Space assets are vulnerable to a variety of threats that include jamming of communications, command and control systems/links, physical attacks on satellites and ground stations, dazzling or blinding of satellite sensors; high-altitude nuclear detonations (HAND). Though in the past space has been used to support military operations, it has remained a conflict -free zone, and this may hold true in the future also. Space is a global common. Despite this some nations are developing a wide spectrum of anti-satellite (ASAT) weapon capabilities. The main driver for this is either their quest for space control or probably they are made to believe that air and space are analogous. For India, cheaper and softer options, like development of electronic warfare and cybernetic attack capabilities, will yield better results than blindly following costly propositions that vitiate the space environment.

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Introduction

Information technology has shrunk the globe through a well synergised network of communications. Space systems have played an important part in bringing the world closer and virtually made the year to shrink into minutes or seconds, by providing global connectivity. Space is and will remain an important arena to support future military operations. The integration of space support systems with other war fighting systems will be crucial for the Indian army in the coming years. Information domination through net-centricity coupled with space based assets would become an important factor that could determine the outcome of war. Satellites are increasingly becoming dual-use (for both military and non-military purposes). In the past, space systems supported the troops on the ground, without becoming another battle zone. Therefore a distinction must be made between the militarisation of space and the weaponisation of space. **The militarisation of space is the utilisation of space systems by defence forces to support military operations, and weaponisation can be termed as design, development, and deployment of weapons to be used in and from space; thereby turning space into a conflict zone.**

There are some mechanisms to protect satellites against natural hazards and the harsh space environment, but satellites will remain easy targets for space weapons such as kinetic energy direct hit weapons, and a variety of electronic/cyber attacks. Till now no weapons have ever been used in or from space. Despite this many nations are developing capabilities to target satellites for gaining a military edge over their adversaries. Space capabilities are largely dual use and will affect how operations are undertaken depending upon the extent to which a nation relies on its space assets in conduct of operations. In the event of onset of hostilities the adversary will attack all the possible targets to achieve or further his aim, which includes both civil and military facilities. This makes some nations believe that future wars will/may be fought in all arenas including space, targeting both civil and military satellites. However one has to carefully analyse, exactly when conflicts will reach such a level that space, which is a global common, will also become a battlefield. Some military officials and scholars i**n the race for making a strong argument for anti-satellite weapon programmes, compare space with air with reference to superiority, dominance, and control, which in actuality is far from the reality, and needs to be understood in terms of the peculiarity of space dynamics.** The laws of aerodynamics do not apply to space. Space as an operating medium[1] is entirely different from sea, air and land. Space as a medium should be treated differently and separate operational doctrines should be formulated to take into account its unique physical characteristics that are governed by gravitational force.

Satellites follow pre-determined orbital paths. Motion in space is not affected by the earth's surface because it has no geographic boundaries[2]. The use of space assets for military purposes must take into account these specific space characteristics that may constitute drawbacks or advantages. One of the major advantages of utilising space assets for military and civil use is that these offer global access, unrestricted by any terrain limitations; however this very advantage makes them highly vulnerable to different kinds of attacks. Space assets have a lifespan of generally six to seven years for low earth orbit satellites and 10 to 15 years for geo-stationary satellites depending upon the weight and fuel of the satellites, and whether their use is continuous. Their orbital motion severely limits manoeuvrability and makes them very predictable; thereby making

1 Low earth orbit (LEO) is generally been referred from 100 to 400 km, between sensible atmosphere and bottom of Van Allen belt followed by Medium earth Orbit and Geo-stationary orbit at approximately36,000 km. Military Space Forces; 'The Next 50 Years' by John M Collins, pp 15-16.

2 United States Joint Chiefs of Staff, Joint Doctrine for Space Operations, Washington DC, 2002, p.I-2. Cited in Document A/1932, 21 June 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; (accessed on 01 December 2009).

them virtually sitting ducks for a variety of attacks. For low orbit satellite applications such as imagery/surveillance, it will be almost impossible to have continuous real time coverage of the area of interest due to technical constraints of continuous availability of space and associated ground segments to receive and process huge amounts of data in real time for further distribution to the user. In addition to this, launch sites, command and control facilities and ground-to-satellite links which are fixed remain extremely vulnerable to attack.

India is increasingly taking steps to exploit space assets to enhance its operation capability in order to support network centric warfare of the future. However the actual exploitation of space should be seen in terms of overall indigenous development and induction of space systems. The requirements of forces for both communications and imagery are presently being met through ISRO dual use satellites. For navigation applications also, similar arrangement can continue, as and when India's Regional Navigational Satellite System becomes operational[3]. However there are issues which require to be addressed if the Indian armed forces are to fully exploit space assets for Network-centric warfare (NCW), as an integrated force.

This paper focuses on the general issues concerning threats to space assets, and suggests the possible measures that India or the Indian defence forces can adopt to mitigate the threat.

To analyse the threat and remedial measures one has to answer three basic questions: What is the threat? What does it involve? What is the solution?

The answer to first lies in the perception of many military officials and researchers who believe that there exist a fare amount of threat

3 Bhaskaranarayana a senior scientist of ISRO says that Antrix provided these services only on a commercial or civilian basis, and not for defence purposes. Defence services may use the data, he says, but Antrix does not offer any specific services for them. Antrix recently launched CARTOSAT-2, which offers the facility to receive data products to international users. http://battakiran.wordpress.com/category/isromilitary-missiles/; (accessed on 01 December 2009).

to our space assets, especially in view of the Anti-satellite (ASAT) capability developed by our neighbour. This perception may be true but needs to be analysed in conjunction with facts and technological, financial and other aspects associated with the issue.

In the event of conflict or planning for future war, any nation will choose its target as per the following:

(a) The value of target to adversary based upon the dependence and economics.

(b) Own aim and the capability to attack the target.

(c) Availability of alternatives and cheaper options to achieve the aim.

(d) The economic viability of attacking the target.

(e) Protection the target enjoys.

(f) International implications.

To address the above issues and questions, this paper has been divided into the following heads:

(a) Space dependence and space economics.

(b) Threats to space assets.

(c) Space weapons.

(d) Protection of space assets.

(e) Peace policies and initiatives.

(f) Threat analysis of Indian space assets.

(g) Recommendations.

(h) Conclusion.

Space Dependence and Space Economics

Space assets are already being utilised by armies the world over for communications, surveillance, position and timing information, early warning, signal intelligence and meteorological information. Approximately 115 countries own a satellite or share the resources of one. In the beginning of 2010, there were over 926 Low Earth Orbit (LEO- 449 Medium Earth Orbit (MEO)- 57, Elliptical Orbit- 39 Geo-stationary Earth Orbit (GEO) and 381 active satellites in various orbits. The US, Russia, and China are the three countries with the most satellites; having 437, 94 and 57 satellites respectively[4]. There are about 150 dedicated military satellites operational worldwide, US having approximately 114 and Russia approximately 30 satellites followed by China[5]. India has about 21 satellites, for use by civil and government agencies[6]. The Indian defence forces also plan to have dedicated defence communications satellites to meet their specific requirement but as of now no dedicated military satellite has been launched[7]. The navy will get its satellite in 2011, followed by air force and army[8].

Dependence of Armed Forces on Satellite Services

It is a well known fact that the armed forces of many nations are heavily dependent on satellite services to enhance their operational capability, especially the US, China, Russia, and NATO, and India may not be an exception to this. In addition to the military satellites,

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4 http://www.ucsusa.org/nuclear_weapons_and_global_security/space_weapons/technical_issues/ucs-satellite-database.html; (accessed on 10 Sep 2010).

5 Ibid.

6 http://www.isro.org/satellites/allsatellites.aspx; (accessed on 01 December 2009)

7 http://battakiran.wordpress.com/category/isromilitary-missiles/; (accessed on 01 December 2009).

8 Shri AK Antony, defence minister; The Times of India, New Delhi 23 Oct 09 and The Times of India, New Delhi 20 May 2010. Also see Space Capability, and India's Defence Communications upto 2022 and beyond, Colonel Deepak Sharma, IDSA.

to support its operations, the US is making extensive use of civil satellites. In 2008, Joseph Rouge, the Director of the National Security Space Office, mentioned that 80 per cent of US defence satellite communication requirements were being met through the commercial satellites. The US is also a major purchaser of imagery data from the commercial satellites and bought $5 million worth of commercial synthetic aperture radar imagery from the Canadian Radarsat system and indicated their commitment to a further purchase $197 million worth of imagery in the first 18 months of GeoEye-1 operation"[9]. Other space faring nations like China, France, UK and India too are focusing on dual use civil space assets to support their military requirements.

Space Economics. It must be understood that there is a strong interconnect between space weaponisation and space-dependent commerce. The *Space Report* 2009 gives vital economic data about the $257 billion space industry[10]. Here also the US controls almost 90 per cent of space economics. According to *World Prospects for Government Space Markets*, a Paris-based Euro-consult report published in the year 2008, the China National Space Administration's (CNSA) 2008 budget was about $1.3 billion, up 6 per cent from 2007[11]**.** India's space budget allocation for 2009 – 2010 is comparable to China's space budget of 2008 – 2009. The total fund allocation for ISRO for 2009-10 was $1.01 billion (Rs.4, 959 cr)[12] and the 2010-11 budget was also approximately the same[13].

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9 Chapter 4, Space Security 2009, Oct 09 Publication; available at www.spacesecurity.org, (accessed on 01November 09).

10 ibid

11 China making leaps in space By Peter J Brown; http://www.atimes.com/atimes/China/JL23Ad02.html; (accessed on 21 December 2009).

12 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; July 6th, 2009 - 6:50 pm ICT by IANS, New Delhi, July 6 (IANS) India's space research programme will get a boost as the union budget for 2009-10 presented by Finance Minister Pranab Mukherjee Monday has given a 40 percent hike in fund allocation for the Indian Space Research Organisation (ISRO).

13 http://ibnlive.in.com/news/full-text-of-pranab-mukherjees-budget-201011-speech/110744-7.html ibnlive.com; Updated Mar 03, 2010 at 02:39pm IST; (accessed on 01 September 2011).

Threats to Space Assets

Satellites and space assets are expensive and technologically very complex systems that are very susceptible to variety of threats. The functioning of the system can be easily obstructed and interfered with. These drawbacks have always existed but certain countries have relied heavily on these assets for conduct of operations. This makes these countries take aggressive measures to protect their space assets. A space system is important for both civil and military applications. A weaker country with the capability of developing electronic/ cyber and other forms of anti-satellite systems to disable space assets can pose an asymmetric threat, and could exploit the space dependence of its stronger adversary. During the Cold War both the US and the Soviet Union tested and developed anti-satellite (ASAT) weapons, to destroy surveillance satellites in low earth orbit, and have the technology to further improve ASAT capability.

In January 2007 China demonstrated ASAT capability by destroying its disused weather satellite[14], and thus demonstrated to US, and other space dependent nations that it can pose a threat to their satellites if it so desires. However this aspect needs to be analysed in terms of its present and future plans and more so with regard to India's dependence on space systems for both military and civil applications. Since it is not possible to predict the future threats it is important to study the threats to space assets so that it is possible to analyse whether or not there is any real threat to India's space assets.

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14 D. Wright, "Colliding Satellites: Consequences and Implications," Union of Concerned Scientists (February 26, 2009), online: http://www.ucsusa.org/assets/documents/nwgs/SatelliteCollision-2-12-09.pdf (accessed on 10 December 2010).

The variety of threats to space systems, in the order of decreasing likelihood are listed below[15]:

(a) Electronic warfare such as jamming communications, and command and control systems/links and cybernetic attack on space systems.

(b) Physical attacks on satellite ground stations.

(c) Dazzling or blinding of satellite sensors.

(d) Hit-to-kill anti-satellite weapons.

(e) Pellet cloud attacks on low-orbit satellites.

(f) Attacks by micro-satellites to act as space mines.

(g) High-altitude nuclear detonations (HAND).

(h) Space debris.

Except for electronic and cybernetic attack/weapon systems the ground based ASAT weapons are generally effective against the LEO satellites. Directed energy weapons, such as high-powered microwaves, particle beams both charged and neutral and "heat-to-kill" ground-based lasers also pose a threat to space assets. As of now these systems are under various stages of testing, and development[16]. The directed energy, conventional, and nuclear ASAT weapon systems are discussed briefly in succeeding paragraphs since in future these may form a potent threat to space assets.

Directed Energy Weapons

Directed energy weapon systems project energy at the speed of light, and do not affect the space environment in their vicinity. They possess a soft kill capability to blind sensors and other electronic systems of the satellite well beyond the range of hard kill weapon systems. But

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15 Deblois Bruce M, and Jeremy C Marwell et al., "Space Weapons Crossing the US Rubicon." International Security issue vol 29, No 2 (Fall 2004), pp 50-84.

16 Military Space Forces, The Next 50 Years by John M Collins, pp 31-32.

their performance against a satellite in space is not very satisfactory because they are adversely affected by the atmospherics. Low power lasers can be used to "dazzle" unhardened satellites in LEO, and many countries may already have this capability[17]. The US tested the ground based Mid-Infrared Advanced Chemical Laser(MIRACL) in 1997, which damaged satellite sensors orbiting at 429 km, indicating that even a commercially available laser system can be used to blind/ dazzle satellites temporarily. Adaptive laser technology is being developed by US, Canada, China, Japan, Russia, and India[18]. France, Germany, and Japan, are pursuing research on laser based satellite communication technology and also have the ability to track and direct a laser beam at a satellite. China in particular has a dedicated programme for developing high power solid state laser and adaptive optics to maintain the quality of laser over large distance, which can be used against satellites[19]. It is reported that in 2006 China used a ground laser to dazzle America's reconnaissance satellite[20]. Indian defence scientists are also experimenting with "high-power laser weapons"[21]. The ground based lasers as anti satellite weapons are being developed by many countries but they have the inherent limitation of being hampered by the atmosphere which acts as a shield between satellite and the laser directing system. A lot of work is still required before it can become a potent ASAT weapon.

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17 S. Karamow, "Army Scores a Hit on Satellite in Test of Laser," USA Today (October 21, 1997) at pg 6.

18 Adaptiveoptics.org, "Adaptive Optics Establishments," online: http://www.adaptiveoptics.org/Establishments.html (date accessed: 10 July 2008).

19 Zhu Jianqiang, "Solid-State Laser Development Activities in China," Conference on Lasers and Electro-Optics (2007), online: http://ultralaser.iphy.ac.cn/cleo/data/papers/CThE6.pdf, and Yang Wen-shi, Wang Wei-li, Sun Wei-na, Bi Guo-jiang, Zhu Chen, and Wang Xiao-han, "Beam Quality of the High Power DPL," Infrared and Laser Engineering (2005) at 511-516. Shi Xiangchun, Chen Wei-biao, and Hou Xia, "Application of All Solid State Laser in Space," Infrared and Laser Engineering (2005) at 127-131.

20 USA Today, "China Jamming Test Sparks US Satellite Concerns" (October 5, 2006), online:http://www.usatoday.com/tech/news/2006-10-05-satellite-laser_x.htm?POE=TECISVA.

21 Rajat Pandit, "Space Command must to check China," Times of India (June 17,2008), online:http://timesofindia.indiatimes.com/India/Space_command_must_to_check_China/articleshow/3135817.cms; (accessed on 10 July 2009).

Conventional Kinetic Energy Weapons

Conventional weapons work differently in space. A conventional weapon must hit the target and should have the precise target homing technology. It will be more economical and reliable to target satellites from ground based weapon systems than launching them from any space platform. The US has already deployed ground and sea based exo-atmospheric kill vehicle (EKV) interceptors, which can be used against satellites in LEO[22]. Russia had last carried out anti-satellite tests in 1982. China demonstrated this kind of capability by the intentional destruction of its weather satellite in 2007[23]. However, it must be noted that the satellite China destroyed was its own, and all its parameters were known. And the number of failures before the successful hit are not known. China's ASATs programme therefore is in the development stage but can produce more ASAT kinetic energy weapons to destroy LEO satellites[24].

The UK, Israel, and India are also exploring the development of ASAT weapon systems[25]. As far as Pakistan is concerned, although as of now it does not have an appreciable space capability, but it has plans to acquire space capability to meet the future military requirements should the need arise. In March 2005, General Musharraf authorised renewed research and development for the capability to launch the planned domestically built satellite, the PAKSAT-IR. However, the status of SLV and PSLV remained unclear. It is also speculated that Pakistan has already tested two

22 David Wright and Laura Grego, "ASAT Capabilities of Planned US Missile Defence System," available at: www.ucsusa.org/nuclear_weapons_and_global_security/space_weapons/technical_issues/anti-satellite-asat.html (accessed on 19 December 2010).

23 SPX, "China Says Anti-Satellite Test Did Not Break Rules," Space War (12 February 2007),online;http://www.spacewar.com/reports/China_Says_Anti_Satellite_Test_Did_Not_ Break_Rules_999.html; (accessed on 10 July 2009).

24 Shirley Kan, "China's Anti-satellite Weapon Test," Congressional Research Centre (23 April 2007) at pg 3.

25 Barbara Opall-Rome, "Israel, U.S., Test Compatibility of Arrow-Patriot Interceptors," Space News 14 March 2005; Vivek Raghuvanshi, "India Plans 2nd ABM Test in June," Defence News (29 January 2007).

high-altitude hypersonic sounding rockets; the *Shahpar* solid-fuel two stage rocket which can carry a payload of 55-70 kilograms to an altitude of 950 kilometres, and the *Rakhnum* a three stage liquid-fuel rocket, which can carry a payload of 38-56 kilograms to an altitude of 1000 kilometre[26].

Nuclear Weapons

A nuclear weapon detonated in space will generate radiation and an electromagnetic pulse that is highly destructive to unprotected satellites. X-rays which travel only few metres in the atmosphere will travel thousands of kms in space at the speed of light and could peel off metal skins and destroy delicate mechanism through intense heat or hypervelocity shock waves induced internally[27]. The countries with the capability of launching satellites can effectively place nuclear warheads in space to destroy satellites. North Korea and Pakistan are among the 18 states that possess medium-range ballistic missiles that could launch a mass equivalent to a nuclear warhead into LEO without achieving orbit. The effect of nuclear weapons in space was demonstrated in 1962 by the US programme Starfish Prime test [28].

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26 http://indonesiaarab.wordpress.com/2008/09/17/pakistan-plans-to-launch-its-own-satellite; (accessed on 23 September 2009).

27 Pg 29 of, Military Space Forces; 'The Next 50 Years' by John M Collins.

28 Approximately 80 per cent of all the energy from a nuclear weapon detonated in outer space appears in the form of X-rays. In addition there are small amounts of gamma radiation and neutrons, small fractions in residual radio activity, and in the kinetic energy of bomb debris. An electromagnetic pulse (EMP) is also generated by a HAND when X-rays and gamma rays create an electron flux in the upper atmosphere of the earth that re-radiates its energy in the radio frequency portion of the electromagnetic spectrum. When this radio frequency hits space systems it induces currents and voltages that may damage or destroy electronic systems not hardened against these effects. Satellites in GEO would experience an EMP of smaller magnitude than would either LEO satellites or ground facilities located within line of sight of the HAND. Long after the initial detonation of a nuclear device, electrons liberated by the device would join the naturally occurring radiation in the Van Allen belts. Satellites not specifically designed for operations after detonation of a nuclear weapon may fail quickly in this enhanced radiation environment due to a rapid accumulation of total ionizing doses on the critical electronic parts of a satellite. Wiley J. Larson and James R. Wertz, eds. Space Mission Design and Analysis, 2nd edition. (Dordrecht: Kluwer Academic Publishers, 1992), pp 215-228.

The probability of nuclear attack in space is minimal because of the collateral damage to humanity, the atmosphere and to everyone's space assets across the board. It will be the most barbarous and most heinous act undertaken by any country. Besides, such an attack will only be contemplated by any country once the nuclear threshold on the ground is crossed. Nuclear testing in the atmosphere was banned four decades ago when there were widespread protests by all the nations against the damaging radiation levels generated by the test[29]. Placing any nuclear warhead in the outer space is also prohibited by the Outer Space Treaty.

[29] Limited Test Ban Treaty, 1963, signed by 134 Nations.

Space Weapons

The missile defence programme of the countries and the quest of some nations like the US, USSR, and China; to control space may be the main drivers behind the drive to develop space weapons.

In US, the serious debate on weaponisation began in 2001 with the publication of the Rumsfeld Commission Report on US space security policy[30]. A staff background paper to the Rumsfeld Commission quoted a Xinhua news agency report as to how the Chinese military plans to defeat the US military in a future conflict. The Chinese news report said: "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"[31]. In January 2000, the Hong Kong based *Space Daily* quoted Chinese sources that China was developing a "parasitic satellite" to be used in an anti-satellite (ASAT) mode[32]. Following such reports the Rumsfeld

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30 Report of the Commission to Assess United States National Security Space Management and Organization, Executive Summary, Washington DC, January 2001. Cited in Document A/1932, 21 June 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; (accessed on 10 July 2009).

31 Al Santoli, "Beijing Describes How to Defeat U.S. 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.

32 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," Centre for Nonproliferation Studies, Monterey Institute of International Studies (July 22, 2002), available online at http://cns.miis.edu/pubs/week/020722.htm; (accessed on 10 July 2009).

Commission was tasked to provide inputs on the overall space security structure locate its deficiencies and suggest ways to overcome them. The Majority of the committee's members were retired senior US air force officers and Donald Rumsfeld was later to become US defence secretary. The report suggested the development of relevant capabilities so that the president had the option to deploy weapons in space to deter threats to and, if necessary, defend any attacks on US interests[33]. The committee was of the opinion that the expansion of conflict into space was historically inevitable[34]. The commission stated that "every medium, air, land, and sea, has seen conflict. Reality indicates that space will be no different." To avoid a "Space Pearl Harbour", the report recommended that US should develop superior capabilities for "power projection in, from, and through space" in order to "negate the hostile use of space against US interests"[35].

These views of top officials and policy makers indicate that the US had been long considering the weaponisation of space in order to

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33 Report of the 2001 Space Commission p 12. This echoes US Space Com'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, The Simons Centre for Peace and Disarmament Studies, Liu Institute for Global Issues, UBC, Canada. Outer Space and Global Security, conference; 26-27 November 2002; Space Security: Options and Approaches available at : http://www.ploughshares.ca/libraries/Abolish/OuterSpaceConfGeneva02/JohnsonConf2002.htm; (accessed on 10 July 2009).

34 Report of the Commission to Assess United States National Security Space Management and Organization, Executive Summary, Washington DC, January 2001. pp. 9-10. Cited in Document A/1932, 21 June 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; (accessed on 10 July 2009).

35 "Executive Summary," in Report of the Commission to Assess United States National Security Space Management and Organization (Washington, DC: Commission to Assess United States National Security Space, January 11, 2001), pp. vii–xxxv. Accessed on Apr 8 10 www.stimson.org; also refer: Acronym Institute Report: Space without Weapons, Ballistic Missile Defence and the Weaponisation of Space http://www.acronym.org.uk/space/rejintro.htm; (accessed on 8 April 2010).

establish domination and superiority over space. The US has the maximum stakes both in space assets, and space economics. It has therefore rightly decided to make the protection of its space assets a major part of its defence policy. One of the steps suggested by the US to reduce vulnerability was to arm the satellites, and/or to deploy separate armed satellites dedicated to protecting them[36]. The US has already allocated considerable funds to the development of space-based anti-satellite weapons (ASATs),[37] On April 23, 2010, the US launched the unmanned spacecraft X-37B, which can remain in the orbit for approximately nine months. This triggered concerns in the world community. China believed that this heralded a new arms race in space, as the small shuttle was feared to have the platform to launch new space weapons with ability to carry out anti-satellite operations.[38].

Russia and China are of the view that they must dissuade the US from developing space weapons and missile defences[39]. It is true that the US possesses the essential enabling capabilities for

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36 SCOTT William B, CINCSPACE Wants Attack Detectors on Satellites, Aviation Week and Space Technology, 28 April 1997. Cited in Document A/1932, 21 June 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; (accessed on 8 April 2010).

37 For an exhaustive account of all US space weapons officially under development, see: Lewis Jeffrey, Lift-Off for Space Weapons? Implications of the Department of Defence's 2004 Budget Request for Space Weaponization, Centre for International and Security Studies, Maryland, University of Maryland, July 2003; Cited in Document A/1932, 21 June 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;(accessed on 10 July 2009).

38 Times of India April 25 2010, available at http://timesofindia.indiatimes.com/home/science/US-space-plane-takes-off-on-secret-mission/articleshow/7644159.cms; (accessed on 04 September 2011)

39 Pavel Podvig and Hui Zhang, Russian and Chinese Responses to U.S. Military Plans in Space (Cambridge, MA: American Academy of Arts and Sciences, 2008), http://www.amacad.org/publications/militarySpace.pdf; (accessed on 01 December 2009).

deployment of ASAT weapons both on ground and space. Which particular force-employment alternatives the US chooses to deploy will depend on political decision makers and public acceptance. It is also a fact that the US retains the initiative in this respect and knows that if it continues to show restraint, others may also do so.

Enabling Capabilities and Space Control

A nation will require certain enabling capabilities, if it has to pose any threat to space assets of another. **Table 1 at Appendix A** compares the enabling capabilities of China, India, Israel, Japan, Russia and the US. The details clearly indicate that the US and Russia are two nations with the greatest technological capability to manufacture and deploy ASAT weapons if required. The US, China, European Space Agency, Japan, France and the China have acquired deployable optics and precision attitude control capabilities which can be used for civil applications and can also be utilised for space based strike applications[40]. India and Israel are also planning to develop such capabilities[41].

Space based Strike Capability. No integrated space-based strike systems have been tested or deployed till date[42]. In 1980 under the star wars Strategic Defence Initiative, the US carried out extensive research on the Brilliant Pebbles programme and spent several billions dollars to develop space based strike capability. USSR too pursued a similar programme. Due to the huge financial cost and technological complexities, these programmes have been either abandoned as in the case of Russia or are a low priority. As of now space faring nation has any real space based launch capability.

40 Gunter Dirk Krebs, "Military Satellites," Gunter's Space Page, online: http://www.skyrocket.de/space/sat.htm. (accessed on 10 July 2009).

41 How Secure Was Space in 2009?, Author: Cesar Jaramillo Program: Space Security; Autumn 2010 Volume 31 Issue 3; available at: http://www.ploughshares.ca/content/how-secure-was-space-; (accessed on 04 September 2011).

42 Bob Preston, Dana J. Johnson, Sean J. A. Edwards, Michael D. Miller, and Calvin Shipbaugh, Space Weapons, Earth Wars (Santa Monica: RAND Corporation, 2002).

Table 2, at Appendix B, compares the space-based strike enabling capabilities of China, India, Israel, Japan, Russia and the US[43].

A space-based weapons design and development will require very advanced technological capability and research facilities. These are presently available with the US and to some extent with Russia. Other nations will have to depend on other nation/nations that possess these technologies. These nations may be able to acquire some technology for dual use. However for any one country to acquire or develop the entire spectrum of complex technology will be very cost prohibitive and economically unviable for the next 15 to 20 years.

Space Surveillance. One of the necessary capabilities for controlling space is space surveillance and situation awareness[44]. The US has the most advanced space situational awareness capability and though US and USSR were the pioneers, still no one space capable nation, can claim to have space surveillance capability which can provide them exclusive control of space. Russia has the next advanced space surveillance system after the US. Canada has the Sapphire space based surveillance capability to monitor the satellites in GEO. The monitoring data is shared with the US giving it an edge over other states[45]. However it is not possible for any one country to continuously monitor all satellites because of complexities of detection and data processing. China and India too have the significant satellite capabilities to track and control their satellites. China has 20 ground monitoring stations and six satellite tracking ships and is upgrading its Xi'an Satellite Monitoring Centre, the primary control

43 Space Security Report 2009 pg 169: www.spacesecurity.com; (accessed on 10 July 2009).

44 Amy Butler, "Bush Memo Orders Space Situation Awareness," Aviation Week and Space Technology (12 October 2007), online: http://www.aviationweek.com/aw/generic/story_channel.jsp?channel=defense&id=news/MEMO10127.xml : accessed on 10 September 2010

45 MacDonald Dettwiler and Associates, News, "MDA Awarded Contract To Build Canadian Information Solution For Surveillance of Space Objects" (4 October 2007), online: http://www.newswire.ca/en/releases/archive/October2007/04/c8747.html,: (accessed on 10 September 2010).

centre for China's network[46]. This is likely to give China the capability of monitoring and tracking foreign satellites over a specified region.[47]. The ASAT test conducted by China on January 11, 2007, wherein it destroyed its own disused weather satellite was tracked and targeted from this centre[48]. Other nations who possess substantial space monitoring and surveillance capabilities are Canada, France, Germany, Japan, and the UK. France claims that it has the capability to determine the size, location, orbit, and transmitting frequency of unlisted satellites[49].

Analysis of Space Weapons Utility

Some nations have the agenda to pursue weaponisation of space with the despite its futility. They believe that ASAT capability will act as deterrence and help them dominate and control the activities of others in space. The presumed deterrent value of space weapons is questionable. If existing conventional military and nuclear superiority is ineffective and insufficient deterrent, it is doubtful whether space warfare capability can deter an adversary. The countries that can develop and produce space weapons to kill the satellites have or have the capability to produce nuclear weapons. Supplementing nuclear capability with space weapons, believing that these will enhance the deterrence value of the arsenal only exposes their desire for hegemony. Developing nations like India have to realistically assess the necessity of deploying space weapons in conjunction with the long term geo-political aims, and their capability to design and develop appropriate weapon systems. It is incorrect to compare the deterrence capability of ASATs weapons with nuclear

46 Xinhua, "China Launches New Space Tracking Ship to Serve Shenzhou VII" (September 8, 2008), online: http://english.cri.cn/3126/2008/09/22/902s407814.htm.

47 Xinhua, "China Enhances Spacecraft Monitoring Network" (12 December 2006), online: http://news3.xinhuanet.com/english/2006-12/12/content_5473204.htm;

48 Craig Covault, "China's ASAT Test Will Intensify U.S.-Chinese Faceoff in Space," Aviation Week and Space Technology (21 January 2007), online: http://www.aviationnow.com/aw/generic/story_generic.jsp?channel=awst&id=news/aw012207p2.xml.

49 Peter B. de Selding, "French Say 'Non' to U.S. Disclosure of Secret Satellites," Space News (June 8 2007).

weapons. Nuclear deterrence is based on mutual loss exceeding potential gains. Nuclear deterrence was based on lethal capabilities regularly tested and demonstrated by conducting nuclear tests. ASAT capabilities in contrast, are mostly inferential. Therefore one has to actually analyse –first - the capability of space weapons in conjunction with long term geo-political aims, and the ability to design and develop appropriate weapon systems. In the era of asymmetric warfare, the massive military capabilities in all domain may not necessary ensure security. 9/11 in the US and 26/11 in India, demonstrated the trans-boundary threats in 21st century and the dangers of asymmetric warfare.

The Federation of American Scientists (FAS) Report. The Federation of American Scientists (FAS) panel found that alter-native measures are more effective, cheaper, and less technologically complex than space weapons. The report highlighted that space weapons (ground-based anti-satellite weapons, jamming, space mines, orbital debris, or a high-altitude nuclear explosion) do not constitute the best mitigating strategy to perceived threats to space assets[50].

Union of Concerned Scientists Report. In 2005, the Union of Concerned Scientist also analysed the issues concerning space weapons and prepared the report "Policy implication of space weapons 2005". They said that **a nation cannot deny other countries access to space by use of space weapons, although it could increase the expense of such access.** The also asserted that space weapons are less reliable and their cost is exorbitantly high in comparison to other ground based weapons[51].

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50 FAS Public Interest Report The Journal of the Federation of American Scientists 2004 , Volume 57, Number 4 http://www.fas.org/pubs/_docs/10072004163510.pdf: (accessed on 01 December 2009).

51 Policy Implications of Space Weapons (2005) | Union of Concerned Scientist. This is Section 2 of a report published by the American Academy of Arts and Sciences (AAAS), The Physics of Space Security: A Reference Manual, which was authored by UCS scientists David Wright, Laura Grego, and Lisbeth Gronlund, available at: http://www.ucsusa.org/nuclear_weapons_and_global_security/space_weapons/policy_issues/policy-implications-of-space.html; (accessed on 01 July 2010).

Strategy to Control Space Weaponisation

From the forgoing analysis and peace initiatives taken by the world community for arms control in space, it is evident that the world wants transparency, technology sharing and global cooperation in space. All are aware of adverse effect of space weapons and have concern for space debris that will be created due to uncontrolled weaponisation and flight testing of ASATs weapons. The Outer Space Treaty refers to the importance of international cooperation and peaceful use of outer space. In the era of asymmetric warfare, the massive military capabilities in all domain may not necessary ensure security–. The countries that are pursuing space weapon programme are either not convinced of this fact or are economically so sound that they want to just add another weapon system in their arsenal. This might bring initial advantages to that country, and will also accelerate threats to space assets that are much worse than anything currently existing or planned. If any country decides to concentrate on weaponisation of space, it is possible that as with the US "star wars" plans it might collapse under the weight of its own technological, military or financial contradictions. Notwithstanding, these facts, ASAT weapons have been tested infrequently, and deployed minimally by countries like US, USSR or may be by few more[52]. The Henry L. Stimson Centre has suggested a Code of Conduct to broaden existing peace and protection measures. The nations should adopt these as legally binding treaties under a UN frame work. The code includes provisions to[53]:

(a) Minimise debris.

(b) Refrain from flight-testing or deploying space weapons

(c) Avoid or announce in advance dangerous manoeuvres in space.

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52 'Depolarizing the Space Weaponization Debate', by Karl P Mueller cited in, Royal Air Force Air Power Review Vol I,2004, p.19.

53 The Henry L. Stimson Centre has drafted a Model Code of Conduct for responsible space-faring nations. It can be found at ww.stimson.org/space.

(d) Create special caution areas around satellites.

(e) Refrain from simulating attacks in space.

(f) Refrain from using lasers to disrupt or blind satellites.

(g) Cooperate on space traffic management.

It is clear that the states with space weapon capability to destroy the satellites may make initial temporary military gains but they will lose in the long term. Therefore, the countries that justify the design and development of space warfare capabilities to protect space assets for deterrence or means to control space need to review their arguments.

Space debris

Space debris is created by human space activities and consists of spent satellites, and disused associated satellite systems. All these continue to orbit around the earth as space junk. The uncontrolled activities in the space such as the US Star Wars creation of large space structures in the eighties, flight testing of ASATs weapons/ systems by US, USSR and China over the past three decades has significantly contributed to space debris. If such activities continue unchecked, than it could lead to a situation where, a single satellite failure could cause a cascading failures of many satellites[54]. Till now only one major incident occurred in the year 2009, involving the satellites collision between a functional communication Iridium 33 satellite and Cosmos 2251 (disused Russian satellite)[55]. Although at

[54] If a collision with larger debris does occur, many of the resulting fragments from the damaged spacecraft will also be in the 1 kilogram (2.2 lb) mass range, and these objects become an additional collision risk. As the chance of collision is a function of the number of objects in space, there is a critical density where the creation of new debris occurs faster than the various natural forces that remove these objects from orbit. Beyond this point a runaway chain reaction can occur that quickly reduces all objects in orbit to debris in a period of years or months. This possibility is termed the "Kessler Syndrome", http://www.popsci.com/technology/article/2010-05/dod-space-junk-tipping-point-collision-could-set-catastrophic-chain-reaction (accessed on 19 December 2010).

[55] http://www.space-track.org; (accessed on 10 July 2009).

present the situation is not alarming but there is a need to regulate space activity to ensure satellites safety.

Debris at Higher Altitudes. At higher and geo-stationary orbits the atmospheric drag is negligible and debris takes much longer to decay as compared to objects in LEO. Thus debris posses more of a problem in the valuable Geo-stationary orbit where there is already a shortage of orbital slots. The International Telecom Union (ITU) has laid down various regulations for member countries for ensuring safety of satellites. The owner of a satellite that has been rendered non-functional or is at the end of its life span must move it out of the orbit to the satellite graveyard in space to vacate the orbital slot for further use[56].

Despite strict ITU regulations debris control has not been substantial and ITU requirements are not effective enough to greatly impact collision frequency[57]. For a holistic view of the debris created, the details of unintentional collisions of objects are given at **Appendix C, Table 3; and Appendix D, Table 4**, **and Table 5**[58].

Dealing with Debris. A panel of the Federation of American Scientists studied the effect of debris caused by interception of ballistic missiles in space or destruction of a satellite at low or suborbital level. They found that debris fields so generated at these orbital levels will not pose a significant threat to space infrastructure. However, if an explosion, interception or destruction of satellite takes place in a geo-stationary orbit than the debris field would be extremely dangerous for military and commercial satellites[59]. To

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[56] Anselmo, L. and C. Pardini. "Collision Risk Mitigation in Geostationary Orbit." Space Debris, Volume 2, Number 2, June 2000, pp. 67–82.

[57] Anselmo, L. and C. Pardini. "Collision Risk Mitigation in Geostationary Orbit." Space Debris, Volume 2, Number 2, June 2000, pp. 67–82.

[58] D. Wright, "Colliding Satellites: Consequences and Implications," Union of Concerned Scientists (February 26, 2009), online: http://www.ucsusa.org/assets/documents/nwgs/SatelliteCollision-2-12-09.pdf. (accessed on 10 July 2009).

[59] Federation of American Scientists report available at http://www.fas.org/pubs/_docs/10072004163510.pdf: (accessed on 01 December 2010).

control and minimise the hazard of debris the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) published voluntary guidelines in 2007[60]. There are many other ways to remove debris from the space. Some of these are, to use a remotely controlled vehicle to rendezvous with the debris, capture it, and return to a central station. Another way is collect the debris in a foamy ball of aerogel. However, presently none of these are economically viable[61].

[60] "UN Space Debris Mitigation Guidelines." http://orbitaldebris.jsc.nasa.gov/library/Space%20Debris%20Mitigation%20Guidelines_COPUOS.pdf

[61] Michaels, Daniel. "A Cosmic Question: How to Get Rid Of All That Orbiting Space Junk?" Wall Street Journal, March 11, 2009, and Lovgren, Stefan. "Space Junk Cleanup Needed, NASA Experts Warn." National Geographic News, 19 January 2006; available at; http://news.nationalgeographic.com/news/2006/01/0119_060119_space_junk.html; (accessed on 04 September 2011).

Protection of Space Assets

No one can deny fact that space assets will be vulnerable in case of the breakout of hostility between two nations, who possess the required capability. Two measures can be taken to protect them. The first is physical protection which requires technological development, and the second are peace initiatives treaties and agreements.

To attack a satellite in orbit, kinetic energy weapons have to overcome the earth's gravity and harsh space environment. In addition the earth's atmosphere provides inherent protection from ground based energy weapons. The ionospheric characteristics fluctuate due to the sun's activities and different weather conditions, and predicting satellites positions in LEO becomes that much difficult. The error predictability at about 800 km can be up to a km. For tracking satellites higher than 5000 km, optical systems are required. Any kinetic attack on GEO satellites, will require 10 to 12 hours for the weapon to reach the target satellite, and the attack can be nullified by manoeuvring the satellite slightly[62]. Some nations as mentioned earlier have the capability to destroy satellites, overcoming the natural defence offered by earth and various orbits, and to physically protect a satellite against a direct attack in such a case will be very difficult. Physical protection is thus required for both the satellites and its ground support systems.

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In the event of attack a country must possess the capability to repair, recover and retaliate. While it is easy to repair and recover ground support systems but for space it will be beneficial to have redundant systems and also the alternative systems. This may constitute both active and passive measures. The ASAT attacks are primarily of two types as enumerated earlier: the soft non-lethal (like electronic/ cyber), and the lethal, i.e. a physical hit to kill. The protection mechanisms that can be adopted by states to mitigate the threats to space systems are discussed in succeeding paragraphs. The first and foremost requirement of any protection mechanism is a detection mechanism. A space situational awareness capability can to a great extent protect satellites against the physical hit to kill ASAT weapons by it. The US is world leader in responsive space capabilities to detect variety of attacks.

Detecting Anti-Satellite Weapon (ASAT) Attacks

Detecting Electronic/ Cyber and Directed Energy Attack (Laser): Earlier it was difficult to detect the electronic attack source. As part of its Rapid Attack Identification Detection and Reporting System (RAIDRS), the US has six fixed ground stations and three

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[62] David Wright, Laura Grego, and Lisbeth Gronlund, The Physics of Space Security: A Reference Manual (Cambridge, MA: American Academy of Arts & Sciences, 2005).

deployable ground segments[63], which can detect, locate and report electromagnetic interference on its satellites so that evasive or defensive measures can be initiated[64]. The system has been operating since 2005. Now some other spacefaring nations have also acquired the technology to detect jamming when interference is noticed or loss or corruption of data in case of cyber attack by using space and ground based multiple sensors to geo-locate the source of interference. During peace time it becomes very difficult to ascertain whether the interference is intentional or not. However, early warning for such attacks remains a challenge. Directed energy attacks such as laser dazzling or blinding and microwave attacks move at the speed of light, so an advance warning is very difficult to obtain[65].

Detecting Physical ASAT Attack. Space based detection capability as of now is with the US and Russia. The US plans to deploy space based infrared systems (SBIRS) consisting of a constellation of four satellites in GEO to provide global coverage. The programme is behind schedule and is estimated to cost $11 billion[66]. The US also has a space tracking and surveillance system (STSS) comprising of 20 to 30 LEO satellites. The STSS is presumed to be capable of detecting missiles, differentiating between the decoy and actual warhead and can provide targeting data to the missile interceptor. China's satellite tracking systems are based on four Yuan Wang class

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63 Corey Dahl, "New squadron activates at Peterson," Air Force Print News (21 May 2007); available at http://www.afspc.af.mil/news/story_print.asp?id=123054049; (accessed on 04 September 2011).

64 "A Rapid Attack Identification, Detection, and Reporting System Spiral 2 Studies," FBO Daily, Issue #1033 (24 September 2004), online: http://www.fbodaily.com/archive/ 2004/09- September/24-Sep-2004/FBO-00679518.htm; (accessed on 10 September 2009) .

65 Stephen Kosiak, "Arming the Heavens: A Preliminary Assessment of the Potential Cost and Cost-Effectiveness of Space-Based Weapons," Centre for Strategic and Budgetary Assessments (31October 2007) at pg 66, online: http://www.csbaonline.org/ 4Publications/PubLibrary/R.20071031. Arming_the_Heavens/R.20071031. Arming_the_Heavens.pdf; (accessed on 10 April 2010).

66 Timothy Barnes, "Factsheet on Space Based Infrared System," Centre for Defence Information (18 October 2007), online: http://www.cdi.org/friendlyversion/ printversion.cfm? documentID=4123.

tracking ships and it can be used for missile detection also. It is also believed to have one Large Phased-Array Radar for missile launch detection near Xuanhua in the west[67]. India too is in process of developing and inducting a radar system to track the missiles.

Protection of Satellite System against Electronic Attack

The most vulnerable component of a space system is the ground support component which is vulnerable to conventional as well as electronic weapons. It is practically very difficult to protect the ground system against covert or overt attacks, except by creating alternate or redundant systems. The command and control communication link can be manipulated to pass the wrong telemetry command. However it is possible to take some technological steps to mitigate the effect to some extent. These are[68]:

(a) Robust encryption and decryption mechanism both on ground and onboard satellites.

(b) Robust error correction coding for high tolerance level against errors caused due to interference.

(c) Using directional antennas that reduce interception or jamming vulnerabilities and also use of null antenna technology on board satellite where possible.

(d) Restricting radio emission by shielding and use of directional antennas, to reduce energy in other direction, from where it is possible to intercept or employ jamming signals.

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67 Space Capability and India's Defence Communications up to 2022 and Beyond; by Colonel Deepak Sharma Globalsecurity.org, "Yuan Wang Tracking Ships" (last updated: 23 July 2005), online: http://www.globalsecurity.org/military/world/china/yuan-wang.htm; Globalsecurity.org, "Large Phased-Array Radar (LPAR)" (last updated: 28 April 2005), online: http://www.globalsecurity.org/wmd/world/china/lpar.htm; (accessed on 10 September 2009) .

68 For further study also refer the book, 'Digital Satellite Communication', by Tri Ti HA, 1994 edition, and M.R. Frater and M. Ryan, Electronic Warfare for the Digitized Battlefield (Boston: Artech House, 2001).

For communication satellites and associated ground segments, there are technologies that can mitigate the effect of interference and jamming which can be incorporated both on the ground and on board the satellites system. These technologies are mainly used in military satellites and ground terminals. The advanced protection capabilities include[69].

(a) Bit by bit processing and use of narrow band transmission.

(b) Use of robust modulation techniques and access like Code Division Multiple Access and Spread Spectrum.

(c) Burst transmissions and frequency-hopping radio transmission.

(d) Antenna to reduce side lobes thereby reducing interference and jamming signal from side lobes.

(e) Nulling antenna systems, which discard the unwanted interfering signals by adopting adaptive cancellation/ selection of signal. This technique is very complex and can be employed on both military satellites and ground segments[70].

China has a military satellite with anti-jamming capability for communications (Apstar-4), which was launched in 2005[71]. China has also reportedly upgraded its Xi'an Satellite Monitoring Centre

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[69] M.R. Frater and M. Ryan, Electronic Warfare for the Digitized Battlefield and Don J. Hinshilwood and Robert B. Dybdal, "Adaptive Nulling Antennas for Military Communications," 3 Crosslink, The Aerospace Corporation (Winter 2001/2002) at 30-37. Adaptive antenna systems contain five major components: a means of detecting interference, a means of distinguishing desired signals from interference, a control processor for determining how to combine the antenna elements, antenna elements and circuitry to respond to commands from the control processor, and a performance monitor to identify changes in the interference environment and respond accordingly.

[70] Don J. Hinshilwood and Robert B. Dybdal, "Adaptive Nulling Antennas for Military Communications"; Mark Wade, "Milstar," Encyclopedia Astronautica, online: http://www.astronautix.com/craft/milstar.htm; (accessed on 01 December 2009) .

[71] Space capability and India's Defence Communication up to 2022 and Beyond, by Colonel Deepak Sharma, and China Daily, "China to Launch its First Anti-Jamming Satellite Next Year" (March 4, 2004).

to monitor and diagnose satellite malfunctions, eliminate harmful interference, and prevent purposeful damage to satellite communications links[72]. India does not have advanced indigenous capability to take on EW threats. Though technology to protect satellites and ground systems against radio interference and jamming is improving but it is not possible to fully negate EW threat. It will always be possible to saturate the satellite transponder with high power radio signals to blind the satellite. Another simple way to mitigate the effect of interference and jamming of the network is to use multiple secure networks working in different frequency bands through number of satellites, so that it becomes difficult for the adversary to actually target the critical/ important link.

Protection against Conventional Weapons

It is almost impossible to protect satellites from such conventional weapons. One of the ways to nullify the effect is to have number of satellites forming a constellation of satellites with similar configuration and distributed similar functionality. This pseudo dispersion of targets will achieve increased survivability. At present only US Defence Advanced Research Projects Agency (DARPA) is carrying out the research on such type of satellite architecture that wirelessly communicate with each other[73].

Protection against Nuclear Attack

A nuclear attack on satellite is least likely, since it will cause widespread damage in the atmosphere and space alike without any distinction. Before any country decides on a nuclear attack in space to target space assets the nuclear exchange would have taken place on ground.

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[72] Xinhua, "China Enhances Spacecraft Monitoring Network" (December 12, 2006), online: http://news3.xinhuanet.com/english/2006-12/12/content_5473204.htm; Zhour Honghsun and Liu Wubing, "Status Quo and Assumption of China's Space Satellite Monitoring," China Communications (June 2006) at pg123.

[73] Noah Shachtman, "'Autonomous' Mini-Spacecraft Team up to Replace Big Sats," Wired — Blog (31 July 2007), online: http://blog.wired.com/defense/2007/07/the-objective-o.html; (accessed on 01 December 2009) .

If, this least probable attack does take place, than the Electromagnetic Pulse (EMP), and nuclear radiations will affect the electronics of many satellites without any distinction. The EMP and X-ray will burn out the electronics of the satellite. The US and Russia have hardened some military communication satellites for countering the EMP effect[74]. For communications satellite working in EHF (V-band, SHF; (40/20 GHZ)) can provide protection to satellite network against blackout of electromagnetic waves caused by nuclear detonation. The US has already planned some tactical networks in this band[75] and India too can plan future research in this direction.

Protection against Directed Energy Attack

A simple ground based laser can temporarily dazzle or disrupt satellite sensitive optics. Remote sensing satellites employing optical sensors for imaging and infrared earth sensors that are part of the attitude control system of most satellites would be most susceptible to laser interference. The higher orbits provide significant protection from this type of attack To protect the satellite from such attack, a satellite specific variety of sensors, filters, shutters can be installed for detecting directed energy interference/attack. These sensors can trigger the active and passive onboard defence mechanism[76].

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74 CRS report for congress, updated on 21 July 2008. High Altitude Electromagnetic Pulse (HEMP) and High Power Microwave (HPM) Devices: Threat Assessments; available at: http://www.fas.org/sgp/crs/natsec/RL32544.pdf; (accessed on 03 Sep 2011).

75 Also refer, Space Capability and India's Defence Communications up to 2022 and beyond, Occasional paper No: 16, Colonel Deepak Sharma, IDSA, and Dennis Papadopoulos, "Satellite Threat Due to High Altitude Nuclear Detonations," online: Lightwatcher, http://www.lightwatcher.com/chemtrails/Papadopoulos-chemtrails.pdf; (accessed on: 10 June 2009).

76 Ashton B. Carter, "Satellites and Anti-Satellites: The Limits of the Possible," at pg79, and Journal Article, International Security, volume 10, issue 4, pp 46-98 1984; available at: http://belfercenter.ksg.harvard.edu/publication/43/satellites_and_antisatellites.html; (accessed on 04 September 2011).

Peace Policies and Initiatives

Legal Framework and Adoption of Multilateral Treaties for Outer Space[77]

The world community strongly wants to keep the space a conflict free zone and do not want the space to become another battle zone. A number of peace policies and initiatives are being pursued by world community to control the weaponisation quest of few nations. There has been no progress on space issues in last 30 years. On 5 December 2007, a vote on a UN resolution calling for measures to stop an arms race in space was passed by a count of 178 to one against the United States, with Israel abstaining[78]. In 2008, states continued to express their commitment to international cooperation on the peaceful use of outer space in their civil space policies, with caveats based on their national security concerns.

As of now the agreed rules for outer space are[79]:

(a) No nuclear weapons tests in outer space. Limited Test Ban Treaty, 1963, signed by 134 nations.

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77 Space report 2009, executive summary, available at www.spacesecurity.org; (accessed on 10 December 2010).

78 UN General Assembly, "Resolution Adopted by the General Assembly: 62/20. Prevention of an Arms Race in Outer Space," 62nd session., 10 January 2008, http://disarma ment.un.org/vote.nsf (accessed 20 August 2008). Cited by Trevor Brown Soft Power and Space Weaponisation March 1, 2009, Air & Space Power Journal - Spring 2009; Soft Power and Space Weaponisation:Source: http://www.airpower.au.af.mil/airchronicles/apj/apj09/spr09/brown.html, (accessed on 10 April 2010).

79 Space Ssecurity orSspace Weapons? space security project introduction to outer space. http://www.stimson.org/space/pdf/issueguide.pdf; and Space Security magazine 2009, pp 43-45; available at: http://www.spacesecurity.org/SSI2009.pdf; (accessed on 04 Setember 2011).

(b) No weapons of mass destruction in orbit, no national appropriation of space by any means. Outer Space Treaty, 1967, signed by 125 nations.

(c) Cooperate on search and rescue operations in space. Agreement on the Rescue of Astronauts, 1968, signed by 113 nations.

(d) States are liable for damage caused by their space objects. Liability Convention, 1972, signed by 107 nations.

United Nations Institute for Disarmament Research (UNIDIR) Space Security Conference Report 2009[80]

The United Nations Institute for Disarmament Research (UNIDIR) in Geneva organised a conference "Space Security 2009, on "Moving towards a Safer Space Environment" from June 15 to 16 2009. The aim of this conference was in line with the UNIDIR mandate to assist the delegations to prepare for possible discussions on PAROS at the UN Conference on Disarmament (CD). The conference was attended by over 75 representatives from UN member states, UN observers, NGOs and civil society representatives from all over the world. The views of director general of the United Nations office in Geneva and China's representative on the necessity to control of arms race in space are given in succeeding paragraph.

The UN Director-General of the United Nations Sergei Ordzhonikidze brought out that the world is heavily dependent on space for development and threat nations should work together to protect this natural resource. He warned that the longer the international community waits before taking action, the more difficult it will be to achieve effective arms control in outer space. He emphasised on the necessity, and political will for the world to work together for greater space security. China's representative, Zhang Ze

[80] Space Security Conference Report 2009 available at: http://www.unidir.org/bdd/fiche-ouvrage.php?ref_ouvrage=92-9045-009-E-en (accessed on 8 April 2010)

from the arms control department of the ministry of foreign affairs stated that foundations must be built for a safer global environment and space was an integral part of this. He brought out that the main threats from space weaponisation were an arms race, and the high potential for increased space debris. He emphasised the need for "Zero Weapons Outer Space" and stated that China was ready for bilateral and multilateral talks[81].

81 ibid

Threat Analysis Indian Space Assets

In political and diplomatic domain there are no permanent friends or enemies. Alliances and associations depend on the national interests and the geo-political situation, which can change at any time. In 1971, the US moved its seventh fleet into the Indian Ocean as gunboat diplomacy against India. This implies that for developing and investing into a critical technology for a weapon system we should reduce the dependence on foreign powers, and invest into a capability which can nullify the superiority of adversary by adopting suitable measures in other areas. The threat is a direct function of the intension of the adversary, and own fear and suspicion about adversary's intentions. Therefore irrespective of the peace policies and initiatives by world community to keep space free of weapons, one cannot say with certainty that in the event of hostility the adversary will not attack the space assets. It must be noted that US, USSR, and China space programme still have high military component as compared to other states and along with India, have plans and the capability to develop and deploy ASAT weapons. One of the reasons for this could be that the space programmes of these countries initially started as military programmes and while India's programme was focussed on civil and peaceful aims.

Fear of Asymmetrical Attack on Satellite

For any asymmetric attack the adversary will choose the mode of attack and the target that is technologically and economically viable. There are targets on ground like cities, population centres, airports and such like. Attacking these kinds of target will yield more result, and will successfully meet the asymmetric aim rather than attacks on satellites; which is far costly and questionable in terms of reliability. In the era of the war of networks, our communication and computer networks are frequently being targeted even during peacetime. These targets are far easily accessible to adversaries than satellites in the space. Conventional war fighting capabilities and explosives can cause high causalities more easily than by acquiring ASAT capabilities. If a country or an organisation does not care for humanity than there are many other asymmetric means to cause high impact widespread damage with radiological weapons (dirty bomb) or chemical and biological weapons. The complexities involved in space warfare clearly indicate that fighting a war on ground will pay more dividends to a weaker nation than aspiring to attack space targets. Any attacks on space targets by weaker states will not impact the outcome of the war and would even invite retaliatory attack by countries whose space assets become vulnerable due to damage to space environment. Secondly if one wants to undertake covert operations then it is far easier to conceal actions on ground which can be more lethal and targeted with precision. Hence one can conclude safely that there is negligible chance of any asymmetric attack on satellites.

Indian, China, and Pakistan Space Assets

The types of attacks on space systems as enumerated earlier, both on ground and space (cybernetic or electronic interference, conventional weapons, directed energy (lasers), or nuclear) can be employed by a nation if it has the capability. The stronger nation having capability to attack satellites will employ its war fighting machinery against space systems both on ground and space. The weaker nations, to neutralise the effect of attack on its systems, will choose the cheaper options of attacking ground systems through covert or overt operations, and other form of conventional weapon systems; coupled with electronic and cyber attack against communications and command and control systems of space assets. Other than soft attack on the satellites and directed energy weapons (which are still maturing and being researched), to attack the satellite with other types of space weapons, the nation would require capabilities like space surveillance, tracking precision manoeuvrability as discussed earlier, and the launch capability. These technologies are very complex and difficult to develop, and deploy singularly by a nation. The interruption and interference with communication link and cyber attack on control system is the simplest way of achieving the military aim, however the affect may be temporary. They can, however, seriously disrupt the adversary ability to respond to a more damaging attack. Many capabilities are of dual use and can be manipulated for ASAT capability.

To address the issue of threat to our space assets, we have to consider the ability of the adversary to target any of the sub- systems of space (Space segment and ground segment). The vulnerability of asset stems from threat and threat quotient is derived from the function of dependence. The country will choose the target for attack if it is of value to him or to his adversary. The value of target will depend on its utility, redundancy, and alternatives. It must be noted that space assets are planned as per the requirements and utility, unlike weapons. The US is having the maximum number of satellites including military (almost 50 percent of satellites), followed by Russia and China. This indicates that their dependence on these assets is proportionately high as compared to India or other states. China is an emerging space power and a nation which is of immediate concern to India, who can pose a threat to our space assets. China has formulated a formal information warfare strategy called "Integrated Network Electronic Warfare (INEW)" which combines computer attack as well electronic warfare attack against the adversary network, to fight integrated operations at land, sea, air, and space. This means that network being supported by space system will be highly prone to EW, and cybernetic attack[82].

To analyse the dependence on space assets it is necessary to compare China's and Pakistan Space assets with that of India. Though Pakistan as of now does not have very promising space capability to hit the satellites in the space, however the asymmetry is in favour of Pakistan. It can always pose a threat to Indian space assets by attacking ground segments and can also temporarily disturb the usage of space systems, by employing soft options; the fact which should not be ignored.

82 Integrated Network Electronic Warfare: China's New Concept of Information Warfare, by Colonel Deepak Sharma, IDSA.

The important space capability of these nations are summarised as under[83]:

	India	China	Pakistan
First Satellite	1975[84]	1970[85]	1990[86]
First Astronaut	by 2017[87]	2003[88]	-
First Anti-Satellite Weapon Test	Can develop capability if required	2007[89]	Not in near future
Satellites in Orbit[90]	21	57	01[91]
Launch Sites	01[92]	04[93]	-
Satellite tracking, monitoring and control stations	09	20	01[94]
Satellite tracking and monitoring stations (ship-based)	-	06	-

83 For further details also refer Space Capability and India's Defence Communications up to 2022 and beyond, Occasional paper No: 16, Colonel Deepak Sharma, IDSA.

84 ISRO milestones". ISRO. http://www.isro.org/mileston.htm. (accessed on 01 October 2009).

85 Page 153, The Cambridge Encyclopedia of Space, Mission, Apllications and Exploration by Fernand Verger

86 http://www.suparco.gov.pk/pages/history.asp; (accessed on 01 October 2009).

87 http://www.isro.org/scripts/futureprogramme.aspx#top; (accessed on 01 October 2009).

88 http://www.astronautix.com/country/china.htm; (accessed on 01 October 2009).

89 D. Wright, "Colliding Satellites: Consequences and Implications," Union of Concerned Scientists (February 26, 2009), online: http://www.ucsusa.org/assets/documents/nwgs/SatelliteCollision-2-12-09.pdf; (accessed on 01 October 2009).

90 http://space.skyrocket.de/index_frame.htm?http://www.skyrocket.de/space/doc_sdat/spirale-1.htm; (accessed on 01 October 2009).

91 http://www.skyrocket.de/space/sat.htm; (accessed on 01 October 2009).

92 http://www.isro.org/scripts/futureprogramme.aspx#top; (accessed on 01 Nov 2010).

93 http://www.astronautix.com/country/china.htm; (accessed on 01 November 2010).

94 http://www.suparco.gov.pk/pages/suparco-facilities.asp; (accessed on 01 November 2010).

The conventional kinetic energy (KE) ASAT weapons as brought out earlier are generally effective at the low earth orbit satellites. In low earth orbit, the satellites that could be of value to Indian defence forces for military use are earth observation/ surveillance satellite (resolution 1 Metre and less). These satellites are four in number, and the future population of these will not increase drastically., as of Jan 2010, India has about 21 satellites (communication satellites - 09 in GEO, surveillance/imagery satellites with resolution less than 2.5 metre – 05[95] in LEO, other earth observation satellites in LEO - 05, and meteorological and other satellites - 02), for use by civil and Government agencies[96]. These satellites are GEO and are difficult to target by KE conventional ASAT.

The analysis indicates that in our context ground support facilities that are required for the space assets and ground segments are more vulnerable and can be easily attacked by our adversary/adversaries than employing hit to kill ASAT attack against satellites in the space. The details of important India and China facilities are given **at Appendix E, Table 6 and Appendix F, table 7** respectively[97]. Though space assets of India and China are comparable, the asymmetry is in favour of India. The above details clearly indicate the ground facilities which are critical to both India and China, are vulnerable, and can easily be targeted. To some extent these conditions apply to Pakistan also. This implies that we have to design means to protect our system on ground and develop the capability to hit the space support systems of adversary both on ground and sea.

Views of Indian Chief of Army Staff (COAS). In an interview to News Channel, Headlines Today (30 Jan 2011), in response to question regarding threat from the China, due to its armed forces extensive modernisation and induction of state-of-the-art weapons,

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95 Times of India News dated 13 Jul 2010, India has constellation of 10 earth observation satellites.

96 http://www.isro.org/satellites/allsatellites.aspx; (accessed on 01 November 2010).

97 http://www.isro.org/GroundFacilities/trackingfacility.aspx. accessed on 01 November 2010).

General V.K. Singh, COAS, opined "threat germinates from the intention and not from the modernisation effort of the country. It is the right of every country to modernise its armed forces"[98].

The above views of Indian COAS clearly indicate that India should modernise the forces with a purpose. The necessity of space weapons, technological, and the financial viability of developing and deployment of such weapons will dictate the type and scale of weaponisation of space. We have to take the pragmatic and holistic view of our challenges, capabilities, and the actual threat to national assets that concern us, before deciding on the space weapon induction and programme. All the evidence and scientific analysis indicate that for India pursuing space weapon programme (especially of lethal category that damages the space environment) will be futile.

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98 COAS interview to News Channel, Headlines Today, telecast by TV channelon 30 January 2011 at 2100 hr.

Recommendations

General Recommendations

It is evident that the attacks on space assets, whether by the US or by China or by any other nation, will be initiated when the conflict on ground is inevitable or has reached the stage wherein attacking space assets is going to be decisive in the outcome of war. In this scenario the concept of limited war that holds on ground and nuclear deterrence will be meaningless. Any attack on important satellite/ satellites may escalate the conflict beyond the recoverable threshold. The military response both on ground and space may be disastrous, highly destructive and lethal, and it will be exceedingly difficult to restrict any warfare in space that does not spread elsewhere, whether by asymmetric, conventional, or unconventional means.

The adoption of protection mechanism at any point of time, by states will be dictated by the maturity of threat, and the possibility of employing the particular ASAT capability owned by the adversary. The level of threat therefore can be categorised as high, medium, low, and very low.

The tables below suggest a mitigation/ protection strategy from the threats that can be encountered by space assets[99]:

Threats	Probability	Target satellites	Effect/ Implication	Suggested mitigation/ protection measures
Ground-based kinetic energy anti-satellite weapon (ASAT)	Low to maximum Medium	Reconnaissance /imagery LEO satellites are generally the target.	Each launch candamage a single satellite.	GEO satellites can take evasive action. Use multi-ple satellites and foreign coopera-tion for imagery data, through their satellites. Quick launch ofreplacement satellite in LEO, if critical. Conventional attack on launch site. International treaty banning ASAT.
Small satellites/ space mines	Low	GEO satellites. Co-orbital spaceMine technologyis still maturing.	Damage one or more satellites in GEO. Debris may damage own as well other satellites. This may also lead to high level of debris in GEO and cause damage to precious already starved geo-stationary orbit.	Global cooperation, and improved space surveillance for verification and enforcement. International treaty.

99 Also refer paper on 'Weaponisation of Space and India's Options', by Colonel Deepak Sharma, JDS, IDSA; Apr 2010 issue, ISSN 0976-1004.

Threats	Probability	Target satellites	Effect/ Implication	Suggested mitigation/ protection measures
Ground-based directed energy ASAT	Low	Reconnaissance /imagery LEO satellites are generally the target, when in line of sight of weapon system. Technology not with many countries.	Temporary or permanent damage to vulnerable satellites, particularly reconnaissance satellites.	Use of multiple frequency bands including radar imaging. Installation of detection sensors, protective circuits and electro/optic systems. Foreign cooperation for similar satellite imagery data, through their satellites. Imagery through oblique angle. International treaty
Nuclear explosionin space (HAND)	Very low	All LEO Satellites. Countries with Missile as demonst-rated by North Korea, Pakistan and similar missiles owning states can execute nuclear detonation in space.	Immediate damage to satellites in line of sight. The effect will be ranging from weeks to months, depending upon yield and type of detonation.	Radiation hardened military satellites.Quick launchof replacement Satellites. GEO military communication satellites system (space and ground segment) to work in Ka/ V –band (40/20 GHz). Internationaltreaty ban.

Threats	Probability	Target satellites	Effect/ Implication	Suggested mitigation/ protection measures
Jamming of satellite links	High.	LEO and GEO satellites	Temporarily affect the communication and data reception. Wide band jammers available. Commercial and military satellites systems susceptible	Nulling antenna systems on military satellites. Defence forces should induct the ground systems that have the capability to work in adverse electronic environment to evade the effect of adversary hostile electronic activity against the satellite systems. Have number of secure satellite networks working through different satellites. Enforcement through international norms and sanctions, and threat of similar action.

Threats	Probability	Target satellites	Effect/ Implication	Suggested mitigation/ protection measures
Jamming of control and monitoring links of satelliteOr direct attack on ground facility.	High or medium. Will depend upon the target country satellites, and its depend-ence.	Ground component of space assets (control and monitoring facility).	Effect control and monitoring of space assets and will render satellites non-functional	Cryptic code and adaptive cancellation/ selection of signal Have redundant and number of control and monitoring facilities. Undertake treaties with countries.
Orbital Debris	low	All satellites in LEO and GEO	As of now the debris in LEO are not a serious problem. Could be serious in GEO, if not regulated and controlled may lead to cascading effect.	International controlof disposal ofrocket components, penalties for littering in space. Better surveillance and international cooperation in space surveillance.

Space is the place where every country has equal rights and opportunity unlike air space and sea. It must be noted that space is a different medium than the air. Drawing any analogy with the air with reference to domination, superiority and control will neither be justifiable nor in order. While theory of fluid dynamics that is Bernoullies and Archmadies principles are applicable to air medium and sea but these principles have very little relevance in space which is more governed by gravitational effect. Therefore, the idea of space control, space domination and space superiority will have little value for actual strategic policy in real sense. These facts are equally applicable in the context of India for framing its policy.

Recommendations Specific to India

As has been analysed the threat to space assets can be reduced by reducing the value of asset to the adversary, creating redundancy and alternatives. These factors are infact true for all assets, be in space or ground. As discussed above, satellites are vulnerable to many types of attack and protecting them from all type of threats is difficult.

As stated, the Indian defence forces utilise space assets mainly for communications, imagery and navigation. Communication is the major application of the space and is a real time requirement of forces unlike space based imagery applications. In view of induction of latest state-of-the art ground communication and other systems both for static and mobile operations, it is possible for the forces to reduce the dependence on space system thereby reducing the value of target to adversary. For offshore and air operations the satellite system are complemented with radio, to take care of disruption in satellite based communication. In addition to these measures, the forces should plan the multiple networks in different frequency bands, working through multiple satellites. The integration issue of these networks can be well resolved through connectivity of switches of ground segments. The satellites planned must provide spot beam facility to cover the area of interest as per the operational requirement and technical suitability.

For imagery applications, the data through satellites is primarily required for strategic and static tactical targets, wherein a number of earth observation satellites are employed in collecting data. To disable all satellites simultaneously is not an easy task for an adversary. However, the dependence at the time of operations can be reduced by earmarking other available aerial sources like UAVs, AWACS, reconnaissance aircrafts, and mapping the strategic and static tactical targets during peace time. In addition the imagery data of area of interest can also be obtained through friendly countries or purchased. Therefore, for surveillance, more sophisticated and alternate means of surveillance system should be procured/ inducted by India to supplement and complement space systems.

India's geographical, political, economic, and military operation conditions are entirely different from that of US or any other nations. India's short term and long term policy should be based on its own requirements, rather than on US and other nation's policy perceptions. In view of the above analysis it is recommended that the India should adopt the following policy steps to meet its short term as well as long term goals[100]:

(a) **Space Capabilities**. Space technology is highly complex technology and requires a global cooperation. India therefore needs to concentrate more on space exploitation capabilities development both for space and ground segments than concentrating its effort and finances on space weapon systems. Efforts on weaponisation will retard India's progress in the field of space exploitation and global support in space technology. India should concentrate on development of dual use technology to become self reliant in space technology. No ASAT and space weapons should be developed or deployed in the next 10 to 15 years, although R&D can continue at an appropriate level to develop enabling technologies which are also required for peaceful use and space exploitation.

(b) **Create Redundancy by Deploying Number of Satellites**. India has mastered the technology of Polar Satellite Launch Vehicle, and is capable of launching number of satellites through a single launch. A number of small satellites for surveillance/ earth observation in Low Earth Orbit can be planned at the time of requirement, if necessary. This would reduce the vulnerability. The same should be followed for communication

[100] Ibid.

satellite networks by planning number of networks working in different frequency bands and through a number of civil ISRO/ defence specific satellites.

(c) **Reduce Dependence on Space System**. Develop alternates to space system to support the requirements. The space systems should act only as redundancy or an alternate to terrestrial or aerial platforms. For sea based forces the space system be planned as complementary to the existing systems. This will ensure better exploitation of adversary weakness while one can continue to exploit its own space assets.

(d) **Use of Foreign Satellites.** The use of friendly nation's satellites, especially for imagery data will be advantageous. Adversary shall be reluctant to target foreign satellite due to obvious political implications. Data can be obtained either through mutual cooperation and sharing the resource or may be purchased

(e) **Dedicated Military satellites only if Necessary**. Communication is the major application of space that is being exploited by Indian defence forces. Defence forces should plan their network working through ISRO satellites as far as possible. The ISRO should appropriately configure satellites to provide requisite frequency bands and area coverage. The dedicated military satellites can be planned only if ISRO is unable to meet the requirement of bandwidth and coverage, or the applications and frequency bands where the commercial usage is minimal; like protected communication, and network working in UHF, S, EHF/SHF frequency bands.

(f) **Electronic Warfare (EW) and Cyber Attack.** Electronic warfare coupled with cybernetic attack will make fighting war in space both economical and effective in comparison to employing other forms of weapons against space system. India should concentrate its effort to expand the scope and capability of existing EW units to include the cyber warfare capabilities and other EW measures against the satellites by employing static, mobile and on the move satellite terminals. Mobile and on the move, EW satellite terminals will be effective even at the fringe of footprint of adversary satellite and shall also provide safety against both detection and conventional weapon attack.

(g) **Counter EW Capability**. The most vulnerable link of space system is its command and control link The communication satellites are inherently vulnerable to interference and jamming. Since the concerned adversary of India has the dedicated doctrine of INEW, we must develop, and acquire military systems both satellites and ground segments, which are capable to withstand or minimise the effect of adversary INEW attacks.

(h) **Quick Launch and Mobile Launch Capability**. Quick launch capabilities through a mobile platform be developed as a long term plan for low orbit satellites, in order to replace critical space infrastructure if it is threatened or disabled. This should be planned only after carefully weighing the necessity with reference to dependability of forces on the space assets, finances and other better and cheaper alternative options.

(j) **Space Security Treaty for Non-offensive use of Space**. The objective of space security needs to be promoted in terms of a non-weaponised architecture, with a code of conduct regulating pace activities to enhance the security of space assets and non-offensive uses and activities.

The military applications of space in the next 10 to 20 years are going to remain the same as these are today. To reduce the vulnerability of satellites the countries will be developing and supplementing satellite platforms for some military applications, with terrestrial systems, and high endurance Airborne manned and unmanned aerial vehicles (UAVs). This transition should also serve the basis for arms control in space and institution of peace policies.

Conclusion

The world community is in favour of keeping space as a conflict free zone, since it affects the humanity and is a global common. Adequate measures are being pursued by nations to control arms race in the space through peace policies and arms control negotiations. Despite all the peace initiative to control arms race in space it is true that the US, Russia, and China, and some other countries are working behind the curtain on anti-satellite weapons. If these countries can be pursued even, not to flight-test and deploy such weapons than everyone's space assets will be safe.

The above arguments clearly indicate that the diplomatic, political, and financial costs of vigorously pursuing space weapons can only be justified by the nations who want to justify their uncontrolled ambition of pseudo military dominance. Moreover, improvements in the range, promptness, and lethality of terrestrial weapons are likely to come far sooner, and at a fraction of the political, and financial cost, than the advent of space strike capabilities. Reality suggests that these risks can be avoided and the presumed military advantages of space warfare be pursued at far lesser cost by other war-fighting means, than concentrating on means which pay far less dividends and are exorbitantly a costly venture. The countries must take into account the following facts, before considering space weapons as an option for meeting their political and military aim:

(a) **Enabling Capability**. No nation presently has the entire spectrum of enabling capabilities to control or dominate or deny the space to other. The US has undertaken the dedicated research and development, and finances earmarked to develop and field such capabilities. Other nations especially China may follow the suit to counter US pursuit and domination.

(b) **Space Surveillance Capability.** For counter space operations, effective space surveillance capability is needed. This requires cooperation of many nations. Hence to acquire this capability by single nation in next few decades may not be financially and technically viable.

(c) **Vulnerability of Satellites**. The satellites follow predetermined orbit and are visible globally at some point or other, and their position can be predicted. Hence they can be easily targeted by ASAT weapons and are a sitting duck. GEO satellites as such have a fix orbital slot, and are always vulnerable to variety of EW threats.

(d) **Effective ASAT Weapon**. The most potent technologically and financially viable ASAT capability that any nation can presently execute is electronic and cybernetic attack capabilities, without vitiating the space environment.

(e) **Vulnerability of Ground Component of Space System.** It is far more easy and economical to attack and neutralise ground component of space system than attacking satellites.

(f) **Deterrence Capability of Space Weapons**. Space weapons have very little or no deterrence capability. This is more applicable for India in the present context of geo-political situation.

(g) **Protection of Satellites.** No satellites can be protected from all kinds of threat.

(h) **Reliability and Cost**. The reliability of space weapons is poor and cost exorbitantly high.

(j) **Debris**. As of now there is no alarming situation, but if activities in the space are not regulated and the nations do not refrain themselves from flight testing of ASAT weapons, then the situation may lead to cascading effect which may render LEO and already starved GEO unusable.

From the foregoing analysis, it is evident that the main driver behind the creation of threat hype is the idea of few political, researchers, and military officials. To justify their idea, the arguments like necessity to counter the development by few countries of space weapon capability, the air and space analogy, pseudo fear of imminent danger to space assets, are often being put forth and widely publicised. The policy of dominance, superiority, and control apply more to air than space. Infact, space is analogous to gravity, wherein higher one plans to go against the gravity higher the force is required to overcome the gravitational force. If right force is not applied or force applied is on wrong direction than one falls back to the ground with equally higher force. India must learn the lesson from US, SDI programme.

India has other systems available to complement the space based systems and does not have much dependence on space based systems for military use, as compared to other major space powers. Therefore we do not require alarming or emergent measures to safeguard our assets, by pursuing space weapons programme. We should concentrate our efforts on improving other instruments of war fighting machinery. For satellite based communication systems, we should develop indigenous state-of-the-art jamming resistant satellite ground systems so that we reduce our dependence on foreign nations on ground systems. For surveillance, more alternate ground and aerial platform should be inducted and employed to supplement the space systems. The work on indigenous R&D on space control and protection systems along with development of Electronic Warfare and cyber attack capability and counter measures to evade such threats, should continue, to make us self reliant in the field of space system as a long term policy.

To prove the point in favour of space weapons, some people even put across the argument that though from defence point of view the alternates can be developed and dependence on space assets may be reduced, however civil applications will still remain vulnerable. It must be understood that there is a correlation between attack on space assets supporting military and civil applications. If space based military applications can be made less vulnerable then attack on space assets supporting civil applications will not take the form, wherein these are destroyed completely. At the most adversary will target the applications to temporarily disturb the functioning of space system. If adversary has to attack the civil value targets, it has many more lucrative and high value civil targets to choose on ground like atomic installations, dams and such like targets, than attacking space assets with hard kill weapon systems. These kinds of targets can be attacked with much impunity, ease and very little cost. The second point one must understand that before any nation decides to attack the assets in space, which has global implications; the conflict and environment on ground will be beyond anybody's imagination.

We should ignore the pseudo threat being created by few, and understand the vested financial interest behind some agencies and arms dealers who sell the idea of effectiveness and advantage of lethal kind of ASAT weapon systems and avoid being guided into a trap to buy ASAT technology and systems from foreign agencies at an exorbitant cost, that push us in the space arms race in haste. The world is coming together to protect global environment for our future generations, and global environment is a sub-set of space. Therefore, India should not be the part of conspiracy which spoils the global environment.

It is good to lay down big ideas for the strategic policy, however it must address the basic issues, as to how the policy will actually be implemented and translate on ground, and its practicability in a foreseeable time frame.

Finally it can be safely concluded that though the threat to Indian space assets exist, but it is neither critical nor alarming. The India and its defence forces should concentrate more on exploitation and development of space assets, especially in the area of developing efficient ground systems to effectively utilise space segments, than wasting energy and finances on space weapons. **The technology in the future will make the space weapons an economically viable proposition, however any nation advocating the deployment of space weapons and make the space a shooting gallery, will be disastrous and shall render the greatest disservice to the humanity.**

Appendices

Appendix - A

Table 1: Space Weapon Enabling Capabilities[101]

Capability	China	India	Israel	Japan	Russia	US
Space launch vehicles						
Land — Fixed	E	E	E	E	E	E
Land — Mobile	L	L	L		E	E
Sea	L				E	E
Air					D	E
Space tracking (uncooperative)						
Optical (passive)	E			E	E	E
Radar	E			E	E	E
Laser	E		E	E	E	E
Autonomous rendezvous						
Cooperative					E	D
Uncooperative					F	D
Proximity operations						
Cooperative						E
Uncooperative						E
High-g, E large-Δ-V upper stages	D	E	E	E	E	
Microsatellite construction	E	E	E	E	E	E

Key:

E = Existing capability **F = Flight-tested capability**

D = Under development **L = Latent capability**

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101 Space security Report 2009 page 56: www.spacesecurity.com

Appendix - B

Table 2: Space-Based Strike Enabling Capabilities[102]

Capability	China	India	Israel	Japan	Russia	US
Precision position manoeuvrability	F				F	F
High-G thrusters						D
Large △-V thrusters	F	F	F	F	F	F
Accurate global positioning	D	D	D	D	D	F
Anti-missile homing sensors		D	F	F	F	F
Global missile tracking				F	F	
Global missile early warning					F	F
Launch on demand					D	D
Microsatellite construction	F	F	F	F	F	F
High-power laser systems	F					F
High-power generation					E	D
Large deployable optics	F	D	D	D	F	F
Precision attitude control	D		D	F	F	F

[102] The SBSW section of the table implies neither the existence of a program for integrating these into an actual SBSW system nor the capability to deploy that SBSW, but only the existence of some capability for each of the necessary prerequisite technologies for that particular SBSW system. This clarification is important since integration of these technologies into a working system, including testing, can take many years. Nevertheless, with the prerequisite technologies in hand, the SBSW systems are considerably closer to the reach of that actor. It is clear that only the US and Russia currently have all the prerequisite technologies for SBSW systems.

Capability	China	India	Israel	Japan	Russia	US
Precision re-entry technology	F				F	F
Nuclear power	F	F	F	F	F	F
SBSW						
Space-based laser					L	L
Space-based interceptors					L	D
SB munitions delivery (conventional)						
Neutral particle beam					L	L

Key:

E = Existing capability **D = Under development**

L = Past development **F = Some capability**

Appendix - C

Table 3: Unintentional Collisions Between Space Objects

Year	Event
1991	Inactive Cosmos-1934 satellite hit by cataloged debris from Cosmos 296 satellite
1996	Active French Cerise satellite hit by cataloged debris from Ariane rocket stage
1997	Inactive NOAA-7 satellite hit by uncataloged debris large enough to change its orbit and create additional debris
2002	Inactive Cosmos-539 satellite hit by uncataloged debris large enough to change its orbit and create additional debris
2005	US rocket body hit by cataloged debris from Chinese rocket stage.
2007	Active Meteosat-8 satellite hit by uncataloged debris large enough to change its orbit
2007	Inactive NASA UARS satellite believed hit by uncataloged debris large enough to create additional debris
2009	The 560-kg US satellite, of Iridium Holdings LLC, launched in 1997, collided about 800 km above northern Siberia in Feb 2009, with a defunct Russian military satellite Cosmos-2251, weighing almost a ton, according to the US Strategic Command. The 500 or so pieces of the two satellites floating in space pose a potential threat to satellites[103].

[103] Source: Xinhua News Agency, by Staff Writers Beijing, China (XNA) Feb 14, 2009 http://www.spacedaily.com/reports/Satellite_Collision_Not_To_Delay_China_Space_Program_999.html; (accessed on 10 July 2009).

Appendix - D

Table 4: Intentional Collisions Between Space Objects

Year	Event	Debries created*	Lifetime
1963 - 1982	Nine Soviet co-orbital ASAT testi ntercepts	700+	Decades
1985	US destruction of Solwind using F-15 launched ASAT	285	19 years
2007	Chinese destruction of FY-1C using direct ascent ASAT	2,300	Centuries, as per US estimate may not be fully justified.
2008	US destruction of de-orbiting USA-193 satellite	360	Months

*trackable (greater than 10 centimetres) debris only

Table 5: Summary of 2008 Debris Events[104]

Parent object	Country	date	Estimated number of debris	Cataloged Number of Pieces	Lifespan of Pieces
Cosmos -2125	CIS	16 January 2008	6	None	None
CZ-3A R/B	PRC	27 January 2008	30-40	None	None
SL-6 R/B	CIS	17 February 2008	2	None	None
USA-193	US	21 February 2008	360	173	8 months

104 Data compiled from the public satellite catalog, online: Space Track, http://www.space-track.org (date accessed: 1 February 2009).

Parent object	**Country**	**date**	**Estimated number of debris**	**Cataloged Number of Pieces**	**Lifespan of Pieces**
Cosmos -2421	CIS	14 March 2008**	500+	507	Years
Atlas-5 R/B	US	21 March 2008	25	None	None
Cosmos -1818	CIS	Early July 2008	50+	None	Decades

** Date of first breakup. Object experienced two additional breakups on 28 April and 9 June. Pieces displayed in table are totals for all three breakups.

Appendix - E

Table 6: Important India's Ground Facilities

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, 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.
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).
Master Control Facility	Hassan (Karnataka); 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 at Bhopal[105]
Launch site Satish Dhawan Space Centre	Andhra Pradesh	Sriharikota island facility acts as a launching site for India's satellites.
Equatorial Rocket Launching Station	Thumba	TERLS is used to launch sounding rockets.

105 http://www.isro.org/space_science/images/BalloonXrayStudies.htm; (accessed on 01 Oct 2009).

Appendix - F

Table 7: Important China's Ground Facilities

Launch Sites in China.[106].

(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)[107]

In 2010-11, China has plan to construct its new launch facility on Hainan Island where the new Long March 5 heavy lift launch vehicle will be located.

Satellite Tracking Stations of Chiina[108]. The details of 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.	(i)Jiamusi Station.	Malindi
(e)Nanhai Station.	(j)Dongfeng Station.	Swakopmund
	(k)Hetian Station.	Shared facility: France, Brazil, Sweden and Australia

106 http://www.astronautix.com/country/china.htm; (accessed on 01 Oct 2009).

107 http://en.wikipedia.org/wiki/Space_program_of_China#History _and_recent_ developments #History_and_recent_developments; (accessed on 01 Oct 2009).

108 Ibid.