of space technology and space sciences in terms of promoting India's national development*" (Sheehan, 2007, p. 145). This outlook considerably predated United Nations' recognition of the possibility space technology had for third world nations, when it noted, "*space technology can be a powerful tool to accelerate national development; it provides a way of leapfrogging over obsolete technologies and getting away from percolation and trickle down models of development for which developing countries do not have the time*" (Sheehan, 2007, p. 145 - 46). Several policy factors drove the development of the Indian space program. A newly constituted sovereign state, a nation borne out of colonial bondage, New Delhi sought technological independence from the constraints posed by more technologically advanced nations.

The Nehruvian domestic policy called for developing space applications for socio-economic progress, initially to develop national mass communication capabilities, particularly broadcasting, and to use resource satellites to monitor and manage the nation's natural resources, ensuring productive use. Other space policy considerations included acquiring the international prestige that would accompany a space program; however, this was limited in scope as a motivation in the beginning (unlike China). In addition to economic dividends accrued from a national space program, successive governments to India encouraged the policy of bypassing intermediate technology and go immediately to the high technology arena; space technology was the high tech arena. A cornerstone of the space policy was the strong belief that India would not let itself ever be isolated from the economic and social benefits of advanced technologies, as it had been in the past, isolated from the benefits of the industrial revolution. India did not have the luxury to master intermediate technology first, while advanced nations had already mastered high-end technology, and by the time India mastered high-end technologies, the developed nations would have already mastered the next generation of technologies such as nano technologies, leaving India always one-two steps behind. Herein, India had to leapfrog in space and other technologies as to maintain the same level of technical abilities as developed nations or leave as little deficiency as possible in technology between it and the technically advanced nations.

Cooperation with the advanced space powers was critical to the beginning of India's space efforts and later to its policy with emphasis on indigenous development of space and other technology. International space cooperation was an important component of India's space policy, as it allowed it to access know-how and technologies that had the possibility of accelerating the progress of its space program. Also, the dependence on one nation for access was lessened as India endeavored to cooperate with a number of nations simultaneously (Sheehan, 2007, p. 146). India's space program has attained a level of self-sufficiency comparable to other national space programs, providing India a role in establishment and implementation of international space law, as well the opportunity to cooperate with other space powers and organizations as an equal partner. The nation has been strategic in its space policy, as to cooperate with a broad range of countries and groups, thus lessening the chances of comprising its independence, a posture of its non-aligned status. Global space cooperation being a critical policy of India is an avenue for developing Indian influence, leveraging space commerce opportunities and enhancing its prestige by demonstrating is technological sophistications by working with other advanced space powers. Unlike China, India has a clearly delineated civilian space program and a military missile program. In the past, technology from the SLV-3 launch rocket was implemented in the Agni ballistic missile, as well some space scientists left in the early 1980s for the ISRO to go work for the DRDO on the IGMDP. However, India's policy has been to maintain a wall between the civilian ISRO and the defense entities. The ISRO prides its civilian badge and is keen to avoid international sanctions on its activities. This doesn't mean that under the cover of national security, civilian space technology know-how is not provided to the defense establishment.

Like other space nations, India's launchers and resource and communication satellites can serve dual-use technologies purposes. In case of India, since it has an independent missile program, the launch vehicles wouldn't serve a practical platform for a missile. Additionally, India is developing dedicated military satellites because the IRS and INSAT series can only make a limited contribution in conflict. In the last two decades, India's space policy has been also driven by security needs, as the traditional dichotomy of development and security have been merging to encapsulate a broader definition of security beyond military terms to include, environmental, economic, human and societal security (Sheehan, 2007, p. 155).

Beyond security and national development, India's space program is a reflection of the success of the nation and its people, while able to compete with space powers in an area that has huge economic, human capital, infrastructure and high technology demands. Also, New Delhi's space policy is a vital component of its foreign policy, which is aimed at enhancing its role as the dominant power in the Indian Subcontinent and among the developing nations. The outlines of space policy are subject to values; in terms of India, using technology for national development, these values are correlated with community expectations. In this regard, India can claim to be the most cost-effective advanced space program, a standing accomplished by limiting its ambitions and steering clear of wholly prestige projects (Sheehan, 2007, p. 156). This may not be the case in the 21st century.

In the new century, India's space program has expanded its focus, adding components of space exploration and manned spaceflight, a new direction markedly different than the vision of Vikram Sarabhai. The chairman of ISRO, G. Madhavan explains the additional space policy direction, "*The policy – pronounced four decades ago by Vikram Sarabhai, father of India's space programme – had to change for two reasons. We believe that pushing forward human presence in space may become essential for planetary exploration, a goal we have set for ISRO twenty years from now. Secondly, with India's booming economy, costs should not be a hurdle*" (Sheehan, 2007, p. 157). It has become evident that prestige has become an important factor in space policy considerations, as is maintaining parity with China. However, space applications remain at the core of the space program, belying assumptions that the quest of prestige will dictate policy at the expense of socio-economic development. India didn't initiate its space exploration and manned programs independent of the activities of other space powers such as China but as a reaction to them; as such if militarization of space becomes a reality, India will not be far behind.

China

The motivations of China's space program are sometimes difficult to discern due to the opaque nature of the program. However, over the years Beijing's space policy has been decoded, discernable by its space activities as more is written about the program. The nation's initial space policies are the product of historical wrongs and of the cold war environment. Chairman Mao realized in order for China to achieve great power status and the accompanying prestige, it must be strong militarily, a critical component being the development of nuclear tipped missiles. China would never be subject to past indignities by conquering foes, instead the nation would strive to be a strong, independent nation. Herein, space policy was forged out of nationalist and militaristic notions. Not unlike the US and the Soviet space programs, China sought to build missile capacity and enhance its international and domestic prestige.

Prestige is critical in world affairs, and the space program is one tool of obtaining it. The space program has grown to be an important lever in the CCP's domestic policy arsenal, using space success to incite national flames and to unify the people. In the last two and a half decades, there has been more emphasis on space applications for socio-economic benefits. The policy goal of expanding the military space program with a civilian mix is used for accelerating national development. In addition to improving the life of the common man, the space program gives China the capability to develop high technology and scientific infrastructure. Like India, China's space policy was directed at leapfrogging to mastering high technology in order to gain parity with the technologically advanced nations. The space program's policies are manifold which include military projects, civilian space applications, obtaining the latest science and technology, economic competitiveness, geopolitical aims and enhancing prestige. Domestically, the space policies help elevate the stature of the CCP, thus allowing to win the backing of the people and making easier the sustainability of the communist regime. The hosting of the 2008 Olympics at Beijing was a seminal moment for the Chinese people, that of 'having arrived' at the world stage.

Similarly, the space program inspires the same pride and prestige, as ‘having arrived,’ particularly after the recent Shenzhou manned space missions.

Internal policies have led to a militarily muscular China, using the various missile armories as currencies of power and prestige. The CCP has cleverly overtime, intimated to the people its policies, now they are one in the same. For it is, the people have overtime been inculcated with the party line, that China’s world power status and prestige are an entitlement, payback for historical insults, an inevitability towards achieving manifest destiny of the mythical ‘Middle Kingdom.’ In its quest to acquire supreme power, China’s space policies and activities can be viewed by the adage, ‘by any means necessary,’ irrespective to its legality, moral or ethical norms. In the international arena, its geopolitical policies have included illicit proliferation in nuclear and missile technology, the latter borne from its space program. In its quest for domination of Asia, its myopic geostrategic policies have led it to proliferate nuclear and missile technology to North Korea and Pakistan, among other nations. These nations have acquired the missiles, targeted them at competitors of China. Pakistan flexes its Chinese missiles at India, thus forcing India to expend economic and other resources on defense that could be used toward national development. This prohibits India realizing its full potential, partially inhibiting national development due to being chained down by terrorist antics of its neighbor to its west.

Pakistan, a nation so economically feeble, that it survives day-to-day on US economic aid and IMF loans; has held India hostage to its whims by terrorist acts for over twenty five years; such audacity by Pakistan is only possible because it possess the nuclear and missile umbrella, technology provided by China. This nuclear boogey used against India, has handicapped India into taking decisive action against a state sponsor of terrorism. These are the same tactics being employed by China in East Asia, against Japan and South Korea. Beijing uses its proxy North Korea to make threatening statements and missile tests to keep Japan and South Korea on edge as to avoid them from being future challengers to China's dominance in Asia. China doesn't want a reunification of the two Koreas, a unified Korea has the potential to become a power rival to China. However, China's grand designs have backfired on the Indian Subcontinent and East Asia. Pakistan has been recognized for what it is, an economic basket case and the most dangerous nation in the world, as it is a den of world terrorism backed by nuclear weapons. Due to this threat from the west and the north, India has developed advanced indigenous nuclear and missile programs, self-reliance in space and one of the most advanced military, without sacrificing its national development. This is the direct result of China's actions of attempting to gain strategic depth in the Indian Subcontinent, to stop India's rise.

The myopic policies have led to Japan strengthening its space program and reconnaissance capabilities. Recent North Korean shenanigans have revived the mood in Japan for having an official offensive military capability and a stronger military role in region; there is even talk of Japan buying or developing a missile defense system to protect against potential North Korean missiles. The Korean imbroglio has led South Korea to enhance its own military capabilities by purchasing the latest weapons from the US, developing advanced indigenous military weapons such as high tech naval destroyers and starting its own space program. The intentions of PRC's geostrategic policies were to weaken its neighbors, but it has had the opposite effect, it has emboldened and strengthened them. For it is, Japanese military expansion, stronger US military presence in the region, or a Theater Missile Defense System (TMD) in Japan and Taiwan would counter Beijing's influence in the area and possibly affect its designs on Taiwan; these are real possibilities in the future (Cooper & Contant, n.d., para 7-8). Proliferating missile technology derived from its space program allows China to achieve influence in those nations, so does overt international cooperation. Cooperation with other nations, space agencies and international organizations permits Beijing to build relationships for soft power influence and easier access to high technology and know-how. Also, cooperation opens opportunities for space commerce, to offer China’s launch and satellite services. In its efforts to be considered a peer to the US in space efforts rather than a more apt comparison with peer competitor India, prestige has continued to be central. This has led China to broaden its space policy to include planetary exploration and human spaceflight. Still Beijing’s space policies are primarily dictated by military and prestige considerations. This will continue to be underlying theme of China’s space policy in the future as it pursues its ‘Mandate from Heaven.’

CHAPTER FIVE: INTERNATIONAL ARENA AND POLITICS

Why Start a Space Program

India

The setting up of the Thumba Equatorial Rocket Launching Station in 1963 marked the beginning of the Indian space program. The Department of Space (DOS) and the Space Commission were established by the Government of India in 1972 to pursue united development and application of space science and technology for national goals. ISRO was set up as the research and development arm of the DOS to execute India's national space program. The Indian space program is world class, comparable to the best there is in its areas of focus. It enjoys unwavering political and public support due to the program's emphasis on space applications for improving the quality of life of the ordinary Indian (Mohanty, 2008, p. 5).

The economic upliftment of Indians through space applications are still the underpinnings of the Indian Space Program. In his autobiography *Wings of Fire,* former rocket scientist and President of India Dr. A.P.J. Kalam states, that the vision for the Indian Space program was unambiguous, "*…if the Indians were to play a meaningful role in the community of nations, they must be second to none in the application of advanced technologies to their real-life problems..[with] no intention of using it merely as a means to display our might*" (Kalam & Tiwari, 1999, p. 43). The Father of the Indian Space Program, Dr. Vikram Sarabhai, a visionary who laid the seeds of the ISRO, displayed to the nation the upliftment benefits of a space program through an experiment in which a leased American satellite was used to broadcast educational and health television programs to inexpensive ground stations in 5,000 remote villages of India. The key areas of focus of the Indian space program have included:

- Remote sensing for resources survey & management, meteorological services and environmental monitoring
- Satellite communications for distance education, telephony, mobile communications, television broadcast, radio broadcast, satellite-aided search & rescue, telemedicine, meteorology etc.,
- Development and operation of native satellites launch vehicles, satellites and ground systems for offering these services (Mohanty, 2008, p. 5).

However, there is a past connection between the ISRO and the defense establishment, In July 1983, India embarked upon an Integrated Guided Missile Development Program (IGMDP) pursued through India's Defense Research and Development Laboratory (DRDL). The DRDL is part of the military research and development machinery, the Defense Research and Development Organization (DRDO). During the early years, when headed by Vikram Sarabhai and Satish Dhawan, ISRO time after time opposed any military application for its dual-use ventures such as the Satellite Launch Vehicle 3 (SLV-3). Ultimately, however, the DRDL did borrow technology and experts from the ISRO. In a move resented by the ISRO community, Abdul Kalam left the ISRO, as manager of the SLV-3 project to head India's missile program at the DRDL. Nevertheless, the degree of human resource transfer from the ISRO and DRDL should not be overstated – hardly a dozen scientists left with Kalam from the ISRO to the DRDL. Kalam used his experience with SLV-3 to design the 2,500-kilometre-range Agni (Fire) missile using the SLV-3's first stage.

India's space and missile programs have followed very diverse projects. In addition to the Agni series, the IGMDP included development of the 150 to 250-kilometre range ballistic missile Prithvi, surface-to-air missiles Akash (Fire, 25-kilometre range) and Trishul (Trident, 9-kilometre range) and Nag (Cobra), a "Fire-and-forget" anti-tank missile. IGMDP missiles don't realistically resemble ISRO's sounding rockets or launch vehicles, which theoretically could've been converted for use as short-range and intermediate range ballistic missiles. Over the years many experts have suggested that the GSLV could be converted to an intercontinental ballistic missile but the ground realities and logic have proved them wrong, India's military has not pursued that path. Additionally, outside of India there have been attempts to link the civilian ISRO to the DRDL/DRDO by insisting that certain ISRO technology or projects have potential military implications, military potential doesn't necessarily translate to military use or involvement. This is even truer when one traces the motivations for creating the Indian space program. Herein, while both organizations use technology from the same domestic industrial base, ISRO and DRDL have pursued very dissimilar rocket agendas (Mistry,1998, p. 153). There is a clear delineation between the civilian space program and the missile program. The Indian space program has been unique in the world's space programs in that it first was borne out of a need to help its people improve economically and socially.

China

The period following World War II was a tumultuous one, in Europe, postwar rehabilitation and territorial distributions amongst the allies was the main international focus. Meanwhile in the Pacific, Japan was recuperating from a nuclear holocaust in Nagasaki and Hiroshima, other devastations, as well as facing an occupation by the victor, the United States. Japan's Pacific neighbor China had witnessed devastations of World War II and Chinese civil war. The Chinese leaders were acutely aware of the military disparity between their nation and the West, particularly in missile technology. Their primary interest lay in possessing ballistic missiles capable of reaching far flung targets. The imperative to developing missile technology was intimately related to China's sense of insecurity to a perceived hostile environment. China had confronted Cold War superpowers, Soviet Union and United States.

The United States had threatened China with possible nuclear attack at the end of the Korean conflict in the form of a direct secret threat by President Dwight Eisenhower. On numerous occasions the US violated Chinese airspace for reconnaissance and flying aggressively to test the nation's air defenses. Herein, the above activities combined with memories of the Opium Wars, led Chairman Mao to the conclusion that only a nuclear deterrent through missile delivery systems would guarantee the security of the newly founded Peoples Republic of China (PRC) against hostile powers. He also wanted the accompanying power and prestige that such weaponry would provide China in the international sphere (Handberg & Li, 2007, p. 57). Hence, it becomes evident that the space program arose out of military necessity, following in the footsteps of the United States and the Soviet Union whose space programs were the result of pursuit of missile technology.

Present Dimensions

India

The current Indian space program is an economically and technologically efficient integrated program, self-reliant and applications driven, preserving critical relations to the user community and committed to the pursuit of scientific excellence in the peaceful use of space for the benefit of the common man. The space program has proven capabilities in producing world-class satellites and launch vehicles, and applying them in assorted areas pertinent to national development. India has established two operational space systems. The Indian National Satellite (INSAT) system is at present composed of ten satellites in orbit, the largest domestic satellite communication system in the Asia Pacific and one of the largest in the world. The Indian Remote Sensing satellite (IRS) system, with a collection of eight satellites is regarded as one of the best constellation of satellites in the world for providing information on natural resources. Space launch vehicles developed indigenously by India provide the nation high degree of autonomy in launch capability to orbit these classes of satellites. The Polar Satellite Launch Vehicle (PSLV) is the workhorse of the space program well proven through thirteen successive successful flights and it offers the capability of placing 1.4 tone class satellites in polar sun synchronous orbits. The Geo- synchronous Satellite Launch Vehicle (GSLV) is capable of launching 2 to 2.5 tone class of satellites into geo-stationary orbit. The GSLV as inventory makes India one of the six countries in the world with the ability to place payload in geosynchronous orbit.

The Indian population has benefited immensely due to progress in national development from space applications. The Indian satellites provide television broadcasting, radio transmission, rural area communications, business communication, tele-education and telemedicine. Data and images from the IRS satellites are used for monitoring agricultural crops, to seek zones for availability of ground water, rural development, planning water shed, offering advisories to costal fishermen on possible fishing zones, waste land and disaster management programs. Additionally, the satellites aid in relaying cyclone warnings, support search and rescue, gather meteorological data and help weather forecasting for emergency communication during disasters.

Advanced scientific investigations are being carried out in the fields of astronomy, climate research using satellites, atmospheric sciences, sounding rockets, balloons and ground instruments. Also, India successfully launched the Chandrayaan-1 robotic mission to map the moon surface on October 22, 2008. The mission has received international recognition for its scientific achievements; over a two-year period, it will survey the lunar surface to produce a 3-dimensional topography and a comprehensive map of the moon's chemical characteristics. Chandrayaan-1 is the flagship mission of an ambitious planetary exploration program. The ISRO has also received preliminary government funding for setting up the foundation for the Indian human spaceflight program.

The DOS's commercial arm Antrix Corporation has been successful in commercially promoting the space assets of the ISRO and helping Indian space industries become globally competitive. International marketing of IRS images and data, launching of foreign satellites by PSLV, supply of reliable satellite systems and sub-systems, mission support services of Indian ground stations, execution of telemedicine networks in various parts of India and leasing of INSAT transponder capacity to commercial operators are few of the highlights of the Antrix space enterprise. It also has an alliance with EADS Astrium to jointly manufacture communication satellites using the INSAT bus for global commercial markets. The first example of this cooperation was the manufacture and launch in 2008 of the W2M satellite for Eutelsat Communications.

India has enhanced bilateral co-operative arrangements with more than 20 nations including Australia, China, France, Germany, Russia and USA. The level of the international co-operation is multi-dimensional in form, which includes exchange of meteorological data, carrying out of joint missions, offering opportunity for payloads onboard Indian satellites, and education and training in the area of space. Recently, in the spirit of international cooperation in space, India carried six payloads from other international space agencies including NASA, ESA, and the Bulgarian Aerospace Agency free of cost as part of Lunar Mission Chandrayaan-1. In affiliation with United Nations, India established the Centre for Space Science, Technology and Application Education for Asia and Pacific in 1995 and continues to offer well-structured educational space programs to researchers from various countries of Asia (Kasturirangan, 2006, p. 3-5).

The ISRO continues to build cooperation with universities, academic institutions, and the private sector in various areas of research, manufacture, and sub-contract projects related to space science, applications and technology. The unique approach to the application of space for the common man is still at the core of the Indian Space Program while the natural evolution towards discovering the frontiers beyond Earth has begun.

China

China's space industry has progressed mightily, having many achievements. Several research and development design, production and testing bases of international caliber have been built, noticeably enhancing the country's fundamental capabilities in space science and technology. As a developing nation, China has made historic breakthroughs in manned spaceflight and has embarked on a broad lunar exploration project. Space application systems have been maturing as applications have expanded and benefits enhanced.

In recent years, China has indigenously developed and launched over 22 different types of man-made satellites, increasing its technological skills in this field markedly. China operates several series of satellites -- broadcasting and telecommunications satellites, "FY" (Fengyun, or Wind and Cloud), recoverable remote-sensing satellites, "DFH" (Dongfanghong, or The East is Red), scientific research and technological experiment satellites, "ZY" (Ziyuan, or Resources), meteorological satellites, "SJ" (Shijian, or Practice), Earth resource satellites, the oceanic satellite series (Haiyang) and "Beidou" (Plough) navigation and positioning satellites. In addition, the oceanic satellite series will come into being soon. Substantial progress in key space technologies has led to China's critical independence in satellite development. Recently, on April 15, 2009 it launched its second satellite for the Compass navigational network, the Compass G2 satellite. The Chinese launch vehicle Long March series has become the workhorse of the space program. The latest in the series, Long March 5 is under development.

The fields and scale of satellite technology has led the Chinese to enlarge its small space applications program. Remote-sensing, telecommunication, broadcasting and navigation and positioning programs have been constantly expanded. China regularly uses remote-sensing application systems in the fields of agriculture, disaster mitigation, environmental protection, forestry, land mapping, meteorology, mining, oceanography, surveying, transportation, water conservancy, regional and urban planning. Satellite data plays an important role in major national projects such as, the Three Gorges Project, the South-North Water Diversion Project and the Project to Transmit Natural Gas from West to East. The field of satellite telecommunications and broadcasting has taken shape providing more extensive access. The transmissions are providing villages access to broadcasting and TV.

A satellite telemedicine and tele-education network offers rural communities access to services denied earlier. China's current maritime satellite communication network ranks among the advanced nations in the application of global mobile satellite communication. China has implemented several major related projects, one of which is called "*industrialization of satellite navigation and positioning applications.*" By employing domestic and foreign navigation and positioning satellites, China has made great progress in the development, application and services of satellite navigation and positioning technologies. The range and fields where satellite navigation and positioning are applied are being continuously expanded and the size of the national market for satellite navigation and positioning is doubling every two years. Satellite navigation and positioning technologies have been widely used in transportation, basic surveying and mapping, project surveys, resources investigation, earthquake monitoring, meteorological exploration, oceanic surveys, and so forth.

"*The key thing that China wants out of its space program writ large is prestige*," says Dean Cheng, and China Specialist at the Center for Naval Analysis Corporation (Iannotta, 2008, para. 8). The Chinese space program originally evolved from the Maoist leadership's drive to attain nuclear missiles, which in turn provided the essential launch vehicle for a simple satellite. Intense nationalism coupled with international recognition and prestige were additional motivators behind China's fledgling space policy. Today, China's space efforts have yielded a high degree of technological sophistication without losing sight of past motivations.

Future Dimensions

India

The quest for space frontiers is fresh in the minds of the ISRO team after the successful implementation of India's first lunar mission, Chandrayan-1. A second Chandrayan mission is already in the planning stages to be deployed to the moon by 2012. The mission will include a land rover that collects rock and soil samples from the surface of the moon for analysis. Planetary explorations are likely to follow the current success of the complex Chandrayaan-1 undertaking; plans include missions to Mars and Venus, fly-by asteroids and comets. The ISRO has received official government sanction and preliminary funds for the initial planning of manned space flight by 2015 and lunar manned mission by 2020. Also, the indigenous cryogenic upper cryogenic stage Geosynchronous Satellite Launch Vehicle mark III (GSLV –III) is planned to have its maiden flight in 2010. By 2011, the Indian GPS Aided Geo Augmented Navigation or GPS and Geo Augmented Navigation system (GAGAN) is planned for implementation; a regional Satellite Based Augmentation System (SBAS) is set to be fully deployed. Seeking to break away from the rocket launcher technology of the 20th century, India is developing a Reusable Launch Vehicle (RLV), a forerunner of the Indian version of a space shuttle that uses scramjet engine technology, allowing the spacecraft to achieve hypersonic speeds of upto Mach 8. A RLV technology demonstrator is expected to be flown sometime in 2010.

Is the Indian Space Program deviating from its commitment of using space technology for the benefit of the common man? Or is it simply a natural extension of a space program graduating to the next level of technological progress? The Indians are deeply committed to space applications for economic and social benefits; however, they see manned spaceflight and space exploration as necessary elements of developmental progress, even for a developing nation. The question is not, can developing India with high level of poverty afford to have such ambitions but the real question is how it cannot afford not to pursue such options.

The Indians were denied the benefits of the industrial revolution by their British colonial masters, while the West developed and harnessed all the benefits of industry, India languished, trying to play catch up in the 20^{th} century. The nation is still paying a heavy price, economically for purposefully being isolated from the industrial revolution by the British Raj. Indians want to follow independent and sovereign decisions with regards to national development; this extends to space policy as well. Herein, Chairman of the ISRO, Dr G Madhavan Nair puts it succinctly, "Twenty years from now, when space travel is likely to become mundane like airline travel today, we don't want to be buying travel tickets on other people's space vehicles" (Bagla, 2008, para. 40). India doesn't intend to be an idle spectator of the space revolution and it benefits.

China

Recognized as the third most prominent space program after US and Russia, China has future plans to gain parity with the two superpowers. In that endeavor, China is building upon a strong foundation of space technology. It has significantly expanded the horizon of Compass (Beidou) navigation and positioning program from its inception with regional scope to a global player. The new system will expand from the current constellation of 5 satellites to 35, which include 5 geostationary orbit (GEO) satellites and 30 medium Earth orbit (MEO) satellites, offering complete coverage of the globe by year 2015. The network will provide two levels of service, licensed service for the military and free service for those in China (Compass Beidou Overview, n.d., para. 1-2). Formally, China has declared a three-step program for its manned spaceflight program: launching taikonauts into space, accomplished with Shenzhou V, VI and VII; a space laboratory, and eventually a space station (Johnson-Freese, 2007, p. 14). The future space station named The Tiangong I, or Heavenly Palace I will have a core module, two experimental modules, a manned spaceship and a cargo spaceship. According to Qi Faren, chief designer of the Shenzhou spacecraft, the Tiangong I is planned for launch before 2011 (Dingding, 2009, para. 1-5). A space shuttle or space plane is under development but the details at all levels about the program are minimal and opaque. However, a more powerful Long March-5 (Chang Zheng 5) launcher is expected to debut in 2014.

The Long March 5 once in service will use less fuel for the same amount of payload having the second largest carrying capacity behind the Delta 4 Heavy (Long March 5 Will Have World's Second Largest Carrying Capacity, 2009, para. 1-5). Another area of importance is China’s military space pursuits. On January 11, 2007, the Chinese shocked the world with an anti-satellite test with the intentional destruction of China's Fengyun-1C weather satellite via an anti-satellite (ASAT) device (David, 2007, para. 1-2). The test was an awakening moment for the world about the level of sophistication China’s space program had achieved. The ASAT test raised the specter of weaponization of space and the true future intentions of the Chinese space program.

Due to the opaque nature of the Chinese space program, the intent of future Chinese space capabilities has at many times been difficult to judge, leading to wide-ranging speculation. Some experts proclaim that the PRC plans to build a space-based intelligence gathering system analogous to that of the United States. Others suggest that the PRC will maintain focus on dual-use systems, stressing launcher development over satellite manufacturing. It is even expressed that the real motivation for the Chinese focusing on enhancing launch capabilities, rather than satellites, is because their satellite fabrication capabilities are so poor (China's Space Program: Civilian, Commercial, & Military Aspects, 2006, p. x). China's 2006 white paper on national space activities states:

"The aims of China's space activities are: to explore outer space, and enhance understanding of the Earth and the cosmos; to utilize outer space for peaceful purposes, promote human civilization and social progress, and benefit the whole of mankind; to meet the demands of economic construction, scientific and technological development, national security and social progress; and to raise the scientific quality of the Chinese people, protect China's national interests and rights, and build up the comprehensive national strength…To remarkably improve the country's capabilities and reliability of carrier rockets in space; to build a long-term, stably operated Earth observation system, and a coordinated and complete national satellite remote-sensing application system; to set up a relatively complete satellite telecommunications and broadcasting system, and remarkably enhance the scale and economic efficiency of the satellite telecommunications and broadcasting industry; to establish a satellite navigation and positioning system step by step to meet the demand, and bring into being China's satellite navigation and positioning application industry; and to achieve the initial transformation of

applied satellites and satellite application from experimental application type to operational service type" (China's Space Activities in 2006, 2006, p 2-7).

The above listed developmental goals and aims of the Chinese space program exclude the military underpinnings of the program. Technically, in the recent past, China has separated its space program into a civilian and a military one. However, most likely this is a superficial change for international consumption, as this would unnaturally assume that the People's Liberation Army (PLA) would voluntary give up control to any area of the space program that is critical to its future force projection. While the PRC has issued the White Papers on space in November 2000 and October 2006 that detail aims, progress and accomplishments, conjectures linger about Beijing's true objectives in space. While capabilities are at most times not difficult to gauge, it can be hard to discern intentions. About 95% of the broad space program has technology that is dual-use providing value to the civilian and military arenas, the questions remain as to the true goals of China in space. Not unlike the U.S., China's space technology is for military as well as civilian use, the Compass navigation satellites have the same dual-use nature as remote sensing, with possible force enhancement applications providing improved situational awareness to missile guidance. Space will be exploited by China to reap all benefits, civilian and military in the future (Johnson-Freese, 2007, p. 6-9). On balance, most probably China will continue to modernize and enlarge its military space capabilities; however, Beijing's reliance on space for both civilian and military purposes will amplify with time. Nevertheless, due to budget constraints, China will continue to focus exceedingly on dual-use space technologies that serve domestic socio-economic and military objectives (China's space capabilities and their impact on U.S. national security, 2008, p. 8).

It is an open secret that China wants to gain parity with the U.S. in space, as well as deny the US space dominance within its current capabilities, a possible reason for the ASAT test in 2007. ASAT and other military space assets could be enhanced in the future to deny an enemy, strategic operational space during warfare. This is especially true for a more advanced rival such as the US, in case if Taiwan hostilities breakout. China's space assets and asymmetrical capabilities could be used against the much stronger U.S. to leverage time and enough strategic space to accrue decisive action against Taiwan in a China-Taiwan conflict scenario. Also, the same space capabilities can be leveraged against its peer competitor India in case of conflict. As a developing nation, a restricted budget restrains the depth, breadth, and time frame of its space program. Due to other national economic, environmental and social developmental objectives, pursuing certain expensive space technologies can yield negative returns in the near future. At best, China will pursue a pragmatic path to enhance upon current space technologies in parallel with developing cost-effective asymmetric military space capabilities, such as ASAT, information centric warfare, etc. to deny a much more advanced rival like the US from dominating space. At worst, Beijing will resolve itself to becoming a military space power in an attempt to take full advantage of having freedom of action in space.

Are Indian and Chinese Space Programs Role Models?

How to define a role model? If you look it up in a dictionary it means, "*a person who serves as a model in a particular behavioral or social role for another person to emulate or a person whose behavior in a particular role is imitated by others*." If the developing world were given a choice, to emulate: a democratic nation, law abiding, transparent, accountable to its people and a force of stability in the comity of nations or a totalitarian military dictatorship, unlawful, secretive, unaccountable to its people, domestically oppressive with a horrific human rights record, nuclear and missile technology proliferator and a force of destabilization in the world; who would they choose? Is the logical choice, a democratic India? Even though, the space program is part and parcel of the nation's ideals and what it stands for, the space program must be judged on the merits of providing benefits for the society viewed from an apolitical prism. In the first 4 decades of its space program, the ISRO went to space not to gaze at the stars, but to look back to Earth. Even though, the ISRO operates at one-twentieth of NASA's $16 billion annual budget, some would argue that on a daily basis the ISRO makes its advances more accessible to its citizens (Carney, 2006, p. 2). India's space program is unique among space powers in that it truly represented ideals of performing deeds to uplift its people out poverty so that the common people could have the same opportunities as the more fortunate, the complete socio-economic upliftment of its citizens. The Indian space program is an extension of the vision of Vikram Sarabhai. The space program is transparent; ISRO's annual report is available to all on its website. When one compares the ISRO's website and the information contained on China National Space Administration's (CNSA) website, the level of transparency becomes glaring.

In an open society, the ISRO is accountable to its people, to the government and its activities open to further scrutiny by an independent national media. ISRO prides itself as being truly a civilian program. According to D. Raghunandan, executive secretary of Delhi Science Forum, a nonprofit technology and science think tank on the topic of ISRO's civilian credentials, "ISRO badly wants to preserve its civilian identity and isolate itself from any possible (U.S.) sanctions…There may not be the impenetrable firewall that the U.S. wants, but there is pretty much a separation between the Defence Research & Development Organisation and ISRO" (Carney, 2006, p. 2).

Meanwhile, there is no clear delineation between China's military and civilian space program. China's space assets are owned by Beijing and are directed by the civilian CNSA. Up until recently, the CNSA was under supervisory control of the Commission for Science, Technology and Industry for National Defense (COSTIND). In March 2008 COSTIND was merged with the newly created Ministry of Industry and Information Technology (MIIT) and reconstituted as the State Administration for Science, Technology and Industry for National Defence (SASTIND), and hence, the CNSA enjoys strong ties with China's military. Moreover, the China Aerospace Science and Technology Corporation (CASC) and the China Aerospace Science and Industry Corporation (CASIC) perform research, development and manufacturing of state space equipment, under the supervision of CNSA. In reality, the China Academy of Launch Vehicle Technology (CALT), a central institute within the CASC, is the key lab for not only Launch vehicle technology, but ballistic missile development as well. The military or the PLA supervise launches and satellite tracking control through the China Satellite Launch and Tracking Control General (CLTC), a division of the PLA's General Armament Department.

What's more, on the occasion of the Shenzhou 3 launch on March 15, 2002, President Jiang Zemin proclaimed that the Shenzhou venture held enormous importance for the modernization of China's defense (Ogawa, 2008, p. 23-24). Essentially, the CNSA is a civilian front organization for liaison and international cooperation between the PLA and the Chinese defense community. China space program and strategic expert Kevin Pollpeter sums it up concisely, "*China's space program is inherently military in nature…. Indeed, China's space program is a military-civilian joint venture in which the military develops and operates its satellites and runs its infrastructure, including China's launch sites and satellite operations center*" (China's space capabilities and their impact on U.S. national security, 2008, p. 3).

Since the space program represents the ideals of a nation, China's space program began with military aspirations. Even though the space program in the last two decades has expanded space applications to provide economic, social and technological benefits to its society; the program still remains under military control. As the Chinese nation is not an open society, still secretive, the space program remains nontransparent. The true intentions of the space program are still opaque. Since the PRC is not accountable to its people, neither is its space program. The space program is held accountable to the military and by extension to the communist party. The media is not independent in China, so it is unable to fill the void of being a voice of accountability for the people as are its media peers in India and the West. Even though proclamations are made by China that its space program is for peaceful purposes such as by Deputy general manager of the China Space and Technology Group, Xu Dazhe, "*China has undertaken the space program for scientific and technological progress, so that mankind could make better use of space resources for peaceful purposes*," it should be warily accepted by the international community (China's Space Program Is for Peaceful Use of Resources, 2005, para. 4). If one is to judge the space program as a role model for developing nations, the criteria most important is the use of space for socio-economic upliftment. A space program that concentrates on socio-economic space applications only and doesn't divert national economic funds for prestige projects on space explorations and human spaceflight is a true role model based on this strict criterion. Surely, the latter programs are important for expanding the space scientific understanding of man and have residual benefits as enhancing the scientific technological base of a nation, but these programs don't address the pressing needs of a developing nation. A developing nation needs what space applications provide: resource development, broadcasting, communications, telephony, radio, tele-education, telemedicine, disaster and natural resource management, weather management, and more.

India took the lead in the beginning as being committed to only providing socio-economic benefits by using space technologies and China followed recently in this endeavor. However, both developing nations are expanding their respective programs to space exploration and manned spaceflight which don't derive socio-economic benefits to the extent as space applications. The true ideals of economic, societal and technological benefits provided by space applications to its entire people are only worth emulating by other developing nations. Herein, using the strict criterion of the role model, India and China are no longer role models even though they still expend funds on space application programs.

Domestic Politics

India

The birth of India's space program was partially guided by political motivations. Over time it came to symbolize India's modern technology achievements, thus boost India's prestige internationally. Traditionally, the Indian space program has catered to a domestic constituency, enhancing its monumental popularity with the Indian people, for whom each successful mission swells national morale and pride (Mistry, 1998, p. 155). This was most evident with the

Chandrayan-1 mission, the public, media, and government officials showed their strong support by following the mission from its launch to its trek to the moon with hypnotic zeal. The moonshot not only enhanced the nation's brand value but also deluged the ISRO with more than 135,000 applications for 300 job openings, an unprecedented feat for an organization that receives an average of 4,000 – 5,000 annual applications. Chandrayan's success has prompted the demand for jobs in the ISRO, according to V Jayaraman, director of ISRO's Hyderabad-based National Remote Sensing Agency, he further stated, "*The organization has acquired a glamour value thanks largely to the moon mission*" (Laxman, 2009, para. 1-4).

The chief objective of India's space policy was to achieve self-reliance, giving the nation an ability to pursue an independent course in exploring and using outer space with its own satellites and launch vehicles, without relying on foreign technical assistance which could detract from the sovereignty of the space program and its policies. ISRO enjoys large amount of autonomy in developing particular systems, the choice has been mainly technical rather than politically determined. The organization simply uses the fastest available technologies in quest of its goals, for example, it built the PSLV's liquid-fuel engine based on designs of France's Viking engine and importing a cryogenic engine from Russia for the GSLV (Mistry, 1998, p. 155).

China

China has risen out the ashes of an imperialist past, determined not to let history repeat itself. For it is, China longs for the path towards the status of the mythical 'Middle Kingdom,' its space program is an important avenue to realizing its mythological rightful standing in the world. A critical component of attaining the 'Middle Kingdom' is the prestige that accompanies it.

China's space program is an extension of its national aspiration for power and international prestige. The CCP's political objective is to stay in power, one of the tools it uses to stay in power is by flaming the nationalist pride among the public and another way is to have successful prestige projects such as the 2008 Beijing Olympics for which the CCP can take credit for. Herein, in order to retain its legitimacy in the 21st century, an era of increasing irrelevance of communist ideology, a majestic project like the space program becomes a unifying force, a source of prestige and pride of what China can do. Like a magician trick, the CCP focuses public attention on a prestige project such as space exploration; meanwhile behind the scenes it carries out official corruption, social injustice and other misdeeds, allowing the party to escape scrutiny.

The manned space mission of Shenzhou V to VII received great domestic and international media coverage, moments of great pride for the Chinese people. The taikonauts of the three manned missions were celebrated as national heroes. President Hu Jintao proclaimed the launch of Shenzhou V as reflecting gloriously on the motherland. The space program provides military, economic, social, medical, educational and technological benefits; however, the CCP never loses the opportunity to take the glory for the programs achievements. (Dellios, 2005, p. 4-5).

International Arena

India

The space program began in 1962 within the post-colonial model for a developing nation based on ideals of self-reliance, rapid economic growth through industrialization and social justice. By the 1990s, the space program grew more ambitions, evolving from a program solely focused on socio-economic upliftment to space technology commercialization, coinciding with the momentous changes of the political economy away from socialism and towards a liberalized market oriented model (Political Economy and ICTs for Development: India's Space Program, 1975-2000, 2006, p. 1). This offered new opportunities to the Indian space community to strengthen existing bonds and build new relationships in the international arena. One of the most unlikely relationships developed as a result of the opening up of the economy, that of Israel's strategic relationship with India, quite remarkable for country with the second largest Muslim population in the world, after Indonesia. In 2008, Israel eclipsed Russia as the largest defense equipment seller to India. The evolution of the relationship from military to civilian space cooperation has led India to launch several satellites for Israel, the TECSAR reconnaissance satellite being the latest one, launched in January 2008. As mentioned above, India's level of the international cooperation is multi-dimensional, including exchange of meteorological data, carrying out of joint missions, offering other nations opportunities for payloads onboard Indian satellites, and education and training in the area of Space. This cooperation has the added benefit of space diplomacy in exerting soft power, allowing New Delhi to build influence within the other nation through the relationships built through scientists, scientific exchanges, commercial involvement, inter-governmental committees and other forms of space diplomacy.

In addition to the accessing international prestige, space diplomacy can have foreign policy spin-offs. ISRO can provide PSLV, IRS and INSAT services to other nations, hereby re-enforcing existing or building new economic and political ties with nations. Already, India markets IRS images around the world. Additionally, the Chandrayan-1 not only raised India's stature and prestige internationally, but also earned the goodwill of the U.S., Europe and Bulgaria, along with their respective space agencies. The Chandrayan-1 mission carried scientific payloads from these countries free of cost. Furthermore, the dual-use nature of the IRS and INSAT series of satellites demonstrates that these space assets can greatly enhance India's force multiplication and power projection capability in the Asiatic region, especially affecting the regional strategic balance in New Delhi's immediate neighborhood (Mistry, 2001, p. 1042-43). A recent study, based on two reports: "*the 2008 Space Competitiveness Index*" issued by the Futron Corporation and the "*Authoritative Guide to Global Space Activity*," released by the Space Foundation of Colorado, concluded that India and China, along with Japan, Russia and Europe are set to end U.S. space dominance in the future. Futron's report states the historical advantages the United States enjoyed in all three major dimensions of space competitiveness, human capital, industry and government are being narrowed by emerging world powers India and China, as well as a resurgent Russia, collective Europe, and a stable Japan (India and China set to reduce US dominance in space activity, 2008, para. 1-7).

Futron Corporation's *Space Competitiveness Index* (SCI) uses fundamental economic determinants of space competitiveness across 40 individual metrics to ascertain national space competitiveness in three major dimensions: human capital, industry and government. This approach permits Futron Corporation to generate an exhaustive comparative analysis of ten foremost nations in space and space-related activity. The SCI results show US is still the present leader in space competitiveness, followed by Russia, Europe, China, and India (Insight: The Futron Space Competitiveness Index, 2008, para. 7-12). India's space program has enhanced New Delhi's stature; the program's technological, commercial and socio-economic progress could further facilitate India's currency in the international arena.

China

China's international image is critical to its rise towards world power status. The CCP uses its carefully controlled media managed strategies to portray itself and the nation only in a positive light. Meanwhile, it goes to great lengths to counter or subvert any negative portrayal of China and its activities, anything that might hurt its domestic and international prestige. This type of propaganda and media management is reminiscent of the former Soviet Union but China's is more advanced and sophisticated. The space program is a great tool for enhancing China's prestige. Since the inception of the space program, China has been engaged in international space development cooperation. In recent years, China has been involved in a number of cooperative projects and international initiatives. To forestall overt and covert fears in the international community about China's role in space militarization, Beijing's diplomacy has been carefully orchestrated. In 2002, China and Russia jointly submitted a working paper to the UN Conference on Disarmament that would ban weapons in space (Dellios 2005, p. 4-5).
An important undertaking of international cooperation has been with Brazil, the China-Brazil Earth Resources Satellite (CBERS) program, a technological cooperation program in which both nations develop and operate Earth observation satellites. As part of its manned Shenzhou mission, China entered into cooperative arrangements with Kenya and Namibia to erect tracking stations within their borders (Ogawa, 2008, p. 27). Similar to China's use of international

cooperation in climbing up the scientific, engineering and technological ladders and maximizing resources and building soft power relationships with other nations to benefit it, the space program is no exception.

The international cooperation efforts in the area of space are testament to China's space diplomacy. China has done well in establishing a network of space partnerships. It has partnered with Russia for guidance and technical assistance on its prestigious manned space flight program. There are several ventures China has with Europe, including Galileo navigation and positioning program and communication satellite development, with Canada on space science, relationships with Nigeria and Venezuela on sales of Chinese commercial communication satellites and various ventures with a number of developing nations as well. Actually, China is attempting to supplant India and establish itself as the leader of the developing nations in all areas, including the space arena (Johnson-Freese, 2007, p. 17). China doesn't want any regional competition in the space arena, in the near future seeks to become the premier space power in Asia. This was the main driving force for establishing the regional multilateral space cooperation initiative, APSCO in 2005. It seems the partnership was accelerated by the success of China's manned spaceflight program, and it reflects China's eagerness to proactively take the lead in space efforts in Asia (Ogawa, 2008, p. 28). As China's space efforts continue to grow, it will continue to exploit space activities as a diplomacy tool, an indispensible part of enhancing its national security but international prestige as well.

Inference of Space Policy thru Space Budget

India

"*India is not going to allow on the Asian continent for a Chinese capability that they don't have,*" stated confidently NASA administrator Mike Griffin in his speech before the Space Transportation Association on January of 2008 (Foust, 2008, para. 2). The statement pertains to the frontiers of human spaceflight, an acknowledgement that the next nation to launch humans into space is going to come from India not Europe or Japan. India's Planning Commission gave approval in February 2009 for RS. 12, 400 crore ($2.5 billion) to be used towards the manned space mission, scheduled for 2015. Whether this reflects an expansion of the civilian space program or a permanent shift in priority from the traditional national development program remains to be seen. However, the allocation of $2.5 billion is slightly double the annual budget of the DOS; one can deduce that clearly India is moving beyond space applications for the common man to space frontier exploration. This is a significant development for New Delhi's space policy.

Since the 1990s, India's space program has been in a state of transition. The foundations of the space program laid in practical applications of advanced space technologies for socio-economic development. Initially, space was a primer for helping raise the economic profile of India's citizens, not as an instrument of prestige. The country eschewed other forms of space activities such as, human spaceflight, robotic space exploration and the like in favor of applications like remote sensing and communications that provided practical benefits.

The unique approach towards national development has been highly successful for the developing nation. In a speech at the Center for Strategic and International Studies (CSIS) in January 2008, Madhavan Nair reviewed the accomplishments of the ISRO in benefitting the national development endeavors from disaster and natural resource management to expanding national broadcasting and communication coverage, as well as supporting telemedicine and tele-education to rural areas. Nevertheless, the chairman stated, "*I can confidently say that that vision of Dr. Sarabhai has been fulfilled…Today, we are at a turning point. We are looking at what's next." He further elaborated that the Indian scientific community*, "*…came to the unanimous conclusion that space is going to be the next frontier of humankind…It's not only just looking at the planet Earth and trying to understand it and look for new resources in a very efficient manner for improving the life of other people, but space exploration will also play a very major role*" (Foust, 2008, para. 3-7).

The success of the Chandrayan-1 lunar mission has garnered immense prestige and confidence for Indians. For it is, space exploration is a new realm within the space program and the success of its first official exploratory mission has provided the ISRO enough confidence in its abilities to take on more technically complex missions in the near future. Before future projects can be implemented, it is important to evaluate the budget of the Indian space program to see if space policy inferences can be made. The following are the total budgets and their allocations (detailed budget in Appendix B and C):

Table 1. Indian Space Budget 2007 - 2010

	Interim 2009-2010[1]* (in crores of Rupees)	Revised 2008-2009[2]* (in crores of Rupees)	Revised 2007-2008[3]* (in crores of Rupees)
Launch Vehicle Technology (Total)	1914.56	1479.48	1248.58
Satellite Technology (Total)	731.36	599.55	467.08
Launch Support, Tracking Network & Range Facility (Total)	441.43	404.89	301.34
Space Applications (Total)	546.68	402.75	299.75
Space Sciences (Total)	283.74	268.29	321.60
Direction & Administration / Other Programs (Total)	87.52	101.22	73.18
INSAT Operational (Total)	446.28	235.89	573.57
Grand Total	4459.00 ($892 million)	3499.00 ($700 million)	3290.00 ($658 million)

[1](Union Budget 2009-2010, 2009, p. 216-18)

[2](Union Budget 2008-2009, 2008, p. 216-18)

[3](Union Budget 2007-2008, 2007, p. 213-15)

*includes planned and non-planned outlays, an Indian crore is equal to 10,000,000.

There are various estimates available from different sources, for analysis purposes a uniform exchange rate of 1 dollar equals 50 rupees was used. Herein, a slight variation may occur from official figures as constituted by the Government of India, Union Budget and the Department of Space total outlays. The total outlays have increased over time for the space programs, with the bulk of the funds allocated for space technology (includes Launch Vehicle Technology, Satellite Technology and Launch Support, Tracking Network & Range Facility) , making up 69 percent (2009-10), 70 percent (2008-09 and 61 percent (2007-08) of the space budget. Furthermore, the majority of the space technology funds went towards launch technology, 43 percent (2008-10) and 37 percent (2007-09). The 'needs' based space applications programs were allocated 12 percent (2008-10) and 9 percent (2007-08) of the collective space budget. The Direction &

Administration/Other Programs include, "*Special Indigenisation/Advance Ordering: Indigenisation envisages ISRO to have interface with the Indian Industry to develop various electronic components, materials, chemicals, etc., for the space programme. The scope of the scheme also includes procurement of certain long lead and critical items for futuristic missions. Others: Under this, provision has been included for ISRO Headquarters, International Co-operation and Central Management*" (Union Budget 2009-2010, 2009, p. 221).

The Chandrayan 1 and 2 lunar missions are categorized under Space Sciences, were allocated 90 crores ($18 million). Also, allocation for the Manned Mission Initiatives/Human Space Flight Programme has increased from year 2008-09, 42 crores ($8.4 million) to 50 crores ($10 million) for 2009-10. "*We are spending hardly 0.5% of our national budget on our scientific programs, and what we are spending on Chandrayan is hardly only 3% of our budget over the last five years,*" according to ISRO chief Madhavan Nair (Murthy, 2008, para. 8). The official DOS budget reflects a major emphasis on developing space technologies such as the new GSLV Mark III with the upper stage cryogenic engine. This development is critical to the future of the space program, as India will be able to place heavier payloads into orbit, about 4,400 kg payload to geosynchronous transfer orbit (GTO), or 10 ton to low earth orbit (LEO), joining an elite group of nations with the capability in making the nation completely self-sufficient in launching various satellites (Space Launch Vehicles, n.d., para. 24). The mastering of cryogenic technology is critical to this accomplishment.

Currently, India uses the European services of the Ariane-5 rocket for the heaviest payloads. The previous technology sanctions placed on the Russian-Indo cryogenic deal have been overcome after a decade and a half of indigenous efforts. The GSLV III opens many new frontiers for India's space policies:

- commercially India can compete globally for all types of satellite launches
- it enhances the program's prestige and stature as only a few nations have mastered cryogenic engine technology
- makes the nations self-reliant in launch technology
- it expands the space exploration options for the ISRO
    - future Chandrayan 2 lunar, human spaceflight and mars probe missions will use the rocket, garnering further prestige to the nation

The nation has not deviated from its commitment from space applications, as the funding has increased every year. This shows that even though priorities may have shifted to more prestige projects, the ISRO is still committed to the space socio-economic policies. The pursuit by ISRO for space exploration missions is a policy underlined by the need to maintain relevancy as a space program in the 21st century. China has reignited the imagination and zeal for manned missions to the moon, creating a new space race in Asia. Prestige plays important roles for both space programs, however, traditionally less so for India. The budget also reflects that India's will continue its policy of enhancing autonomous space capability in design, development, manufacturing, launching and operations of its indigenous space program.

The program is expanding its space policies beyond the socio-economic benefits to the common man, but to increase self-sufficiency in space capabilities, access and maintain independent use of space, enhance international cooperation and promote space commerce, explore space as to stay relevant in the new century, accrue recognition and prestige as an elite space program and attain top space power status in Asia.

China

With three successful Shenzhou V – VII missions and Chang'e-1 lunar mission, the wider question is where is China's space policy heading? In an era of growing interest in space exploration, China's space policy expansion is in alignment with other space powers, such as US, Europe and India. Beijing's space policy has been interrelated with its military and domestic policies. The relationship between China's ballistic missile and space program has been there since the program's inception, evolving from strategic considerations of acquiring nuclear missiles for national defense. Mao's ascent required the need for prestige and intense nationalism to dictate the terms of space policy. A space program allowed the developing China to build strong nuclear and missile based defenses, as well providing a fast track towards national development. The space program was the first critical high technology and science effort in the nation. Science and technology were the paths towards socio-economic and defense development, seeking autonomy in science was critical to the power trajectory of China. In the formulation of its space policy, the goal has been to gain 'asymmetric equivalency' with technologically advanced nations.

In the beginning, budget constraints, dearth of skilled scientific labor pool and lack of advanced technology infrastructure led Beijing to adopt the policy of 'asymmetric equivalency,' gain technological parity with developed nations overtime achieving it within the constraints of a developing nation by leveraging international cooperation to access space know and technology, gain technology through illicit means, use cooperation to develop soft power influence with nations, space agencies and international organizations and leverage low-cost labor pool to provide cost-effective development of the space program. These imperatives, along with military and economic gave the space program incentives to create space applications, combined with the requisite launch vehicles, allowed the space program to prosper.

The space program has prospered over the years, overcoming sanctions, technological denial, economic constraints and domestic politics. The space community questions why China sought a manned space program. Even though the question was hotly debated among the Chinese space community, there was strong support for the policy by the CCP as it bolstered its respect and prestige (Gilks, 1997, p. 221). The Chinese people are duly justified being proud of their space program and what it has achieved in military and civilian terms. This achievement is more significant due to the budget constraints the space program has operated in. Unlike the Indian space program the official space budget has not been made public. Also, since the Chinese space program is controlled by the military, it is inherently a military space program; it is difficult to discern how much of the unofficial military budget is sanctioned for the space activities. Furthermore, as missile development and other military technologies are handled under the auspices of the space arena, it becomes even cloudier, thus one cannot clearly delineate portions of the military budget from the official space budget.

Herein, the space program's real budget remains hidden. Authorized documents and China's White Paper on space activities do not offer budgetary figures, though they include the nation's space achievements and future plans. The latest official White Paper, "*China's Space*

Activities in 2006” and the first one released in the year 2000 are without any budgetary numbers. Researchers have to rely on unofficial sources and estimations, as well as statements from Chinese officials to ascertain China’s space policies through broad strokes. India provides an official “*Union Budget*” which contains the DOS budget, which is further broken down into budgets for various space activities. The space budget it freely available on the internet through a Government of India website, along with budgets of all the major ministries and departments. This is in sharp contrast to official CNSA and other government websites, which do not carry any detailed information just broad generalities. According to the World Security Institute, China’s space budget was $500 million (2005) and1.5 billion (2006). Estimates of China's space program by international sources fluctuate considerably. Such estimates are unsupported by documentation; western media claims that Beijing’s annual space expenditures are between $1.3 billion to $3 billion. This budget excludes the likely probability of billions poured into military-linked space activities. However, majority consensus seems to be that China's annual space spending is around $1.5 to $2 billion, if true is more than double of India’s and comparable to Japan’s spending. This compares to the budget of $16 billion annually for NASA and $6 billion for the European Space Agency (China Space Budget, n.d., para. 6).

According to Sun Laiyan, administrator of CNSA, the government had spent: up to late 2006, 19 billion yuan ($2.4 billion) on the initial five Shenzhou spacecraft, one billion yuan ($125 million) on the Shenzhou VI, the primary stage of the three stage Chang'e lunar Program cost slightly over one billion yuan ($125 million) and the Chang'e lunar project budget at 1.4 billion yuan ($170 million) (Chinese Annual Space Budget Exceeds Two Billion Dollars, 2006, para. 1-8). A 2008 report issued by Paris-based Euroconsult, "*World Prospects for Government*

Space Markets", states that CNSA 2009 budget is approximately US$1.3 billion. Launch vehicle technology accounts for about 25% ($325 million) of total space budget followed by Earth observation and human spaceflight, accounting 20% ($260 million) each of the collective space expenditures. Meanwhile, satellite communications and navigation both are estimated to be about 10% ($130 million) of the entire space budget (Brown, 2009, para. 4-5). According to Euroconsult, China spends approximately 65% (2009-10) on space technologies (launch vehicles, satellites, earth observations, compared to India's 69% (2009-10), but China's figures do not include expenses for support of space technologies platforms such as, launch support, tracking network and range facilities. Somehow, if you estimate the cost it is approximate to India's or higher, and then it is clear that both nations' expenses are similar with regards to space technology. This is logical, as China requires investment in its space exploration, is developing a new powerful Long March 5 rocket and it attempting to establish itself as a credible alternative to the West in space commerce.

It is also notable that these figures are best guesses (no documentation support) and even administrator Laiyan's statements must with be viewed with skepticism, as the Chinese government is notorious for fudging official figures. Most likely administrator Laiyan will provide a low-ball estimate of the true higher costs of any space activity because a low estimate can gain higher prestige value in the international arena. For example, China can boast that it cost $25 to develop a certain project while a comparable project may cost $100 in the West; hence China is able to achieve the same project as the West at one-fourth the cost, more cost effective. This is a commonly employed Chinese strategy used for garnering higher prestige value. Also, recent transition in China's space policy to space exploration has been replicated by

India. However, in China's case its space endeavors have a military foundation that is why the international community is wary of China's higher profile in space, even more so than before, especially after Beijing's reckless ASAT military weapons test in 2007.

The revised official military budget for 2009, as per Chinese government stands at 480.6 billion yuan ($70.3 billion), a 14.9 percent jump from 2008 (Lawrence, 2009, para. 1-2). But in its annual report to congress, the Pentagon's "*Military Power of the People's Republic of China 2009*," states that China's entire military-related spending for 2008 was between $105 billion and $150 billion, using 2007 exchange rates and prices. The Pentagon report serves as a better guideline, as the PLA would intentionally understate its true military expenditures. If the Pentagon estimates are accurate than it can be logically surmised that China's space budget is significantly more than publically stated, if the military linked expenses are included.

China's military space program remains opaque to the international community, which complicates peaceful space cooperation. Beijing permits cooperation in the civilian space sector without the military side of it, to bolster the PRC's credentials as a peace-loving nation. This adds to the misgivings and distrust already present within other nations of China, not helped further by Beijing's illicit nuclear and missile proliferation. The space program has continued to accrue legitimacy and prestige to the CCP. Herein, the CCP wouldn't receive the same legitimacy and prestige if military components of the space program were publically acknowledged. Beijing's public space policy has been seen for what is by rational space policy experts, a façade that hides China's true policy intentions, to use the military space program for primary military purposes in order to leapfrog to dominant world power. The lack of transparency in official space budget details available to the public clearly reflects a hidden agenda. Distrust, illicit technology proliferation, hidden agendas and excessive secrecy are the main obstacles to China realizing full potential in international cooperation and space commerce. Herein, its neighbors, Japan, India, South Korea and Taiwan are enhancing their military capabilities.

CHAPTER SIX: CONCLUSION

The quest for space has ignited minds since the nineteenth century. It has taken many thousands of years to reach the current status of space activity and technology. The 20^{th} century may be looked upon by future generations as the true origins of tangible utilization of space for the benefit of mankind or laying the seeds of its destruction through militarization of space; only time will tell. The responsible people of the world are pondering these sentiments now. Certain space powers have already chosen the latter path without the consent of the governed, a path chosen by men in uniforms and blessed by their governments. Some well established space powers see militarization as a natural evolution of the civilian program, some emerging space powers see it as devolution in the concept of space belonging to all mankind, not as a bastion to be dominated by one or the few.

The emerging space powers, India and China are against the concept of a space denial regime, the militarization of space. The full spectrum domination of space is an expensive proposition, especially for developing nations. As developing nations, India and China have followed different paths in their quest for space. India began its space program almost a decade after Mao Zedong declared China would become a world power through space activities. The activities of India's program had origins in the ideals of Nehruvian socialism, the use of space to cure the ills of the common man in India through socio-economic space applications. The space upliftment social project continues to be the cornerstone of New Delhi's civilian space program's objectives.

The objectives of the Chinese space program have at its cornerstone, military applications. Mao wanted China to have great power status and international prestige, this could be accrued by following the footsteps of the space programs of the US and Soviet Union. Both nations' space programs started as military space programs to develop missiles as platforms for nuclear delivery. The missiles not only provided great power status and prestige but the ability to have independence of leverage in a hostile situation. One cannot be powerful without sovereignty of action and means of exerting leverage upon others. Herein, the new China, coming out of the yoke of imperialism laid the genesis for achieving international power and prestige though the militarization of its space program.

Over time, China's space program grew to employ the activities similar to India's civilian space program, that of space applications that provide socio-economic benefits. Both nations have advanced their respective programs to such a degree that they are narrowing the space competitiveness gap with the US. It is natural for Asia's two giants to be competitive in space endeavors. The competition has yielded advanced space technologies that benefit not only civilians but the military as well, dual-use technologies. Both nations possess dual-use technologies such as, launch vehicles, resource, navigation and communication satellites that can have military applications as well. In India's case such technologies were not knowingly manufactured for a military purpose. The ISRO wears it civilian badge with pride and attempts to maintain the distinction as a civilian space agency.

However, in China's case, its space program has, since inception been controlled by the military, in its essence it is a military space program that supports civilian space applications/technologies. The CNSA acts as the civilian public face of Beijing's military space program, allowing it to escape international scrutiny, make easier space diplomacy, access/develop cutting edge space technology and increase its international prestige.

Prestige is important to India and China at the world stage; their space programs raise their international stature. This is truly evident with the success of India's Chandrayan-1 mission and China's Shenzhou V-VII manned missions. Both countries are working actively to promote space exploration programs in the coming years, solidifying their reputations as cutting edge space programs even further. Do the reputations of their space programs translate into being role models for developing countries? While China's space program is nontransparent, accountable to the PLA and the CCP and military at its core; is the polar opposite to India's transparent, accountable to the Indian people and civilian at its core space program. Additionally, the knowledge China has gained from its space program in missile technology and by extension nuclear delivery, hasn't been restricted within the nation's borders. China has been a source of international destabilization for geopolitical strategic gain in the form of nuclear and missile technology proliferation, even though it is a signatory of the nonproliferation regime. India is not a signatory of the nonproliferation regime but has always abided by its principles by never illicitly proliferating technology earned through its space program. Recently, it was recognized as a responsible nuclear and space power by receiving "de facto" international status and recognition as a responsible nuclear power within the comity of nations.

India and China have built remarkable space programs within a span of a few decades with limited resources. The paper has shown that domestics and geopolitics are indeed motivating factors for these developing space programs. For India, the domestic goals were social and economic upliftment of its people and for the Chinese it was military self defense through missile development as well as garnering prestige. Also, geopolitics was a critical determinant in China's space program. The paper findings showed that the China wanted to remedy the military disparity between it and a perceived hostile environment from Cold War powers United Stated and Soviet Union, particularly in missile technology. Chinese principal interest lay in having ballistic missiles capable of reaching distant targets.

It was also revealing that the two programs are developing similarly as they are moving in tandem with emphasis on space exploration and manned spaceflight. It is becoming harder to distinguish the two space programs, the main difference being the military nature of China's space program. Due to the new emphasis on space exploration and human spaceflight, Indian and Chinese space programs are not considered role models for developing nations. It is this researcher's recommendation that the dynamic space programs of India and China be continually reviewed as to see any permanent shift in their respective space policies. Any permanent shift will be more visible in India's case due to the initial motivation of its space program. Ultimately, the capabilities of one nation aspiring for space dominance through weaponization of space will lead others to react in kind to protect their right of sovereign action, and then no space program will be a role model.

APPENDIX A: INDIAN SPACE CENTERS

Vikram Sarabhai Space Centre (VSSC)

- Premier center for rocket and launch vehicle development
- Research and development activities include aeronautics, avionics, mechanical engineering and materials, composites and solid propulsion
- Systems reliability, polymers and chemicals, propellants, and computer and information
- Functional Ammonium Perchlorate Experimental Plant
- Space Physics Laborator does research in atmospheric and associated space sciences
- Developed sounding rockets, launch vehicles, SLV 3, ASLV, PSLV, and GSLV (Vikram Sarabhai Space Centre, n.d.).

ISRO Satellite Centre (ISAC)

- Satellite technology lead center
- Performs activities related to power systems, digital systems, microwave systems and communication, control systems, systems reliability and space physics, spacecraft assembly integration and testing, thermal, spacecraft mission planning and analysis, structures, spacecraft mechanisms, computers and information
- Satellite projects facilities include fabrication and testing
- ISAC umbrella includes Laboratory for Electro-Optic Sensors (LEOS)

- Realization of success in design and development of diverse types of 23 satellites thus far, including, communication, scientific and remote sensing (ISRO Satellite Centre, n.d.).

Satish Dhawan Space Centre, SHAR

- India’s premier launch centre, 62 mi north of Chennai
- Conducts ground tests and processes solid propellant motors
- Thumba is the launch range
- Established launch complexes for Sounding rockets, SLV- 3, ASLV, PSLV, GSLV (Satish Dhawan Space Centre, n.d.)

Liquid Propulsion Systems Centre (LPSC)

- Develops liquid and cryogenic propulsion stages for launch vehicles and auxiliary propulsion systems for both satellites and launch vehicles
- Activities connected to liquid propulsion stages, cryogenic propulsion stages and control systems for launch vehicles and spacecraft
- In Banglore are the precision fabrication facilities, production of transducers and integration of satellite propulsion systems
- Developed control systems for SLV-3, ASLV, PSLV and GSLV, liquid propellant stages for PSLV, satellite propulsion systems as well as those for IRS and INSAT production of pressure transducers (Liquid Propulsion Systems Centre, n.d.).

Space Applications Centre (SAC)

- A major component of the Indian Space Research Organization engaged in the research, development and exhibition of applications of Space Technology in the field of Remote Sensing, Communications, Meteorology and Satellite Navigation
- R&D on ground systems, onboard systems, and end user equipment software and hardware
- Developed meteorological and communication payloads for INSAT, microwave and pptical payloads for IRS satellites
- Offers infrastructure for training courses to the students of CSSTEAP (Space Applications Centre, n.d.).

Development and Educational Communication Unit (DECU)

Deals in the conception, definition, planning and socio economic appraisal of space applications programs, below are its main roles:

- Conceives space applications programs to meet social needs
- Examines existing societal needs and projects future needs to serve as inputs to the planning of space applications system
- Planning for experimental and operational space applications programs
- Studying social, economic and cultural impact of mew technologies.
- Designing and producing suitable system software strategies (Development and Educational Communication Unit: About Us, n.d.)

ISRO Telemetry, Tracking and Command Network (ISTRAC)

- Gives mission support to near-earth satellites and launch vehicle missions
- Network of ground stations at Bangalore, Lucknow, Port Blair, Sriharikota, Thiruvananthapuram
- Additional network of TTC stations at Brunei, Bearslake (Russia), Biak (Indonesia) and Mauritius. Banglore houses multi-mission Spacecraft Control Centre
- Supports IRS-1B, IRS-1C, IRS-1D IRS-P3, IRS-P4 and SROSS-C2 satellites
- Part of the international Satellite-Aided Search and Rescue Program (ISRO Telemetry, Tracking and Command Network, n.d.)

INSAT Master Control Facility (MCF)

- In charge of INSAT post-launch operations, such as station keeping, orbit maneuvers, and on-orbit operations
- Supports on-orbit operations on series INSAT-3A, INSAT-3B, INSAT-3C, INSAT-3E, Kalpana-1 and GSAT-3 satellites (INSAT Master Control Facility, n.d.).

ISRO Inertial Systems Unit (IISU)

- Develops inertial sensors and systems for launch vehicles and satellites, including satellite inertial systems, navigation systems, bearing and space tribology and inertial systems integration and simulation
- Performs precision fabrication, assembly, integration and testing
- Developed inertial systems for ISRO satellites and launch vehicles, solar array drive assemblies, scanning mechanisms, and more (ISRO Inertial Systems Unit, n.d.).

National Remote Sensing Agency (NRSA)

- An independent institution supported by the Department of Space
- Responsible for acquiring, processing and delivering of data from remote sensing satellites
- Performs projects involving remote sensing application in collaboration with the users
- In command of production and implementation of specific action plans under Integrated Mission for Sustainable Development in 174 districts of India
- In charge of the Indian Institute of Remote Sensing at Dehra Dun
- Shadnagar satellite earth-station, near Hyderabad, receives data from Indian remote sensing satellites, NOAA and US Landsat, French SPOT and microwave data from the European remote sensing satellite ERS
- Supplied data from series IRS-1B, IRS-1C, IRS-1D, IRS-P3 and IRS-P4 to the end users (National Remote Sensing Agency, n.d.).

Regional Remote Sensing Service Centre

Setting up of the center arose out of the importance and need of natural resources management in the country; Government of India formed the National Natural Resources Management System (NNRMS). NNRMS is a combined approach for management of natural resources, integrating the advantages of information derived remote sensing technology and conventional systems. With the long standing mission the Indian Space program of optimum use of space technology for national development, the Department of Space (DOS) has been responsible, as the nodal department in India for evolution, establishment of NNRMS and all remote sensing related actions. Herein, DOS has established five Regional Remote Sensing

Service Centers (RRSSCs) for analysis of remote sensing data to develop planning related inputs on natural resources management. These centers reside at Bangalore (Southern Region), Dehradun (Northern Region), Jodhpur (Western Region), Kharagpur (Eastern Region), and Nagpur (Central Region) and function under RRSSC and ISRO.

Additional Area of activities:

- Support execution of national projects and promote remote sensing applications
- Develop software
- Education and training (Regional Remote Sensing Service Centre, n.d.)

Physical Research Laboratory (PRL)

- Center for research in space and allied sciences, such as astronomy and astrophysics, aeronomy and earth sciences, planetary atmosphere, solar system studies and theoretical physics (Physical Research Laboratory, n.d.).

National Atmospheric Research Laboratory (NARL)

NARL is an independent research laboratory with funding provided by the Department of Space, working on fundamental and applied research in Atmospheric and Space Sciences. Since its inception in 1992 as the National Mesosphere-Stratosphere-Troposphere (MST) Radar Facility, it has evolved into a premier center for atmospheric research in India (National Atmospheric Research Laboratory, n.d.).

Antrix Corporation Limited

Since 1992, Department of Space (DOS) commercial arm, Antrix promotes commercial exploration of services and products from the Indian Space Program. Antrix markets space services and products to diverse international customers, based on remarkable assortment of accomplishments and developments over the last four decades in the Indian space program. (Antrix Corporation Limited: About Us, n.d., para. 1).

Semi-Conductor Laboratory

- Lays R&D foundation in India in the field of microelectronics
- Design & Development of cutting edge systems/devices
- Manufactures MEMS/ VLSI based systems & sub-systems (Semi-Conductor Laboratory: Preamble, n.d.).

Indian Institute of Space Science and Technology (IIST)

IIST offers Bachelors, Masters, Doctoral and Post-Doctoral programs in Space Technology, with specialization in Aerospace Engineering, Avionics and Integrated MSc in Apllied Science. Also, promote stimulation, conservation, and dissemination of knowledge in varied scientific and academic fields (Indian Institute of Space Science and Technology: Objectives, n.d.).

National Natural Resources Management System (NNRMS)

It is an inter-agency system for integrated management for natural resources in India. The major activities of NNRMS include:

- Determine user/application requirements for remote sensing
- Establish proper utilization systems for use of remote sensing images and traditional data for resource management activities
- Maximize use of information for disaster management support, environmental monitoring, natural resource management and empowering society (National Natural Resources Management System, n.d.).

APPENDIX B: INDIAN SPACE BUDEGT 2009-2010

DEPARTMENT OF SPACE

DEMAND NO.89

Department of Space

A. The Budget allocations, net of recoveries, are given below:

(In crores of Rupees)

	Major Head	Budget 2008-2009			Revised 2008-2009			Budget 2009-2010		
		Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total
Revenue		1820.50	474.00	2294.50	1708.08	685.00	2393.08	2008.88	859.00	2867.88
Capital		*1779.50*	...	*1779.50*	*1105.92*	...	*1105.92*	*1591.12*	...	*1591.12*
Total		**3600.00**	**474.00**	**4074.00**	**2814.00**	**685.00**	**3499.00**	**3600.00**	**859.00**	**4459.00**
1. Secretariat - Economic Services	3451	...	5.46	5.46	...	6.93	6.93	...	7.45	7.45
Space Research										
Space Technology										
Launch Vehicle Technology										
2. Geo -Synchronous Satellite Launch Vehicle	3402	1.00	...	1.00	...	...	...	...	...	...
3. GSLV MK-III Development	3402	167.00	...	167.00	152.00	...	152.00	135.86	...	135.86
	5402	103.00	...	103.00	88.19	...	88.19	81.14	...	81.14
	Total	*270.00*	...	*270.00*	*240.19*	...	*240.19*	*217.00*	...	*217.00*
4. Cryogenic Upper Stage Project [CUSP]	3402	0.10	...	0.10	0.70	...	0.70	0.37	...	0.37
5. Polar Satellite Launch Vehicle - Continuation (PSLV-C) Project	3402	170.00	...	170.00	143.50	...	143.50	162.00	...	162.00
	5402	10.00	...	10.00	6.50	...	6.50	18.00	...	18.00
	Total	*180.00*	...	*180.00*	*150.00*	...	*150.00*	*180.00*	...	*180.00*
6. Vikram Sarabhai Space Centre (VSSC)	3402	122.04	128.41	250.45	175.16	188.36	363.52	173.72	273.26	446.98
	5402	181.83	...	181.83	131.17	...	131.17	166.44	...	166.44
	Total	*303.87*	*128.41*	*432.28*	*306.33*	*188.36*	*494.69*	*340.16*	*273.26*	*613.42*
7. Indian Space Research Organisation - Inertial Systems Unit(IISU)	3402	10.79	...	10.79	13.02	...	13.02	14.20	...	14.20
	5402	12.37	...	12.37	10.17	...	10.17	16.64	...	16.64
	Total	*23.16*	...	*23.16*	*23.19*	...	*23.19*	*30.84*	...	*30.84*
8. Liquid Propulsion Systems Centre	3402	123.76	46.33	170.09	128.86	67.85	196.71	160.99	73.70	234.69
	5402	34.10	...	34.10	12.65	...	12.65	51.24	...	51.24
	Total	*157.86*	*46.33*	*204.19*	*141.51*	*67.85*	*209.36*	*212.23*	*73.70*	*285.93*
9. GSLV Operational Project	3402	235.00	...	235.00	230.64	...	230.64	257.71	...	257.71
	5402	20.00	...	20.00	9.36	...	9.36	17.29	...	17.29
	Total	*255.00*	...	*255.00*	*240.00*	...	*240.00*	*275.00*	...	*275.00*
10. Space Capsule Recovery Experiment (SRE)	3402	10.00	...	10.00	10.00	...	10.00	12.00	...	12.00
11. Manned Mission Initiatives/ Human Space Flight Programme	3402	100.00	...	100.00	29.01	...	29.01	20.00	...	20.00
	5402	25.00	...	25.00	13.00	...	13.00	30.00	...	30.00
	Total	*125.00*	...	*125.00*	*42.01*	...	*42.01*	*50.00*	...	*50.00*
12. Indian Institute of Space Science & Technology	3402	65.25	...	65.25	65.25	...	65.25	175.00	...	175.00
13. Semi Cryogenic Engine Development	3402	15.00	...	15.00	1.99	...	1.99	15.00	...	15.00
	5402	7.50	...	7.50	2.10	...	2.10	60.00	...	60.00
	Total	*22.50*	...	*22.50*	*4.09*	...	*4.09*	*75.00*	...	*75.00*
Total - Launch Vehicle Technology		**1413.74**	**174.74**	**1588.48**	**1223.27**	**256.21**	**1479.48**	**1567.60**	**346.96**	**1914.56**
Satellite Technology										
14. Oceansat-2 and 3	3402	3.00	...	3.00	2.80	...	2.80	2.30	...	2.30
	5402	7.00	...	7.00	9.20	...	9.20	3.70	...	3.70
	Total	*10.00*	...	*10.00*	*12.00*	...	*12.00*	*6.00*	...	*6.00*
15. Resourcesat-2 and 3	3402	3.00	...	3.00	2.88	...	2.88	3.16	...	3.16
	5402	32.00	...	32.00	22.12	...	22.12	31.84	...	31.84
	Total	*35.00*	...	*35.00*	*25.00*	...	*25.00*	*35.00*	...	*35.00*
16 ISRO Satellite Centre (ISAC)	3402	93.74	51.36	145.10	130.46	83.10	213.56	147.83	111.80	259.63
	5402	70.75	...	70.75	39.88	...	39.88	45.24	...	45.24
	Total	*164.49*	*51.36*	*215.85*	*170.34*	*83.10*	*253.44*	*193.07*	*111.80*	*304.87*
17. Laboratory for Electro-Optics System(LEOS)	3402	22.59	...	22.59	19.49	...	19.49	24.48	...	24.48
	5402	14.55	...	14.55	12.14	...	12.14	20.11	...	20.11
	Total	*37.14*	...	*37.14*	*31.63*	...	*31.63*	*44.59*	...	*44.59*

(In crores of Rupees)

	Major Head	Budget 2008-2009			Revised 2008-2009			Budget 2009-2010		
		Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total
18. Radar Imaging Satellite-1 (RISAT-1)	3402	2.68	...	2.68	2.31	...	2.31	1.96	...	1.96
	5402	22.32	...	22.32	27.69	...	27.69	3.04	...	3.04
	Total	*25.00*	...	*25.00*	*30.00*	...	*30.00*	*5.00*	...	*5.00*
19. G.SAT-4	3402	5.00	...	5.00	3.75	...	3.75	2.90	...	2.90
	5402	2.00	...	2.00	0.55	...	0.55	...	...	...
	Total	*7.00*	...	*7.00*	*4.30*	...	*4.30*	*2.90*	...	*2.90*
20. Navigational Satellite System (NSS)	3402	18.00	...	18.00	16.85	...	16.85	21.96	...	21.96
	5402	252.00	...	252.00	183.15	...	183.15	248.04	...	248.04
	Total	*270.00*	...	*270.00*	*200.00*	...	*200.00*	*270.00*	...	*270.00*
21. Semi-conductor Laboratory (SCL)	3402	34.28	...	34.28	39.48	...	39.48	45.00	...	45.00
22. Advanced Communication Satellite	3402	15.00	...	15.00	...	...	...	1.00	...	1.00
	5402	7.50	...	7.50	1.00	...	1.00	4.00	...	4.00
	Total	*22.50*	...	*22.50*	*1.00*	...	*1.00*	*5.00*	...	*5.00*
23. Earth Observation - New Missions (Cartostat-3, SARAL, TES Hyperspectral, DMSAR-1)	3402	20.00	...	20.00	1.00	...	1.00	3.00	...	3.00
	5402	45.00	...	45.00	1.70	...	1.70	10.00	...	10.00
	Total	*65.00*	...	*65.00*	*2.70*	...	*2.70*	*13.00*	...	*13.00*
Total - Satellite Technology		**670.41**	**51.36**	**721.77**	**516.45**	**83.10**	**599.55**	**619.56**	**111.80**	**731.36**
Launch Support, Tracking Network & Range Facility										
24. Satish Dhawan Space Centre - SHAR	3402	95.29	55.25	150.54	112.57	75.84	188.41	121.38	99.91	221.29
	5402	87.45	...	87.45	130.54	...	130.54	119.12	...	119.12
	Total	*182.74*	*55.25*	*237.99*	*243.11*	*75.84*	*318.95*	*240.50*	*99.91*	*340.41*
25. ISRO Telemetry, Tracking & Command Network (ISTRAC)	3402	32.77	16.42	49.19	33.92	24.13	58.05	36.23	31.31	67.54
	5402	14.09	...	14.09	27.89	...	27.89	33.48	...	33.48
	Total	*46.86*	*16.42*	*63.28*	*61.81*	*24.13*	*85.94*	*69.71*	*31.31*	*101.02*
Total-Launch Support, Tracking Network & Range Facility		**229.60**	**71.67**	**301.27**	**304.92**	**99.97**	**404.89**	**310.21**	**131.22**	**441.43**
Total-Space Technology		**2313.75**	**297.77**	**2611.52**	**2044.64**	**439.28**	**2483.92**	**2497.37**	**589.98**	**3087.35**
Space Applications										
26. Space Applications Centre (SAC)	3402	54.51	58.67	113.18	61.61	95.45	157.06	72.65	119.37	192.02
	5402	56.66	...	56.66	38.07	...	38.07	62.08	...	62.08
	Total	*111.17*	*58.67*	*169.84*	*99.68*	*95.45*	*195.13*	*134.73*	*119.37*	*254.10*
27. Development and Educational Communication Unit (DECU)	3402	52.35	4.60	56.95	50.98	6.76	57.74	49.16	7.72	56.88
	5402	1.46	...	1.46	2.26	...	2.26	1.25	...	1.25
	Total	*53.81*	*4.60*	*58.41*	*53.24*	*6.76*	*60.00*	*50.41*	*7.72*	*58.13*
28. National Natural Resources Management System (NNRMS)	3402	28.23	...	28.23	26.63	...	26.63	20.00	...	20.00
29. Earth Observation Application Mission(EOAM)	3402	2.68	...	2.68	2.59	...	2.59	4.40	...	4.40
30. Regional Remote Sensing Service Centres (RRSSCs)	3402	7.62	...	7.62	9.94	...	9.94	10.82	...	10.82
	5402	3.48	...	3.48	3.83	...	3.83	11.07	...	11.07
	Total	*11.10*	...	*11.10*	*13.77*	...	*13.77*	*21.89*	...	*21.89*
31. National Remote Sensing Agency(NRSA)	3402	3.00	32.00	35.00	...	...	...	...	...	...
32. National Remote Sensing Centre (NRSC)	3402	...	...	...	25.10	30.00	55.10	68.96	35.30	104.26
	5402	...	...	...	15.21	...	15.21	36.90	...	36.90
	Total	...	...	...	*40.31*	*30.00*	*70.31*	*105.86*	*35.30*	*141.16*
33. Disaster Management Support System (DMS)	3402	50.00	...	50.00	24.32	...	24.32	30.00	...	30.00
	5402	15.00	...	15.00	5.00	...	5.00	10.00	...	10.00
	Total	*65.00*	...	*65.00*	*29.32*	...	*29.32*	*40.00*	...	*40.00*

(In crores of Rupees)

	Major Head	Budget 2008-2009 Plan	Budget 2008-2009 Non-Plan	Budget 2008-2009 Total	Revised 2008-2009 Plan	Revised 2008-2009 Non-Plan	Revised 2008-2009 Total	Budget 2009-2010 Plan	Budget 2009-2010 Non-Plan	Budget 2009-2010 Total
34. North Eastern Space Applications Centres (NE-SAC)	3402	4.35	0.65	5.00	4.00	1.00	5.00	5.90	1.10	7.00
Total - Space Applications		**279.34**	**95.92**	**375.26**	**269.54**	**133.21**	**402.75**	**383.19**	**163.49**	**546.68**
Space Sciences										
35. Physical Research Laboratory(PRL)	3402	35.72	15.72	51.44	36.05	24.86	60.91	38.49	23.83	62.32
36. National Atmospheric Research Laboratory(NARL)	3402	10.35	0.96	11.31	10.78	2.00	12.78	13.13	2.30	15.43
37. RESPOND	3402	13.00	...	13.00	12.65	...	12.65	13.00	...	13.00
38. Sensor Payload Development / Planetary Science Programme	3402	5.00	...	5.00	4.50	...	4.50	5.00	...	5.00
39. Megha-tropiques Project	3402	2.22	...	2.22	2.23	...	2.23	2.38	...	2.38
	5402	17.78	...	17.78	17.77	...	17.77	12.62	...	12.62
	Total	*20.00*	...	*20.00*	*20.00*	...	*20.00*	*15.00*	...	*15.00*
40. Astrosat 1 & 2	3402	0.65	...	0.65	0.57	...	0.57	1.17	...	1.17
	5402	24.35	...	24.35	20.43	...	20.43	18.83	...	18.83
	Total	*25.00*	...	*25.00*	*21.00*	...	*21.00*	*20.00*	...	*20.00*
41. Indian Lunar Mission - Chandrayan - 1 & 2	3402	3.85	...	3.85	4.43	...	4.43	5.38	...	5.38
	5402	74.15	...	74.15	83.57	...	83.57	84.62	...	84.62
	Total	*78.00*	...	*78.00*	*88.00*	...	*88.00*	*90.00*	...	*90.00*
42. ISRO Geosphere Biosphere Programme (ISRO GBP)	3402	19.00	...	19.00	21.50	...	21.50	25.78	...	25.78
43. Atmospheric Science Programmes	3402	14.49	...	14.49	15.30	...	15.30	20.96	...	20.96
44. Small Satellites for Atmospheric Studies	3402	10.00	...	10.00	...	...	...	2.00	...	2.00
45. Other Schemes	3402	19.38	1.75	21.13	9.90	1.75	11.65	12.50	1.75	14.25
Total - Space Sciences		**249.94**	**18.43**	**268.37**	**239.68**	**28.61**	**268.29**	**255.86**	**27.88**	**283.74**
Direction & Administration / Other Programmes										
46. Special Indigenisation/ Advance Ordering	3402	20.00	...	20.00	21.07	...	21.07	12.86	...	12.86
	5402	330.00	...	330.00	2.00	...	2.00	1.00	...	1.00
	Total	*350.00*	...	*350.00*	*23.07*	...	*23.07*	*13.86*	...	*13.86*
47. Others	3402	3.15	44.38	47.53	3.17	61.09	64.26	3.17	51.28	54.45
	5402	11.05	...	11.05	13.89	...	13.89	19.21	...	19.21
	Total	*14.20*	*44.38*	*58.58*	*17.06*	*61.09*	*78.15*	*22.38*	*51.28*	*73.66*
Total - Direction & Administration / Other Programmes		**364.20**	**44.38**	**408.58**	**40.13**	**61.09**	**101.22**	**36.24**	**51.28**	**87.52**
INSAT Operational										
48. Master Control Facility(MCF)	3252	12.66	12.04	24.70	10.76	15.88	26.64	10.40	18.92	29.32
	5252	30.11	...	30.11	27.46	...	27.46	35.24	...	35.24
	Total	*42.77*	*12.04*	*54.81*	*38.22*	*15.88*	*54.10*	*45.64*	*18.92*	*64.56*
49. INSAT-3 Satellites	3252	3.00	...	3.00	3.41	...	3.41	1.76	...	1.76
	5252	7.00	...	7.00	16.69	...	16.69	6.94	...	6.94
	Total	*10.00*	...	*10.00*	*20.10*	...	*20.10*	*8.70*	...	*8.70*
50. INSAT-4 Satellites (Including Launch Services)	3252	80.00	...	80.00	30.95	...	30.95	40.96	...	40.96
	5252	260.00	...	260.00	130.74	...	130.74	332.04	...	332.04
	Total	*340.00*	...	*340.00*	*161.69*	...	*161.69*	*373.00*	...	*373.00*
Total - INSAT Operational		**392.77**	**12.04**	**404.81**	**220.01**	**15.88**	**235.89**	**427.34**	**18.92**	**446.26**
51. Aid Materials & Equipment-Gross	3606	...	0.02	0.02	...	...	...	...	...	...
Deduct-Transfers to Functional Major Head	3606	...	-0.02	-0.02	...	...	...	...	...	...
Net-Aid Materials & Equipment	*Total*	...	...	...	...	...	...	...	...	...
Grand Total		***3600.00***	***474.00***	***4074.00***	***2814.00***	***685.00***	***3499.00***	***3600.00***	***859.00***	***4459.00***
C. Plan Outlay	Head of Dev	Budget Support	IEBR	Total	Budget Support	IEBR	Total	Budget Support	IEBR	Total
1. Space Research	13402	3600.00	...	3600.00	2814.00	...	2814.00	3600.00	...	3600.00

1. **Secretariat – Economic Services:** Provision is made for expenditure to be incurred on the Secretariat of the Department of Space.

2. **Geo-Synchronous Satellite Launch Vehicle (GSLV) Project:** The GSLV Project envisaged the development of a launch vehicle capable of launching 2 tonne INSAT-class satellites into Geo-synchronous Transfer Orbit (GTO). The third test flight will carry the indigenous cryogenic engine & stage.

3. **GSLV Mk-III Development:** GSLV Mk-III is intended to develop a cost-effective launch vehicle capable of launching 4 tonne class of communication satellites in Geo-synchronous Transfer Orbit (GTO). The Project envisages the development of a number of technologies which include, among other, 200 tonne solid stage booster (S-200), 25 tonne cryogenic engines (C-25), and L-110 tonne liquid stage engines as core boosters. The first developmental flight of GSLV MK III is expected by 2010-2011.

4. **Cryogenic Upper Stage (CUS) Project:** The objective of the Project is to develop and qualify an indigenous restartable cryogenic stage employing liquid oxygen as oxidizer and liquid hydrogen as fuel for the upper stage of GSLV. The first flight of the indigenous cryo stage is targeted for flight testing by GSLV during 2009-2010.

5. **Polar Satellite Launch Vehicle-Continuation (PSLV-C) Project:** The PSLV is capable of placing 1400-1600 kg class IRS satellites in Polar Sun- Synchronous Orbit, 1000 kg class satellites into Geo-synchronous Transfer Orbit and upto 2800 kg class satellites into Low Earth Orbit. The PSLV-C-11 in its fourteenth flight successfully launched Chandrayaan-1 spacecraft carrying 11 scientific payloads on October 22, 2008.

6. **Vikram Sarabhai Space Centre (VSSC):** VSSC is the lead Centre for the development of satellite launch vehicles and sounding rockets and houses the major test and fabrication facilities for launch vehicles.

7. **ISRO Inertial Systems Unit (IISU):** IISU is responsible for research & development in the area of inertial sensors & systems for launch vehicles, satellites and allied satellite elements.

8. **Liquid Propulsion Systems Centre (LPSC):** LPSC is the lead Centre in the area of liquid and cryogenic rocket engines and stages for launch vehicle and small thrust engines for launch vehicles and spacecraft control.

9. **GSLV-Operational Project:** The GSLV-Operational Project has been conceived to meet the launch requirement of 2 tonne class of operational INSAT satellites. The GSLV-F06 carrying INSAT-3D will be launched during 2009-2010.

10. **Space Capsule Recovery Experiment (SRE):** The main objective of the Space Capsule Recovery Experiment (SRE) is to develop and demonstrate capability to recover on orbiting capsule back on earth. SRE-I has successfully launched on-board PSLV on January 10, 2007 and was also successfully recovered from Bay of Bengal on January 22, 2007. The SRE-II will be launched by PSLV-C16 during the third quarter of 2009-2010.

11. **Manned Mission Initiatives/Human Space Flight Programme:** The main objective of the Indian Manned Mission Space program is to develop a fully autonomous manned space vehicle to carry two crew to 400 km LEO and safe return to earth. Detailed studies have been initiated on the technologies required for realizing the flight safety and reliability, propulsion systems, advanced materials etc. The project proposal has been submitted for approval of the Government.

12. **Indian Institute of Space Science & Technology:** Indian Institute of Space Science & Technology is an autonomous body under DOS with the objective of creating quality human resources tuned to suit the state-of-art space technology requirement of Indian Space Programme. The Institute offers graduate, post-graduate and doctrol programme in the area of space science technology and applications. The Institute has started functioning from the academic year 2007-2008 around the existing infrastructure of ISRO Centres in Thiruvananthapuram. A permanent infrastructure for the Institute is in progress near LPSC, Valiamala.

13. **Semi Cryogenic Engine/Stage Development:** The objective of the project is to develop and qualify a high thrust Semi Cryogenic engine and stage (employing kerosene of required grade/spar as fuel and Liquid Oxygen as oxidizer) for the future advanced launch vehicle.

14. **Oceansat-2 & 3:** The main objective of Oceansat-2 is to provide continuity of data & services hitherto provided by Oceansat-1 on Oceanography and coastal studies. The launch of Oceansat-2 onboard PSLV is planned during the first quarter of 2009-2010. Oceansat-3, planned to be initiated towards end of 11th plan will be a follow-on satellite for Oceansat-2 to provide continuity of data on Ocean & Coastal resources.

15. **Resourcesat-2 & 3:** Taking into account the increased use of space imageries for different applications and continued Earth Observation services required from the IRS satellites, Resourcesat-2 has been conceived as a continuity mission with enhanced capabilities which will be mainly for crop applications, vegetation dynamics and natural resources census applications. The Payload realization and sub-system fabrication are targeted for 2009-2010. Resourcesat-3 will provide continuity of data after Resourcesat-2.

16. **ISRO Satellite Centre (ISAC):** ISAC is the lead Center for the design, fabrication, testing and management of satellite systems for scientific, technological and application missions.

17. **Laboratory for Electro-Optics Systems (LEOS):** LEOS is responsible for research & development and production of electro-optics sensors.

18. **Radar Imaging Satellite-1 Project (RISAT-1):** Radar Imaging Satellite (RISAT) is intended to provide all-weather, day and night imaging capability providing vital inputs for various agricultural and disaster applications. The satellite is targeted to be launched by PSLV-C-13 during first quarter of 2009-2010.

19. **GSAT-4:** The satellite will be utilized for conducting various experiments in the communications area and early introduction of geo-based navigation system. The satellite is targeted for launch during 2009-2010.

20. **Navigation Satellite System (NSS):** The Indian Regional Navigation Satellite System (IRNSS), is planned to be a constellation of 7 satellites – 3 in GEO and 4 in GSO orbit. This satellite is expected to provide position accuracies similar to GPS in a region centered around India with a coverage extending upto 1500 km from India. The configuration of the satellite has been finalized and procurement of components & materials has been initiated.

21. **Semi-conductor Laboratory:** SCL is engaged in the Design, Development and Manufacture of very large scale integrated circuits (VLSIs) and Board Level Products to meet the stringent quality requirement of strategic sectors. SCL is to undertake radiation hardened devices and about more than 60 types of ASICs have been identified for development by SCL for Space Programme.

22. **Advanced Communication Satellite:** The main objective is to develop a 4 tonne class communication satellite incorporating advanced technologies of relevance for future.

23. **Earth Observation – New Missions (SARAL, TES-Hyp, DMSAR-1 & Carto-3):** Indian Earth Observation program is directed towards providing continuity of EO data for resource management applications and enhancing the imaging capability. Towards this, it is planned to undertake development of small satellite with Argos & Altimeter (SARAL) for oceanography studies, Technology Experiment Satellite in Hyper Spectral Imaging (TES-HYP), Radar Imaging Satellite for Disaster Management (DMSAR) & advanced cartography satellite (Carto-3).

24. **Satish Dhawan Space Centre-SHAR (SDSC-SHAR):** SDSC-SHAR provides the launch infrastructure as well as solid propellant processing.

25. **ISRO Telemetry, Tracking and Command Network (ISTRAC):** ISTRAC provides spacecraft TTC and Mission Control services to major launch vehicle and spacecraft missions.

26. **Space Applications Centre (SAC):** SAC is the lead Center for the development of communication, meteorological and remote sensing payloads besides R&D in space applications.

27. **Development and Educational Communication Unit (DECU):** DECU is involved in the conception, definition, planning, implementation and socio-economic evaluation of developmental space applications.

28. **National Natural Resources Management System (NNRMS):** The National Natural Resources Management System (NNRMS) has the objective of ensuring optimal management/ utilization of natural resources by integrating information derived from remote sensing data with conventional techniques.

29. **Earth Observation Applications Mission (EOAM)**: The main goal of the Earth Observation Application Mission (EOAM) are to (i) evolve newer application/R&D programmes based on technology trends leading to operational applications programmes; (ii) guiding total remote sensing applications programmes towards implementation of remote-sensing based solutions, and (iii) steering commercial activities of remote sensing involving development of value-added services.

30. **Regional Remote Sensing Services Centres (RRSSCs)**: The five Regional Remote Sensing Services Centres (RRSSCs) at Bangalore, Dehradun, Jodhpur, Kharagpur and Nagpur have been established under the aegis of NNRMS with the prime objective of providing remote sensing application services to the user in the respective regions for better planning and optimal utilization of natural resources and also bring about awareness amongst the users on the potential of remote sensing and associated technologies.

31. **National Remote Sensing Agency (NRSA)**: NRSA is a registered society and is the nodal agency for operational remote sensing activities in the country. It is responsible for acquisition, processing, distribution and archiving of data from remote sensing satellites. NRSA has been converted from a Registered society to a Government entity called "National Remote Sensing Centre" (NRSC) from 1.9.2008.

32. **National Remote Sensing Centre (NRSC)**: Considering the fact that the NRSA is closely associated with various programmes of DOS/ISRO, in particular the Earth Observation Programme, Disaster Management Support and other Programmes of national importance and to enable NRSA to carryout its responsibilities in a more effective manner, the Government have decided to convert it into a Government entity, to be called as National Remote Sensing Centre (NRSC), a center under DOS/ISRO w.e.f. 01.09.2008. NRSC has facilities for generation of data products for various applications from remotely sensed data. NRSC also operates a fleet of instrumented aircraft and has a satellite receiving station at Shadnagar, near Hyderabad.

33. **Disaster Management Support (DMS)**: The main objective of Disaster Management Support Programme is to provide Space inputs & services on a timely & reliable basis, for the Disaster Management System in the country.

34. **North Eastern Space Applications Centres (NE-SAC)**: NE-SAC set up as an autonomous society jointly with North Eastern Council, is supporting the North Eastern region by providing information on natural resources utilization and monitoring, infrastructure developmental planning and interactive training using space technology inputs of remote sensing and satellite communication.

35. **Physical Research Laboratory (PRL)**: PRL, an autonomous institution funded by the Department of Space through grant-in-aid, is one of the premier research institutions in the country carrying out basic research in several areas of experimental & theoretical physics, earth sciences, astronomy & aeronomy & planetary exploration.

36. **National Atmospheric Research Laboratory (NARL)**: NARL, a registered Society, is responsible for carrying out advanced research in atmospheric and space sciences and related disciplines.

37. **RESPOND**: The (RESPOND) Programme of ISRO supports sponsored research activity in Space Science, Space Applications and Space Technology in various national academic/ research institutions and Space Technology Cells in premier technological institutes of the country through grants-in-aid.

38. **Sensor Payload Development/Planetary Science Programme**: It includes funding requirement for advance action for activities related to scientific payload developments for space science and planetary exploration studies in different institutions and universities.

39. **Megha-tropiques Project**: Megha-Tropiques is an ISRO-CNES(France) joint mission and is intended for studying tropical atmosphere and climate related to aspects such as monsoons, cyclones, etc., using a satellite platform.

40. **Astrosat 1 & 2**: The objective of the Astrosat project is to build and launch an astronomical observatory satellite for expanding the scientific knowledge about the evolution of stellar objects and gather valuable scientific data on high energy Astronomy and Astrophysics research. The satellite is planned for launch in 2010 onboard PSLV.

41. **Indian Lunar Chandrayaan-1 & 2**: The main objective of Indian Lunar Chandrayaan-1 is for expanding the scientific

knowledge about the moon, upgrading the technological capability and providing the challenging opportunity for planetary research for a large number of growing young people of the country benefiting the human society at large. The Chandrayaan-1 was successfully launched on October 22, 2008 on-board the PSLV-C11. The follow-on mission Chandrayaan-2 has been recently approved by the Government.

42. **ISRO Geosphere-Biosphere Programme (ISRO-GBP)**: ISRO-GBP encompasses the study of land and ocean interaction, past climate, changes in atmospheric composition, aerosols, carbon cycle, bio-mass estimation, bio-diversity and other related areas of scientific investigation.

43. **Atmospheric Science Program**: Atmospheric Science Program is intended to develop advanced observation tools & techniques of atmospheric modeling, leading to operational end user products indifferent domains of atmospheric science.

44. **Small Satellite for Atmospheric Studies & Astronomy**: The project envisages development of small satellites for study of Earth's near-space environment, magnetometer studies, study of aerosol and gases, tropical weather and climate studies.

45. **Other Schemes**: These includes Microgravity Research, Space Science promotion, Multi-institutional research programs, Space Station experiment, setting up of Digital workflow systems, support for conferences, symposia, etc.

46. **Special Indigenisation/Advance Ordering**: Indigenisation envisages ISRO to have interface with the Indian Industry to develop various electronic components, materials, chemicals, etc., for the space programme. The scope of the scheme also includes procurement of certain long lead and critical items for futuristic missions.

47. **Others**: Under this, provision has been included for ISRO Headquarters, International Co-operation and Central Management.

48. **Master Control Facility**: MCF is responsible for initial orbit raising, payload testing and in-orbit operation of all geo-stationary satellites.

49. **INSAT-3 Satellites (including Launch Services)**: The objective of INSAT-3 Spacecraft Project are to (i) build five INSAT-3 satellites, (INSAT-3A to INSAT-3E) keeping the flexibility for mid-course corrections to accommodate emerging requirements, carry out mission planning, launch campaign and initial phase operations, and (ii) establish required programme elements for carrying out the same. INSAT-3D the last satellite in INSAT-3 series is targeted for launch during 2009-2010.

50. **INSAT-4 Satellites (including Launch Services)**: The fourth generation INSAT-4 Satellite series has been planned to meet the capacity and service requirements projected by various users and development needs of the country. INSAT-4A, 4B & 4CR satellite in the INSAT-4 series have been launched & operationalised. Work on INSAT-4D, 4E, 4F (User funded) and INSAT-4G is in progress.

APPENDIX C: INDIAN SPACE BUDEGT 2008-2009

DEPARTMENT OF SPACE

DEMAND NO.89

Department of Space

A. The Budget allocations, net of recoveries, are given below:

(*In crores of Rupees*)

	Major Head	Budget 2007-2008			Revised 2007-2008			Budget 2008-2009		
		Plan	Non-Plan	Total	Plan	Non-Plan	Total	Plan	Non-Plan	Total
Revenue		1838.90	438.60	2277.50	1486.72	459.00	1945.72	1820.50	474.00	2294.50
Capital		*1581.10*	...	*1581.10*	*1344.28*	...	*1344.28*	*1779.50*	...	*1779.50*
Total		**3420.00**	**438.60**	**3858.60**	**2831.00**	**459.00**	**3290.00**	**3600.00**	**474.00**	**4074.00**
1. Secretariat - Economic Services	3451	...	4.69	4.69	...	4.90	4.90	...	5.46	5.46
Space Research										
Space Technology										
Launch Vehicle Technology										
2. Geo -Synchronous Satellite Launch Vehicle	3402	9.00	...	9.00	8.00	...	8.00	1.00	...	1.00
3. GSLV MK-III Development	3402	231.00	...	231.00	173.86	...	173.86	167.00	...	167.00
	5402	104.00	...	104.00	110.22	...	110.22	103.00	...	103.00
	Total	*335.00*	...	*335.00*	*284.08*	...	*284.08*	*270.00*	...	*270.00*
4. Cryogenic Upper Stage Project [CUSP]	3402	1.30	...	1.30	1.30	...	1.30	0.10	...	0.10
5. Polar Satellite Launch Vehicle - Continuation (PSLV-C) Project	3402	155.61	...	155.61	155.00	...	155.00	170.00	...	170.00
	5402	4.39	...	4.39	5.00	...	5.00	10.00	...	10.00
	Total	*160.00*	...	*160.00*	*160.00*	...	*160.00*	*180.00*	...	*180.00*
6. Vikram Sarabhai Space Centre (VSSC)	3402	134.02	116.24	250.26	129.28	121.28	250.56	122.04	128.41	250.45
	5402	101.94	...	101.94	79.56	...	79.56	181.83	...	181.83
	Total	*235.96*	*116.24*	*352.20*	*208.84*	*121.28*	*330.12*	*303.87*	*128.41*	*432.28*
7. Indian Space Research Organisation - Inertial Systems Unit(IISU)	3402	10.94	...	10.94	14.78	...	14.78	10.79	...	10.79
	5402	10.31	...	10.31	8.76	...	8.76	12.37	...	12.37
	Total	*21.25*	...	*21.25*	*23.54*	...	*23.54*	*23.16*	...	*23.16*
8. Liquid Propulsion Systems Centre	3402	150.41	46.37	196.78	107.71	46.12	153.83	123.76	46.33	170.09
	5402	21.17	...	21.17	17.76	...	17.76	34.10	...	34.10
	Total	*171.58*	*46.37*	*217.95*	*125.47*	*46.12*	*171.59*	*157.86*	*46.33*	*204.19*
9. GSLV Operational Project	3402	251.36	...	251.36	218.33	...	218.33	235.00	...	235.00
	5402	13.64	...	13.64	18.17	...	18.17	20.00	...	20.00
	Total	*265.00*	...	*265.00*	*236.50*	...	*236.50*	*255.00*	...	*255.00*
10. Space Capsule Recovery Experiment (SRE)	3402	9.45	...	9.45	4.45	...	4.45	10.00	...	10.00
11. Manned Mission Initiatives/ Human Space Flight	3402	25.00	...	25.00	2.50	...	2.50	100.00	...	100.00
	5402	25.00	...	25.00	1.50	...	1.50	25.00	...	25.00
	Total	*50.00*	...	*50.00*	*4.00*	...	*4.00*	*125.00*	...	*125.00*
12. Indian Institute of Space Science & Technology	3402	10.00	...	10.00	10.00	...	10.00	65.25	...	65.25
	5402	65.00	...	65.00	15.00	...	15.00	...	...	...
	Total	*75.00*	...	*75.00*	*25.00*	...	*25.00*	*65.25*	...	*65.25*
13. Semi Cryogenic Engine/Stage Development	3402	10.00	...	10.00	...	...	...	15.00	...	15.00
	5402	15.00	...	15.00	...	...	...	7.50	...	7.50
	Total	*25.00*	...	*25.00*	...	...	...	*22.50*	...	*22.50*
Total - Launch Vehicle Technology		**1358.54**	**162.61**	**1521.15**	**1081.18**	**167.40**	**1248.58**	**1413.74**	**174.74**	**1588.48**
Setellite Technology										
14. Cartosat-2	3402	0.15	...	0.15	0.15	...	0.15	...	...	...
15. Oceansat-2 and 3	3402	9.00	...	9.00	3.15	...	3.15	3.00	...	3.00
	5402	21.00	...	21.00	26.85	...	26.85	7.00	...	7.00
	Total	*30.00*	...	*30.00*	*30.00*	...	*30.00*	*10.00*	...	*10.00*
16. Resourcesat-2 and 3	3402	6.00	...	6.00	2.74	...	2.74	3.00	...	3.00
	5402	44.00	...	44.00	45.26	...	45.26	32.00	...	32.00
	Total	*50.00*	...	*50.00*	*48.00*	...	*48.00*	*35.00*	...	*35.00*
17. ISRO Satellite Centre (ISAC)	3402	75.12	47.25	122.37	105.15	49.89	155.04	93.74	51.36	145.10
	5402	90.92	...	90.92	22.08	...	22.08	70.75	...	70.75
	Total	*166.04*	*47.25*	*213.29*	*127.23*	*49.89*	*177.12*	*164.49*	*51.36*	*215.85*

(In crores of Rupees)

	Major Head	Budget 2007-2008 Plan	Budget 2007-2008 Non-Plan	Budget 2007-2008 Total	Revised 2007-2008 Plan	Revised 2007-2008 Non-Plan	Revised 2007-2008 Total	Budget 2008-2009 Plan	Budget 2008-2009 Non-Plan	Budget 2008-2009 Total
18. Laboratory for Electro-Optics System(LEOS)	3402	11.67	...	11.67	12.10	...	12.10	22.59	...	22.59
	5402	9.54	...	9.54	3.66	...	3.66	14.55	...	14.55
	Total	*21.21*	...	*21.21*	*15.76*	...	*15.76*	*37.14*	...	*37.14*
19. Radar Imaging Satellite-1 (RISAT-1)	3402	12.00	...	12.00	3.01	...	3.01	2.68	...	2.68
	5402	44.00	...	44.00	53.47	...	53.47	22.32	...	22.32
	Total	*56.00*	...	*56.00*	*56.48*	...	*56.48*	*25.00*	...	*25.00*
20. G.SAT-4	3402	7.34	...	7.34	4.50	...	4.50	5.00	...	5.00
	5402	0.66	...	0.66	...	...	...	2.00	...	2.00
	Total	*8.00*	...	*8.00*	*4.50*	...	*4.50*	*7.00*	...	*7.00*
21. Satellite Navigation System	3402	15.00	...	15.00	12.48	...	12.48	18.00	...	18.00
	5402	86.00	...	86.00	81.52	...	81.52	252.00	...	252.00
	Total	*101.00*	...	*101.00*	*94.00*	...	*94.00*	*270.00*	...	*270.00*
22. Semi Conductor Development(SCL)	3402	36.12	...	36.12	38.07	...	38.07	34.28	...	34.28
	5402	5.00	...	5.00	3.00	...	3.00	...	...	...
	Total	*41.12*	...	*41.12*	*41.07*	...	*41.07*	*34.28*	...	*34.28*
23. Advanced Communication Technology Satellite	3402	10.00	...	10.00	...	...	...	15.00	...	15.00
	5402	2.00	...	2.00	...	...	...	7.50	...	7.50
	Total	*12.00*	...	*12.00*	...	...	...	*22.50*	...	*22.50*
24. Earth Observation - New Missions[Geo-HR Imager,	3402	5.00	...	5.00	...	...	...	20.00	...	20.00
Cartostat-3, SARAL, Technology Experiment Satellites, Disaster Management Satellite)	5402	25.00	...	25.00	...	...	...	45.00	...	45.00
	Total	*30.00*	...	*30.00*	...	...	...	*65.00*	...	*65.00*
Total - Satellite Technology		**515.52**	**47.25**	**562.77**	**417.19**	**49.89**	**467.08**	**670.41**	**51.36**	**721.77**
Launch Support, Tracking Network & Range Facility										
25. Satish Dhawan Space Centre - SHAR	3402	69.15	55.51	124.66	74.02	58.00	132.02	95.29	55.25	150.54
	5402	74.28	...	74.28	81.36	...	81.36	87.45	...	87.45
	Total	*143.43*	*55.51*	*198.94*	*155.38*	*58.00*	*213.38*	*182.74*	*55.25*	*237.99*
26. ISRO Telemetry,Tracking & Command Network (ISTRAC)	3402	22.15	15.04	37.19	22.84	14.57	37.41	32.77	16.42	49.19
	5402	26.16	...	26.16	44.90	...	44.90	14.09	...	14.09
	Total	*48.31*	*15.04*	*63.35*	*67.74*	*14.57*	*82.31*	*46.86*	*16.42*	*63.28*
27. ISRO Radar Development Unit (ISRAD)	3402	4.32	...	4.32	5.45	...	5.45	...	...	...
	5402	0.17	...	0.17	0.20	...	0.20	...	...	...
	Total	*4.49*	...	*4.49*	*5.65*	...	*5.65*	...	...	...
Total-Launch Support, Tracking Network & Range Facility		**196.23**	**70.55**	**266.78**	**228.77**	**72.57**	**301.34**	**229.60**	**71.67**	**301.27**
Total-Space Technology		**2070.29**	**280.41**	**2350.70**	**1727.14**	**289.86**	**2017.00**	**2313.75**	**297.77**	**2611.52**
Space Applications										
28. Space Applications Centre	3402	57.39	54.11	111.50	41.27	56.77	98.04	54.51	58.67	113.18
	5402	37.64	...	37.64	28.23	...	28.23	56.66	...	56.66
	Total	*95.03*	*54.11*	*149.14*	*69.50*	*56.77*	*126.27*	*111.17*	*58.67*	*169.84*
29. Development and Educational Communication Unit	3402	76.77	4.59	81.36	64.60	4.76	69.36	52.35	4.60	56.95
	5402	4.00	...	4.00	3.12	...	3.12	1.46	...	1.46
	Total	*80.77*	*4.59*	*85.36*	*67.72*	*4.76*	*72.48*	*53.81*	*4.60*	*58.41*
30. National Natural Resources Management System	3402	53.97	...	53.97	15.78	...	15.78	28.23	...	28.23
31. Earth Observation Application Mission(EOAM)	3402	3.97	...	3.97	3.38	...	3.38	2.68	...	2.68
32. Regional Remote Sensing Service Centers(RRSSC)	3402	6.97	...	6.97	7.63	...	7.63	7.62	...	7.62
	5402	6.73	...	6.73	1.44	...	1.44	3.48	...	3.48
	Total	13.70	...	13.70	9.07	...	9.07	11.10	...	11.10
33. National Remote Sensing Agency(NRSA)	3402	2.46	27.54	30.00	2.46	27.54	30.00	3.00	32.00	35.00

(In crores of Rupees)

	Major Head	Budget 2007-2008 Plan	Non-Plan	Total	Revised 2007-2008 Plan	Non-Plan	Total	Budget 2008-2009 Plan	Non-Plan	Total
34. Disaster Management	3402	40.00	...	40.00	28.46	...	28.46	50.00	...	50.00
Support System	5402	30.00	...	30.00	9.31	...	9.31	15.00	...	15.00
	Total	70.00	...	70.00	37.77	...	37.77	65.00	...	65.00
35. North Eastern Space Applications Centre	3402	4.35	0.65	5.00	4.35	0.65	5.00	4.35	0.65	5.00
Total - Space Applications		**324.25**	**86.89**	**411.14**	**210.03**	**89.72**	**299.75**	**279.34**	**95.92**	**375.26**
Space Sciences										
36. Physical Research Laboratory(PRL)	3402	33.02	13.50	46.52	34.26	15.61	49.87	35.72	15.72	51.44
37. MST Radar Based Research(NARL)	3402	8.77	0.85	9.62	6.74	1.21	7.95	10.35	0.96	11.31
38. RESPOND	3402	13.00	...	13.00	12.00	...	12.00	13.00	...	13.00
39. Sensor Payload Development / Planetary Science Programme	3402	23.25	...	23.25	7.50	...	7.50	5.00	...	5.00
40. Megha-tropiques	3402	8.00	...	8.00	2.07	...	2.07	2.22	...	2.22
	5402	12.00	...	12.00	12.93	...	12.93	17.78	...	17.78
	Total	20.00	...	20.00	15.00	...	15.00	20.00	...	20.00
41. Astrosat 1 & 2	3402	5.00	...	5.00	0.55	...	0.55	0.65	...	0.65
	5402	35.00	...	35.00	43.45	...	43.45	24.35	...	24.35
	Total	40.00	...	40.00	44.00	...	44.00	25.00	...	25.00
42. Indian Lunar Mission -	3402	8.00	...	8.00	4.06	...	4.06	3.85	...	3.85
Chandrayan - 1 & 2	5402	88.00	...	88.00	127.11	...	127.11	74.15	...	74.15
	Total	96.00	...	96.00	131.17	...	131.17	78.00	...	78.00
43. ISRO Geosphere Biosphere Programme (ISRO GBP)	3402	25.32	...	25.32	25.28	...	25.28	19.00	...	19.00
44. Atmospheric Science Programmes	3402	18.63	...	18.63	17.15	...	17.15	14.49	...	14.49
45. Small Satellites for Atmospheric Research and Astronomy	3402	2.00	...	2.00	...	...	...	10.00	...	10.00
46. Other Schemes	3402	15.21	1.30	16.51	9.98	1.70	11.68	19.38	1.75	21.13
Total - Space Sciences		**295.20**	**15.65**	**310.85**	**303.08**	**18.52**	**321.60**	**249.94**	**18.43**	**268.37**
Direction & Administration / Other Programmes										
47. Special Indigenisation/Advance	3402	30.45	...	30.45	12.95	...	12.95	20.00	...	20.00
Ordering	5402	208.55	...	208.55	1.00	...	1.00	330.00	...	330.00
	Total	*239.00*	...	*239.00*	*13.95*	...	*13.95*	*350.00*	...	*350.00*
48. Others	3402	3.00	39.86	42.86	3.15	44.85	48.00	3.15	44.38	47.53
	5402	9.58	...	9.58	11.23	...	11.23	11.05	...	11.05
	Total	*12.58*	*39.86*	*52.44*	*14.38*	*44.85*	*59.23*	*14.20*	*44.38*	*58.58*
Total - Direction & Administration / Other Programmes		**251.58**	**39.86**	**291.44**	**28.33**	**44.85**	**73.18**	**364.20**	**44.38**	**408.58**
INSAT Operational										
49. Master Control Facility(MCF)	3252	13.91	11.10	25.01	13.06	11.15	24.21	12.66	12.04	24.70
	5252	26.67	...	26.67	16.50	...	16.50	30.11	...	30.11
	Total	40.58	11.10	51.68	29.56	11.15	40.71	42.77	12.04	54.81
50. INSAT-3 Satellites	3252	29.35	...	29.35	6.16	...	6.16	3.00	...	3.00
	5252	12.75	...	12.75	43.94	...	43.94	7.00	...	7.00
	Total	42.10	...	42.10	50.10	...	50.10	10.00	...	10.00
51. INSAT-4 Satellites	3252	75.00	...	75.00	55.01	...	55.01	80.00	...	80.00
(Including Launch Services)	5252	321.00	...	321.00	427.75	...	427.75	260.00	...	260.00
	Total	396.00	...	396.00	482.76	...	482.76	340.00	...	340.00
Total - INSAT Operational		**478.68**	**11.10**	**489.78**	**562.42**	**11.15**	**573.57**	**392.77**	**12.04**	**404.81**
52. Aid Materials & Equipment-Gross	3606	...	0.02	0.02	...	0.02	0.02	...	0.02	0.02
Deduct-Transfers to Functional Major Head	3606	...	-0.02	-0.02	...	-0.02	-0.02	...	-0.02	-0.02
Net-Aid Materials & Equipment	*Total*	...	...	...	...	...	...	...	...	...
Grand Total		***3420.00***	***438.60***	***3858.60***	***2831.00***	***459.00***	***3290.00***	***3600.00***	***474.00***	***4074.00***

C. Plan Outlay	Head of Dev	Budget Support	IEBR	Total	Budget Support	IEBR	Total	Budget Support	IEBR	Total
1. Space Research	13402	3420.00	...	3420.00	2831.00	...	2831.00	3600.00	...	3600.00

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1. **Secretariat – Economic Services:** Provision is made for expenditure to be incurred on the Secretariat of the Department of Space.

2. **Geo-Synchronous Satellite Launch Vehicle (GSLV):** The GSLV Project envisaged the development of a launch vehicle capable of launching 2 tonne INSAT-class satellites into Geo-synchronous Transfer Orbit (GTO). The third test flight will carry the indigenous cryogenic engine & stage.

3. **GSLV Mk-III Development:** GSLV Mk-III is intended to develop a cost-effective launch vehicle capable of launching 4 tonne class of communication satellites in Geo-synchronous Transfer Orbit (GTO). The project envisages the development of a number of technologies which include, among others, 200 tonne solid stage booster (S-200), 25 tonne cryogenic engines (C-25), and L-110 tonne liquid stage engines as core boosters. The first developmental flight of GSLV MK III is excepted by 2009-2010.

4. **Cryogenic Upper Stage (CUS) Project:** The objective of the Project is to develop and qualify an indigenous restartable cryogenic stage employing liquid oxygen as oxidizer and liquid hydrogen as fuel for the upper stage of GSLV. The first flight of the indigenous cryo stage is targeted for flight testing by GSLV during 2008-2009.

5. **Polar Satellite Launch Vehicle-Continuation (PSLV-C) Project:** The PSLV is capable of placing 1400-1600 kg class IRS satellites in Polar Sun- Synchronous Orbit, 1000 kg class satellites into Geo-synchronous Transfer Orbit and upto 2800 kg class satellites into Low Earth Orbit. The Chandrayaan-1 – Indian Lunar Mission is also planned for launch by PSLV.

6. **Vikram Sarabhai Space Centre (VSSC):** VSSC is the lead Centre for the development of satellite launch vehicles and sounding rockets and houses the major test and fabrication facilities for launch vehicles.

7. **ISRO Inertial Systems Unit (IISU):** IISU is responsible for research & development in the area of inertial sensors & systems for launch vehicles, satellites and allied satellite elements.

8. **Liquid Propulsion Systems Centre (LPSC):** LPSC is the lead Centre in the area of liquid and cryogenic rocket engines and stages for launch vehicle and small thrust engines for launch vehicles and spacecraft control.

9. **GSLV-Operational Project:** The GSLV-Operational Project has been conceived to meet the launch requirement of 2 tonne class of operational INSAT satellites. The first operational flight of GSLV-F01 was successfully launched on 20.09.2004 placing EDUSAT Satellite into orbit. The launch of GSLV-F02 on 10.07.2006 was unsuccessful due to malfunctioning of one of the strapon stages. A National level failure analysis committee has reviewed the flight data and recommended certain additional tests/improved inspection process, which were carried out and GSLV-F04 carrying INSAT-4CR was successfully launched on September 2, 2007.

10. **Space Capsule Recovery Experiment (SRE):** The main objective of the Space Capsule Recovery Experiment (SRE) is to develop and demonstrate capability to recover on orbiting capsule back on earth. SRE-I has successfully launched on-board PSLV on January 10, 2007 and was also successfully recovered from Bay of Bengal on January 22, 2007. The work on SRE-II is in progress.

11. **Manned Mission Initiatives/Human Space Flight Programme:** The main objective of Indian Manned Mission Initiatives/Human Space Flight programme is to develop a fully autonomous manned space vehicle to carry two crew to 400 km LEO and safe return to earth. Detailed studies have been initiated on the technologies required for realising the flight safety and reliability, propulsion systems, advanced materials etc. Formulation of the project proposal for approval of the Government is in progress.

12. **Indian Institute of Space Science & Technology:** Indian Institute of Space Science & Technology is an autonomous body under DOS with the objective of creating quality human resources tuned to suit the space pogramme. The institute offers graduate, post-graduate and research programme in the area of space science technology and applications. The Institute has started functioning from the academic year 2007-2008 around the existing infrastructure of ISRO Centres in Thiruvananthapuram.

13. **Semi Cryogenic Engine/Stage Development:** The objective of the project is to develop and qualify a high thrust Semi Cryogenic engine and stage (employing kerosene of required grade/spar as fuel and Liquid Oxygen as oxidizer) for the future advanced launch vehicle.

14. **Cartosat-2:** The Cartosat-2 Project is an advanced high resolution satellite to support large scale cartographic mapping and thematic applications. Cartosat-2 was successfully launched on board PSLV-C7 on January 10, 2007.

15. **Oceansat-2 & 3:** The main objective of Oceansat-2 is to provide continuity of data & services hitherto provided by Oceansat-1 on Oceanography and coastal studies. The launch of Oceansat-2 onboard PSLV is planned in 2008-2009. Oceansat-3, planned to be initiated towards end of 11th plan will be a follow-on satellite for Oceansat-2 to provide continuity of data on Ocean & Coastal resources.

16. **Resourcesat-2 & 3:** Taking into account the increased use of space imageries for different applications and continued Earth Observation services required from the IRS satellites, Resouresat-2 has been conceived as a continuity mission with enhanced capabilities which will be mainly for crop applications, vegetation dynamics and natural resources census applications. The Payload realisation and sub-system fabrication are targeted for 2008-2009. Resourcesat-3 will provide continuity of data after Resourcesat-2.

17. **ISRO Satellite Centre (ISAC):** ISAC is the lead Center for the design, fabrication, testing and management of satellite systems for scientific, technological and application missions.

18. **Laboratory for Electro-Optics Systems (LEOS):** LEOS is responsible for research & development and production of electro-optics sensors for satellites.

19. **Radar Imaging Satellite-1 (RISAT-1):** Radar Imaging Satellite (RISAT) is intended to provide all-weather, day and night imaging capability providing vital inputs during Khariff season for various agricultural and disaster applications. The satellite is targeted for launch during 2009.

20. **GSAT-4:** The satellite will be utilized for conducting various experiments in the communications area and early introduction of geo-based navigation system. The satellite is targeted for launch on board GSLV during 2008-2009.

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21. Navigation Satellite System: The Indian Regional Navigation Satellite System (IRNSS), is planned to be a constellation of 7 satellites – 3 in GEO and 4 in GSO orbit. This satellite is expected to provide position accuracies similar to GPS in a region centered around India with a coverage extending upto 1500 km from India.

22. Semi-conductor Laboratory: SCL is engaged in the Design, Development and Manufacture of Very Large Scale Integrated Circuits (VLSIs) and Board Level Products to meet the stringent quality requirement of strategic sectors. SCL is to undertake radiation hardened devices and about more than 60 types of ASICs have been identified for development by SCL for Space Programme.

23. Advanced Communication Satellite: The main objective is to develop a 4 tonne class communication satellite incorporating advanced technologies of relevance for future.

24. Earth Observation – New Missions (Saral, Geo-HR Imager, TES-Hyp, DMSAR & Carto-3): Indian Earth Observation program is directed towards providing continuity of EO data for resource management applications and enhancing the imaging capability. Towards this, it is planned to undertake development of small satellite with Argos & Altimeter (SARAL) for oceanography studies, Geostationary Imager (Geo-HR) for constant environment surveillance, Technology Experiment Satellite in Hyper Spectral Imaging (TES-HYP), Radar Imaging Satellite for Disaster Management (DMSAR) & advanced cartography satellite (Carto-3).

25. Satish Dhawan Space Centre-SHAR (SDSC-SHAR): SDSC-SHAR provides the launch infrastructure as well as solid propellant processing.

26. ISRO Telemetry, Tracking and Command Network (ISTRAC): ISTRAC provides spacecraft TTC and Mission Control services to major launch vehicle and spacecraft missions.

27. ISRO Radar Development Unit (ISRAD): ISRAD is responsible for research, development and productionalisation of radars systems required for tracking and weather forecasting.

28. Space Applications Centre (SAC): SAC is the lead Centre for the development of communication, meteorological and remote sensing payloads besides R&D in space applications.

29. Development and Educational Communication Unit (DECU): DECU is involved in the concept, definition, planning, implementation and socio-economic evaluation of developmental space applications.

30. National Natural Resources Management System (NNRMS): The National Natural Resources Management System (NNRMS) has the objective of ensuring optimal management/ utilization of natural resources by integrating information derived from remote sensing data with conventional techniques.

31. Earth Observation Application Mission (EOAM): The main goal of the Earth Observation Application Mission (EOAM) are to (i) evolve newer application/R&D programmes based on technology trends leading to operational applications programmes; (ii) guiding total remote sensing applications programmes towards implementation of remote-sensing based solutions, and (iii) steering commercial activities of remote sensing involving development of value-added services.

32. Regional Remote Sensing Services Centres (RRSSCs): The five Regional Remote Sensing Services Centres (RRSSCs) at Bangalore, Dehradun, Jodhpur, Kharagpur and Nagpur have been established under the aegis of NNRMS with the prime objective of providing remote sensing application services to the user in the respective regions for better planning and optimal utilization of natural resources and also bring about awareness amongst the users on the potential of remote sensing and associated technologies.

33. National Remote Sensing Agency (NRSA): NRSA is a registered society and is the nodal agency for operational remote sensing activities in the country. It is responsible for acquisition, processing, distribution and archiving of data from remote sensing satellites.

34. Disaster Management System (DMS): The main objective of Disaster Management Support Programme is to provide Space inputs & services on a timely & reliable basis, for the Disaster Management System in the country.

35. North Eastern Space Applications Centres (NE-SAC): NE-SAC set up as an autonomous society jointly with North Eastern Council, is supporting the North Eastern region by providing information on natural resources utilization and monitoring, developmental planning and interactive training using space technology inputs of remote sensing and satellite communication.

36. Physical Research Laboratory (PRL): PRL, an autonomous institution funded by the Department of Space through grant-in-aid, is one of the premier research institutions in the country carrying out basic research in several areas of experimental & theoretical physics, earth sciences, astronomy & aeronomy & planetary exploration.

37. National Atmospheric Research Laboratory (NARL): NARL, a registered Society, is responsible for carrying out advanced research in atmospheric and space sciences and related disciplines.

38. RESPOND: The RESPOND programme of ISRO supports sponsored research activity in Space Science, Space Applications and Space Technology in various national academic/ research institutions and Space Technology Cells in premier technological institutes of the country through grants-in-aid.

39. Sensor Payload Development/Planetary Science Programme: It includes funding requirement for advance action for activities related to scientific payload developments for space science and planetary exploration studies in different institutions and universities.

40. Megha-Tropiques Project: Megha-Tropiques is an ISRO-CNES of France joint mission and is intended for studying water cycle and energy exchanges in the tropics using a satellite platform.

41. Astrosat 1 & 2: The objective of the Astrosat project is to build and launch an astronomical observatory satellite for expanding the scientific knowledge about the evolution of stellar objects and gather valuable scientific data on high energy Astronomy and Astrophysics research. The Astrosat-1 satellite is planned for launch in 2009 onboard PSLV.

42. Indian Lunar Mission Chandrayaan-1 & 2: The main objective of Indian Lunar Mission - Chandrayaan-1 is high resolution remote sensing of the Moon in low energy and high energy x-ray regions, etc., for preparing 3-dimensional atlas of regions of scientific interest of the Moon and chemical mapping of the entire lunar surface for various elements.. The Chandrayaan-1 is targeted for launch during 2008 on board the PSLV. Detailed studies on mission objectives & payload instruments for the follow-on satellite Chandrayaan-2 has been initiated.

43. **ISRO Geosphere Biosphere Programme (ISRO GBP)**: ISRO GBP encompasses the study of land-air-ocean interaction, past climate, changes in atmospheric composition, aerosols, carbon cycle, bio-mass estimation, bio-diversity and other related areas of scientific investigation.

44. **Atmospheric Science Program**: Atmospheric Science Program is intended to develop advanced observation tools & techniques of atmospheric modeling, leading to operational end user products in different domains of atmospheric science.

45. **Small Satellite for Atmospheric Studies & Astronomy**: The project envisages development of small satellites for study of Earth's near-space environment, magnetometer studies, study of aerosol and gases, tropical weather and climate studies.

46. **Other Schemes**: These includes Microgravity Research, Space Science promotion, Multi-institutional research programs, setting up of Digital workflow systems, support for conferences, symposia, etc..

47. **Special Indigenisation/Advance Ordering**: Indigenisation envisages ISRO to have interface with the Indian Industry to develop various electronic components, materials, chemicals, etc., for the space programme. The scope of the scheme also includes procurement of certain long lead and critical items for futuristic missions.

48. **Others**: Under this, provision has been included for ISRO Headquarters, International Co-operation and Civil Engineering Division.

49. **Master Control Facility**: MCF is responsible for initial orbit raising, payload testing and in-orbit operation of all geo-stationary satellites (INSAT/GSAT/Kalpana).

50. **INSAT-3 Satellites (including Launch Services)**: The objective of INSAT-3 Spacecraft Project are to (i) build five INSAT-3 satellites, (INSAT-3A to INSAT-3E) keeping the flexibility for mid-course corrections to accommodate emerging requirements, carry out mission planning, launch campaign and initial phase operations, and (ii) establish required programme elements for carrying out the same. The INSAT-3A, 3B, 3C & 3E Satellites in the series have been launched and operationalised. INSAT-3D is targeted for launch during 2008-2009.

51. **INSAT-4 Satellites (including Launch Services)**: The fourth generation INSAT-4 Satellite series has been planned to meet the capacity and service requirements projected by various users and development needs of the country. INSAT-4A, 4B & 4CR satellite in the INSAT-4 series have been launched & operationalised.

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