Military organisations worldwide have steadily increased reliance on space assets for communications, surveillance, and navigation. The military use of space includes communication, imagery, navigation, signal/electronic intelligence, early warning, and meteorology. Of all these, communication followed by imagery and navigations are the most important, widely and extensively used applications, both by civil and military organisations. India has sufficient space capability as compared to China, to support its defence forces especially in the field of communication and sufficient capability for surveillance, the two major and most important applications of space systems.

Colonel Deepak Sharma was commissioned in Corps of Signals in 1984. He has an M. Tech degree in Communications from IIT, Kanpur and has also done Technical Staff Course. He commanded Corps Engineering Signals Regiment in Counter Insurgency Environment and the unit was responsible for provisioning communication in entire Assam and Arunachal Pradesh. As a Commanding Officer in North-East in 'OP RHINO', he was awarded Army Commanders' Commendation Card for provisioning communication to troops of Corps who took part in flushing out Insurgents from Bhutan. After completion of M Tech from IIT Kanpur, in 1994, he was posted as Deputy Director from 1994 to 1997 and subsequently as Director from Dec 2006 to Jun 2009 in Directorate dealing with all the satellite communication aspects of the Army. Col. Sharma joined IDSA in July 2009, and is working on projects related to space capability and other aspects of the space system.

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ISBN 81-86019-84-7
9 798186 019848

IDSA Occasional Paper No. 15

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ISBN: 81-86019-84-7

First Published: November 2010

Price: Rs 175/-

Published by: Institute for Defence Studies and Analyses
No.1, Development Enclave, Rao Tula Ram Marg,
Delhi Cantt., New Delhi - 110 010
Tel. (91-11) 2671-7983
Fax.(91-11) 2615 4191
E-mail: idsa@vsnl.com
Website: http://www.idsa.in

Cover &
Layout by: Geeta Kumari

Printed at: M/s Printline
H-10, IInd Floor, NDSE-I
New Delhi - 110049
Tel: (91-11) 24651060, 24643119
E-mail : printline2003@yahoo.co.in

Background

The space assets are being exploited by our defence forces for communication, utilising our own satellite systems since 1990. However there are issues which require to be addressed in detail for enhancing the space based capability of our defence forces and enabling them to exploit the space assets for Network-centric warfare (NCW), as an integrated force. The space is an important third dimension area to be exploited by defence forces to have a decisive edge over its adversary, especially in nuclear threat and other similar environment. Space is emerging as an important 'arena' for future military operations. Information domination through space-based assets would become the key to this pursuit and would shape the outcome of war. Therefore the important space based capabilities desired and essential for military use are the following:

(a) Space-based Observation/surveillance Capabilities.

(b) Position and Navigational information.

(c) Reliable Communication Capabilities.

Of all the above, communication is the most important application which is widely and extensively used by the Indian defence forces, followed by imagery and navigation. **One of the most important features of space-based system is that it provides global coverage. The footprint of the satellite can be planned and managed to suite global scenario of operations.** Space systems are most suited for global, continuous and near continuous coverage and communication connectivity to allow the defence forces to execute its missions effectively. Ultimately, the exploitation of space by using satellite will facilitate real time connectivity between 'sensor, decision-makers, and shooters' at geographically separated locations. **Communication in the defence forces is multi layered and flexible. The media could be terrestrial, radio or satellite. Satellite media is planned to provide global coverage and redundancy to other communication media.** The satellite communication systems are ideal as primary means of communication for mobile, remote inhospitable terrain and for sea operations. The satellite payloads for a defence specific satellite should therefore cater for the needs of the forces to support NCW in the long term.

Legal Framework and Adoption of Multilateral Treaties for Outer Space[1]

The international legal framework for outer space establishes the principle that space should be used for "peaceful purposes." Since the signing of the Outer Space Treaty (OST) in 1967, this framework has grown to include the Astronaut Rescue Agreement (1968), the Liability Convention (1972), the Registration Convention (1979), and the Moon Agreement (1979), as well as a range of other international and bilateral agreements and relevant rules of customary international law. The OST prohibits the stationing of nuclear weapons or any other weapons of mass destruction anywhere in space. The US withdrawal from the Anti-Ballistic Missile Treaty in 2002 eliminated a longstanding US/USSR-Russia prohibition on space-based conventional weapons, stimulating renewed concerns about the potential for space weaponisation. What began as a focus on multilateral space treaties, however, has transitioned to a focus on what some describe as 'soft law' referring to a range of non-binding governance tools including principles, resolutions, confidence-building measures, and policy and technical guidelines.

The US has always been resisting international move for any legally binding treaties banning anti-satellite tests. In 2008, at the UN General Assembly, US had reiterated its rejection of legally binding approaches to security in space. The US has expressed the view that destruction of failed satellite by any nation is in consistent with the Outer Space Treaty. International legal events in 2008 had mainly focused on non-binding governance tools, which some refer to as 'soft law', such as transparency and confidence-building measures and codes of conduct. Support for these measures indicates a growing commitment on the part of some leading space-faring countries to better regulate activities in outer space by codifying generally accepted behaviours. However, the potential risk with this approach is that implementation will be arbitrary and selective, as demonstrated by the ongoing challenges faced by the Hague Code of Conduct, and that de facto international law will be made via the unilateral actions of states, as demonstrated by the US destruction of one of its own satellites. The US action to destroy its satellite and official responses by other governments may stand as precedents for procedures

1. Space report 2009, executive summary, available at www.spacesecurity.org

under which the use of force in outer space is legitimised, in the absence of specific treaty law.

A range of international institutions, such as the UN General Assembly, the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS), the International Telecommunication Union (ITU), and the Conference on Disarmament (CD), have been mandated to address issues related to space security. But the CD has been deadlocked without an agreed plan of work since 1996 and there has been no progress on space issues in 30 years, despite efforts to move forward on the Prevention of an Arms Race in Outer Space (PAROS) mandate to develop an instrument relating to the weaponisation of space. COPUOS remains active, with a focus on non-binding, technical approaches to security in space. Activities surrounding the UN COPUOS in 2008 reinforced the continued focus on nonbinding, technical approaches to international governance of outer space noted in. Despite drawbacks, these are the only mechanisms that are garnering widespread support and leading to improvements in the security of outer space in the face of continued lack of consensus on new treaties in both the UN COPUOS and the CD. However, the increased interaction between these two organisations suggests that addressing security concerns in space more comprehensively may become possible in the future, although the stark division between civil and safety issues and military and weapons issues remains institutionalised. All space-faring states emphasise the importance of cooperation and the peaceful uses of space, but with caveats based on national security concerns. States continued to express commitment to international cooperation on the peaceful use of outer space in their civil space policies in 2008. Some peaceful uses of space are increasingly viewed as strategic, however, which could limit opportunities for cooperation and cause political tensions in space, depending on whether states pursue independent or collective measures to achieve the strategic goals set out in their space policies.

As per the stated national policy India does not have the interest in any nation's territory and has the focus to protect the integrity of its boundaries and borders. Thus it can be safely said that we as the nation will have our focus concentrated to regions around us. The policy on space and future plan for space assets and development of various capabilities will evolve from India's stated policy on national security.

This paper examines the capabilities of major space capable states specifically the capabilities of nations concerning India viz, United

States, China and Pakistan with particular emphasis to the aspects of satellite communications for the defence forces. The paper has been covered under following heads:

(a) Space assets.

(b) Launch capable countries.

(c) Space industry economics.

(d) Space capabilities of US.

(e) Space capabilities of China.

(f) Space capabilities of Pakistan.

(g) Space capabilities of India.

(h) Ground system.

(j) Comparative analysis of space capabilities.

(k) Recommendation and conclusion.

This paper has focused on the military use of space and not the weaponisation issues. However, a distinction must here be made between the "militarisation of space" and the "weaponisation of space". These terms are sometimes used as if they are interchangeable, but they are not. While there are no specifically deployed weapons in space yet, there are satellites that could be manoeuvred to act as weapons and disable or destroy the space assets of others. Therefore, when considering questions of space security, it must be recognised that though space has not yet been specifically weaponised, it is already heavily militarised.[2] One can exploit the space assets without the support of space-based weapons. The aspect of weaponisation is briefly discussed in succeeding paragraphs.

Weaponisation of Space

The major driver behind space weaponisation is missile defence. Paul Wolfowitz, US Deputy Secretary of Defence, noted in October 2002, 'Space

2. Rebecca Johnson, "Space Security: Options and Approaches", Outer Space and Global Security conference, at the Simons Centre for Peace and Disarmament Studies, Liu Institute for Global Issues, UBC, Canada, November 26-27, 2002, available at http://www.ploughshares.ca/libraries/Abolish/OuterSpaceConfGeneva02/JohnsonConf2002.htm

offers attractive options not only for missile defence but for a broad range of interrelated civil and military missions. It truly is the ultimate high ground'[3]. The issue of weaponisation of space raises the important yet ultimately intractable question of whether the migration of combat operations to orbital space is bound to take place sooner or later or it is simply a speculation of few scholars and military brass. Many regard such an eventual development simply as a given. As former US Air Force General Joseph Ashy declared during his incumbency as C-IN-C SPACE, "it's politically sensitive, but it's going to happen. Some people don't want to hear this, and it sure isn't in vogue . . . but absolutely we're going to fight in space. We're going to fight from space, and we're going to fight into space."[4] This widespread belief in the eventual inevitability of space weaponisation stems in part from air analogies and, in particular, from a conviction that the space experience will naturally repeats the air experience.

The latest debate on US space weaponisation plans began in 2001 with the publication of the Rumsfeld Commission Report on US space security policy[5]. This commission was chaired by Donald Rumsfeld, who was soon to become US Defence Secretary, and included an overwhelming majority of retired high-ranking USAF officers, its purpose being to investigate the United States' overall space security structure, report on its deficiencies and propose ways to rectify them. The report powerfully evoked the image of a potential "Space Pearl Harbour". The Rumsfeld Report argued that the US Government should pursue the relevant capabilities "to ensure that the

3. Transcript Wolfowitz Outlines Missile Defence Successes, Way Ahead, US State Department (Washington File), October 25, 2002, cited by Rebecca Johnson, "Space Security: Options and Approaches", in Outer Space and Global Security Conference at the Simons Centre for Peace and Disarmament Studies, Liu Institute for Global Issues, UBC, Canada, on November 26-27, 2002, available at http://www.ploughshares.ca/libraries/Abolish/OuterSpaceConfGeneva02/JohnsonConf2002.htm

4. William B. Scott, "USSC Prepares for Future Combat Missions in Space," Aviation Week and Space Technology, August 5, 1996, p. 51. Quoted by Benjamin S. Lambeth, "Next Steps in the Military Uses of Space, Mastering the Ultimate High Ground", prepared for the United States Air Force, available at http://www.rand.org/pubs/monograph_reports/ Mr1649 /index.html accessed on April 19, 2010.

5. Report of the Commission to Assess United States National Security Space Management and Organisation, Executive Summary, Washington DC, January 2001. Cited in Document A/1932, June 21, 2006, Weapons in Space Report submitted on behalf of the Technological and Aerospace Committee, by Alan Meale, Rapporteur (United Kingdom, Socialist Group) available at http://www.assembly-weu.org/en/documents/sessions_ordinaires /rpt/2006/1932.php#P213_45786

President will have the option to deploy weapons in space to deter threats to and, if necessary, defend against attacks on US interests".[6] Given its disproportionate reliance on space assets, it is no wonder that the US is worried about the vulnerability of these assets, but the fundamental question US advocates of space weaponisation have to answer is why they think weaponising space would be a sensible response to such vulnerabilities.

Russia and China believe that they must respond to this strategic challenge by taking measures to dissuade the US from pursuing space weapons and missile defences.[7] A staff background paper to the Rumsfeld Commission prominently featured a Xinhua news agency report on how China's military plans on defeating the U.S. military in a future conflict. The Xinhua article noted, "For countries that could never win a war by using the method of tanks and planes, attacking the US space system may be an irresistible and most tempting choice."[8] In January 2000, the Sing Tao newspaper based in Hong Kong quoted Chinese sources saying that China was developing a "parasitic satellite" to be used in an anti-satellite (ASAT) mode[9]. In January

6. Report of the 2001 Space Commission, p 12. This echoes US SpaceCom's Long Range Plan, which stated, "At present, the notion of weapons in space is not consistent with US national policy. Planning for this possibility is the purpose of this plan should our civilian leadership later decide that the application of force from space is in our national interest." United States Space Command, Long Range Plan, March 1998, p 8. Cited by Rebecca Johnson, "Space Security: Options and Approaches", at the Outer Space and Global Security Conference, in the Simons Centre for Peace and Disarmament Studies, Liu Institute for Global Issues, UBC, Canada, November 26-27, 2002, available at http://www.ploughshares.ca/libraries/Abolish/OuterSpaceConfGeneva02/JohnsonConf2002.htm

7. Pavel Podvig and Hui Zhang, Russian and Chinese Responses to US Military Plans in Space (Cambridge, MA: American Academy of Arts and Sciences, 2008), vvi, http://www.amacad.org/publications/militarySpace.pdf. Cited by Trevor Brown, "Soft Power and Space Weaponization", *Air & Space Power Journal*, Spring 2009, 1 March 2009, available at http://www.airpower.au.af.mil/airchronicles/apj/apj09/spr09/brown.html, accessed on April 10, 2010

8. Al Santoli, "Beijing Describes How to Defeat US in High-Tech War," China Reform Monitor No. 331, September 12, 2000, available online at http://www.afpc.org/crm/crm331.htm, cited in Tom Wilson, "Threats to United States Space Capabilities", Washington, DC, prepared for the Commission to Assess United States National Security Space Management and Organization, 2001, p. 5.

9. Cheng Ho, "China Eyes Anti-Satellite System," *Space Daily*, January 8, 2000. In January 2001, two additional articles in the Hong Kong press discussed development and testing of "parasitic" or "piggyback" ASATs. See Philip Saunders, et al, "China's Space Capabilities and the Strategic Logic of Anti-Satellite Weapons," Center for Non-proliferation Studies, Monterey Institute of International Studies, July 22, 2002, available online at http://cns.miis.edu/pubs/week/020722.htm.

2007 China demonstrated ASAT capability by destroying its disused weather satellite which further escalated the debate on weaponisation, and threat to space environment due to debris.[10]

As noted above, the space weaponisation rest on three assumptions inevitability, vulnerability and control. The higher the level of reliance on space assets for military purposes, the greater will be the vulnerabilities. Moreover, states with the capabilities to launch intercontinental ballistic missiles or put satellites in space will also be capable of launching an ASAT attack[11]. Many space-faring nations are concerned that the pursuit of space weaponisation would be expensive, provocative and escalatory[12].

Military Use of Space Systems

Satellites are increasingly being utilised as dual-use (can be used for both military and non-military purposes). The United States (US), Russia, and China are the three countries that own most satellites. Military organisations worldwide have steadily increased reliance on space assets for communications, surveillance, and navigation. This increased usage can create asymmetric threats whereby a weaker power or near-peer could exploit the space dependence of its stronger adversary as a force equalizer. The military use of space includes:

(a) **Communication.** In military operations this enables exchange of information so that decisions can be based on up-to-date intelligence and information.

(b) **Imagery.** Imagery of area of interest and identification of targets.

(c) **Navigation.** Apart from navigation, the system is used for target location and guiding weapons systems etc. There are two main systems; the US global positioning system or GPS (used by UK armed

10. D. Wright, "Colliding Satellites: Consequences and Implications," Union of Concerned Scientists, February 26, 2009, available at http://www.ucsusa.org/assets/documents/nwgs/SatelliteCollision-2-12-09.pdf.

11. Rebecca Johnson, no. 2

12. For further arguments from the military advocates of creating a "space sanctuary" along the lines of Antarctica, see Lt. Col. Bruce M. Deblois, "Space Sanctuary: a Viable National Strategy," (1997), available at http://www.airpower.maxwell.af.mil/airchronicles/apj/apj98/win98.deblois.html.

forces also) and the Russian GLONASS system. GPS is usually accurate to within a few metres.

(d) **Signals Intelligence (SIGINT).** Detecting communication, including broadcasting signals.

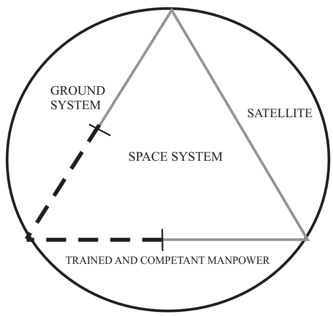
(e) **Early Warning.** Infrared satellite sensors can spot missile launches by detecting their hot plumes.

(f) **Meteorology.** To provide weather data to defence forces.

Space Assets

Space System

The space system means both a satellite and its ground station(s). Trained and technically competent manpower is the part of both the systems. For any country to be considered a true space capable state, it should have satellite design and manufacturing capability, launch capability and satellite tracking and monitoring capability. The space system therefore can be broadly depicted as shown under:



The US and USSR/Russia have launched more than 3,000 military satellites, while the rest of the world has launched under 100. At the end of 2008 there were over 900 satellites and out of these about 150 operational dedicated military satellites worldwide, with the US operating approximately 107 and Russia approximately 36 satellites followed by China[13]. As far as India is concerned, during 2008 India announced plans to create an Integrated Space Cell, a nodal agency within the Government of India that coordinates space-based military and civilian systems. A key factor in the creation of the cell was China's anti-satellite test. The cell, formed in June 2008, is under the command of the Integrated Defence Services Headquarters, and is responsible for coordinating activities of ISRO and the Indian Armed Forces[14]. On the Earth observation front, India has targeted enhanced

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13. Union of Concerned Scientists, "UCS Satellite Database", January 21, 2009, online http://www.ucsusa.org/nuclear_weapons_and_global_security/space_weapons/technical_issues/ucs-satellite-database.html

14. Staff Writers, New Delhi, India (SPX), June 12, 2008, http://www.spacewar.com/Military_Technology.html,

military capability a process that is distinctly tied to the country's growing military relationship with Israel. India has launched a military satellite TECSAR, for Israel, and launched a similar Israeli-built Indian-operated RISAT-1 in early 2009[15]. It should be noted that though defence forces can use the ISRO assets which are of dual use, however as of now there is no dedicated military satellite for Indian defence forces[16]. The countries who own the dedicated military satellites are indicated as under:

Year	State	Satellite	Description
1958	US	Project SCORE	Communications and Experimental satellite
1962	USSR	Cosmos-4	Remote sensing (optical)
1969	UK	Skynet-1A	Communications
1970	NATO	NATO-1	Communications
1975	China	FSW-0 No. 1	Remote sensing (optical)
1988	Israel	Ofeq-1	Remote sensing (optical)
1995	France	Helios-1A	Remote sensing (optical)
1995	Chile	Fasat-Alfa	Communications and Remote sensing (optical)
1998	Thailand	TMSAT	Communications
2001	Italy	Sicra	Communications
2003	Australia	Optus and Defence-1	Communications
2003	Japan	IGS-1A and IGS-1B	Remote sensing (optical)
2006	Spain	Spainsat	Communications
2006	Germany	SAR Lupe-1	Remote sensing (radar)

Other states have civil or commercial satellites that may be used for military purposes.

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15. Futron's 2009 Military Satellite Magazine, http://www.milsatmagazine.com/cgi-bin/display_article.cgi?number=875113067#top#top]

16. Battakiran's Weblog, October 22, 2008, http://battakiran.wordpress.com/category/isromilitary-missiles/

Bhaskaranarayana the senior scientist of ISRO says that Antrix has made the most of the IRS system and achieved global success, with a business of Rs 10 billion ($231.9 million). He claims that the IRS is the best remote sensing satellite system, with ground stations across 23 nations. The IRS provides services in establishing international ground stations (IGS) and the international reseller network to receive, process and market IRS data products and IRS image processing. Bhaskaranarayana says that Antrix provided these services only on a commercial or civilian basis, and not for defence purposes. The defence services may use the data, he says, but Antrix doesn't have any specific services for them. Antrix recently launched CARTOSAT-2, which offers the facility to receive data products to international users. It has already launched a series of commercial satellites Kitsat (Korea), Tubsat (DLR Germany), BIRD (DLR Germany), PROBA (Verhaert, Belgium), Lapan Tubsat (Indonesia), Pehuensat-1 (Argentina) aboard ISRO's polar satellite launch vehicle (PSLV) in addition to the dedicated launch of Agile (Italy).

Satellite Details[17]

As on Jul 09, approximately 902 operational satellites orbit around Earth according to the details of Union of Concerned Scientist (UCS) satellite database. The relative numbers of military and non-military satellites operated by countries are given as under **figure 1 and figure 2:**

Satellite Quick Facts			
Total number of operating satellites :902			
LEO: 430	MEO: 56	Elliptical: 40	GEO: 376
United States: 433	Russia:85	China: 55	
Total number of U.S. Satellites: 433			
Civil: 10	Commercial: 194	Government: 122	Military: 107

Figure 1: Based on data from July 09 database

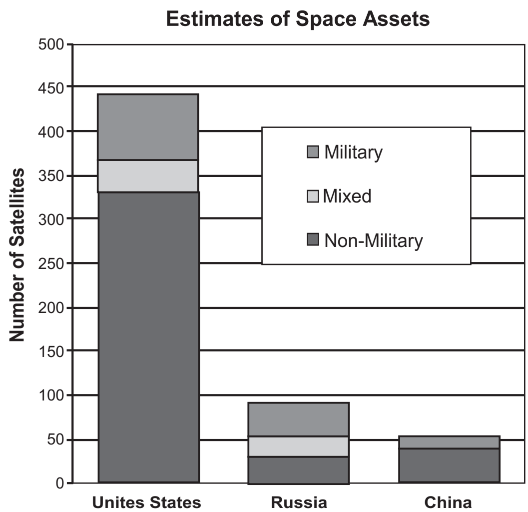


Figure 2: Based on data from January 09 database

17. http://www.ucsusa.org/nuclear_weapons_and_global_security/space_weapons/technical_issues/ucs-satellite-database.html.

Satellites in Various Orbits

The details of satellites in various orbits are given in the figures below:

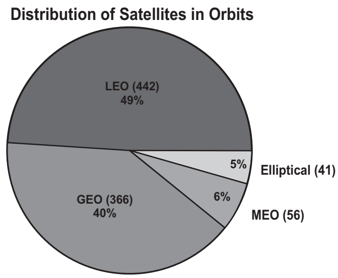


Figure 3: Based on data from January 21, 2009 database

Types of Satellites in Low Earth Orbit (figure 4)

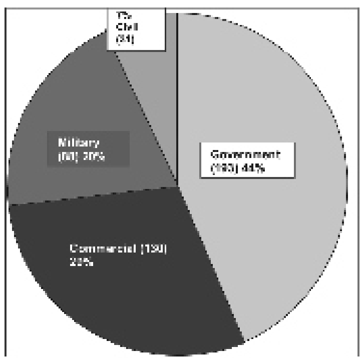


Figure 4: Based on data from January 21, 2009 database

Types of Satellites in Geosynchronous Orbit (figure 5)

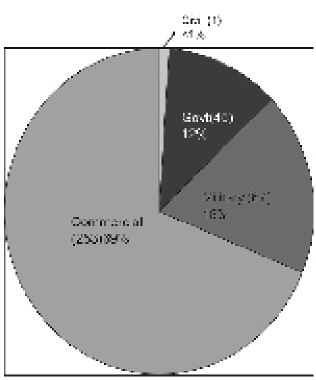


Figure 5: Based on data from January 21, 2009 database

There are twice as many commercial satellites in GEO as there are in LEO. In LEO, the government is the largest investor, but commercial investors own two-thirds of GEO satellites. The United States, Russia, and China are the three countries with the most satellites owned outright. A number of other countries and partnerships own between 10-20 satellites, but at least 115 countries in total own a satellite or a share in one.

Military Dependence on Commercial Satellite Services

Joseph Rouge, Director of the National Security Space Office, in June 2008 said that 80 per cent of the US defence satellite communication with fixed ground stations are provided by commercial operators. The European Defence Agency has created a special group to bring together satellite communications requirements of the various European defence forces to coordinate purchases of commercial capacity. Defence Forces are also one of the most significant purchasers of commercial satellite remote sensing imagery. In 2008 the US Department of Defence bought $5-million worth of commercial synthetic aperture radar imagery from the Canadian Radarsat system. The US Department of Defence is also committed to purchase $197 million worth of imagery over the first 18 months of operation of GeoEye-1[18]. The US has also cancelled two large military programmes, the BASIC, which was focused on high-end observation satellites, and $26 billion transformational satellite programme, *TSAT*. These decisions will facilitate the continued and increased reliance on commercial vendors for imaging and communications solutions[19].

Communication Satellites

Of all the applications satellite communication sometime abbreviated as SATCOM will continue to dominate the commercial satellite industry, with 34 payloads launched in 2008[20]. As per the Space Report of 2008, there were approximately 524 communication satellites owned by various countries and organisations as per details listed below, signifying the importance of space based communication.

18. Space Security 2009, Chapter 4, October 2009 Publication, www.spacesecurity.org, accessed on November 1, 2009.
19. Executive Summary, Space Report 2009, http://www.thespacereport.org/files/09executivesummary.pdf
20. Information collected from US Federal Aviation Administration (FAA), "Year in Review 2008"; Dr. Jonathan McDowell; and Gunter's Space Page, http://www.skyrocket.de/space/.

Communications Satellites, as of December 31, 2007[21]

Satellites		Satellites	
Algeria-	1		
Argentina-	3	Australia-	5
Brazil-	4	Canada-	7
Russia-	43	Egypt-	2
France-	2	Germany-	1
Greece-	1	India-	11
Indonesia-	5	Israel-	2
Italy-	1	Japan-	24
Luxembourg-	13	Malaysia-	3
Mexico-	3	Netherlands-	5
Nigeria-	1	Norway-	2
Pakistan-	1	PRC (China)-	14
Philippines-	1	Saudi Arabia-	8
South Korea-	3	Spain-	5
Singapore-	1	Sweden-	2
Thailand-	4	Turkey-	3
UAE-	2	UK-	3
US-	193	US/Brazil-	1
Organisation			
NATO- European Space	1		
Agency - countries(ESA)	2		
Company			
EUTELSAT			19
GlobalStar			52
INMARSAT			10
IntelSat			24
New ICO			1
ORBCOMM			29
Region			
Arabia			3
AsiaSat			3
Total			**524**

21. Space Report 2008, availble at http://www.thespacereport.org/resources/satellites/comm_satellite.php; www.SpaceFoundation.org.

Growing Demand for Orbital Slot and Radio Frequency Spectrum[22]

Expanding satellite applications are driving demand for limited resources in space, including radio frequencies and orbital slots. Satellite operators spend significant time addressing frequency interference issues, including conflicts such as the disagreement over frequency allocation between the US Global Positioning System, the EU Galileo System, and the Chinese Beidou System. There are more than 900 operational satellites in orbit today. Increased competition for orbital slot assignments, particularly in GEO where most communications satellites operate, has caused occasional disputes between satellite operators. The International Telecommunication Union has been pursuing reforms to address slot allocation backlogs and related financial challenges. Developments in 2008 further highlight both the scarcity of available slots in the radio frequency spectrum and the challenges with the existing governance mechanisms. In particular, the Chinese plan for Beidou appears to be consistent with current ITU regulations, and efforts to resolve the issue of frequency coordination were complicated by untimely release of technical details about Galileo. Moreover, as military and economic interests drive the growth of competing systems for similar services, additional demands are also made on their related orbits in this case, highly elliptical orbit. Determining the nature of solutions to satellite signal interference, both accidental and hostile, will continue to be a challenge for the foreseeable future and is a significant deterrent to space security.

Certain widely used frequency ranges have been given alphabetical band names. The communication satellites tend to use the L-band (1-2 gigahertz) and S-band (2-4 gigahertz) for mobile phones, ship communications, and messaging. The C-band (4-8 gigahertz) is widely used by commercial satellite operators to provide services such as roving telephone services, and the Ku-band (12-18 gigahertz) is used for communication, DTH services and to provide connections between satellite users. The Ka-band (27-40 gigahertz) is now being used for broadband communications. Most of the satellite communication falls below 60 gigahertz; During the US-led invasion of Afghanistan in 2001, when the US military used some 700 megabytes per second of bandwidth, up from about 99 megabytes per second used during the 1991 US operations in Iraq.

22. Space Security October 2009 availble at www.spacesecurity.org

IEEE Radar Band Designations[23]

Frequency	Wavelength	IEEE Radar Band designation
1 - 2 GHz	30 - 15 cm	L Band
2 - 4 GHz	15 - 7.5 cm	S Band
4 - 8 GHz	7.5 - 3.75 cm	C Band
8 - 12 GHz	3.75 - 2.50 cm	X Band
12 - 18 GHz	2.5 - 1.67 cm	Ku Band
18 - 27 Ghz	1.67 - 1.11 cm	K Band
Frequency	**Wavelength**	**IEEE Radar Band designation**
40 - 75 Ghz		V Band
75 - 110 Ghz		W Band
110 - 300 GHz		mm Band
300 - 3000 Ghz		u mm Band

Radio Band Designations

Frequency	Wavelength	Radio Band designation
30 - 300 Hz	10 - 1Mm	ELF (extremely low frequency)
300 - 3000 Hz	1000 - 100 km	ULF (ultra low frequency)
3 - 30 kHz	100 - 10 km	VLF (very low frequency)
30 - 300 kHz	10 - 1 km	LF (low frequency)
300 - 3000 kHz	1000 - 100 m	MF (medium frequency)
3 - 30 Mhz	100 - 10 m	HF (high frequency)
30 - 300 Mhz	10 - 1 m	VHF (very high frequency)
300 - 3000 Mhz	100 - 10 cm	UHF (ultra high frequency)
3 - 30 Ghz	10 - 1 cm	SHF (super high frequency)
30 - 300 Ghz	10 - 1 mm	EHF (extremely high frequency)

23. http://www.altair.org/labnotes_RadioBands.html.

Launch Capable Countries

For any nation to be truly considered a space capable state, it should have the capability to launch the satellite into the orbit. There are very few countries with an independent capability to place satellites in the orbit, including production of the necessary launch vehicle. The details of countries capable of launching satellites indigenously, and the date this capability was first demonstrated are given as under at Table 1:

Table 1: Worldwide Launch Vehicles (As of June 2009) [24, 25]

Vehicle	First Launch	Reliability*	Active Sites	LEO kg	GTO kg
		Europe			
Ariane 5 (G, G+, GS, ECS)	1996	42/44	Kourou	16,000-21,000	6,200-10,500
		China			
Long March 2C (SD, CTS,SMA)	1975	31/31	Jiuquan, Taiyuan, Xichang	3,200	1,000
Long March 2D	1992	10/10	Jiuquan	3,500	1,250
Long March 2F	1999	7/7	Jiuquan		
Long March 3A	1994	16/16	Taiyuan, Xichang	6,000	2,600
Long March 3B	1996	10/11	Xichang	13,562	4,491
Long March 4B	1999	11/11	Taiyuan	2,800	N/A
Long March 4C	2007	4/4	Taiyuan	4,200	1,500

24. Data from Gunter Dirk Krebs, online: Gunter's Space Page, http://www.skyrocket.de/space/ (accessed June 10, 2009).
25. www.spacesecurity.org (*Space security,* October 2009)

Vehicle	First Launch	Reliability*	Active Sites	LEO kg	GTO kg
		India			
PSLV	1993	14/15	Satish Dhawan	3,700	800
GSLV	2001	4/5	Satish Dhawan	5,000	2,500
		Japan			
H-2A	2001	15/15	Tanegashima	11,730	5,800
		Israel			
Shavit 1	1988	5/7	Palmachim	225	N/A
		US			
Atlas 5	2002	15/15	CCAFS, VAFB	12,500 20,520	4,950 8,670
Delta 2	1990	67/68	CCAFS	6,100	2,170
Delta 4	2002	9/9	CCAFS, VAFB	9,150 (M) 13,360(M+) 22,560 (H)	4,300 (M) 8,670 (M+) 12,980 (H)
Falcon-1	2008	1/4	Omelek Island	470	N/A
Minotaur	2000	8/8	VAFB, MARS	640	N/A
Pegasus XL	1994	28/30	CCAFS, Kwajalein, MARS, VAFB	443 500	N/A
Taurus XL	1994	6/8	VAFB	1,275	445
		Russia			
Dnepr	1999	11/12	Baikonur, Dombarovskiy	3,700	N/A
Kosmos 3M	1967	421/444	Plesetsk	1,350	N/A
Molniya	1960	331/342	Baikonur, Plesetsk	1,800	N/A
Proton K	1967	315/341	Baikonur	19,760	4,430
Proton M	2000	28/30	Baikonur	21,000	5,500
Rockot	1994	9/11	Baikonur, Plesetsk	1,850	N/A
Soyuz	1958	1314/1366	Baikonur, Plesetsk	6,708	1,350
Tsiklon 2/3 (retired in January 2009)	1965	242/259	Baikonur	3,000	N/A
Zenit 2/2M	1985	31/37	Baikonur	12,030	N/A

Vehicle	First Launch	Reliability*	Active Sites	LEO kg	GTO kg
		Sea Launch			
Zenit 3SL	1999	30/32	Pacific Ocean	N/A	6,100
		Land Launch			
Zenit 3SLB	2008	2/2	Baikonur	N/A	3,750
		Iran			
Safir	2008	½	Semnan	?	?

Russia and Ukraine inherited launch capability from the Soviet Union rather than developing it indigenously. France, United Kingdom launched their first satellites by own launchers from foreign spaceports[26].

North Korea (1998) and Iraq (1989) have claimed orbital launches (satellite and warhead accordingly), but these claims are unconfirmed. In addition to the above, countries such as South Africa, Spain, Italy, Germany, Canada, Australia, Argentina, Egypt and private companies such as OTRAG, have developed their own launchers, but have not had a successful launch. As of 2009, only eight countries from the list above (Russia and Ukraine instead of USSR, also USA, Japan, China, India, Israel, and Iran) and one regional organisation (the European Space Agency, ESA) have independently launched satellites on their own indigenously developed launch vehicles (the launch capabilities of the United Kingdom and France now fall under the ESA.)[27].

Several other countries, including South Korea, Brazil, Pakistan, Romania, Taiwan, Indonesia, Kazakhstan, Australia, Malaysia and Turkey, are at various stages of development of their own small-scale launcher capabilities. As per schedule South Korea may launch a KSLV rocket (created with assistance of Russia) by end of year 2009[28].

North Korea claimed a launch in April 2009, but US and South Korean defence officials and weapons experts later reported that the rocket failed to send a satellite into orbit, if that was the goal. It is believed that what has been

26. http://en.wikipedia.org/wiki/Satellite#endnote_RUS-UKR1#endnote_RUS-UKR1.
27. http://www.space.com/spacenews/businessmonday_070409.html, retrieved on July 4, 2009.
28. "North Korean Missile Launch Was a Failure, Experts Say", *The New York Times*. http://www.nytimes.com/2009/04/06/world/asia/06korea.html?hp. Retrieved on April 6, 2009.

done was an attempt to test a ballistic missile rocket rather than launch a satellite into orbit and even the ballistic missile test was a failure[29].

Private ventures are also gaining the ground in this field. Despite the maturity of some of the key technology involved, new milestones continue to be reached. In March 2008, an Atlas V rocket marketed by the United Launch Alliance, a Lockheed Martin-Boeing joint venture, lifted ICO's G1 commercial communication satellite into orbit. Weighing in at 6,800 kilograms, or 15,000 pounds, it was the heaviest commercial communication satellite ever launched[30].

Launch Capable Private Entities. On September 28, 2008, the private aerospace firm Space X successfully launched its Falcon 1 rocket into the orbit. The rocket carried a prism shaped 1.5 m (5 ft) long payload mass simulator[31].

29. "NORAD and USNORTHCOM monitor North Korean launch", United States Northern Command, http://www.northcom.mil/News/2009/040509.html
30. Space Report 2009, http://www.the spacereport.org/files/09executivesummary.pdf.
31. "SpaceX Successfully Launches Falcon 1 Rocket Into Orbit", Space.com. http://www.space.com/missionlaunches/080928-spacex-falcon1-fourthtest.html

Space Industry Economics

The Space Report 2009 presents vital economic data about the $257 billion space industry, ranging from the launch industry to space-dependent consumer services for the year 2008 -2009. The important details are[32]:

(a) US Government Space Budgets - 26%, ($66.63 B).

(b) International Government Space Budgets - 6% ($16.44 B).

(c) Commercial Infrastructure - 32% ($81.97 B).

(d) Infrastructure Support Industries - <1% ($1.14 B).

(e) Commercial Satellite Services - 35%, ($91.0 B).

(f) Space Commercial Transportation Services - <1% ($0.04 B).

Total $257.22 Billion

China space budget, according to a report issued by Paris-based Euro-consult in the year 2008, "World Prospects for Government Space Markets", the China National Space Administration's (CNSA) 2008 budget was about US$1.3 billion, up six per cent from 2007[33]. India space budget allocation for 2009-2010 has been comparable with that of China's space budget of 2008-2009. The total funds allocation for Indian Space Research Organisation (ISRO) for 2009-10 is Rs. 4,959 crores (Rs.49.59 billion or $1.01 billion), up from Rs.3,499 crores of previous year[34].

32. Executive Summary, Space Report 2009, http://www.thespacereport.org/files/09executivesummary.pdf.

33. Peter J Brown, "China making leaps in space", http://www.atimes.com/atimes/China/JL23Ad02.html.

34. http://www.thaindian.com/newsportal/business/space-programme-gets-boost-with-40-percent-more-funds_100214254.html; "Space programme gets boost with 40 per cent more funds", IANS, July 6, 2009 - 6:50 pm ICT, New Delhi. India's space research programme will get a boost as the union budget for 2009-10 presented by Finance Minister Pranab Mukherjee on Monday has given a 40 per cent hike in fund allocation for the Indian Space Research Organisation (ISRO).

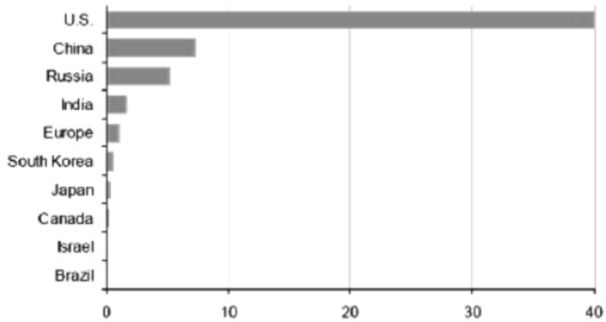
Military Space Budgets

A clear distinction between military space and civil space spending is often blurred in the case of dual-use programmes and applications. The ranked comparison, therefore, represents a best-estimate examination of military space funding. Using a combination of quantitative and qualitative assessments, Futon's 2009 Space Competitiveness Index provides a focused analysis of the comparative positions of the 10 leading space participant nations in the global military space segment.

Military space budget is weighted at 40 per cent of the model findings, military doctrine and structure accounts for 20 per cent of the model outputs and military capability is valued at 40 per cent of the model.

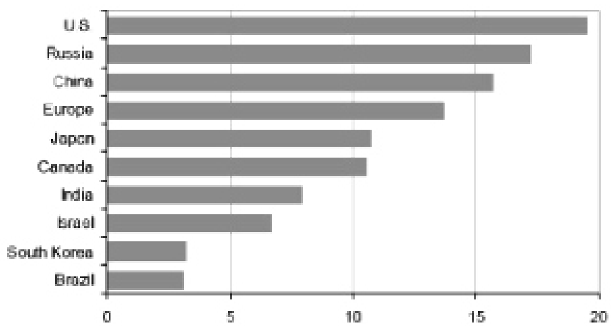
From the Futon estimates, as given under, the US leadership in military space remains significant based on a considerable head start[35] :

Military Space Budget	
Country	**Score**
U.S.	40.00
China	7.26
Russia	5.19
India	1.70
Europe	1.08
South Korea	0.53
Japan	0.33
Canada	0.25
Israel	0.10
Brazil	0.05



Military space Budget weighted at 40

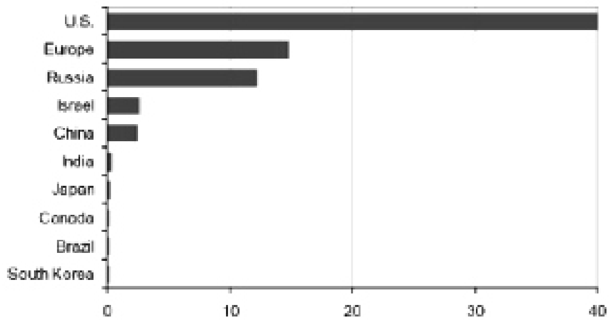
Doctrine and Structure	
Country	**Score**
U.S.	19.50
Russia	17.22
China	15.67
Europe	13.67
Japan	10.72
Canada	10.56
India	7.94
Israel	6.66
South Korea	3.22
Brazil	3.11



Military Space Doctrinal and Structure weighted at 20

35. Futron's 2009 Space Competitiveness Index availble at http://www.milsatmagazine.com/cgi-bin/display_article.cgi?number=875113067#top#top.

Military Space Capability	
Country	Score
U.S.	40.00
Europe	14.82
Russia	12.17
Israel	2.62
China	2.34
India	0.36
Japan	0.27
South Korea	0.18
Brazil	0.18
Canada	0.18



Military Space Capability weighted at 40

Space Capabilities of US[36]

The satellite communication has been a vital part of the US military throughout the space age, beginning in 1946, when the Army achieved radar contact with the moon. In 1954, the Navy began communication experiments using the moon as a reflector, and by 1959, it had established an operational communication link between Hawaii and Washington, D.C. The first artificial communication satellite, Project SCORE (Signal Communication by Orbiting Relay Equipment), was launched in 1958. US Military satellite communication or milsatcom systems are typically categorized as wideband, protected, and narrowband. Wideband systems emphasise high capacity, protected systems with antijam features, covertness, and nuclear survivability. The narrowband systems emphasise support to users who need voice or low-data-rate communications and who also may be mobile or otherwise disadvantaged because of limited terminal capability, antenna size, environment, etc.

Wideband Systems

The wideband systems are the Defence Satellite Communication Systems (DSCS) II and III and the Global Broadcast Service (GBS) payload on the UHF Follow-On (UFO) satellite. The Global Broadcast Service (GBS) mission is to deliver high-rate intelligence, imagery, and map and video data to tactical forces using small, portable terminals. The payload uses 30-gigahertz uplink and 20-gigahertz downlink frequencies, often called Ka-band (EHF).

UFO and Interim Polar EHF

The Interim Polar Programme adapted the UFO/EHF payload for use on host satellites in high-inclination orbits. These payloads communicate with military forces operating above 65 degrees north latitude, where visibility to geostationary-orbit satellites is poor or impossible.

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36. The Aerospace Corporation Magazine of Advances in Aerospace Technology http://www.aero.org/publications/crosslink/winter2002/01.html. Retrieved on November 6, 2009.

Narrowband Communication

Narrowband needs, generally in the ultrahigh-frequency (UHF) range are supported by the UFO constellation, which will be replaced by a component of the Advanced Narrowband System.

Wideband Gap-filler Satellites

The Wideband Gap-filler Satellite programme provides the next generation of wideband communications. Programme includes a high-capacity two-way Ka-band capability to support mobile and tactical personnel and Global Broadcast Service.

Protected Systems

Systems in the protected segment of the milsatcom architecture are the Milstar system and the Air Force Satellite Communications (AFSATCOM) and extremely high frequency (EHF) payloads. The Milstar system is designed to emphasise robustness and flexibility. The terminal segment, developed by the Air Force, Navy, and Army, contains more than 1000 terminals of many types; some are vehicle-transportable or human-portable, while others are located at fixed sites or on airborne command posts or other aircraft, ships, or submarines. Antenna diameters vary from 14 centimetres for submarine terminals to 3 metres for fixed command-post terminals.

Advanced Wideband System

The successor to the Defence Satellite Communications System and the Wideband Gap-filler Satellite programme is the Advanced Wideband System. A constellation of advanced wideband-capable satellites is planned with a first launch by 2010.

Advanced EHF

In November 2001, the Advanced Extremely High Frequency (AEHF) System contract was awarded to the Lockheed Martin Space Systems and TRW Space and Electronics. The system will eventually give way to the AEHF system. The AEHF System will have up to 12 times the total throughput of Milstar.

Advanced Polar System

Two satellites in highly inclined, highly elliptical molniya orbits have been recommended for protected polar satellite communication to support submarines, aircraft, and other platforms and forces operating in the high northern latitudes.

Advanced Narrowband System

The Advanced Narrowband System is next-generation narrowband tactical satellite communications system. Advanced Narrowband System is estimated to be fully operational by 2013. The number of narrowband satellite communication terminals of all types is expected to approach 82,000 in 2010. The details of important US dedicated military space systems are summarised in the Table 3 given as under:-

Table 3: US DEDICATED MILITARY SPACE SYSTEMS[37, 38]

Current programmes	Function	Orbit	Constellation	systems
Defence Satellite Communications System III	Communication	GEO	9	Wideband Global SATCOM (2007); Advanced Wideband System(2009)
Military Satellite Communication System (Milstar)	Communication	GEO	5	Advanced Extremely High Frequency(2008); transformational satellite Communications System (TSAT) (2016)
Interim Polar Satellite Programme	Communication	GEO	2	Enhanced Polar System (2014)
UHF Follow-on Satellite	Communication	GEO	9	Mobile User Objective System (MUOS) (2010)
Satellite Data System	Communication	GEO	4	
Defence Meteor-ological Satellite Programme	Weather	LEO	5	

37. *Space Security*, October 2009 at www.spacesecurity.org.
38. Union of Concerned Scientists, "Satellite Database" (January 2007).

Current programmes	**Function**	**Orbit**	**Constellation**	**Systems**
Defence Support Programme	Early Warning	GEO	7	Space Based Infrared System (2009);Space Tracking and Surveillance System (2007)
N/A	Tactical Warning			Space Radar (2016)
Crystal	Remote sensing	LEO	4	
Lacrosse	Remote sensing	LEO	4	
Misty	Remote sensing	LEO	1	Programme cancelled (2007)
Naval Ocean Surveillance System (NOSS)	SIGINT	LEO	17	
Mentor (Advanced Orion)	SIGINT	GEO	4	
Vortex (Mercury)	SIGINT	GEO	2	
Trumpet (SB-WASS)	SIGINT	HEO	3	

The US has cancelled Misty Stealth Reconnaissance Imaging programme due to costs, schedule delays, and poor performance.[39, 40] In addition to these dedicated systems, space-based military communications use commercial operators such as Globalstar, Iridium, Intelsat, Inmarsat, and Telstar. The US DOD will likely to remain dependent on these services in the future, even with the deployment of new systems.[41]

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39. Philip Taubman, "In Death of Spy Satellite Program, Lofty Plans and Unrealistic Bids," *New York Times*, November 11, 2007, referred from www.spacesecurity.org (Space Security 2009 Oct 09 Publication), accessed on November 2009.
40. Mark Mazzetti, "Spy Director Ends Program on Satellites," *New York Times*, June 22, 2007, referred from www.spacesecurity.org (Space Security 2009 Oct 09 Publication) accessed on November 1, 2009.
41. www.spacesecurity.org (Space Security 2009 Oct 09 Publication) accessed on November 1, 2009.

Space Capabilities of China

China's space programmes reflect a typical power and independence scenario using knowledge obtained in the field of ballistic missiles. In 1970, China launched its first satellite and became the fifth space power.[42] Initially the space programme of the People Republic of China (PRC) was organised under the People's Liberation Army, particularly the Second Artillery Corps. In the 1990s, however, the PRC reorganised the space programme as part of a general reorganisation of the defence industry to make it resemble with the Western defence procurement. The China National Space Administration (CNSA), an agency within the Commission of Science, Technology and Industry for National Defence, is now responsible for launches. The Long March rocket is produced by the China Academy of Launch Vehicle Technology, and satellites are produced by the China Aerospace Science and Technology Corporation. These organisations are state-owned enterprises. However, it is the intent of the PRC government that they are not only state managed but also behave as private companies like the companies in the West.[43] China has an extensive array of space capabilities which range from satellite design and manufacture to launch services and on-orbit operations. The summary of China's major space systems concerning military applications are tabulated in Table 4.

Table 4: SPACE PROGRAMME OF CHINA[44]

Mission Type	Current Programme	Last Launch	On-orbit Life	Characteristics
Imagery	ZY-2A(JB-31) ZY-2B(JB-32) ZY-2C(JB-33)	Sep 2000 Oct 2002 Nov 2004	2+ years 2+ years 2+ years	Data downlink; manoeuvrable believed to have 2 m resolution.
	FSW- 35(JB-4)	Aug 2005	18 days	De-orbited to develop imagery; manoeuvrable; 1 m resolution

42. Fernand Verger, *The Cambridge Encyclopaedia of Space, Mission, Applications and Exploration*, p. 153.

43. http://en.wikipedia.org/wiki/Space_program_of_China# History_and _recent_ developments#Historyand_recent_developments.

44. http://www.au.af.mil/au/awc/awcgate/awc/smith.pdf, PSP -- China and Space Superiority, File Format: PDF/Adobe Acrobat. And http://www.astronautix.com/country/china.htm; and http://space.skyrocket.de/index_frame.htm?http: //www.skyrocket.de /space/ doc_sdat/spirale-1.htm

Mission Type	Current Programme	Last Launch	On-orbit Life	Characteristics
ELINT	SJ-6-2A SJ-6C SJ-6-2B SJ-6D	Oct 2006		Official purpose was to measure the space environment, but foreign analysts suspected a SIGINT role.[45]
	Amstar 2R	Oct 1997	10+ years	27 C-band, 13 Ku-band transponders
	Amstar 5	Nov 2004	13 years	28 C-band, 16 Ku-band transponders.
	Amstar 6		14 years	28 C-band, 12 Ku-band transponders.
	Nigcomasat	Apr 2005 13 May 2007		**DFH-4 communication** satellite; China's first commercial payload sale, and Nigeria's first commercial communications satellite. Payload consist of 4 C-band, 14 Ku-band, 8 Ka-band, and 2 L-band transponders.
	Shingling 22A	10 Mar 2007		Military communications satellite, launched to replace Zhongxing 22[46].
	Tina Lain 1	25 April 2008		Configuration unknown, but possibly based on the **DFH-4 platform.**
Navigation	Beidou	May 2003	8	China will develop a global navigation system by 2020. Two satellite constellation with on-orbit spare; regional system focused on China. China will launch more navigation satellites in 2009-2010 to develop the second-generation Beidou satellite navigation system-China's equivalent to the US GPS navigation system. In future, the whole Beidou (Compass) constellation will consist of 30 stars, including 27 MEO satellites (9 stars for each orbit plane) and 3 GSO satellites. Beidou-II is developed from the DFH-3 platform.[47]

45. http://www.astronautix.com/country/china.htm
46. http://www.astronautix.com/country/china.htm.
47. http://www.china-defense-mashup.com/?tag=china-space-power Beijing, 01Jan 09 (China Military News cited from *China Daily*).

Mission Type	Current Programme	Last Launch	On-orbit Life	Characteristics
Remote Sensing	ZY-1 (CBERS)	Oct 2003	2+ years	China-Brazil Earth Resources Satellite; sun-synch orbit; 20m resolution CCD camera; visible, IR spectral scanners
	HY-1A	May2002	2+ years	Maritime surveillance satellite; 360 kg
	Haiyang 2	Late 2009	-	3rd maritime surveillance satellite.[48]

Additional Details

Remote Sensing

Yaogan-1 satellite is JB (JianBing)-5 SAR reconnaissance satellite and the Yaogan-2 is JB-6(FWS-2) digital imaging spy satellite. JB-5 is China's first practicable Space real-time SAR reconnaissance satellite. And JB-6 is China's most advanced decimetre level digital imagining reconnaissance satellite. On April 23, 2009 China launched "Yaogan VI" imaging reconnaissance satellite. China has launched six Yaogan series of Remote Sensing satellites with decimetre resolution. In addition China has launched HJ-1, a back-up for JB satellites, including two small imaging spy satellites and one SAR satellite. The primary star was launched in the later half of 2007. HJ-1 system is a formation flying and distributing constellation for tracking aircraft carrier group. China's plan is to build a 4+4 constellation through international cooperation. Finally HJ-1 can help partner countries to monitor the naval forces on their peripheral sea area. Iran, Pakistan, Brazil and Egypt are probably the potential clients of China.[49]

Military Space Projects

The military specific space projects of China are tabulated as under Table 5.[50]

48. http://www.atimes.com/atimes/China/JL23Ad02.htm
49. http://www.china-defense-mashup.com/?p=12.
50. http://space.skyrocket.de/index_frame.htm?http://www.skyrocket.de/space/doc_sdat/spirale-1.htm

Table 5: Military Space Projects

Military satellites Communication	FH 1, 2 (ZX 22, 22A) ST 1 (ZX 20)
ELINT	JSSW 1, 2, 3 (CK-1 1, 2 ,3)
Navigation	BD 1A, 1B, 1C, 1D BD 2G, BD 2M
Reconnaissance, Imaging	FSW-0 1, 2, 3, 4, 5, 6, 7, 8, 9 (JB-1 1, .9) FSW-1 1, 2, 3, 4, 5 (JB-1A 1, 2, 3, 4, 5) FSW-2 1, 2, 3 (JB-1B 1, 2, 3) FSW-3 1, 2, 3, 4, 5 (JB-4 1, 2, 3, 4, 5) Yaogan 2, 4, 7 (JB-6 1, 2, 3) Yaogan 5 (JB-8 1) Yaogan 6 (JB-7 1) Yaogan 8 Yaogan 9A, 9B, 9C ZY 2A, 2B (JB-3 1, 2)
Reconnaissance, Radar	Yaogan 1, 3 (JB-5 1, 2)
ASAT[51]	SC-19 , Space-Based ASAT System.

Launch Sites in China.[52]

(a) South China. Sea Launch Area. *Latitude*: 24.0000. *Longitude*: 116.0000.

(b) Taiyuan. Orbital Launch Site. *Location*, Taiyuan Space Center, Wuzhai. *Latitude*: 39.1432. *Longitude*: 111.9674.

(c) Xichang. Type: Orbital Launch Site. *Location*, Xichang Space Center. *Latitude*: 28.2465. *Longitude*: 102.0281.

(d) Wenchang Obital Satellite Launch Center (WSLC)[53]

In 2009-10, China has plan to construct its new launch facility on Hainan Island where the new Long March 5 heavy lift launch vehicle will be based[54].

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51. China National Space Administration (CNSA), http://en.wikipedia.org/wiki/China_National_Space_Administration
52. http://www.astronautix.com/country/china.htm.
53. See No. 43.
54. Peter J Brown, no. 33.

Tracking Stations[55]. The details of domestic tracking stations are:

(a) Weinan Station.	(f) Tianshan Station.	**Overseas Tracking Stations**
(b) Changchun Station.	(g) Xiamen Station.	Karachi
(c) Qingdao Station.	(h) Lushan Station.	Tarawa
(d) Zhanyi Station.	(j) Jiamusi Station.	Malindi
(e) Nanhai Station.	(k) Dongfeng Station.	Swakopmund
	(l) Hetian Station.	**Shared facility:** France, Brazil, Sweden and Australia

55. http://en.wikipedia.org/wiki/Space_programofChina#History_and_recent_developments#History_and_recent_developments.

Space Capabilities of Pakistan

The Pakistan Space Agency or Space and Upper Atmosphere Research Commission (SUPARCO) is the Pakistan government space agency responsible for Pakistan's space programme. It was formed in September 1961.[56] It is a semi-civilian controlled space agency of Pakistan. The headquarters of SUPARCO is located in Karachi. Pakistan was the first South Asian country to start its space programme.[57] On June 7, 1962 Rehbar-I was successfully launched from Sonmiani Satellite Launch Centre with two US rocket motors the Nike-Cajun, setting the beginning of programme of continuing cooperation in space research of mutual interest.[58] The Programme was decommissioned on April 8, 1972.[59]

Communication Satellites

Badr-1 Digital Communication Satellite

Pakistan launched its Badr-1, Pakistan's first indigenously developed Digital Communication Experimental satellite in 1990 from Xichang Satellite Launch Centre, People's Republic of China aboard a Long March 2E. The satellite successfully completed its designed life. The launch of satellite was the key success to SUPARCO.[60]

PAKSAT-1 Telecommunication Satellite

Pakistan's Paksat-1 (C and Ku band) satellite was originally known as Palapa. It was launched by Hughes Space and Communications Company for Indonesia. Later Indonesia declared the satellite unusable after an electric power anomaly. The satellite was then acquired by Pakistan from M/s Hughes Global Services on full time leasing and relocated the satellite to

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56. http://www.suparco.gov.pk/pages/history.as
57. http://worldofaerospace.googlepages.com/Aerospace.htm
58. http://www.wisconsinproject.org/countries/pakistan/hatf.html
59. See No. 56
60. http://en.wikipedia.org/wiki/Pakistan%27s_Satellite_Launch_VehicleCommission.

Pakistan's reserved slot at 38 Degree East longitude on 20 Dec 2002, with 0-degree inclination.The PAKSAT Satellite will be decommissioned from its services in the late 2012.[61]

Badr-4 Communication Satellite

On November 8, 2006, SUPARCO launched its BADR-4 on a Proton Breeze M rocket from Baikonur Cosmodrome, Russia. BADR-4 is located at 26.0°E. BADR-4 was developed by Pakistani space agency SUPARCO.[62]

Badr-6 Communication Satellite

After the success of BADR-4, communication satellite, the Arabsat led another agreement with SUPARCO on June 16, 2007, in which SUPARCO will develop another upgrade version of BADR Satellite. The fifth-generation satellite is to be located at the 30.5°E. The satellite is expected to be launched in late 2009 or early 2010.[63]

PAKSAT-1R Communication Satellite

By the end of 2011, Pakistan plans to replace PAKSAT-1 with a new high technology powered communication satellite, PAKSAT-1R, which will be manufactured exclusively for Pakistan in People's Republic of China. The satellite will have a total of 30 transponders, 18 in Ku-band and 12 in C-band.[64] SUPARCO also has plan that the satellite will be launched from either a Pakistan-build Polar Satellite Launch Vehicle (PSLV) or a Satellite Launch Vehicle (SLV).[65]

Earth Observational Satellite

Badr-B (Earth Observational Satellite)

On December 10, 2001, Pakistan launched its second satellite, Badr-B, an

61. http://space.skyrocket.de/index_frame.htm?http://space.skyrocket.de/doc_sdat/palapa-c.htm
62. "Badr 4 at 26.0°E". LyngSat. http://www.lyngsat.com/badr4.html.
63. http://en.wikipedia.org/wiki/Pakistan%27s_Satellite_Launch_VehicleCommission
64. http://www.suparco.gov.pk/pages/paksat1r.asp?satlinksid=1
65. http://pakistanledger.com/2009/05/14/pakistans-own-slv-and-paksat-launch/

Earth observation satellite from Baikonur Cosmodrome, Kazakhstan aboard a Russian Zenit-2 rocket, Russia.[66]

Resolution Remote Sensing Satellite (RRSS)

After successful launching and operation of BADR series of experimental Low Earth Observational satellites (BADR-1 and BADR-B) in the 1990s and early 2001, SUPARCO now plans to launch high resolution 'Resolution Remote Sensing Satellite System (RRSSS)' to meet the national and international user requirements in the field of satellite imagery.[67] SUPARCO plans to launch the satellite with payload of 2.5 meter PAN in 700 km sun-synchronous orbit by the end of year 2011[68].

Polar Satellite Launch Vehicle Project (PSLV)

In March 2005, President General Musharraf authorised renewed research and development on an indigenous launch capability, which would be able to launch a planned domestically built satellite, the PAKSAT-IR. However, the status of SLV and PSLV remained unclear.[69]

Hypersonic Rocket Launch Vehicle Project (HRLV)

Recently, Pakistan has already tested two high-altitude hypersonic sounding rockets; Shahpar solid-fuel two stage rocket can carry a payload of 55-70 kilograms to an altitude of 950 kilometres, and Rakhnum is a three stage liquid-fuel rocket, which can lift a payload of 38-56 kilograms to an altitude of 1000 kilometre.[70]

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66. http://images.google.com/imgres?imgurl=http://centaur.sstl.co.uk /SSHP/pix /zenit_fitchack.jpg&imgrefurl=http://centaur.sstl.co.uk/SSHP/micro/micro2001.html&usg=__tCbSsWsGjGwA4n8avLSFlKsQ4UE=&h=823&w=904&sz=125&hl=en&start=4&um=1&tbnid=Ys7loCNbV-zy2M:&tbnh=134&tbnw=147&prev=/images%3Fq%3DSUPARCO%26hl%3Den%26sa%3DN%26um%3D1.
67. http://www.suparco.gov.pk/pages/prss.asp.
68. Ibid.
69. http://indonesiaarab.wordpress.com/2008/09/17/pakistan-plans-to-launch-its-own-satellite/
70. http://en.wikipedia.org/wiki/Pakistan%27s_Satellite_Launch_VehicleCommission.

Space Capabilities of India

Indian Space Research Organisation (ISRO)

In 1957, the Soviet Union successfully launched the Sputnik and opened up possibilities for the rest of the world to conduct a space launch. Government support became visible by 1950 when the Department of Atomic Energy (India) was founded with Homi Bhabha as secretary. The Department of Atomic Energy provided funding for space research throughout India. The Indian National Committee for Space Research (INCOSPAR) was found in 1962 with Vikram Sarabhai as its chairman. The ISRO in its modern form was established in 1968 and is the primary body for space research under the control of the Government of India.[71] The prime objective of ISRO is to develop space technology and its application to various national tasks. The Indian space programme was driven by the vision of Dr Vikram Sarabhai, considered as the father of Indian Space Programme. Antrix Corporation is the commercial wing of ISRO, the marketing agency under government control established at Bangalore in 1992[72].

Launch Vehicles[73]

Satellite Launch Vehicle (SLV)

Its first launch took place in 1979 with two more in each subsequent year, and the final launch in 1982. Only two of its four test flights were successful.[74]

Augmented Satellite Launch Vehicle (ASLV)

The first launch test was held in 1987, and after that three others followed in 1988, 1992 and 1994, out of which only two were successful, before it was decommissioned.[75]

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71. http://en.wikipedia.org/wiki/Space_program_of_India#searchInput#searchInput.
72. http://en.wikipedia.org/wiki/Space_program_of_India#cite_ref-daniel488_3-3.
73. Ibid.
74. "ISRO milestones", ISRO. http://www.isro.org/mileston.htm. Retrieved on October 1 2009
75. ASLV". ISRO. http://www.isro.org/aslv.htm. Retrieved on October 10 2009.

Polar Satellite Launch Vehicle (PSLV)

PSLV is used to launch Remote Sensing (IRS) satellites into sun synchronous orbits. PSLV can also launch small satellites into geostationary transfer orbit (GTO). The reliability and versatility of the PSLV is proven by the fact that it has launched 30 spacecraft (14 Indian and 16 from other countries) into a variety of orbits so far. In April 2008, it successfully launched 10 satellites at once, breaking a world record held by Russia.[76]

Geosynchronous Satellite Launch Vehicle (GSLV)

The Geosynchronous Satellite Launch Vehicle, known by its abbreviation GSLV, is an expendable launch system developed to enable India to launch its INSAT-type satellites into geostationary orbit and to make India less dependent on foreign rockets. At present, it is ISRO's heaviest satellite launch vehicle and is capable of putting a total payload of up to five tons to Low Earth Orbit.[77]

Tracking and Control Facilities[78]

Facility	Location	Description
Indian Deep Space Network (IDSN)	Bangalore	This network receives, processes, archives and distributes the spacecraft health data and payload data in real time. It can track and monitor satellites up to very large distances, even beyond the Moon.
National Remote Sensing Agency	Hyderabad	The NRSA applies remote sensing to manage natural resources and study aerial surveying. With centres at Balanagar and Shadnagar it also has training facilities at Dehradun in form of the Indian Institute of Remote Sensing.

76. http://en.wikipedia.org/wiki/Space_program_of_India#cite_ref-daniel488_3-3
77. Ibid.
78. http://en.wikipedia.org/wiki/Space_program_of_India#searchInput#searchInput

Facility	Location	Description
Indian Space Research Organisation Telemetry, Tracking and Command Network	Bangalore (headquarters) and a number of ground stations throughout India and World.	Software development, ground operations, and Tracking Telemetry and Command (TTC), support are provided by this institution. ISTRAC has its headquarters and a multi-mission Spacecraft Control Centre at Bangalore. It has a network of ground stations at Bangalore, Lucknow, Sriharikota, Port Blair and Thiruvananthapuram in India besides stations at Port Louis (Mauritius), Bearslake (Russia), Brunei and Biak (Indonesia)[79]. The master control facility (MCF) at Hassan in Karnataka monitors and controls INSAT-4A and utilises the ground stations at Beijing (China), Fucino (Italy) and Lake Cowichan (Canada). The ISRO telemetry, tracking and command network (ISTRAC) ground station at Biak in Indonesia also monitors the satellite. The satellite's orbit is precisely determined by continuous ranging from the participating ground stations[80].
Master Control Facility	Hassan; Bhopal	Geostationary satellite orbit raising, payload testing and in-orbit operations are performed at this facility. The MCF has earth stations and Satellite Control Centre (SCC) for controlling satellites. A second MCF-like facility named 'MCF-B' is being constructed at Bhopal[81]

79. http://www.isro.org/GroundFacilities/trackingfacility.aspx.

80. http://battakiran.wordpress.com/category/isromilitary-missiles/Battakiran's Weblog, October 22, 2008.

81. http://www.isro.org/space_science/images/BalloonXrayStudies.htm.

Communication Satellites[82]

On the communications front, about 210 transponders of the INSAT series of satellites were in orbit in the year 2008. ISRO is looking forward to increase the number of transponders from 210 to 500.

The details of important geo-stationary and LEO satellites are tabulated in Table 7 and Table 8, respectively.

Table 7: Communications and Geo-stationary Satellites details of Isro Satellites[83]

Satellite	Date	Launch Vehicle	Type of Satellite
INSAT-4CR	02.09.2007	GSLV-F04	Geo-Stationary communication Satellite. Carries 12 Ku band transponders and a Ku band beacon that aids satellite based tracking. It is designed to provide DTH television, VSAT, and high bit-rate data transmissions. It is a replacement for INSAT-4C that was lost in a launch failure in June[84].
INSAT-4C	10.07.2006	GSLV-F02	Geo-Stationary communication satellite.
INSAT-4B	12.03.2007	Ariane-5ECA	Geo-Stationary Satellite. It carries 24 transponders, 12 in the high-power Ku band. Twelve transponders in the C band are for TV, radio and telecommunications[85].
INSAT-4A	22.12.2005	Ariane-5GS	Geo-Stationary Communication Satellite. INSAT-4A carries payloads of: 12 ku-band 36 MHz bandwidth transponders; 12 C-band 36 MHz bandwidth.

82. See No. 81
83. http://www.isro.org/satellites/allsatellites.aspx.
84. http://www.isro.org/pressrelease/Sep02_2007.htm.
85. Hindu Business Line, http://www.thehindubusinessline.com/2007/03/13/stories/2007031303381000.htm, March 13, 2007.

Satellite	Date	Launch Vehicle	Type of Satellite
EDUSAT (GSAT-3)	20.09.2004	GSLV-F01	Geo-Stationary Communication Satellite. Edusat is built to serve the educational sector.
INSAT-3E	28.09.2003	Ariane-5G	Geo-Stationary communication Satellite. Carries 24 Normal C-band transponders; 12 Extended C-band transponders[86].
GSAT-2	08.05.2003	GSLV-D2	Geo-Stationary communication Satellite. Carries four C-band transponders, two Ku-band transponders, one MSS payload consisting of S-band forward link and C-band return link.
INSAT-3A	10.04.2003	Ariane-5G	Geo-Stationary Communications, Meteorology Satellite. Carries 12 C-band, six extended C-band, six Ku-band for voice, and video and data transmission to West Asia, East Asia, India.
KALPANA -I	12.09.2002	PSLV -C4	Geo-Stationary MET Satellite.
INSAT-3C	24.01.2002	Ariane-42L H10-3	Geo-Stationary Satellite. It carries Fixed Satellite Services (FSS) transponders, Broadcast Satellite Services (BSS) transponders and Mobile Satellite Services (MSS) transponders.
INSAT-3B	22.03.2000	Ariane-5G	Geo-Stationary communication Satellite[87].

86. *The Hindu*, http://www.hindu.com/2003/09/23/stories/2003092300981300.htm, September 23, 2003.

87. http://www.isro.org/insat3b.htm.

Table 8: REMOTE-SENSING/LEO SATELLITES[88, 89]

Satellite	Date	Launch Vehicle	Type of
CARTO-SAT-3	Planned to be launched in 2010	PSLV	Earth Observation Satellite and strategic applications for reconnaissance and military spying, having a resolution of 25 cm[90].
Oceansat-II	23.09.2009	PSLV-C14	Earth Observation Satellite. Multi-spectral swath has been enhanced from 23 km to 70 km based on user needs[91].
ANUSAT	20.04.2009	PSLV-C12	Experimental / Small Satellite
RISAT-2	20.04.2009	PSLV-C12	Earth Observation Satellite, SAR
Chandrayaan-1	22.10.2008	PSLV-C11	Space Mission
CARTO-SAT - 2A	28.04.2008	PSLV-C9	Earth Observation Satellite, resolution sub-metre. For use by MoD[92].
IMS-1	28.04.2008	PSLV-C9	Earth Observation Satellite
CARTO-SAT - 2	10.01.2007	PSLV-C7	Earth Observation Satellite. Resolution sub-metre[93].
SRE - 1	10.01.2007	PSLV-C7	Experimental / Small Satellite
CARTOSAT-1	05.05.2005	PSLV-C6	Earth Observation Satellite. Resolution 2.5M[94].
HAMSAT	05.05.2005	PSLV-C6	Experimental / Small Satellite
IRS-P6	17.10.2003	PSLV-C5	Earth Observation Satellite

88. http://en.wikipedia.org/wiki/CARTOSAT-1.
89. http://www.isro.org/satellites/allsatellites.aspx.
90. http://en.wikipedia.org/wiki/CARTOSAT-3.
91. http://www.isro.org/scripts/futureprogramme.aspx#top.
92. *Business Daily* from THE HINDU group of publications, http://www.thehindubusinessline.com/2008/01/23/stories/2008012350332800.htm, Wednesday, January 23, 2008.
93. http://en.wikipedia.org/wiki/Cartosat-2A.
94. http://en.wikipedia.org/wiki/CARTOSAT-1.

Forthcoming Satellites[95]

Megha-Tropiques

ISRO and French National Space Centre (CNES) signed a Memorandum of Understanding (MOU) in 2004-05 for the development and implementation of Megha-Tropiques (Megha meaning cloud in Sanskrit and Tropiques meaning tropics in French). The launch of Megha-Tropiques is planned in 2010.

GSAT-4

GSAT-4 is envisaged as a technology demonstrator. The communication payload consists of multi-beam Ka-band bent pipe and regenerative transponder and navigation payload in C-band, L1 and L5 bands. Its launch is planned in early 2010.

INSAT-3D

INSAT-3D is a meteorological satellite planned to be launched in the year 2010.

ASTROSAT

ASTROSAT is a multi-wavelength space borne astronomy satellite to be launched during 2010.

GSAT-5 / INSAT-4D

It is a C-band and Extended C-band satellite, carrying 18 transponders. It will provide wider coverage in uplink and downlink to cover Asia, Africa and Eastern Europe/Zonal coverage.

GSAT-6 / INSAT-4E

The primary goal of GSAT-6/INSAT-4E which is a Multimedia mobile S-band satellite The satellite is planned to be launched during 2010 by GSLV.

GSAT-7 / INSAT-4F

GSAT-7/INSAT-4F is proposed as a multi-band satellite carrying payloads in UHF, S-band, C-band and Ku-band.

95. http://www.isro.org/scripts/futureprogramme.aspx#top

GSAT-8 / INSAT-4G

GSAT-8/INSAT-4G is proposed as a Ku-band satellite carrying 24 transponders similar to that of INSAT-4A and INSAT-4B. It will also carry the second GPS Aided Geo Augmented Navigation (GAGAN) payload.

GSAT- 11

India will soon design and develop its heaviest communications satellite GSAT-11 (4.5 ton), to provide advanced telecom services from 2011-12. The satellite will be consisting of 40 transponders in Ku/Ka band and GSLV-Mark III will be used to launch the satellite. With a dry mass of 2.1 ton, the spacecraft will provide 10 GHz of bandwidth, equivalent to about 220 transponders of 36 MHz .[96]

Defence Communication Satellites

To meet the space-based communication requirements of defence forces dedicated military satellites have been planned by Navy, Air Force and the Army. Navy will have the satellite by 2010, followed by Air Force and Army.[97]

Forthcoming Launch Vehicle / Launches[98]

GSLV-D3

Preparations for the next flight Geo-synchronous Satellite Launch Vehicle (GSLV-D3) carrying GSAT-4 is in advanced stage. The GSLV-D3 is expected to use indigenous cryogenic engine and will place the GSAT-4 in geosynchronous transfer orbit during 2010.

GSLV-F06

Geo-synchronous Satellite Launch Vehicle (GSLV-F06) for carrying INSAT-3D is in advanced stage of realisation. The GSLV-F06 is expected be launched during 2010.

GSLV-Mk III

GSLV-Mk III is envisaged to launch four ton satellite into geosynchronous

96. http://www.spacemart.com/reports/India_Building_Four_Tonne_Satellite_Bus_999.html, By Staff Writers, Bangalore, India (IANS) July 27, 2009

97. AK Antony, Defence Minister, *The Times of India*, New Delhi, October 23 2009

98. http://www.isro.org/scripts/futureprogramme.aspx#top.

transfer orbit. GSLV-Mk III. GSLV Mk-III will have a lift-off weight of about 629 ton and will be 42.4 m tall.

Reusable Launch Vehicle-Technology Demonstrator (RLV-TD)

The RLV-TD will act as a flying test bed to evaluate various technologies. First in the series of demonstration trials is the hypersonic flight experiment (HEX).

Human Space Flight Mission Programme

The programme envisages vehicle carrying two or three crew members to 275 km low earth orbit and their safe return. It is planned to realise the programme in about seven year time frame.

Space Capsule Recovery Experiment (SRE-II)

The main objective of SRE II is to realise a fully recoverable capsule and provide a platform to conduct microgravity experiments on Micro-biology, Agriculture, Powder Metallurgy, etc.

Aditya-1

Aditya-1 is the first Indian space-based Solar Coronagraph to study solar corona in visible and near IR bands. Launch of the Aditya mission is planned during the next high solar activity period - 2012.

Satellite Navigation

GAGAN

The Ministry of Civil Aviation has decided to implement an indigenous Satellite-Based Regional GPS Augmentation System also known as Space-Based Augmentation System (SBAS) as part of the Satellite-Based Communications, Navigation and Surveillance (CNS)/Air Traffic Management (ATM) plan for civil aviation. The Indian SBAS system has been given an acronym GAGAN - GPS Aided GEO Augmented Navigation. The first navigation payload is being fabricated and it is proposed to be flown on GSAT-4, which is expected to be launched in 2010. Two more payloads will be subsequently flown, one each on two geostationary satellites GSAT-8 and GSAT-12[99].

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99. http://www.isro.org/scripts/futureprogramme.aspx#top

Ground System

To analyse the requirement of ground satellite terminals of Indian defence forces, the US systems can be considered for future planning. The details are enumerated in succeeding paragraphs.

US Ground Terminals[100]

To meet the ground terminals requirement, it is expected that by 2010, the US will induct about 2500 terminals in the protected communications inventory for the Air Force, Navy, Army, and Marines. Portable, mobile, and fixed terminals with low, medium, and high data rates will support ground units, aircraft, surface ships, and submarines. Standard antennas will range in size from a few centimetres to about three metres. Applicable milsatcom terminals include the Family of Advanced Beyond line-of-sight Terminals (FAB-T), the Single-Channel Antijam Man-Portable Terminal (SCAMP), Secure Mobile Antijam Reliable Tactical Terminal (SMART-T), and Submarine High Data Rate (Sub HDR) system. The FAB-T combines two previous programmes, the Airborne Wideband Terminal and Command Post Terminal. The Ground Multiband Terminal is a tactical satellite communications ground terminal that will support operations in the X, C, Ku, and military Ka bands. The Army's Enhanced Manpack UHF Terminal with US defence forces, is capable of being carried, set up, and can be used by a single soldier. It communicates via the UFO satellites.[101]

Mobile Users

The Mobile User Objective System will employ commercial technology to enable communications with users of large terminals and small or handheld terminals. Commercial systems such as Thuraya in the Middle East and AceS in Southeast Asia have shown that more than 10,000 low-data-rate handheld terminals can be serviced over a region with one satellite.[102]

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100. http://www.aero.org/publications/crosslink/winter2002/01.html.
101. Ibid.
102. Ibid.

First Advanced Satcom Production Terminal[103]

Raytheon and the US Army recently completed successful testing of the first Advanced Extremely High Frequency, or AEHF, satellite communication production terminals). Raytheon's Secure Mobile Anti-jam Reliable Tactical Terminal (SMART-T) offers the next generation of protected communications with AEHF satellites.

SATCOM Ground Terminals for Indian Defence Forces of Future

From the analysis of US ground terminals it is clear that the future India's armed forces SATCOM terminals of all types must be smaller, lighter, embedded with secrecy. The satellite terminal with protected communication features like that provided by US Milstar and its follow-on AEHF (V-band) is not a luxury but a necessity for defence forces to operate in the hostile electronic environment. Some of the specific features of military satellite ground terminals are as given in following paragraphs.

The Multiband/Multimode Integrated Satellite Terminal

Today most terminals used by the forces are a single purpose/single user classification. In the future, the numbers, types, and size of communication terminals should be reduced. The multiband multimode integrated satellite terminal as being used and supported by US Advanced MILSATCOM should be planned by defence forces/army for mobile formation and Navy especially for submarine communication. Multiband means that the terminal is able to communicate over three or more bands with the band designated for transmission determined by the system using best available transmission/reception paths with sufficient capacity available to satisfy information requirements. Multimode means that the terminal is capable of selecting a terrestrial or space-based path for transmission based upon best available path. A small multi-capable terminal would significantly improve the tactical mobility and survivability.

Antenna Technology

Moving satellite communications technology into higher frequency bands

103. "The Secure Mobile Anti-jam Reliable Tactical Terminal (SMART-T)", by Staff Writers, Marlborough MA (SPX) July 15, 2009; http://www.spacewar.com/reports/First_Advanced_SatComms_Production_Terminals_Complete_Testing_999.html.

(EHF) would increase capacity, availability and provide fast, high quality transmissions. One of the major problems in moving to higher frequency band (EHF) is to deal with very high fading of signal caused by rain fog and other adverse weather conditions. The potential exists to build with advanced onboard operations and bit-by-bit signal regeneration coupled with new optimization techniques to overcome rain fade problems in the EHF frequencies. Certainly by 2020, these technologies will be a reality and India can plan their system accordingly. The "smart helmet" worn by a future soldier, can be designed to act as antenna and would improve mobility for the foot soldier and assist in decreasing the amount of space needed for storage and transport.

Indigenous Capability

As of now there is no indigenous capability with India to design, develop and manufacture the ground satellite terminals. Some current SATCOM terminals available ex-trade in Ku/Ka bands can be panned to meet the short term/immediate requirements. However there is a need for a concerted effort to reduce the foreign dependence in this important area of space system.

Comparative Analysis of Space Capabilities

The space capabilities of nations with specific reference to US, China, Pakistan and India have been analysed in detail to ascertain India's space preparedness to meet the defence forces space-based communication requirements. The Tables **(Table 9, Table 10 and Table 11)** as listed below analyse/compare the space segment, ground system and other space capabilities of US, China, Pakistan and India based upon the details discussed and brought out in this paper.

Table 9: COMPARATIVE TABLE FOR SPACE SEGMENT

	Frequency	USA	China	Pakistan	India	Remarks
EHF						
	V-Band 43 - 45 GHz / 20-21GHz	Plan by 2010	Cannot say	No	No	Secure, survivable, anti-jam communi-cation
	Ka-Band: 30 - 31 GHz / 20-21 GHz	Yes	Cannot say but most likely	No	Plan by 2010 -11	
SHF						
	Ku-Band: 12 - 14 GHz (Commercial)	Yes	Yes	Yes	Yes	
	X-Band: 7- 8 GHz (Military)	Yes	Cannot say but most likely	No	No	
	C-Band: 4 - 6GHz (Commercial)	Yes	Yes	Yes	Yes	

	Frequency	USA	China	Pakistan	India	Remarks
UHF						
	S/L-Band: 2.5-2.57/1.6 - 1.7 GHz Mobile Satellite Service (MSS)	Yes	Yes	Yes	Yes	
	Military UHF Band: 225 - 400 MHz (SATCOM channels of 5-kHz and 25-kHz bandwidth)	Yes	Yes	No	Plan by 2010	

Table 10: COMPARATIVE TABLE FOR GROUND SEGMENT

	Frequency	USA	China	Pakistan	India	Remarks
EHF						
	V-Band 43 - 45 GHz / 20-21GHz	Plan by 2010	Cannot say	No	No	Secure, survivable, anti-jam communi-cation
	Ka-Band: 30 - 31 GHz / 20-21 Ghz	Yes	Cannot say but most likely	No	Plan by 2010 - 2012	
SHF						
	Ku-Band: 12 - 14 GHz (Commercial)	Yes	Yes	Yes	Yes	
	X-Band: 7- 8 GHz (Military)	Yes	Cannot say but most likely	No	No	
	C-Band: 4 - 6GHz (Commercial)	Yes	Yes	Yes	Yes	

	Frequency	USA	China	Pakistan	India	Remarks
UHF						
	S/L-Band: 2.55-2.57/1.6-1.7 GHz Mobile Satellite Service (MSS)	Yes	Yes	No, the terminals work by hiring channels through foreign service provider	Yes	
	Military UHF Band: 225 - 400 MHz (SATCOM channels of 5-kHz and 25-kHz bandwidth)	Yes	Yes	No	Plan by 2010 - 2012	

Table 11: COMPARATIVE TABLE FOR SPACE CAPABILITIES

Capability	USA	China	Pakistan	India
Communication	Yes	Yes	Yes	Yes
Imagery (less than metre resolution and all weather)	Yes	Yes	No, dependent on foreign source	Yes
Navigation	Yes	Yes	No, dependent on foreign source	Yes planned by 2012
Meteorology	Yes	Yes	No, dependent on foreign source	Yes
Early Warning	Yes	Cannot say	No	No, being less effective
Signal Intelligence	Yes	Yes, less effective [104, 105]	No	No, less effective
GEO Launch capability	Yes	Yes	No	Yes

104. http://www.au.af.mil/au/awc/awcgate/awc/smith.pdf.
105. http://www.spacesecurity.org/publications.htm.

Analysis of the Capabilities to Support Communications

Space Segment

One of the most important features of space-based system is that it provides global coverage. The footprint and beams of the satellite can be planned and managed to suite the regional as well as global scenario of operations. As far as the communication capability for military use is concerned, it is the type of frequency bands of operation that the satellites provide, and type of ground satellite terminals (secure, anti-jam, and other state-of-the-art features); being used by the forces. The requirement of space segment is dependent on the number, type of ground systems and overall communication plan of the forces. Space segment capability and requirements for communication are planned with reference to satellite ground segments and whether it is a primary/secondly media of use. For Indian defence forces satellite communication is a secondary media to most of the locations and primary for remote and offshore communications. From the above, and the capability being planned, it is clear that India has the sufficient space capability to support its defence forces especially in the field of communication, as compared to China.

For communication satellites capability in higher bands, Ka and V-band, which are suitable for protected and survivable communication even in the event of nuclear environment for communication, it is essential that defence forces should carry out adequate trials and develop suitable high performance space and ground segments to ascertain its use in different weather conditions. These bands are extremely susceptible to fading during rain, fog and humidity, and are more suitable for dry weather conditions. Therefore, the planning of communication in higher bands bandwidth should be worked out only after detailed deliberation and trials, in conjunction with ground segment requirements and deployment. Though India's interest in next 10 to 15 years is going to remain regional, unlike US, however a number of satellite beams can/should be planned to provide global coverage, to cover both present and future area of interest at sea and land with steerable beam capability if possible. Few beams which are not needed during peace time can be kept switched off initially, to be switched on at the time of operation when requirement so arise. These features should be incorporated in both dedicated defence and dual use satellites of ISRO.

Ground Segment

For ground satellite communication system, though India's requirements are being met through indirect procurements from foreign nations, India should have indigenous design and manufacturing capability to ensure self reliance in the field of communication space capability in true sense. In communication system it is the ground satellite terminals which are required to be designed to take care of inherent disadvantage of susceptibility of space communication system to jamming. The country therefore, cannot rely on foreign controlled systems for critical communications connectivity. This is the important area, which should require a concerted effort of our developing and production agencies, especially when ISRO can meet/plan the defence bandwidth or satellite requirements indigenously. The ground system being planned by India should be based upon state-of-the-art technology with anti-jam capability with adequate inbuilt redundancy, as discussed under the head of Ground System.

Other Capabilities

As far as other military space applications are concerned, India has imagery capability to provide sub-metre resolution suitable for military needs. For navigation, India has the plan to have regional navigational system by 2011-14,[106] and GPS augmented navigation system by 2011-12. As of now India does not have the capability and interest in the Signal Intelligence and Early Warning Systems, because these applications are not very effective in the present context. However, India should continue R&D to develop the capability indigenously which is cost effective and available to it in future should the requirement so arise.

106. http://www.rediff.com/news/2007/sep/27gps.htm and ISRO Space India Newsletter, April - September 2006 Issue.

Recommendation and Conclusion

Recommendations

Communication in the defence forces is multi layered and flexible. The media could be terrestrial, radio or satellite. Satellite media is planned to provide global coverage and redundancy to other communication media. The satellite communication systems are ideal as primary means of communication for mobile, remote and inhospitable terrain. The above analysis indicates that sufficient space capability exist with India to meet the requirements of its defence forces. The satellites planned by ISRO should carry desired frequency band payload with capability to support hand held narrow band terminals in S-band and wide band terminals (static, transportable and Communication on the Move) in Ku and Ka band. Some payload requirement of large size static terminals (6M, 3M) can also be catered in C-band. Defence forces should plan the dedicated military satellites only when either ISRO is unable to meet the requirement through commercial satellites planned by them or to support protected communication and to meet higher data rate transmission in the frequency band where the commercial usage is limited due to cost and other factors (mainly in UHF, S-band and higher Ka and V-band) and sufficient numbers of ground terminals are inducted to exploit satellite capability. Initially ISRO can configure the commercial satellites planned by them, to carry few numbers of transponders, to support the ground terminals of defence forces. This will help in optimum utilisation of space assets, especially when there is always the constraint of desired orbital slot in geo-stationary orbit and frequency coordination with international body. The aim of any communication planning is that the communication should be reliable, robust and redundant. Space-based communication system has the inherent disadvantage of getting affected by adversary interference and jamming. The dual use satellites for frequency bands being used by both civil and defence, and working through number of satellites having different networks, will also help masking the defence communications, which will indirectly provide protection to defence communication against adversaries' interference/ jamming, thereby virtually achieving the aim of reliability, robustness, and redundancy. The recommended road map and plan for induction of space assets (dedicated military satellites and associated ground system) up to 2022 and beyond are given as under:-

RECOMMENDED ROAD MAP AND PLAN FOR SPACE SEGMENT AND INDUCTION OF GROUND SEGMENT (2022 AND BEYOND)

	Frequency	2012	2012-2017	2017-2022	Beyond 2022	Remarks
EHF						
	V-Band 43 - 45 GHz/ 20 - 21 Ghz	-	-	**Plan space segment** and induct after trials, mobile/ transport -able terminals for forward mobile regiments.	**Plan dedicated satellite** Induct mobile/ Transpor -table, man pack Terminal	**For secure, survivable anti-jam commun- ication, for use by services as per the suitability.**
	Frequency	**2012**	**2012-2017**	**2017-2022**	**Beyond 2022**	**Remarks**
	Ka-Band: 30 - 31 Ghz/ 20 - 21GHz	Plan to induct man pack/ Transport -table terminals after carrying out techn- ical trials of ground segment	**Plan to improve space segment** and induct mobile/ transport -able terminals for army forward mobile /static regiments, survei- llance elements UAV and at Air force as per their require- ment	Induct mobile on the move/ Transport -table and man pack/ portable terminals for defence forces as per require- ment	**Plan dedicated satellite.** Plan to induct multi band terminal to work in V, Ka and Ku band	**For broad band and single channel connec- tivity for all three services.**

	Frequency	2012	2012-2017	2017-2022	Beyond 2022	Remarks
SHF						
	Ku-Band: 12 - 14 GHz (Commercial)	Induct mobile/ Transpor -table terminals for mobile /static regiments surveill -ance elements UAV and at Air force and Navy as per their require -ment	**Improve space segment To support sub metre antenna.** Induct mobile/ Transport -table and man pack/ portable terminals for defence forces as per require- ment	Induct mobile, on the move and man pack/ portable terminals for defence forces as per require- ment	**Plan to improve space segment** Induct and up grade mobile and man pack terminal and replace the terminal inducted initially by 2012	**For Broad band connec- tivity for all three services.**
	X-Band: 7- 8. GHz (Military)	NOT RECOMMENDED FOR DEFENCE SINCE HIGHER BANDS WILL PROVIDE LARGE BANDWIDTH AND TERMINALS BE PLANNED IN Ku, Ka AND V BANDS.				
	C-Band: 4 - 6GHz (Commercial)	For static commu -nication for remote areas and overlay communi- cation to other media.	For static communi- cation for remote areas and overlay commun- ication to other media	Plan up- graded terminals and replace the terminals inducted initially by 2012		For Static communi- cation for defence forces.

	Frequency	2012	2012-2017	2017-2022	Beyond 2022	Remarks
UHF						
	S - Band: 2.5 - 2.57 Mobile Satellite Service (MSS)	**Plan dedicated satellite,** since present satellites do not support handheld terminals Induct man pack/ portable terminals to meet urgent require-ments of defence forces	**Dedic-ated satellite.** Induct mobile and up-graded briefcase terminals for high data rate and hand held terminals for narrow band commun-ication as per require-ment	Induct up-graded hand held terminals and replace the terminals inducted initially by 2012	Induct up-graded hand held to support both wide band and narrow band commu -nication and helmet mount-ed antenna terminal	**The satellite to provide spot beams to cover all area of interest of defence forces.** For troops at all level of all the three services.
	Military UHF Band: 225-400 MHz (SATCOM channels of 5-kHz and 25-kHz bandwidth)	**Use UHF band of satellite being planned by ISRO.** Induct manpack terminals after carrying out technical trials of ground segment	Induct man pack/ portable terminals for defence forces at forward troops level only	Induct man pack/ portable terminals for defence forces as per require-ment		**For troops deployed in forward areas, aviation use, and for Navy and Air Force communi -cation as per require -ment**

Notes:-

1. ISRO/Defence should plan a separate multiband (UHF, S, C, Ku), low capacity satellite, to meet Navy's requirement, to cover the area of interest or additional spot beams with desired payload be catered in the commercial satellites.
2. All communications be planned either on ISRO or defence satellites.
3. All defence ground satellite terminals to work with secrecy only.
4. A number of satellite beams should be planned, to cover both present and future area of interest at sea and land with steerable beam capability if possible. Few beams which are not needed during peace time can be kept switched off initially, to be switched on at the time of operations when requirement so arise.

The above table/roadmap indicates the plan for utilisation and induction of dedicated defence satellites. The various frequency bands for operation are suggested based upon the available/likely availability of technology with India. The US has recently inducted AEHF (V-band) space system for its military use, as brought out earlier. It is assumed that by 2017 India may also be able to master the V-band technology and accordingly both space and ground systems are suggested for planning and induction during that period. The above recommended road map can take care of emergence of different types of war scenario that may unfold in future.

Ka and V-band, are suitable for protected and survivable communication even in the event of nuclear environment, and provide large bandwidth to support high data rate, and the ground terminal size is reduced drastically in comparison to similar terminals in lower frequency bands. Hence the systems working in these bands are most suitable for military communications. However in these bands, the electronic complexity increases many fold and bands are extremely susceptible to fading during rain, fog and humidity, and are more suitable for dry weather conditions. Extensive trials in various weather conditions are necessary to be carried out by Indian defence forces, to ascertain the suitability of applications in these bands, before planning dedicated satellites and large scale induction of ground terminals in these bands.

It should be noted that though we have national capability for planning, designing and launching satellites, however, there is no indigenous capability in real sense to design and manufacture the ground terminals needed to exploit the space system. Having a dedicated defence satellite capability and dependence for ground terminals on foreign nations will actually serve no meaningful purpose, especially when ISRO can meet/plan the defence bandwidth requirements on nation's dual use satellites. This is important because foreign governments, companies, or other international agencies may not respond to or support India's requirements due to political or other issues. The country cannot rely on foreign controlled systems for critical communications connectivity.

Organisation

The various organisations being created and planned should have to look at the space systems in totality that is space and ground systems. Therefore, there should be one competent and qualified agency in each service headquarters for space system that should be fully responsible to conceptualise, plan and implement the projects in totality. Adequate working level staff/officers should be posted to the organisation dealing with the space system. The organisations should be overall responsible for technical planning and complete execution of the project. Creating organisations having only scrutiny/supervisory or coordination role will be inefficient. Space systems are highly technical and require persons who actually understand the system and nuances of space technology. Therefore it must be ensured that persons who are selected for the task have adequate background of the subject and right persons with basic skill sets are imparted training.

Conclusion

The US leadership in military space remains significant based on a significant head start, large budgets, organisational capacity, asset base and capability. The US military space leadership position is likely to be reduced as near-peer challengers Russia and China continue to commit increased resources for military space.

Over the last several decades, China has consistently and effectively invested in developing military space capability through a robust programme focused on developing technological capability and expanding regional coverage. While many Chinese programmes are dual-use, China has built a sophisticated organisational infrastructure supported by an research and development facilities, a robust industrial base, and has publicised its technical prowess in areas of launch vehicles, sensor capability, command and control know-how, anti-satellite technology, and a variety of other essential and advanced military space technologies, supported by a strong organisation and doctrine most of which remains secret. The Chinese military is likely to continue with its high level of investment in space platforms and capabilities. While the force multiplication of these assets impact regional power and gain ground with leaders of military space capability but in the near-term will lag the United States and Russian in terms of overall space capability.

It is a known fact that in the absence of any comprehensive legally binding international treaty on protection of space assets and ban on weaponisation of space, the space assets will remain vulnerable to varieties of threats. For example geo-stationary communication satellite is vulnerable to interference, spoofing and jamming. Low earth orbit satellites are targets of space debris and other ASAT weapons already developed/being developed by various space faring nations.

The threat to space assets is a function of vulnerability and probability of attack by the adversary. The adversary will choose the target for attack only if it is of value to its user, which will be governed by user's dependence on it. Therefore, level of threat can be well equated to degree of dependence as; low, medium and high. The ASATs weapons are generally effective at the low earth orbit satellites and have little or no affect on Geo-stationary communication satellites, which are more vulnerable to electronic interference and jamming. As far as India is concerned, as of now there are about 21 satellites (communication satellites- 10 in GEO, surveillance/imagery satellites with resolution less than 2.5 metre - 04 in LEO, and met/other earth observation satellites- 07), for use by civil and government agencies. Therefore, in low earth orbit the satellites which could be of value for military use are four, and the future population of these satellites will not drastically increase. If we have to grade our military dependence factor for space assets vis-à-vis availability of other alternative systems to support our operations, then the pointer will fall in the area of low dependency unlike US, whose dependence is very high; implying low level of vulnerability and threat for us. To achieve reliability and redundancy for communication systems working through satellite, the defence forces should plan their networks on multiple dual use ISRO satellites along with military specific satellites, as recommended above. To disable all satellites and other platforms simultaneously will not be an easy task for an adversary. In addition, the defence forces should induct the ground systems that have the capability to work in adverse electronic environment to evade the affect of adversary hostile electronic activity against the satellite systems as suggested earlier.

The Indian defence forces satellite communication requirements are still maturing. Satellite is a secondly media to most of the locations and primary to remote locations. Therefore the space segment requirement can be supported by Indian satellites. For India it is possible to reduce dependence on space systems and develop potent alternatives over a period, where the space systems acts only as redundancy or an alternate to terrestrial or aerial platforms. The defence forces should therefore plan to develop secure terrestrial, radio (also to complement satellite systems for offshore and air operations) as well as mobile cellular (for mobile operations) media/systems as forward as possible in border areas for its primary communications, backed up with space-based systems and reduce the primary dependence on space-based communication for remote areas, offshore and air operations. It does not mean that we should stop exploiting space assets. In fact lesser the dependence on space systems better will be the exploitation of space systems. This would virtually reduce the threat/vulnerability of space assets from adversaries counter space operations, and will provide the defence forces discrete edge over the adversary who may be dependent on space assets as primary means.

Moreover, it is quite possible that if a potential enemy did want to develop and employ the ability to attack space systems, it would first choose to do so in ways that would not involve weaponising space, such as investing in computer network attack capabilities, non-space weapons to attack the terrestrial elements of space systems, or ASAT capabilities that are not weapons in the conventional sense and against which the logical defensive countermeasures would not involve deploying space weapons. For military as well as commercial satellites, a transition to redundant networks of satellites would do much to reduce their vulnerability, perhaps together with supplementing satellite platforms for military functions with new types of state-of-the-art secure terrestrial, radio and mobile cellular (for mobile operations). For offshore and air operations the satellite system should be complemented with radio, as is being followed now, to take care of disruption in satellite based communication. Even for surveillance the alternate systems, such as high endurance unmanned aerial vehicles (UAVs, AWACS and recce aircraft) and mapping the strategic targets during peace time and till actual disruption occur; should be adopted. In addition the imagery data of area of interest can also be obtained through friendly countries or purchased. These measures will help eradicate the fear of non-availability of facility in the event of non-availability of satellite systems due to adversary action.

In the end, most of the inevitability arguments for extensive weaponisation of space are weak. Even the best one that space weapons will provide irresistible military advantages for those who employ them, are plausible but not decisive. Many of those who assert it probably harbour exaggerated expectations about the capabilities that space weapons will offer. Despite the fact that many people believe that weaponisation of space is inevitable, it is likely that the military space policy of space faring countries like US, will be one of the factors, though not the only one, that will determine space weaponisation policy of other countries. Our short term and long term policy should therefore be formulated based on these factors and own perception rather than following other nation's policy perceptions blindly. The aim of our development of instrument of force should be to increase the cost to adversary and reduce the same to self. This can be achieved by reducing the dependence on particular system, and in our case it is possible to do so.

The argument of some of the scholars and military officials that having an ASAT weapon capability will deter adversary for using them is less logical and premature to accept. If existing conventional military and nuclear weapons prove insufficient to deter, it is doubtful that the addition of space warfare capabilities would make an appreciable difference in an adversary's calculus of decision. Hence, India should only decide to become the part of the race of weaponisation concept of few states, after considering above aspects, and technological complexities and enormous economical burden involved in supporting such a venture. However, India can continue R&D in this field at an appropriate level, to keep in pace with the global technological development in the field of counter space technology.

India being one of the major space power, should pursue the international body to have a legally binding treaty under the framework of UN, charter of disarmament, prohibiting use of space for any kind of weaponisation and deployment of all kinds of ASATs.

China might be ahead of India in some sphere of satellite technology and few other aspects, but India is steadily progressing and working in that direction to reduce the gap. It is also a fact that for meeting the defence forces need with respect to supporting the number of ground communication satellite systems, the space capability is sufficient as of now, and what additional capabilities are required in terms of frequency bands/bandwidth and dedicated military satellites for future applications, the same have been recommended as above. However, India needs to concentrate more on indigenous design, development and manufacture of anti-jam, protected military satellite ground segment capability of space assets; ground segment being the oxygen of space segment.