# Chinese Anti-Satellite Means: Criticality and Vulnerability of Indian Satellites

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On January 11, 2007, China shot out its malfunctioned weather satellite, the Fengyun 1C (FC-1C), literally like a dragon swatting a fly. Unannounced, this test, a destabilising move, made every power look up and take notice of its technological accomplishment. Since then and till date, China, working to a plan, has successfully demonstrated its Anti-Satellite (ASAT) capabilities using differing techniques and different weapon systems. In 2008, 2010 and 2013, the Chinese demonstrated co-orbital techniques that could have ASAT spin-offs. In 2013, China conducted a sub-orbital launch, "almost to Geo-Synchronous Orbit (GSO)," demonstrating the capability of injecting a Kinetic Kill Vehicle (KKV) to hit a satellite in GSO or Geo-Stationary Orbit (GEO). In 2015, it tested an advanced system that is capable of hitting ballistic missiles as well as satellites in space. Surely and surefootedly, it appears to be in the process of acquiring a full quiver of ASAT capabilities. Its earnestness, diversity and regularity in testing, cannot be disregarded. This period also coincides with India launching key satellites such as the Cartographic Satellites (CARTOSAT), Radar Imaging Satellites (RISAT)and Indian

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**N.B.** The views expressed in this article are those of the author in his personal capacity and do not carry any official endorsement.

Regional Navigation Satellite System (IRNSS). The only dedicated military satellite of India, the Geo-Stationary Satellite-7 (GSAT-7) was also launched during this period. All Indian GEO/GSO satellites are placed between 30 and 135 degrees East longitudes; while all Indian Earth Observation (EO) satellites are in Low Earth Orbit (LEO). When related with the proximity of mainland China to India, the Chinese ASAT capabilities are a clear and present threat to Indian assets in space and India needs to review these ominous developments.

Then there is a symbiotic connect between ASAT and Ballistic Missile Defence (BMD) weapon systems. A BMD weapon system designed for mid-course interception, with some tweaks, can be employed as an ASAT weapon against LEO satellites and its development can be justified as for genuine national self-defence. In addition, capabilities shown being developed for civilian space application such as inspection satellites and robotic arms for a space station and remote docking, could as well be spun off as co-orbital ASAT weapons. Clearly, such amorphous dualities lend themselves well to surreptitious development of ASAT capabilities. It is clear that these means are being developed by China as asymmetrical capabilities to balance the US' dominance in military–space applications, probably as a sub-set of China's larger Anti-Access Area Denial (A2/AD) strategy. By having a capability to hit space-based ballistic missile early warning satellites, China also aspires to enhance its nuclear deterrence. China could as well be signalling to deter its regional rivals from expanding their respective capabilities in space.

The Chinese are being encouraged in this direction because of weak international laws. The Outer Space Treaty (OST) of which China is one of the signatories, and which prophesises peaceful use of space, is not very succinct on the use of ASAT weapons as long as a nuclear weapon is not put in space. America's dogged opposition to any new instrument of arms control in space has spurred the Chinese further. The conspicuousness of the omission of the lines "the international community should negotiate and conclude the necessary legal instrument as soon as possible to prohibit the deployment of weapons in outer space and the use or threat of use of force against objects in outer space," from the 2006 Chinese Defence White Paper makes it is evident that the Chinese are likely to proceed down this path till the time their ASAT systems are proven and operationalised. This paper reviews open-source information available on Chinese ASAT capabilities as well as Indian satellites of national security relevance. It would also make an effort to examine the threat to certain Indian satellites and crystal gaze on the impact of their loss.

## Chinese ASAT Capabilities

The Chinese have successfully demonstrated Direct Ascent (DA) ASAT weapons of three types and a variety of co-orbital ASAT techniques. It is suspected that they have also developed a ground-based LASER (Light-Amplification by Stimulated Emission of Radiation) system capable of degrading electro-optical earth observation satellites. This section briefly analyses ASAT tests carried out by China in the recent past. The January 2007 test involved a SC-19 DA-ASAT weapon launched from a mobile Transporter–Erector–Launcher (TEL) from a pad at Xichang. This weapon was successful in destroying the FY-1C satellite, in a polar orbit at an approximate altitude of 860 km, by a direct impact. The weapon utilised a launch vehicle derived from the DF-21 Intermediate Range Ballistic Missile (IRBM) and a KKV derived from the HQ-19 long range Surface-to-Air Missile (SAM) system. The KKV could have featured either active radar or passive multi-spectral Infra-Red (IR) homing guidance or a combination of both. Prior to 2007, the launch vehicle had been tested untipped in 2005 and 2006. After 2007, the weapon has been used in 2010, 2013 and 2014 to carry out successful intercept of three incoming ballistic missile targets. Thus, after two cold and four hot tests, it can be surmised that the weapon has been proven and is likely to be operational on date. The

SC-19, since rechristened the Dong Ning–1 (DN-1), is capable of hitting any satellite in LEO or a ballistic missile during its mid-course.

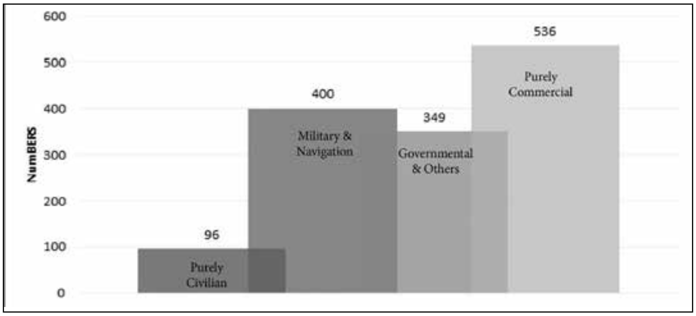
On May 13, 2013, China tested the second DA-ASAT weapon, again from a TEL at Xichang. The weapon has since then been classified as the Dong Ning–2 (DN-2). This multi-stage rocket is a derivative of the Kuaizhou commercial satellite launch vehicle, which too traces its lineage to the DF-21C, having been designed by the same entity. As per the Chinese, it carried the Kunpeng-7 scientific experiment payload for study of the magnetosphere and achieved an altitude of approximately 10,000 km. The statement belies the fact that the bright plume of the rocket motor was seen as far as Hong Kong. The US termed it as "a suborbital launch that appeared to be on a ballistic trajectory nearly to a GSO earth orbit." It was a cold test with no impact detected in space and nothing being injected into orbit. The rocket was launched towards the equator over Taiwan and as per the US, "re-entered the Earth's atmosphere above the Indian Ocean." The point of splashdown analysis hints at a time of flight of more than five hours, a time in which, in a high angle trajectory, a rocket of its class could achieve an apogee in the region of 30,000 km. Thus, the American version appears closer to the truth than the one given by the Chinese. With a little development, this rocket could as well be made to reach an altitude of 36,000 km and when coupled with the KKV (that has already been tested on the SC-19), it would threaten the relatively jam-packed GEO and GSO satellites.

It was reported by an online newspaper, *The Washington Free Beacon*, that China had carried out a non-destructive test on October 30, 2015, from the Korla Test Site, employing its third type of DA - ASAT weapon, the Dong Ning-3 (DN-3). Apparently, the Chinese ASAT inventory has more variety than was thought earlier. The test was accompanied by the typical Chinese denial and subterfuge, that the test was not an ASAT test but "a mid-course anti-missile test." However, the US continued to maintain that it was indeed an ASAT test.

The capability to perform energy management manoeuvres, as evident from contrails seen in the Chinese sky, differentiates the DN-3 from the DN-1 and DN–2. The DN-3, in some of its parameters, is now comparable to the much in the news Terminal High Altitude Area Defence (THAAD) missile system of the US. DA-ASAT weapons carry out a very difficult and technologically challenging engagement in view of the long range, high relative velocity and small size of the KKV as well as the target. It is a pre-planned engagement and is carried out under the cover of sensors. The rocket puts the KKV in a 'narrow cone' in space based on information updated by the sensor network. The KKV then switches to its on-board homing sensor for the terminal part of the engagement.

The more worrisome issue is that destruction of a satellite generates substantial space debris. As the debris becomes a threat to the spacecraft of other entities, such an act invites worldwide condemnation too. For example, the destruction of the FC-1C resulted in 3,428 pieces of trackable debris, of which 2,948 pieces (86 per cent) continue to be in orbit. These pieces comprised 10.41 per cent of total debris in space as on March 01, 2016. The impact of debris, if a satellite is hit in GEO/GSO, would be calamitous because satellites are parked closely in a very narrow altitude band.

**Fig 1: Assessed Purpose of Operational Satellites, as on January 01, 2016**




Source: Union of Concerned Scientists Satellite Database, http://www.ucsusa.org/

As on date, more than 70 states, in addition to a number of commercial and multinational organisations, operate satellites.[1] Moreover, unlike in the past when most satellites had military roles, today, most have purely commercial roles.[2] As per Article VII of the Outer Space Treaty, China can be held liable for compensation if the debris generated by its ASAT attack damages the satellites of any other state or organisation. [3] Moreover, such accidental damage will complicate issues if the satellite concerned is multinational or commercially owned. One of the reasons for the Chinese not carrying out any destructive test since 2007 is the criticism that they received in the aftermath of the FC-1C the test. In the last few years, China has demonstrated some remarkable co-orbital rendezvous manoeuvres, supposedly to prove technologies for its space station and on-orbit spacecraft inspection programmes. However, the dual use nature of the involved technologies and the secrecy surrounding these manoeuvres, point towards anti-satellite testing. A co-orbital weapon can destroy, divert or degrade its target by impacting it. It can also do so by using an explosive charge, LASER weapon, radio frequency device or robotic arm.[4] The signatures of a co-orbital weapon are so subtle that they are likely to be missed, denying any warning to the adversary.

On September 27, 2008, during the third Chinese manned space flight, the Banxing 1 (BX-1) miniature satellite was released. It initially entered orbit around the Shenzhou–7 but after a few days, manoeuvred away and passed unannounced just 45 km of the International Space Station (ISS).[5] The BX-1 had stereo cameras and was tested as an "inspector satellite." Such small and lithe satellites, in addition to collecting intelligence on other satellites at close ranges, may also be used to ram enemy satellites. On June 15, 2010, China launched the Shi Jian-12 (SJ-12) science and technology research satellite aboard a Long March 2D rocket. Between mid-June and mid-August, the SJ -12 conducted a number of orbital manoeuvres to gradually rendezvous with a Shi Jian 6F (SJ-6F) satellite, which had been launched earlier in October 2008. Moreover, on August

21, 2010, the orbit of the SJ-6F appeared to be disturbed, indicating that the SJ-12 may have impacted it.[6]Thankfully, no debris was produced. The Chinese could contend that their co-orbital rendezvousing tests are benign proving of technologies for non–military purposes, but it should not be overlooked that the relative velocity at impact can always be tempered to deliberately destroy or damage an enemy satellite.

On July 20, 2013, China launched a Long March 4C rocket carrying three satellites: the Shiyan 7 (SY-7), Shi Jian 15 (SJ-15) and Chuangxin 3 (CX-3). Initially, the SY-7 chased the SJ-15, even changing track to follow the SJ–15. Soon after, the SY-7 lost orbit by 93 miles, coming closer to the CX-3 but then suddenly made a surprise rendezvous with the Shi Jian 7 (SJ-7), a satellite that had been launched in 2005. The SY-7 reportedly carried an experimental robotic arm for proving in-space manipulation technologies.[7] The Chinese may argue that the robotic arm is being tested for the next generation Shenzhou Space Station, however, it can also be used to alter the orbit of, or cause irreparable damage to, an enemy satellite. Protruding solar panels, parabolic antennae, external instruments and the outer protective casing of satellites are particularly vulnerable to such an attack.

Co-orbital rendezvous tests performed by China till date have been under a cooperative arrangement where both the spacecraft concerned were Chinese. The ground controllers had access to the telemetry and tracking data of the target as well as the rendezvousing spacecraft and, therefore, found it easy to accomplish their objective. It is only a matter of time and testing for Chinese technology to mature to enable it to perform such manoeuvres against a non-cooperative (enemy) satellite. These tests were carried out in LEO but China has to wait for paradigmatic improvement in the deep space cover to extend these capabilities to GSO/GEO. It must also be noted that rendezvousing is a slow and iterative process, involving numerous changes in orbit, that consumes precious on-board fuel. Additionally, some fuel is required to achieve and maintain the desired orbit. And such co-orbital satellites, being small, stealthy and highly manoeuvrable will not carry much fuel. When considered together, it can be assessed that co-orbital weapons have a limited lifespan, limited rendezvousing opportunity and limited utility in short conflicts. But if China chooses to maintain a constellation of co-orbital spacecraft in different planes, they will become the ultimate stealthy ASAT weapons.

In the past, China has aimed LASER fired from ground-based stations on certain US earth observation satellites in LEO[8], albeit harmlessly. China is a bonafide member of the International LASER Ranging Service, a worldwide network of LASER ground stations used for ranging and tracking cooperative satellites.[9] Therefore, some may argue that the illumination of US satellites was accidental and unintended. However, it must also be noted that at low power, such a LASER is capable of dazzling an electro-optical earth observation satellite by overloading its sensor array. At high power, such a LASER can blind the same electro-optical satellite by irreparably damaging its sensor. At greater power, theoretically, it could damage the body of a satellite by burning through. LASER ASAT weapons are technically difficult to perfect. The challenge of aiming and dwelling a narrow beam of electro-magnetic energy on a small target hundreds of kilometres away demands mastering the technologies of space weather prediction, adaptive optics, space surveillance and satellite tracking, which China is still to achieve. Besides, the large sized and fixed installation of such LASER ASAT systems on high ground makes them intrinsically vulnerable to physical counter-measures. However, deniability of the attack, near instantaneous speed of the attack, capability to attack multiple targets in quick time as well as absence of resultant space debris, make LASERs promising ASAT candidates.

In addition to the hard ASAT techniques and tests reviewed above, China also has a plateful of soft ASAT techniques. Chinese writings quoted in the 2015 Report to Congress by the US-China Economic and Security

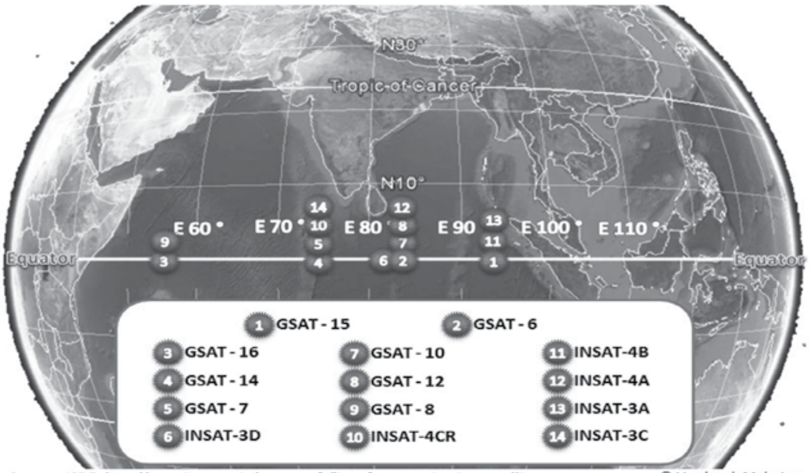
Review Commission indicate that China prefers soft attacks over hard attacks because of their plausible deniability, low risk of escalation and avoidance of debris.[10] Therefore, soft attacks are likely to be options of first choice. Chinese achievements in cyber attacks are well known. China is capable of launching such attacks against the satellites themselves as well as the Telemetry, Tracking and Command (TTC) system. It is suspected that in June and October 2008, cyber actors working on behalf of China took full control of the National Aeronautics and Space Administration's (NASA's) Terra Earth Observation System Satellite.[11] China also has ground-based satellite jammers. These jammers are capable of degrading signals to and from satellites which are over or within a few hundred kilometres of the Chinese mainland.[12]

To support its ASAT programme, China has invested heavily in its space surveillance network. China is building a geographically distributed network of static and mobile radio telescopes, radar and optical sensors; to detect and track space objects.[13] It is attempting to improve the accuracy and resolution of these sensors to support its ASAT missions.[14] As on date, the near earth cover is good, ASAT engagements in LEO are possible with ease, and China is working to improve deep space cover, to enable engagement of satellites in higher orbits. Clearly, there is some work to be done in this field till China achieves coverage, persistency and capability similar to that of the US Space Surveillance Network.

## Critical Indian Satellites

India has vibrant space applications and exploration programmes. The Indian Space Research Organisation (ISRO) is also working on manned space flight and orbital space station programmes. This section will discuss Indian satellites that could be prospective targets of a Chinese ASAT attack under three broad categories: communication, earth observation and navigation.

**Fig 2: Positioning of INSAT/GSAT Satellites**

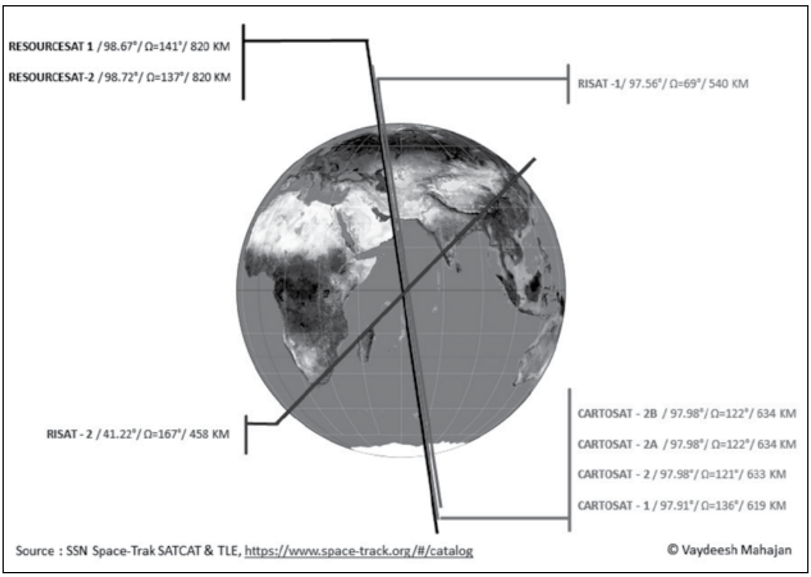



Source : ISRO, http://www.isro.gov.in/spacecraft/list-of-communication-satellites © Vaydeesh Mahajan

The Indian Satellite System (INSAT) satellites are multi-purpose satellites that serve a large variety of informational, entertainment, societal, national security and commercial purposes. Using different beam shapes, these services are provided selectively over the Indian mainland, and island territories, and South Asian and Indian Ocean Regions. INSAT satellites carry C, S, extended C and Ku band transponders with a majority providing telecommunication and TV, cable and radio broadcasting services. Some satellites also carry Very High Resolution Radiometers (VHRR) and electro-optical cameras for meteorology. On some newer satellites, certain transponders are configured for rebroadcasting of distress signals received from emergency transponders. Recently, some satellites have carried dedicated transponders for rebroadcast of signals in space for GAGAN, the Indian satellite based GPS (Global Positioning System) augmentation service. These satellites, fourteen functioning as on date, are positioned in GEO between 55 degrees and 93.5 degrees East longitudes.[15] The two newer RESOURCESATs carry three different multi-spectral optical sensors imaging in visible, near IR and shortwave

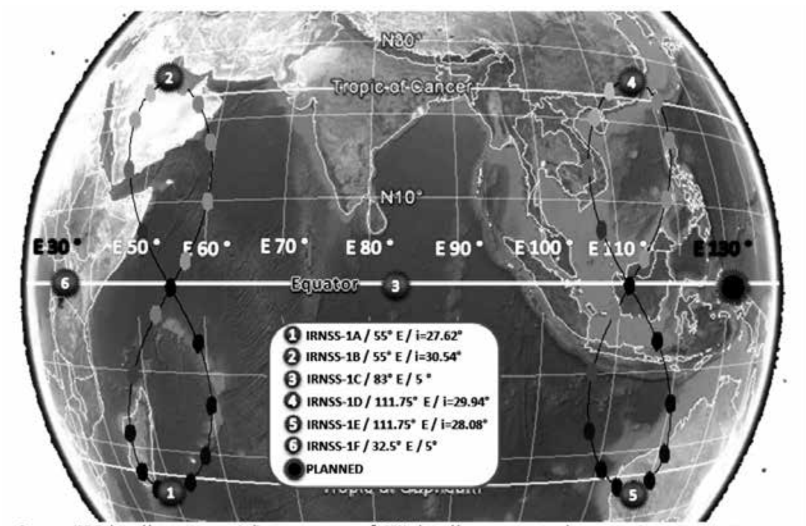
IR regions. They have resolutions varying from a few metres to tens of metres. Some of these cameras are steerable, providing these satellites a revisit capability of five days.[16] RESOURCESAT-2 also carries an Automated Identification System (AIS) receiver for picking up AIS transmissions from ships fitted with a compliant transponder.[17] The two RISAT satellites carry the Synthetic Aperture Radar (SAR) payload capable of imaging through cloud cover. RISAT 2, in a LEO with inclination of 41.2 degrees, has an Israeli X-band radar, while the RISAT 1, in a polar sun synchronous orbit, has an Indian C-band radar. These satellites have spatial resolution of near one metre.[18]

**Fig 3: Orbital Characteristics of Indian Earth Observation Satellites (RAAN as on March 01, 2016)**




The space segment of the Indian Regional Navigation Satellite System (IRNSS) comprises of seven satellites, all of which have been launched. This regional navigation network would provide services comparable to the GPS, GLONASS or Bei Dou systems. The constellation shall comprise three GEO satellites at 32.5 degrees, 83 degrees, and 131.5 degrees East longitudes and a pair each on two inclined GSOs crossing the equator at 55 degrees East and 111.75 degrees East longitudes.[19] The system will provide (standard) Special Positioning Service for civilian applications and (an encrypted military specification) Restricted Service for authorised users.[20] With operationalisation of this network, strategic Indian systems are anticipated to shift from GPS to IRNSS.

**Fig 4: Positioning of IRNSS Satellites**




Source : ISRO, http://www.isro.gov.in/irnss-programme & SSN, http:// www.space-track.org © Vaydeesh Mahajan

## Threat to Critical Indian Satellites from Chinese ASAT Measures

INSAT satellites provide critical voice, video and data services. The armed forces, to meet the requirements of remote and strategic communications, also have leased transponders on a number of INSATs.[21] In addition, the GSAT-7 is a dedicated military communication satellite for the Indian Navy. All communication satellites are in GEO in a band of longitudes close to the Chinese mainland. The Chinese DA ASAT missiles, by virtue of being launched from a TEL, can be easily positioned in mainland China for easier targeting of INSATs and GSATs. Moreover, these communication satellites are large and heavy; relatively slow moving, with large Radar Cross-Section (RCS).[22] Resultantly, they would be easily detected and tracked by sensors of the Chinese space surveillance network as well as the homing head of the KKV. Some of these satellites enable the Indian armed forces to synergise and synchronise forces across distributed locations and over large distances. Thus, the loss of some of these satellites will have a telling effect on the capability to conduct joint and integrated operations. Additionally, there will be an adverse impact on the Indian national economy and critical infrastructure. To some extent, the adverse impact of the loss of satellite-based communication can be managed by switching to other terrestrial links, which India must strive to continuously improve upon. In fact, in the Indian case, there is greater prudence in not having dedicated military satellites, and, but instead, utilising transponders on multiple satellites, thereby increasing the adversary's target list.

The earth observation satellites, evidently, serve the Indian armed forces in some measure.[23] These satellites, in LEO, are well within the cover of the Chinese space surveillance network. They can be addressed by both DN–1 and DN–3 interceptors. Because of their orbital peculiarities and the large expanse of the Chinese mainland, either the ascending or the descending track of these satellites passes over China every two to three days, making their engagement easier. They can also be targeted by co-orbital ASAT weapons, technologies which have already been proven. Loss of these satellites, especially the RISATs, will impact the Indian capability to gather strategic visual intelligence. To some extent, this impact can be mitigated by the use of alternate means such as manned and unmanned aerial reconnaissance platforms, purchase of satellite imagery from commercial organisations (high quality imagery is available now) and assistance from other powers.

The space segment of IRNSS is likely to be fully operational by 2017-18. Despite that, it is unlikely that for most users in India, it will dethrone the American GPS as the timing, location and navigation service of choice. However, for the military, it will become a strategic service. Like in the US, Russia and China, it is likely that restricted service signal will be used to improve the accuracy of Indian ballistic and cruise missiles. As a natural progression, like in the case of other states, it is likely that the restricted service signal would be used by the guidance unit of air-to-surface and surface-to-surface weapons for precision targeting.[24] A receiver of IRNSS, like others, would require signals from at least three different satellites, if not more, for fixing a location. And, therefore, destruction of more than four IRNSS satellites will render the system non-operational. In the event of their loss, most routine functions could be shifted back to GPS or GLONASS signals, but the offensive capability as foreseen above, would suffer. IRNSS satellites can be targeted by the DN-1 and DN–3.

All Indian satellites are vulnerable to Chinese soft kill measures. Low signatury soft kill measures can be undertaken faster and with less preparation compared to hard kill measures. Therefore, they are likely to be the first choice. On the other hand, propelled by advances in information–communication technologies, most space-faring nations, including India, have developed resilient, geographically distributed, fixed and mobile Telemetry, Tracking and Command (TTC) facilities with sufficient redundancies. Satellites too are being designed to be resilient to electronic counter-measures. These aspects, to some extent, mitigate the soft threat to satellites and associated systems. In addition to the few discussed above, India has some more options to manage the threat from the Chinese ASAT means. India must start by expanding its space surveillance network so that there is some warning of the launch of a DA-ASAT weapon against its satellite(s), giving precious time for some evasive measures. India should endeavour to make its satellites stealthier, thereby making their detection by ground-based sensors and lock by KKV relatively difficult. India could also consider hardening key satellites against hard and soft kill weapons; protecting its ground-based TTC assets from physical and cyber attacks; and building jam resistant TTC links. In the times to come, operationally ready spares of key satellites and launch vehicles could also be considered to quickly replace a destroyed or damaged satellite during a prolonged conflict.

## Conclusion

Satellites undertake a very arduous journey to their final orbits. Furthermore, they are complex machines, move at very high velocities, operate in a very hostile environment and have few on-board redundancies. It is difficult for them to recuperate and few have been repaired or serviced on orbit. India does not maintain ready spares of either satellites or rockets to replace a non-functional or damaged satellite in space quickly. Thus, during a conflict with China, loss of critical satellite(s) by India will have a telling impact on the Indian national economy, military and critical infrastructure. The means available to India to mitigate the ASAT threat fall under three broad categories: technical, policy and legal. Technical measures aim at protecting satellites with their contingent challenges and limits. Policy measures aspire to reduce the lucrativeness of satellites as targets and suggest reducing over-reliance on satellites. Legal space-arms control measures, though seemingly distant, provide a lasting escape from this quagmire. It is worth reinvigourating the debate on Prevention of an Arms Race in Outer Space Treaty (PAROS) or its new avataar, the Sino–Russia proposed Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force against Outer Space Objects (PPWT).

The motives of China to tread this path do not require speculation. However, the sense of urgency and purpose in these tests with effect from 2005 indicates the Chinese zeal to prove these key technologies before a moratorium on such tests or a new treaty banning such tests comes out. It is certain that China 'can', but 'will' it? Is India that reliant on its satellites that China would use a kinetic weapon against an Indian satellite during a crisis and risk international condemnation when persistent debris is generated by that attack? Or, is China more likely to use soft kill ASAT against Indian assets? Space is one of the global commons. There must be freedom of movement and action in space, with it being utilised for the greater good of humankind. There is a lot to lose if a front opens in space as the impact of a war in space will be felt by states other than the belligerents. Therefore, realism lies in partnering with any and all to bring in a legally binding treaty to prevent a destructive war in space.

## Notes

1. USSTRATCOM Space-Track BOXSCORE data available at https://www.space-track.org. Accessed February 20, 2016.
2. The Union of Concerned Scientists maintains a widely cited database of *operational satellites*. There were 1,381 as on January 01, 2016, http://www.ucsusa.org/nuclear_weapons_and_global_security/solutions/space-weapons/ucs-satellite-database.html#.VQ7jp_yUeSo
3. For more details, see http://www.unoosa.org/pdf/publications/STSPACE11E.pdf
4. 2015 Annual Report to the Congress, p. 293.
5. Ibid., p. 295.
6. See Rachel Courtland, "Two Chinese Satellites Rendezvous in Orbit," *New Scientist*, http://www.newscientist.com/article/dn19379-two-chinese-satellites-rendezvous-in-orbit.html#.VQt5B9KUeSo, "Data Point to Chinese Orbital Rendezvous," SpaceNews.com, http://spacenews.com/data-point-chinese-orbital-rendezvous/also see, Jeremy Hsu, "Chinese Satellites Bump During Secret Maneuvres," space.com, http://www.space.com/9062-chinese-satellites-bump-secret-maneuvers.html
7. See Leonard David, "Mysterious Actions of Chinese Satellites Have Experts Guessing," space.com, http://www.space.com/22707-china-satellite-activities-perplex-experts.htmland Marcia S Smith, "Surprise Chinese Satellite Maneuvers Mystify Western Experts,"available at http://www.spacepolicyonline.com/news/surprise-chinese-satelllite-maneuvers-mystify-western-experts
8. The purpose could as well be benign such as ranging or tracking a satellite; see Laura Grego, "A History of Anti–Satellite Programs," Union of Concerned Scientists, http://www.ucsusa.org/sites/default/files/legacy/assets/documents/nwgs/a-history-of-ASAT-programs_lo-res.pdf
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2016, p. 247.
10. n. 4, p. 292.
11. Ibid.,p. 296.
12. Ibid.,p. 297.
13. "Chinese Space Surveillance," GlobalSecurity.org, http://www.globalsecurity.org/space/world/china/space-surveillance.htmand Leonard David, "China Space Program Ramping Up Capabilities, Pentagon Says," Space.com, http://www.space.com/21251-china-space-capabilities-pentagon-report.html
14. A KKV is small enough to be lightweight and agile and, therefore, carries a small aperture sensor. It demands an in-flight command update from the space surveillance network to navigate close to the target before switching to an on-board homing sensor. Secondly, the requirement of accurate and high-resolution tracking to engineer a rendezvous does not require elucidation. Thirdly, a LASER weapon will have a narrow beam and would have to be accurately aimed at the target. Thus, a high quality space surveillance and tracking network is mandatory for any of the ASAT missions.
15. Indian Space Research Organisation, "List of Communication Satellites," http://www.isro.gov.in/spacecraft/list-of-communication-satellites
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22. Assessment made from classification of RCS as 'large' in USSTRATCOM Space-TrackSATCAT data, available at https://www.space-track.org as well as from raw SATCAT data available at celestrak.com which lists RCS in square metres, https://celestrak.com/pub/satcat.txt
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