ORF OCCASIONAL PAPER
224
NOVEMBER 2019

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ISBN: 978-93-89622-06-5

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ABSTRACT

Despite testing and confirming the acquisition of Kinetic Energy Weapons (KEW)—an integral part of strategic defence systems that are an alternative to nuclear warheads—India remains in need of a more robust military space programme. The country’s principal rival in the space military arena, China, has significantly more expansive and diverse capabilities. Although KEWs as part of its counter-space programme are not a panacea for India’s increasing space-military deficit vis-à-vis China, they are critical instruments of deterrence and in extreme contingencies proffer benefits for asymmetric escalation. Indian decision-makers would do well to not prematurely foreclose strengthening India’s KEW capabilities. However, a more diversified kinetic capability coupled with particularly space-borne Directed Energy Weapons (DEWs) such as laser and microwave weapons can help bridge the gap in space military power between China and India. The expansion of India’s space military capabilities to service a range of missions is vital to the balance of power in the Indo-Pacific.

(This paper is part of ORF’s series on National Security. Find other research in the series here: https://www.orfonline.org/series/national-security/).

Attribution: Kartik Bommakanti, "‘Soft Kill’ or ‘Hard Kill’? The Requirements for India’s Space and Counter-Space Capabilities", *ORF Occasional Paper No. 224*, November 2019, Observer Research Foundation.

I. INTRODUCTION

Space weapons can be categorised into two groups based on their capabilities: "soft kill" and "hard kill." Hard-kill space weapons include Kinetic Energy Weapons (KEWs), while soft-kill space weapons include electronic-warfare measures (e.g. jamming) and Direct Energy Weapons (DEWs) such as lasers.

All countries with space capabilities are potentially in possession of both soft-kill and hard-kill weapons; however, only a few actually develop and deploy them. China, for instance, tested its first KEW in January 2007—a modified DF-21 two-stage medium-range ballistic missile (MRBM). Beijing deployed the weapon to destroy the Fengyun-1C (FY-1C), a non-operational weather satellite, at an altitude of 863 km above the earth's surface.[1] Since then, China has undertaken the development of a range of hard-kill and soft-kill capabilities. In comparison, India's efforts in building space weapons have been limited. On 27 March 2019, the Narendra Modi government used a KEW to carry out an anti-satellite (ASAT) test, destroying a small earth-observation (EO) satellite called the Microsat-R. Before this test, there were extensive debates amongst India's own military officials, strategists, scientists and technologists about the merits of testing and acquiring kinetic interception capability.[2] The success of this test heralded a shift in how India's military space programme tackles threats to its space-borne assets—from a passive approach to a more active one.

This paper makes the case for both hard-kill and soft-kill capabilities and justifies them in the context of India's larger strategy to balance Chinese power, secure itself against the collusive threat posed by the Sino-Pakistan nexus, and develop the operational strengths and flexibility that space weapons provide to Indian decision-makers and military planners. While they will not be the weapons of first choice during a situation of war with China or Pakistan, or a combination of both, the paper also justifies the operational utility of KEWs. Both KEWs and DEWs have their strengths and weaknesses, and on their own, neither may be sufficient to deal with China, let alone a two-front threat involving Pakistan.

The rest of the paper is structured as follows: The next section justifies the acquisition of space weapons, particularly KEWs to sustain the balance of power in Asia. The subsequent part demonstrates why the operational utility of KEWs is important, despite being debris-generating weapons. The paper then makes an assessment of how an air- and sea-launched kinetic capability are imperative for reasons of flexibility and redundancy, and analyses the role and importance of electronic warfare and DEWs in India space military posture while underlining the importance of Electronic Warfare (EW) capabilities. Section VI demonstrates that the development of KEWs and DEWs will count for little without better Space Situational Awareness (SSA) and Space Surveillance (SS). The paper concludes with recommendations.

II. KEWs: INDIA'S SPACE WEAPONS AND BALANCE OF POWER

A key justification for the development of space weapons is preserving the balance of power, which requires a state's active effort to enhance its power and secure its interests against the dominant or near-dominant states in the international system. "Balancing" involves engineering a shift in the existing distribution of power, away from the dominant state in the system or region.[3]

India currently faces two adversarial states—China and Pakistan—both of them with active space military capabilities and having a history of strategic cooperation. To achieve a balance of power, India must improve its hard-kill and soft-kill capabilities in the space domain and work towards "internal balancing," i.e. accumulating capabilities through domestic effort, instead of "external balancing," i.e. relying on the power of other states.[4] Internal balancing gives a state the power to prevent the escalation of conflict and war. American realist scholar John J. Mearsheimer observed, "…the balance of power is largely synonymous with military power."[5]

The success of India's ASAT test of March 2019 demonstrated the country's ground-launched KEW capability. However, the country's kinetic capabilities are not without limitations vis-à-vis its situation with Pakistan and China. The challenge is summarised by Vipin Narang: "If Pakistan starts hitting Indian satellites, India can knock out Pakistan's very few satellites whereas India cannot do the same to China. So it's kind of a weird balance for India if it's interested in getting into the anti-satellite deterrence game [because] it doesn't really have an advantage in either of its dyads."[6]

While Pakistan, too, does not have a confirmed kinetic capability, it could develop one with China's assistance, which is consistent with Narang's observation. According to another scholar, "…the number of countries able to undertake such intercepts is much larger…"[7] and Pakistan is one of them. While its space programme is not as expansive as India's, Pakistan has an extensive missile programme and is in a position to undertake a KEW test in the not-so-distant future. (The barriers to entry in KEW-related space technology for states such as Pakistan, which is otherwise not a leading spacefaring nation, are not too high.)

Another legitimate concern is that a conventional war can escalate to a nuclear war, involving space as a domain and a medium. A potential two-front attack is one of the major reasons that India must develop triadic KEWs, since it gives the country asymmetric escalation capabilities, allowing it to put at considerable and direct risk both Chinese and Pakistani space assets. According to a 2015 Indian study, which ties partially into Narang's reference to the two-front military challenge facing India, "There is also little doubt that space, nuclear weapons, conventional weapons and strategies of war and deterrence are now inextricably connected with each other."[8] However, this statement is not entirely accurate, and in the context of India's conflictual relationships with China and Pakistan, alternative scenarios are equally plausible. For example, in the event of a China–India war or an India–Pakistan war, traditional weapons and space weapons could be used without the involvement of nuclear arms. The Kargil conflict is an example of a "limited-aims conventional war," fought under the cover of nuclear weapons.[9] Similar conflicts in the future, however, are likely to involve the space segment, especially in the case of a Sino-Indian military conflagration. On the other hand, a joint attack by China and Pakistan could potentially escalate to the nuclear level, as the 2015 study suggests. However, it is equally likely to remain confined to conventional and space warfare, for terrestrial territorial gains. The study also ignores the fact that a two-front war against India will be a function of the common objectives pursued by China and Pakistan against India, and vice versa. An inextricable link between space, nuclear and conventional deterrence and warfighting strategies is limited and conditional, if not tenuous.

According to Narang's assessment, India lacks an "advantage" in the two conflict dyads. However, what India needs primarily is not an advantage but parity (especially if Pakistan tests its own KEW), which will enable it to militarily balance the collaborative space power of the People's Republic of China (PRC) and Pakistan. Due to the vulnerabilities created by the two-front ASAT challenge and the absence of a robust capability, let alone a distinct advantage, India will need a triadic ground-, air- and sea-launched KEW capability to maintain a credible space deterrent. As one important study observed, "Though its [India's] space assets are smaller than those of the other major powers they are not insignificant. At the least they may need to be protected against the direct and indirect consequences of actions taken by the other space powers."[10] Former Indian National Security Adviser Shiv Shankar Menon, alluding to the differential in strength recently, observed, "The basic reason is the power gap between the two [China and India]..."[11] Consequently, creating a triad-based KEW capability assumes considerable importance, since it creates mutual risks and threats. In the event of deterrence breakdown, it gives New Delhi the option to escalate during the course of a military confrontation.

American strategic studies scholar Ashley J. Tellis argues, "India's ASAT test was perhaps necessary, but it will not suffice to protect India's space assets during any major conflict with China."[12] While this is a valid point, Tellis overlooks the fact that India does not have kinetic capabilities that can be launched from diverse platforms, which can boost flexibility and offer redundancy to the extent that adversaries will need to contend with a larger "menu" of targets. Thus, it provides a diverse array of hard-kill capabilities. A kinetic ASAT capability may be a last-resort weapon, as Tellis correctly asserts, but the 27 March 2019 test was only a ground-launched projectile adapted from a missile-defence interceptor and launched from the Interim Test Range (ITR). The test is, therefore, insufficient to sustain the Indian space deterrent posture vis-à-vis China, and additional tests from sea- and air-launched platforms are required. The Peoples Liberation Army Navy (PLAN) has undertaken a prototype laser weapon test, which is a Directed Energy Weapon (DEW) from presumably surface vessel.[13] Beijing has also invited bids for a nuclear powered ship-breaking vessel,[14] which could potentially enable the PLAN to develop nuclear-powered aircraft carriers serving as future platforms for the employment DEWs such as laser weapons against space targets.[15]

Indeed, Tellis' claim that India's ASAT amounted to an "incomplete success" is accurate, but not for the reasons he believes. His prescription specifically requires moving away from "debris-generating kinetic tests" and emulating China in developing non-kinetic capabilities.[16] On the contrary, the March test was incomplete because it did not fully test India's kinetic capabilities from diverse platforms. KEW tests from diverse platforms will make India's space deterrent more robust, inject caution into India's adversaries, and create shared risks essential to sustaining credible deterrence. Tellis also leaves unexplained why Beijing, despite the debris-related risks that accompany any direct ascent KEW tests, pursues the acquisition of KEWs such as the SC-19, DN-1 and DN-3, which are capable of striking Indian space assets in GEO in parallel with its development and deployment of DEWs and other non-kinetic counter space capabilities.

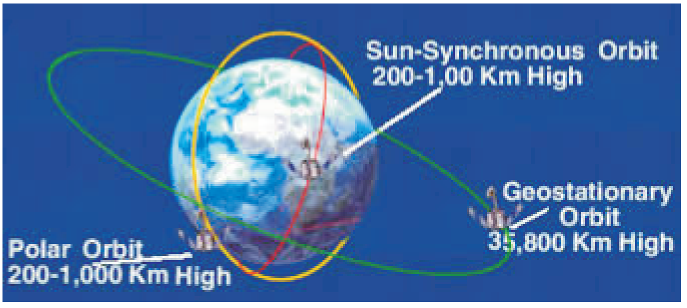
The point to underline here is that India will need standalone kinetic capabilities as well as non-kinetic means to deter China. India's Defence Research and Development Organisation (DRDO) appears to have foreclosed the option of further kinetic tests, with G. Satish Reddy declaring, "Though we tested the interceptor missile for an altitude below 300 km as a responsible nation after multiple simulations, it has the technical capability to go beyond 1,000 km. That will cover most of the orbiting satellites in LEO. For the same purpose we don't need more tests."[17] This misses the point about survivability, redundancy and flexibility, which can only be assured if additional tests are conducted from sea- and air-launched platforms. However, the DRDO chief's statement *is* revealing in terms of the altitude of the test, which is important inasmuch as future tests must not be conducted beyond an altitude of 300 km, to prevent the creation of longer-lasting space debris. In 2012, the DRDO declared that simulated electronic tests were sufficient to meet India's ASAT requirements.[18] However, the Modi government decided to carry out an actual test, rejecting the view that simulated tests were sufficient. For a credible space-deterrent posture, which Reddy conceded was important, a diversified kinetic capability appears not integral to that effort. Moreover, taking into account the two-front ASAT challenge, it would be unwise to forego the additional tests required for establishing a KEW triad.

A 2017 Indian study recommended the creation of a KEW triad, albeit without explaining the military-operational and technical reasons for the same.[19] Another analysis draws attention to the vulnerability of Indian satellites—radar, earth-observation (EO), cartographic and navigation satellites—particularly in low-earth orbit (LEO), where a large number of India's satellites are concentrated. The study proposes several soft-kill capabilities, including counter-measures such as building a more robust Space Surveillance Network (SSN), hardening satellites and making them stealthier to avoid detection, thus reducing their vulnerability to Chinese KEWs.[20] It further recommends developing resilient satellites against electronic countermeasures and geographically spread static and mobile telemetry, tracking and command (TTC) facilities as critical mitigatory measures against soft-kill attacks. However, the study precludes the development of whole categories of weapons. For instance, hard-kill weapons or KEWs have not been included in the mix of capabilities India should possess. Interestingly, the paper does acknowledge that pure soft-kill capabilities in the form of cyber weapons, electronic-warfare capabilities and DEWs are insufficient.[21] As a solution, however, it recommends policy, normative and legal restraints against space weapons, instead of R&D or the deployment of space weapons.[22]

Distant Indian space targets, such as the Indian Regional Navigation Spacecraft System (IRNSS), in geosynchronous orbit (GEO), are difficult to strike kinetically. However, China does possess the capabilities for doing so.[23] In May 2013, China tested the SC-19 ASAT system that can hit targets in GEO.[24] Its successor missile, the DN-3, too is ASAT capable and is likely a ballistic missile interceptor meant for intercepting targets in LEO.[25] Both these capabilities represent significant and critical advances in hit-to-kill kinetic capabilities to strike space assets well beyond LEO. In 2010, 2013 and 2014, China conducted ASAT non-debris-generating tests using adapted land-based ballistic missile interceptors.[26] Co-orbital ASATs are another arrow in China's space quiver. In 2008, the BX-1, a miniature imaging satellite was deployed in-orbit close to its mother satellite and passed within 45 km of the International Space Station (ISS). While this is speculative, the BX-1 was likely released from a spring-loaded device, which does not conclusively prove counter-space capability but does establish China's ability to undertake a co-orbital ASAT.[27] As a follow-up to their BX-1 test in 2008, China launched the SJ-12 satellite, which is believed to possess counter-space capabilities such as jamming.[28] In 2011, the SJ-12 undertook a close manoeuvre to test docking capabilities, possibly as a test run for the actual docking of the Shenzhou capsule with the Tiangong-1 space station. In 2013, China tested a robotic arm, which grabbed one satellite from another. These tests demonstrate China's ability to conduct orbital proximity operations, allowing it to execute microwave attacks against enemy satellite systems. While of the technologies and capabilities tested by China are seemingly for civilian applications, given the dual nature of space technology, they are potentially applicable in the military arena.

Thus, China have developed a whole slew of kinetic capabilities that can target Indian satellites in LEO, sun-synchronous orbit (SSO), medium-earth orbit (MEO) and GEO (See Figure 1). These include cyber weapons to attack space assets, co-orbital attack capabilities, as well as kinetic earth-to-space and air-to-space kinetic capabilities.[29] In light of China's expertise, India cannot afford to confine itself to passive means of defending against Chinese space assets and infrastructure.

Figure 1: Satellite Orbits



Source: European Space Agency.

III. DETERRENT AND OPERATIONAL UTILITY OF A KEW TRIAD

A KEW triad offers operational value, in addition to being instrumental in preserving the balance of power. However, many critics consider a KEW triad unnecessary. A scholar who anonymously reviewed this paper contests the merits of a sea- and air-launched KEW capability, observing, "The deterrence value of mobile land-based missile assets is greater than those of sea- or air-based missiles. If this logic is extended, why diversify into ship- and air-based ASAT KEWs that do not add any deterrence or war-fighting value? While air- or sea-based ASAT capabilities do have advantages in terms of geographic reach, they are also more visible that make them vulnerable."

While this is a valid concern, there are rationales for expanding India's existing KEW capability into a triadic capability that extend beyond survivability. Although land-based mobile KEWs are more "survivable," they are also less operationally flexible. While the anonymous review acknowledges their superior geographical reach, it overlooks another critical advantage, i.e. reduced time between launch and target destruction. Speed and flexibility are crucial in time-critical warfighting missions, which is where both an air-launched and sea-based kinetic capabilities have an edge. Developing and integrating air-launched KEWs offers another unique function, i.e. the ability to control the timing of an attack and thus launch a lethal attack with more precision. As Laura Greco noted about the 1985 ALMV test conducted by the United Air Force (USAF), "…the range of the F-15 and the ALMV allowed considerably more flexibility in which satellites could be engaged and when. Second, the time between ASAT weapon launch and target destruction was significantly reduced."[30] Moreover, KEWs do not suffer the disadvantage (as ground-based DEWs do) of being affected by natural elements such as the weather or atmospheric interference.

The addition of KEW-enabled launch platforms improves redundancy by increasing the number of targets for India's adversaries, thereby contributing to deterrence. Land-mobile KEWs have greater survivability through dispersion from their host bases, well in advance of military hostilities. (It has not yet been revealed whether India's KEW test was from a stationary platform or a mobile one.[31]) An airborne capability is survivable, since once the launch aircraft carrying the kinetic interceptor is airborne; it is likely to be lighter and more manoeuvrable, making it harder to be intercepted. In addition to survivability, range, flexibility and reliability are the crucial indexes of an air-launched capability.

Space systems are vulnerable to a wide variety of threats, including threats to space-borne assets (e.g. satellites) and space stations. India has a growing satellite presence in space, with applications in the military, civilian and the commercial domains. Beyond space-borne infrastructure, the ground nodes of India's space infrastructure are also vulnerable to disruption and attacks. The latter could occur through non-kinetic cyber-borne attacks. Just as it is the case for its adversaries, cyber capabilities and DEWs are integral to India's counter-space operations and missions against adversaries.

China is capable of kinetically targeting Indian satellites, and Pakistan is soon likely to join the ranks. Already, China practises an asymmetric or offensive KEW space posture as part of its Anti-Access-Area Denial (A2/AD) strategy.[32] To create shared risks, India must establish a triadic KEW, which will improve the country's space-deterrent posture. Kinetic ASATs also bequeath asymmetric value to the attacker, which will be essential if India is compelled to initiate a KEW attack in the event of a two-front war with China and Pakistan. In 2016, General John E. Hyten[33] said while speaking about kinetic strikes against space infrastructure by the Chinese, "…you go back to World War II. You go back to industrial age warfare."[34] This is precisely what India will be compelled to do by fighting a space war stemming from a terrestrial campaign against not only China but also Pakistan, making it a mutually destructive affair.

Currently, India's space assets face several vulnerabilities. Take, for instance, India's IRNSS satellites, which send out signals crucial for precision-targeting during the course of a conflict. A minimum of three satellites from the seven-satellite GEO-based constellation are required to pinpoint the location of a target. If China neutralises three or more satellites, the Indian armed services could migrate to the Global Positioning Satellite (GPS) or the Russian GLONASS. However, India's capability to defend against China's offensive operations, which the Indian Army's Mountain Strike Corps is deployed for executing, will be undermined following the destruction of a large segment of its IRNSS constellation.[35] Compounding this problem is that communications via satellites are generally difficult in mountain terrain, which is the geography covering the Sino-Indian boundary.[36]

Indian GEO-based satellites are not the only spacecraft exposed to kinetic strikes, according to a US military assessment, the destruction of one of the US Air Force (USAF) Advanced Extremely High Frequency communications satellites in GEO "…could have devastating consequences on communications for land forces." The loss could black out communications to approximately 6,000 ground terminals, effectively terminating communications capacity to all ground forces beyond the line of sight.[37] As previously noted, China's DN-1 and DN-3 are more than capable of destroying the IRNSS satellites.[38] V. Mahajan accurately observes that while soft-kill measures may be the first choice of use due to the advantages of speed, plausible deniability and low signature, counter-measures through a distributed network of TTC centres can significantly limit the effectiveness of soft-kill capabilities by enabling redundancy and satellite-hardening to insulate their spacecraft from electronic warfare.[39]

Diverse kinetic anti-satellite capabilities, developed through additional tests, will thus grant India an operationally flexible space-military posture. Many scholars suggest that simulations can replace kinetic tests. Admittedly, there are alternative means to test KEWs, such as electronic simulations. However, they are not adequate substitutes for actual tests, since they offer neither psychological value nor demonstrable military value to the armed services. Real tests also provide the most accurate data. Concerns about the political fallout of additional tests are also exaggerated, since the interceptions will be within a 300-km suborbital belt. For example, the debris generated from the 27 March test was limited and any remnants have likely been almost entirely burnt through the atmosphere.[40] Consequently, the test did not trigger a global outrage. The alternative to both real tests and less-effective simulations are tests conducted against "empty points," as the US did prior to its first actual test in 1985.[41] However, these substitutes are only valuable following an *actual* test. The Indian Air Force (IAF) can thus consider conducting such tests by launching attacks against "empty points" in space instead of striking actual spacecraft in-orbit or sub-orbit.[42]

Further, actual KEW tests boost the confidence of India's strategic managers with regard to Indian counter-space capabilities and its end-users, the military. To minimise any adverse international impact, the sea- and air-launched KEW strikes must be conducted against satellite targets at sub-orbital altitude, as was the case with India's March-2019 test. Sustaining the security and safe operation of spacecraft and establishing a potent space deterrent are core challenges for a major spacefaring state such as India, which is in geopolitical competition with not one but a combination of adversarial states.

IV. THE IMPERATIVE OF AN AIR- AND SEA-LAUNCHED KINETIC SPACE CAPABILITY FOR INDIA

As stated earlier, for a diversified kinetic capability, a direct-ascent space missile serves as a key deterrent when launched from multiple platforms. India's two main adversaries, China and Pakistan, field a range of missile capabilities. A cursory look at them will reveal why the case is compelling for India to establish kinetic ASAT capabilities that can be launched from multiple platforms.

Pakistan is India's notionally weaker antagonist. Its longest-range missile, the Shaheen-III (or the Hatf-6), has a 2,700-km projectile and can strike all land-based targets across the Indian land mass[43] (See Table 1). Additionally, Pakistani missiles are potentially convertible to direct-ascent kinetic projectiles capable of satellite intercepts. China, on the other hand, already possesses a whole range of missile capabilities that can target every conceivable land-based strategic target in India. These include the Dongfeng (DF)-4, which is a land-based missile with a 5,500-kilometre range; the DF-31, with a 7,000-km range; and the Submarine Launched Ballistic Missile (SLBM) JL-2, with a 7,000-km range[44] (See Table 2). Together, Chinese and Pakistani missile forces can render India's land-based ASAT system vulnerable, as was tested on 27 March 2019 at Balasore. The latter being a land-based kinetic system could be subjected to destruction by Pakistani and Chinese missile forces on the ground before launch. Indian ground-based ASAT forces are even more exposed to a joint strike by both states in the event of a two-front war.

Table 1: Pakistani Missile Forces

Type: US/Pakistani Designation	Launchers Deployed	Year First Deployed	Range (Km)
Aircraft	36		
F-16/B	24	1998	1,600
Mirage III/V	12	1998	2,100 (possibly carries Ra'ad !LCM)
Land Based Missiles	102 (estimated)		
Abdali (Hatf-2)	10	(2015)	200
Ghaznavi (Hatf-3)	16	2004	290
Shaheen-I (Hatf-4)	16	2003	750
Shaheen-IA (Hatf-4)	NA	(2017)	900
Shaheen-II (Hatf-6)		2014	1,500
Shaheen-III (Hatf-6)		(2018)	2,750

Ghauri (Hatf-5)	24	2003	1,250
Nasr (Hatf-9)	24	(2013)	60–70
Abadeel (Hatf..)	0	NA	2,200
Cruise Missiles (Ground-Launched Cruise Missile (GLCM), Sea-Launched Cruise Missile (SLCM) and Air Launched Cruise Missile (ALCM)	12		
Babur GLCM (Hatf-7)	12		350
Babur-2 (GLCM) (Hatf-..)	NA		700
Babur-3 SLCM (Hatf-..)	0	First test from underwater platform in January 2017	450
Ra'ad !LCM (Hatf -8)	NA	2017	350
Ra'ad-2 ALCM (Hatf-..)	NA	2018	>350

Source: Adapted from SIPRI Yearbook 2018.

Note: The table only contains information about deployment dates and range of missiles.

Table 2: Chinese Missile Forces, 2018

Type of Missile/Chinese Designation	**Launchers Deployed**	**Year first deployed**	**Range (Km)**
Land-Based Ballistic Missiles	131		
Dong Feng (DF)-4	5	1980	5,500
DF-5A	10	2015	12,000
DF-5-B	10		
DF-15	NA	1994	

DF-21	<50	1991	2,100
DF-21 (Modified)		2016	2,100
DF-26	16	(2018)	>4,000
DF-31	8	2006	>7,000
DF-31A	32	2007	>11,000
DF-31AG	NA	2018	12,000
DF-41	NA	2016	>7,000
Sea-based Ballistic Missiles	48		
JL-2	48	2016	>7,000

Source: Adapted from SIPRI Yearbook 2018.

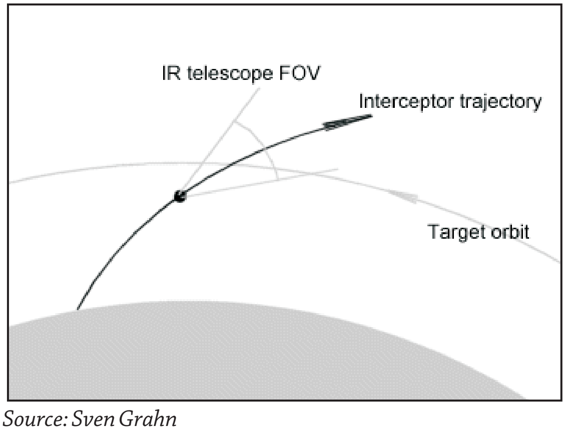
Note: The table only contains information about deployment dates and range of missiles.

As of 2019, India has demonstrated land-based ASAT capability, but not sea-based and air-launched capabilities. Surface vessels such as guided missile destroyers in the Indian Navy (IN) and fighter jets, such as the Sukhoi-30 MKI in the IAF, could potentially serve as launch platforms, but they must be adapted substantially to undertake kinetic ASAT-related missions.

The development of an air-launched ASAT capability faces technical hurdles. While it has advantages over other forms of ASAT hit-to-kill methods, a cursory evaluation of the USAF's ASAT test demonstrates the need for meticulous planning. Following three years of active development, in 1985, the USAF launched the ASM-135 ASAT, also known as the Air-Launched Miniature Vehicle (ALMV), using the F-15 Eagle fighter jet (See Figure 2). The missile destroyed the Solwind weather satellite target at a distance of 550 km in LEO.[45] While the ALMV was a two-stage missile, the entire weapon system, including the aircraft, had three elements. The first was the aircraft on which the missile was loaded. Then, the missile had a miniature homing vehicle

(MHV), which was an autonomous vehicle designed to destroy the target satellite with kinetic force. The USAF first tested the ASM-135 by targeting (but not striking) a star, via a sensor that had an infrared signature directed at the target to confirm the capability of the ASM-135.[46] Starting in 1982, a team of four pilots conducted several practice missions, using precise mathematical calculations to determine the correct angle and altitude at which to release the MHV. The goal was to calculate the precise velocity at launch and the orbital distance and velocity of the target satellite. Finally, the actual test was conducted at an altitude ceiling of 38,000 feet and the MHV released at a 65-degree angle. The Solwind satellite travelling at 23,000 feet per second and the MHV rocket accelerated at 13,000 feet per second collided, with a closing speed of 36,000 feet per second.[47] To date, it remains the only successful ASAT test of its kind. While the former Soviet Union planned a similar launch using a MiG-31 fighter aircraft, Moscow abandoned the project without conducting the actual test.[48]

Figure 2: Intercept Geometry of Interceptor Flight and Target Orbit of the ALMV



Source: Sven Grahn

While an air-launched ASAT capability has advantages, it is also technically demanding. The IAF will have to identify and train at least four to six pilots for executing the test. They will have to run practice missions over land and the sea before the actual test. There will need to be several attempts to strike pre-designated "empty points" in space, which would require developing precise coordinates, an infrared seeker, spin stabilised capabilities, short pulse rocket motors, all of which need to be sufficiently miniaturised to fit into the interceptor. Another demanding requirement with an ALMV-like kinetic ASAT is "timing" of the release from the aircraft.[49] Additionally, the angle at which the aircraft launches the interceptor is crucial. Apart from miniaturised subsystems, the overall design of a kinetic vehicle has to be sufficiently light to fit the fuselage centreline of the underbelly of the aircraft.[50] However, the IAF as far as the actual test is concerned need not fly its own designated aircraft to the altitude that the USAF F-15 did in 1985 and execute the intercept at an altitude of 560 km above the earth.[51] Rather the IAF's assigned jet could climb to a lower altitude, as the intercept needs to happen within a 300 km sub-orbital altitude. The latter is indispensable, because the American ALMV test was undertaken in a different context when there was little concern over space debris.

Nevertheless, an air launched kinetic capability can be flexibly launched against a satellite target at a specific time and a specific place. The ALMV-type ASAT capability reduces the time between the launch and the destruction of the target, which gives the attacker the advantage of speed, essential in time-critical missions and operations. This is what distinguishes an ALMV capability from a co-orbital ASAT capability. (Co-orbital ASATs have only been tested by the Soviet Union, and its successor, the Russian Federation, is confirmed to possess it.)[52] This ASAT capability requires the attacking satellite or ASAT system to be within the orbit of the target satellite and must be sufficiently close for a destructive strike. Currently, the US is not known to have a co-orbital capability, but it has been confirmed that China is making efforts to acquire it.[53]

India now faces a challenge in developing not only a diversified earth-to-space kinetic attack capability but also a space-to-space co-orbital capability, which China is close to achieving.[54] However, the budgetary allocations to the defence forces in recent years are insufficient for such developments. The Modi government's decision to carry out the ASAT test was not as daunting as it might seem, since India had a confirmed ground-launched BMD in the form of the MK-II ballistic missile mid-course interceptor. Adapting the latter to execute a satellite interception was not technologically demanding. Similarly, India's existing sea-based and air-launched platforms can serve as potential platforms. As noted earlier, the IAF-operated SU-30 MKI, a multirole deep-penetration fighter, fulfils the technical requirements of such a launch. The SU-30 is an upgraded variant of the Soviet-built SU-27, both of which are the same class of jet as the American-built F-15 in terms of thrust-to-weight ratio, which is crucial for air-launched kinetic capabilities. Since an F-15A launched the ALMV against the Solwind satellite, the SU-30 MKI can be the ideal platform for testing and demonstrating an Indian air-launched ASAT capability.

A sea-launched ASAT capability, too, can provide both flexibility and survivability. While mobile land-based interceptors may have greater survivability,[55] they cannot offer the same level of flexibility and geographic reach that a sea-based kinetic interceptor can. Sea-based kinetic interceptors can pose a threat to a significant portion of China's, and almost all of Pakistan's space assets. For example, a large number of surface vessels equipped with KEWs can be positioned to perform a "sweep attack" against satellites almost simultaneously, even against moving targets.[56] The deployment of a sea-based kinetic interceptor capability can be a potent deterrent and, if used in the event of war, devastating for any adversary or a combination of them.

However, unlike the United States Navy (USN), the IN does not have a sea-based missile defence capability that can intercept satellite targets.

The USN, as part of Operation Burnt Frost, destroyed "a non-responsive" intelligence satellite in February 2008. It launched a modified SM-3 missile as part of its Aegis Ballistic Missile Defence from a USN Cruiser *Lake Erie*.[57] All surface vessels including cruisers and destroyers equipped with the Aegis missile defence system could have carried out the interception. All that the USN had to do was modify the software, which likely involved providing information to the seeker of the interceptor and the infrared signatures of the non-functional intelligence satellite.[58]

In developing sea-launched ASAT capability, the IN faces significant challenges. BMD capabilities are required for kinetic strikes against satellites. However, the IN's existing inventory of surface platforms does not include an SM-3-level "hit-to-kill" BMD capability to facilitate a sea-launched ASAT test. Indeed, even the latest Vishakhapatnam-class destroyers, the first of which is yet to enter service, are not equipped with anything that qualifies as such.[59] A sea-based BMD would be ideal for adaptation. Alternatively, India may need to consider adapting its sea to surface and anti-ship ballistic missiles, e.g. the Dhanush, to carry out the interception.

Since 2011, the Dhanush has been successfully test-fired from the IN's Offshore Patrol Vessel (OPV) with the INS Subhadra serving as the testbed for all the Dhanush missile tests except one. However, it is still unclear which of India's surface vessels can be equipped with the Dhanush. Generally, almost any class of ballistic missiles with a range of 100 km or more can potentially destroy orbital targets, especially in LEO.[60] The Dhanush is a surface-to-surface short-range ballistic missile, which has undergone extensive testing. It is the sea-based variant of the land-based Prithvi Short Range Ballistic Missile (SRBM).[61] However, for a "hit-to-kill" direct-ascent interception, the Dhanush must undergo certain modifications. For example, in the case of satellite interception for a spacecraft in LEO, it can be equipped with a warhead. This would make it lighter and allow it to meet the range and speed requirements, thus converting the Dhanush into a kinetic energy weapon. Additionally, the DRDO and the IN must develop the required software to feed the Dhanush seeker the target satellite's information and infrared signature.

Some LEO satellites orbit in 90-degree inclined or near-polar orbits, which means that they pass over any part of the earth at least twice a day (See Figure 2). China has satellites in several orbits, and any Indian KEW counter-space capabilities must be effective against Chinese satellites in all orbital belts. As Ashley Tellis concedes, "Direct ascent interceptors in particular are especially dangerous because of their ability to rapidly hold Indian (and other) satellites in all orbits at risk. Consequently, Beijing continues to produce and deploy these weapons, such as the SC-19 and its successor the DN-3, in order to be able to threaten high-value space platforms owned by ... India."[62] While Beijing continues to make non-kinetic counter-space investments, it is equally invested in its kinetic capabilities. India must keep up by testing and acquiring a sea-launched KEW capability as well as space-surveillance capabilities to track and fix orbital paths of Chinese satellites.

As previously noted, a substantial number of reconnaissance, EO, signals intelligence (SIGINT) and weather satellites move through LEO. Just like India, China has a number of these satellites in LEO, making them ripe targets for kinetic strikes. Although, Chinese space assets are deployed across all orbits, such as GEO and SSO, there is a large concentration of Chinese spacecraft performing military-related functions in LEO, which are vulnerable to a range of counter-space operations and missions Consequently, a state, including India, can choose the timing and geometry[a] to execute an attack by launching the

a The "geometry" of attacks means the angle and trajectory at which the kinetic inceptor is launched from the platform such as a fighter plane or a warship.

missile strike when the satellite is right overhead, since such a situation only requires the missile has to reach the highest altitude, avoiding more complex lateral or horizontal strikers. Thus, a sea-based kinetic capability is likely to be less expensive than an air-launched capability. Of course, the DRDO and the IN must calculate the burn-out of the Dhanush ballistic missile adapted as a Kinetic Kill Vehicle (KKV), or the extent of energy required to reach a given altitude, at which point it will cease powered flight.[63]

While an Indian kinetic capability may be considered a weapon of 'last resort' against a Chinese earth-to-space kinetic attack or a co-orbital satellite attack, it does meet the test of redundancy and flexibility to limit and neutralise China's physical and non-kinetic attacks against Indian space assets. Moreover, a satellite is easier to intercept kinetically because its orbital path is predictable and repeated.[64] India's only ASAT test so far has been a ground-launched capability, which can be destroyed by both Chinese and Pakistani missile forces with ease. Therefore, to ensure greater flexibility and redundancy, India must build a triadic KEW capability. This is not a panacea to India's space military challenges, but a means of redressing a few of the existing gaps in its capabilities, which will allow it to limit the growing space power asymmetry between India and China. Even if India does not develop an air- and sea-launched capability, it must at least consider developing and testing additional ground-based interceptors against GEO-based spacecraft, without destroying satellites.

As an analyst observed, "Technology trends suggest that it is inherently more difficult to locate land-based mobile targets than sea- or air-based targets. Both China and India have demonstrated these land-based mobile ASAT capabilities."[b] India has conducted only one

b An anonymous reviewer for an early version of this paper's draft made this observation.

test, whereas China has conducted at least four, including the January 2007 test. Indeed, China's KEW capability can reach GEO, while India's cannot, making it essential for New Delhi to conduct additional land-based kinetic tests, at least against "empty points" in space. Ideally, land-, sea- and air-launched KEWs are necessary for credible deterrence and, *in extremis*, as warfighting instruments. However, there are other—less powerful but equally important—ways to bridge the space military power gap, i.e. non-kinetic capabilities.

V. ELECTRONIC WARFARE AND DEWs: THE IMPORTANCE OF "SOFT KILL" WEAPONS

In addition to hard-kill capabilities, there are several other types of weapons that can be used for counter-space operations and missions. Electronic-warfare capabilities, as well as DEWs such as lasers and microwave-based weapons, are critical for counter-space operations. Electronic-warfare operations attack both downlink and uplink transmissions, by jamming satellite-to-satellite or satellite-to-ground communication and ground-to-satellite communication, respectively. Electronic warfare is conducted through various jamming and spoofing techniques.

India possesses tactical mobility systems for conducting limited electronic warfare by jamming satellite systems, as well as static or strategic ground installations to intercept satellite communications.[65] China, on the other hand, wields a significantly more powerful host of platforms geared towards executing electronic-warfare operations to support its counter-space missions. Moreover, China has unified and centralised warfare service in the form of the People's Liberation Army Strategic Support Force (PLASF), which integrates space-, cyber- and electronic-warfare operations. All counter-space missions are to be executed by the PLASSF, and the country does not view electronic and cyber warfare in silos. American expert Dean Cheng says, “But for the Chinese [cyber and electronic] has long been characterized as integrated network and electronic warfare. That the two are two sides of the same coin; one focusing on the data, the other on the electronic equipment.”[66] However, the scope of this paper is restricted to electronic warfare and DEWs. The PLA possesses electronic-warfare capabilities that can jam satellites through suppression and deception, to target Synthetic Aperture Radar (SAR) aboard satellites in LEO. Additionally, Beijing is developing electronic-warfare capabilities to jam advanced military communications satellites in GEO.[67]

So far, Indian advances in electronic countermeasures have helped mitigate, if not neutralise, electronic-warfare threats. However, as previously noted, it would take the destruction of only four of India’s IRNSS satellites to effectively destroy its offensive capabilities. There are reasonable indications that the DRDO, presumably in consultation with the ISRO, is already working towards making India’s satellites resilient against electromagnetic pulse (EMP) as well as cyber and DEW, such as high-powered microwaves (HPMs) and high-energy lasers (HELs).[68] Further, there is evidence that India is pursuing R&D into DEWs. In August 2019, DRDO Chief G. Sateesh Reddy said, “DEWs are extremely important today. The world is moving towards them. In the country [India] too, we are doing a lot of experiments. We have been working in this area for the past three to four years to develop 10KW-20KW [weapons].”[69] The Hyderabad-based Centre for High Energy Systems and Sciences (CHESS) is at the forefront of developing DEW technology.

Certain challenges remain. The development of DEWs is still at a nascent stage in the Indian context, and it will be a while before they become militarily credible and effective. Further, there are trade-offs for laser and microwave DEWs, both financial and engineering ones. China has spent a sustained amount of money to build a sufficiently powerful ground-based laser to target spacecraft. India will take significantly longer to develop the same, since the 10–20 KW laser that CHESS is currently developing is not sufficient to strike space targets in LEO. Lase energy tends to dissipate when travelling through the atmosphere, so the maximum range of laser is usually limited. The effectiveness of laser DEWs is a function of the intensity of the energy required to damage a target. Laser propagation through the atmosphere is susceptible to scattering by aerosols and molecules in the air, and they have self-induced "refraction fluctuations," which makes the laser beam "bend" and "wander."[70] Further, the air could cause a complete breakdown of propagation at very high intensities. For instance, if laser DEWs were deployed at sea on ships, they will not function in certain weather conditions due to scattering, turbulence and atmospheric absorption.[71]

Ground-based lasers need a large aperture, with a beam whose highest intensity is attained after moving out of the densest part of the atmosphere.[72] Ground-based and sea-based lasers are also vulnerable to precision attack, since they must be deployed on platforms, which are targetable. On the other hand, space-based lasers do not suffer from the propagation constraints and the characteristics imposed by the atmosphere on laser energy. Laser transmission through vacuum gives lasers greater energy through a process called "coupling." Space-based lasers are also likely to be more damaging to the target due to the ignition of plasmas and the energy intensity at the surface of the target.[73] It is speculated that by 2020, China will field ground-based laser to target space sensors in LEO.[74]

Microwaves are another form of DEWs. Like lasers, they are a form of electromagnetic radiation. They travel at the speed of light and propagate differently through different mediums. However, despite facing similar propagation constraints, they can be more effective as space weapons in the near future.[75] The crucial features that differentiate microwaves from lasers are their frequency and wavelength. Microwave DEWs tend to perform better in the vacuum of space than in air. There are several military targets that are actually microwave receivers[76] and are sensitive to the weak signals they have to receive and interpret. This renders them more vulnerable to microwave DEWs. On the other hand, most military systems are not vulnerable to light, with the exception of the human or optical detectors.[77] Thus, microwave transmitters can cause damage at a lower threshold of power than a laser DEW can. While the latter needs intense power and focused energy to damage a target, microwaves can damage a target through a process known as "diffraction,"[c] without the need for high energy that lasers require. As a result of their long wavelengths, microwaves diffract more and can penetrate small apertures or openings on a target's surface.[78] For instance, a microwave weapon can target an opening for a wire passing through a "black box," enabling the energy to travel through the system and cause irreparable damage.[79] Satellites, in particular, have complex electronic circuitry and are highly vulnerable. Further, radar or communication links are sometimes microwave receivers, making them susceptible to attack.

There are two forms of microwave attacks based on the type of damage they cause: *in-band* and *out-band*. In-band damage occurs when the microwave attack is in the same frequency band as the target and damages its circuitry. Out-band damage occurs when the target is in a different frequency band.[80] Despite this tangible advantage, however, microwave attacks face one limitation. Compared to other weapons, the vulnerability of a target to microwave attacks is difficult to quantify. Nevertheless, R&D into microwave weapons is underway, and there is a strong possibility of India, as well as other states, deploying microwave weapons in the near future.

c The penetration of waves through slits or small apertures is known as diffraction.

Space-based laser and microwave weapons are the most promising forms of space weapons, and India must prioritise them over ground-based lasers, for use against satellite targets. Indeed, the development and deployment of non-kinetic DEW space-borne capabilities should be integral to India's space military effort. The advantage of DEWs is that, unlike KEWs, they do not generate debris, making them more beneficial for development and integration into India's larger military strategy. Capital investments, too, will be high for both space-based lasers and space-based microwaves. However, the single-most important reason for India to focus on and invest in DEWs is the lack of treaty prohibitions in this area, which will allow China to feely build these capabilities, including HPMs for anti-satellite operations.[81] While HPM integration into satellite platforms will be demanding for both nations, the challenge will be substantially greater for India. To field a space-borne HPM, it is necessary to miniaturise the HPM's size, weight and power for integration into a spacecraft.[82] To this end, China is already capable of deploying miniaturised HPMs on ships and can potentially deploy mobile HPMs to destroy the electronics of anti-radiation missiles and aircraft.[83]

VI. CHINA AND INDIA: SPACE SURVEILLANCE AND SPACE SITUATIONAL AWARENESS

Increased knowledge about space assets is the result of space situational awareness (SSA) and space surveillance. Both are crucial to understanding the orbital trajectory, characteristics and location of spacecraft, as well as of the large amount of debris in space. China's space-borne Intelligence, Surveillance and Reconnaissance (ISR) capabilities are evolving quickly. As with counter-air missions intended to tackle air-borne threats, counter-space operations require ISR capabilities, which come from radar and electro-optical sensors.

The effectiveness of counter-space operations is a function of the capacity of space networks to track satellites and orbital debris. For satellites to be tracked, electronic surveillance by radar and electro-optical sensors are necessary to locate, track and engage enemy spacecraft. Several states already possess sensors, space object and identification (SOSI) radar and telescopes to trace, identify and locate spacecraft and debris in earth orbit.[84]

China possesses a robust SOSI network. Although it does not acknowledge this, it is evident that China employs radar for SSA. It also possesses a set of phased array radar at various locations across the mainland (See Table 3). In 2018, China built and located two first-of-their-kind parabolic antennas inclined in a horizontal direction. These are most likely being used for tracking and monitoring satellites in GEO and for deep-sensing in the region of Patagonia in Argentina.[85] While the Chinese claim that the antennas have no military utility because they cannot be rotated at high speeds, satellite imagery proves otherwise, showing that the antenna has been horizontally inclined at 35 degrees, making it capable of performing "deep-space sensing" and telemetry to track satellites in GEO.[86] Further, China's Purple Mountain Observatory tracks space debris, and the country has four tracking ships to monitor space launches, telemetry and satellite movement. The vessel *Yuan Wang* tracks and supports Chinese space launches and is part of China's SSA capability.[87] Beijing also has several ground-based telemetry, tracking and control centres known as China Satellite Launch and Tracking Control (CLTC) (See Table 4). In addition to China's SSA capabilities, the country is spearheading the Asia-Pacific Space Cooperation Organisation, through which it oversees the Asia-Pacific (Ground-Based) Optical Space Object Observation System (APOSOS). Through APOSOS, Beijing has given 15-cm optical telescopes to Peru, Pakistan and Iran, to track space objects in LEO and GEO.[88]

Table 3: Postulated Chinese Phased Array Radar Network for LEO Space-Object Tracking

Location	Coordinates	Maximum Range	Sector in Azimuth
NW China	87.5 E, 43.0 N	3,000 km	-60 to + 60 deg
Kashi	76.02 E, 39.54 N	3,000 km	180 to 359 deg
Kunming	102.74 E, 24.99 N	3,000 km	200 to 320 deg
Hainan	109.4 E, 19.0 N	3,000 km	120 to 240 deg
Jiangxi	114.93 E, 26.8 N	3,000 km	60 to 180 deg
Changchun	125.69 E, 44.0 N	3,000 km	0 to 120 deg
Xuanhua, Hebei, Prov.	115.04 E, 40.61 N	3,000 km	-60 to +60 deg
Henan, Prov.	112.97 E, 34.76 N	2,500 km	30 to 150 deg

Source: *Global Space Situational Awareness, Secure World Foundation*.

Table 4: China Launch and Tracking Centres

Xi'an Satellite Control Centre
Xichang Space Launch Centre
Jiuquan Space Launch Centre
Taiyuan Space Launch Centre
Hainan Space Launch Centre
The Beijing Institute of Tracking and Telecommunications Technology (BITTT)
The Luoyang Institute of Tracking and Telecommunications Technology (LITTT)
The Beijing Special Engineering Design and Research Institute (BSEDRI)

Source: Nuclear Threat Initiative.

Relative to China, India's space surveillance capabilities are still limited. Known as the ISRO Telemetry, Tracking and Command Network (ISTRAC), the Indian Space Surveillance Network provides support to satellites and launch-vehicle missions. For Telemetry, Tracking and Command (TTC), there is a network of ground stations, which are located in Bengaluru, Lucknow, Mauritius, Sriharikota (SHAR-I & II), Port Blair, Thiruvananthapuram, Brunei, and Biak (Indonesia). For deep-space surveillance, the ISRO also runs two Deep Space Network (DSN) stations, called DSN-32 and DSN-18, from Byalalu near Bengaluru.[89] A navigation centre based in Byalalu and a set of Code Division Multiple Access (CDMA) stations across the Indian mainland at Hassan, Bhopal, Jodhpur and Shillong supports the Indian space programme's IRNSS satellites. Supplementing these are a network of range- and integrity-monitoring stations at Bengaluru, Hassan, Bhopal, Jodhpur, Shillong, Dehradun, Port Blair, Mahendragiri, Lucknow, Kolkata, Udaipur and Shadnagar, and a single IRNSS Network Timing Facility (IRNWT) in Bengaluru.[90]

The 2015 NIAS study recommended a substantial increase in the number of satellites to meet India's SSA and C4ISR requirements, specifically, to launch 17 satellites annually into various orbits ranging from SSO to GSO. However, as of 2019, India is yet to meet these requirements.[91,92] Consequently, there is currently a substantial gap between India and China in terms of their space capabilities. New Delhi must recalibrate its focus and prioritise the kind of space weapons and the surveillance assets necessary to support them. At least in the medium-term, a combination of space-based HPMs, KEWs and improved space surveillance capabilities should form the basis of India's counter-space strategy.

VII. CONCLUSION AND RECOMMENDATIONS

This paper makes the following recommendations.

1. India must ignore the pleas for a complete ban on all debris-generating kinetic tests in space in the international fora. As with the ASAT test conducted in March 2019, sea- and air-launched tests should be sub-orbital in nature. Alternatively, to mitigate concerns regarding debris-generation, India could carry out its tests against "empty points" in space, whereby a kinetic projectile passes through the area or predetermined point in space instead of striking a spacecraft. This helps avoid creating debris. Nevertheless, direct-ascent kinetic ASATs are vital to hold at risk Chinese space assets.

2. While survivability is important, flexibility and redundancy are key determinants of the robustness of India's space deterrent posture. India should double its efforts to expand the diversity of its delivery capabilities (i.e. sea and air) for the test launch of kinetic weapons, and the DSA and the DRDO must prioritise this task. Greater budgetary support must be provided to the IN and the IAF to enable them to work in concert with the DRDO and develop kinetic interceptors. The GoI must conduct additional ground-based DA-ASAT tests, without destroying orbital targets. Since land-based interceptors are more difficult to locate, more DA-ASAT tests and deployments are necessary to successfully strike targets.

3. The government must prioritise space-based lasers and microwaves over ground-based ones. The former have greater military effectiveness when used through the medium of space than those from earth to space. Between space-based lasers and space-borne HPMs, the latter might be a better investment in the medium term. However, integrating DEWs into India's larger space-military

posture should not preclude the further development of kinetic ASAT weapons.

4. The ISRO's budget needs to expand significantly to sustain Space Situational Awareness (SSA), if it is to meet the demands of a credible counter-space strategy against China and Pakistan. SSA will determine the effectiveness of KEWs and DEWs. Further, the ISRO can collaborate with the DRDO in integrating HPMs into satellites.

The paper has argued that it is not sufficient for India to build a purely ground-based satellite interceptor capability. Developing sea- and air-launched kinetic capabilities will allow greater redundancy, by expanding the target set for China as well as Pakistan; allow greater flexibility; reduce India's vulnerability to devastating strikes against land-based interceptors; and cut down India's excessive or exclusive dependence on more passive military counter-space measures such as EW, microwave and laser-based DEWs. As weapons, KEWs are meant to be the last resort. However, they act as vital deterrents and can enable a state to escalate asymmetrically in the event of a conflict. At the same time, India must focus equally on soft-kill electronic warfare and DEW capabilities. It can stand to learn from the Chinese tests conducted against "empty points" in space, without striking actual spacecraft and thus avoiding the generation of debris.

Therefore, both KEWs and DEWs are necessary for credible deterrence and as warfighting instruments. It is time that India's defence and strategic policymakers acknowledge the importance of diversified kinetic capabilities. Ultimately, the efficacy of all counter-space operations will be conditional on the SSAs that India deploys. The country's space-based surveillance currently needs greater optimisation. To secure itself in space and preserve the balance of power in the Indo-Pacific, India must possess a comprehensive KEW capability in addition to a range of DEWs.

ENDNOTES

1. Brian Weeden, "2007 Chinese Anti-Satellite Test Fact Sheet", Secure World Foundation, 23 November, 2010, https://swfound.org/media/9550/chinese_asat_fact_sheet_updated_2012.pdf

2. See for a for good overview about the background debate for a kinetic ASAT in Victoria Samson, "India and Space Security", *The Space Review,* 9 May 2011, http://www.thespacereview.com/article/1838/1

3. Kenneth Waltz, *Theory of International Politics,* (Reading: MA, Addison-Wesley Publishing Company, 1979), p. 126, John J. Mearsheimer, *The Tragedy of Great Power Politics,* (New York: NY: W.W. Norton and Company, 2001), p. 139.

4. Waltz, *Theory of International Politics,* p. 126

5. John J. Mearsheimer, *The Tragedy of Great Power Politics,*2nd Edition (New York: NY: W.W. Norton and Company), p. 56

6. Cited in Daniel Oberhaus, "India's Anti-Satellite Test Wasn't Really About Satellites", *Wired,* 27 March, 2019, https://www.wired.com/story/india-anti-satellite-test-space-debris/

7. Ashley J. Tellis, "India's ASAT Test: An Incomplete Success", Carnegie Endowment for International Peace, 15 April, 2019, https://carnegieendowment.org/2019/04/15/india-s-asat-test-incomplete-success-pub-78884#comments

8. S. Chandrashekar, "Space, War & Security – A Strategy for India", International Strategic and Security Studies Programme, National Institute of Advanced Studies, Bengaluru, December 2015, p. 22

9. Ashley J. Tellis, C. Christine Fair and Jamison Jo Medby, *Limited Conflicts Under the Nuclear Umbrella: Indian and Pakistani Lessons from the Kargil Crisis,* (Santa Monica, CA: RAND Corporation, 2001), https://www.rand.org/pubs/monograph_reports/MR1450.html.

10. S. Chandrashekar, "Space, War and Security – A Strategy for India", National Institute of Advanced Study (NIAS), Bengaluru, December 2015: 22

11. See Shivshankar Menon interview "India Should focus on outcomes with China", *ETV Bharat,* 16 October, 2019, https://www.etvbharat.com/english/national/bharat/bharat-news/india-should-focus-on-outcomes-with-china-ex-nsa-says/na20191016134305327

12. Tellis, "India's ASAT Test: An Incomplete Success".

13. Andrew Tate, "Chinese navy trials laser weapon", *Janes Defence Weekly,* 19 April 2019, https://www.janes.com/article/87820/chinese-navy-trials-laser-weapon

14. Trym Aleksander Eiterjord, "Checking in on China's Nuclear Icebreaker", *The Diplomat,* 5 September, 2019, https://thediplomat.com/2019/09/checking-in-on-chinas-nuclear-icebreaker/

15. Kyle Mizokami, "China Is Planning a Nuclear-Powered Icebreaker", *Popular Mechanics,* June 25, 2018, https://www.popularmechanics.com/military/navy-ships/a21934944/china-is-planning-a-nuclear-powered-icebreaker/

16. Tellis, "India's ASAT Test: An Incomplete Success".

17. Rajat Pandit, "Satellite-killer not a one-off, India working on star wars armoury", *The Times of India,* 7 April, 2019, https://timesofindia.indiatimes.com/india/satellite-killer-not-a-one-off-india-working-on-star-wars-armoury/articleshow/68758674.cms

18. Sandeep Unnithan, "India attains the capability to target, destroy space satellites in orbit", *India Today,* 28 April, 2012, https://www.indiatoday.in/magazine/nation/story/20120507-agni-v-launch-india-takes-on-china-drdo-vijay-saraswat-758208-2012-04-28

19. See for instance Kartik Bommakanti, "A Conceptual Analysis of Sino-Indian Space Deterrence and Space Warfighting", Observer Research Foundation, New Delhi, April 2017, 27

20. Vaydeesh Mahajan, "Chinese Anti-Satellite Means: Criticality and Vulnerability of Indian Satellites", *CLAWS Journal,* 2016: 182-186.

21. Ibid.

22. Ibid.

23. See Brian Weeden, "Through a glass, Darkly Chinese, American, and Russian Anti-satellite Testing in Space", Secure World Foundation", Washington D.C., 17 March, 2014, https://swfound.org/media/167224/through_a_glass_darkly_march2014.pdf

24. Ibid

25. Ankit Panda, "Revealed: The Details of China's Latest Hit-to-Kill Interceptor Test", *The Diplomat,* 21 February, 2018, https://thediplomat.com/2018/02/revealed-the-details-of-chinas-latest-hit-to-kill-interceptor-test/, Indeed this is also conceded in Mahajan, "Chinese Anti-satellite means: Criticality and Vulnerability of Indian Satellites": 184

26. Mike Gruss, China turned Debris-Free ASAT Tests Following 2007 Outcry", *Space News,* 11 January, 2016, https://spacenews.com/u-s-official-china-turned-to-debris-free-asat-tests-following-2007-outcry/. See also, Brian Weeden, "Anti-satellite Tests In Space – The Case of China", Secure World Foundation, 16 August, 2013, https://swfound.org/media/115643/china_asat_testing_fact_sheet_aug_2013.pdf.

27. Todd Harrison, Kaitlyn Johnson and Thomas G. Roberts, "Space Threat Assessment 2018", A Report of the CSIS Aerospace Security Project, Washington D.C., April 2018, p. 8, https://aerospace.csis.org/wp-content/uploads/2018/04/Harrison_SpaceThreatAssessment_FULL_WEB.pdf#page=12

28. Ibid

29. Ibid.

30. Laura Greco, "A History of Anti-Satellite Programs", Union of Concerned Scientists, Washington D.C. January 2012: 5.

31. Clarity is missing on this issue even in India's post-test official position, "Frequently Asked Questions on Mission Shakti, India's

Anti-Satellite Missile test conducted on 27 March, 2019", Ministry of External Affairs, New Delhi, 27 March, 2019, https://mea.gov.in/pressreleases.htm?dtl/31179/Frequently+Asked+Questions+on+Mission+Shakti+Indias+AntiSatellite+Missile+test+conducted+on+27+March+2019

32. Anthony H. Cordesman and Joseph Kendall, "How China Plans to Utilize Space for A2/AD in the Asia-Pacific", *The National Interest,* 17 August, 2016, https://nationalinterest.org/blog/the-buzz/how-china-plans-utilize-space-a2-ad-the-pacific-17383

33. Currently Commander of US Strategic Command (USSSTRATCOM). He made this statement in his earlier role as Commander of US Space Command (USSPACECOM).

34. Ibid.

35. Mahajan, "Chinese Anti-Satellite Means: Criticality and Vulnerability of Indian Satellites", p. 185, See also Yogesh Joshi and Anit Mukherjee, "From Denial to Punishment: The Security Dilemma and Changes in India's Military Strategy towards China, *Asian Security,* Vol. 15, No. 1, 2019, p. 33.

36. LTC (R) Lester W. Grau and LT Jason Falivene, "Mountain Combat: Hard to move, hard to shoot, even harder to communicate", *The Journal Slavic Military Studies,* Issue 3, Volume 19, 2006, pp. 619-625.

37. Maj. Andrew H. Boyd (US Army), "Satellite and Ground Communications Systems: Space and Electronic Warfare Threats to the United States Army", A Monograph, School of Advanced Military Studies, United States Army Command and General Staff College, Fort Leavenworth, Kansas: 20, https://apps.dtic.mil/dtic/tr/fulltext/u2/1038881.pdf

38. Ibid.

39. Ibid

40. Colin Clark, "India Anti-Satellite Strike: Less Debris Likely, Not Like China's", *Breakingdefense.com,* 28 March 2019,

https://breakingdefense.com/2019/03/india-anti-satellite-strike-less-debris-likely-not-like-chinas/

41. See Greco, "A History of Anti-Satellite Programs", p. 5

42. Ibid.

43. *SIPRI Yearbook 2018,* p. 274.

44. Ibid, p. 262.

45. Paul Glenshaw, "The First Space Ace", *Air&Space Magazine,* April 2018, https://www.airspacemag.com/military-aviation/first-space-ace-180968349/

46. Ibid.

47. Ibid.

48. Laura Greco, "A History of Anti-Satellite Programs", Union Of Concerned Scientists, January 2012: 5, https://www.ucsusa.org/sites/default/files/legacy/assets/documents/nwgs/a-history-of-ASAT-programs_lo-res.pdf

49. Paul Glenshaw, "The First Space Ace", *Air&Space Magazine,* April 2018, https://www.airspacemag.com/military-aviation/first-space-ace-180968349/

50. "Vought ASM-135 *ASAT*", *Directory of U.S. Military Rockets and Missiles,* http://www.designation-systems.net/dusrm/m-135.html

51. Ibid.

52. "A History of Anti-Satellite Programs", Union of Concerned Scientists, Washington D.C., 1 March 2012, https://www.ucsusa.org/resources/history-anti-satellite-programs

53. Ian Easton, "The Great Game in Space", Report, Project 2049 Institute, May, 2018: 5, https://project2049.net/wp-content/uploads/2018/05/china_asat_weapons_the_great_game_in_space.pdf

54. Harsh Vasani, "How China is Weaponising Outer Space", *The Diplomat,* 19 January, 2019, https://thediplomat.com/2017/01/how-china-is-

weaponizing-outer-space/, Also see Brian Chow, "China's new space threat and the justification of pre-emptive self-defense", 18 January, 2016, http://www.thespacereview.com/article/2903/1

55. It would be as valid for land-based mobile kinetic interceptors as it would be for ballistic missiles, John R. Harvey, "Regional Ballistic Missile and Advanced Strike Aircraft: Comparing Military Effectiveness", *International Security,* Vol. 17, No. 2, Fall, 1992: 45

56. See Laura Greco, "The Anti-Satellite Capability of the Phased Adaptive Approach Missile Defense System", *Public Interest Report,* Federation of American Scientists, Winter 2011, 4.

57. Ibid, 1-4

58. Ibid.

59. Franz Stefan-Gady, "India Launches Third Project 15B Guided Missile Destroyer", *The Diplomat,* 22 April, 2019, https://thediplomat.com/2019/04/india-launches-third-project-15b-guided-missile-destroyer/

60. Theresa Hitchens, "Space Weapons of the Future", *Scientific American,* 18 February, 2018, https://www.scientificamerican.com/article/space-weapons-of-the-future/

61. "India: Missile", *Nuclear Threat Initiative,* https://www.nti.org/learn/countries/india/delivery-systems/, Also see Fergus Kelly, "India conducts 3rd missile test in 4 days – this time it's a Dhanush missile", *The Defense Post,* 23 February, 2018, https://thedefensepost.com/2018/02/23/india-dhanush-missile-test-flight/

62. Tellis, "India's ASAT Test: An Incomplete Success".

63. See more how BMD interceptor can be adapted as a kinetic energy interceptor in Greco, "The Anti-Satellite Capability of the Phased Adaptive Approach Missile Defense System", p. 3

64. Greco, "The Anti-Satellite Capability of the Phased Adaptive Approach Missile Defence System", 2

65. "Electronic Warfare Systems", Bharat Electronics Limited,

http://www.bel-india.in/Products.aspx?MId=13&LId=1&link=65

66. Cited in Mark Pomerleau, "Breaking down China's electronic warfare tactics", *C4ISRNET,* 22 March, 2017, https://www.c4isrnet.com/c2-comms/2017/03/22/breaking-down-chinas-electronic-warfare-tactics/

67. *Challenges to Security in Space*, p. 20

68. Rajat Pandit, "Satellite-killer not a one-off, India working on star wars armoury", *Times of India,* 7 April, 2019, https://timesofindia.indiatimes.com/india/satellite-killer-not-a-one-off-india-working-on-star-wars-armoury/articleshow/68758674.cms

69. Special Correspondent, "Laser Weapons, swarm drones on DRDO menu", *The Hindu,* 12 August, 2019, https://www.thehindu.com/sci-tech/science/drdo-focus-on-stealth-weapons-drones/article28988571.ece

70. Philip E. Nielsen, *Effects of Directed Energy Weapons*, (Washington D.C.: Library of Congress, 1994), p. 219

71. Andrei Akulov, "Analysis: Advantages and Disadvantages of US Seaborne Laser Weapon System", Strategic Culture Foundation, 20 July, 2017, https://www.strategic-culture.org/news/2017/07/20/analysis-advantages-disadvantages-us-seaborne-laser-weapon-system/

72. Ibid, p. 193

73. Ibid.

74. *Challenges to Security in Space,* Report, Defense Intelligence Agency, Washington D.C., 2019, p. 20, https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Space_Threat_V14_020119_sm.pdf

75. Ibid.

76. Ibid, p. 218

77. Ibid.

78. Ibid, p. 250

79. Ibid, p. 218

80. Ibid, p. 250

81. See Mark A. Stokes, "Revolutionizing Taiwan's Security: Leveraging C4ISR for traditional and non-traditional challenges", Project 2049 Institute, 2011, pp. 10-11.

82. Harrison, Johnson and Roberts, "Space Threat Assessment 2018", p. 10

83. Ibid.

84. Lt. Col. Lincoln E. Bonner, "Defending Our Satellites", *Air and Space Power Journal,* November-December 2015, p. 78

85. Ernesto Londono, "From a Space Station in Argentina, China Expands Its Reach in Latin America", *New York Times,* 28 July, 2018, https://www.nytimes.com/2018/07/28/world/americas/china-latin-america.html

86. Victor Robert Lee, "China Builds Space Monitoring Base in the Americas", *The Diplomat,* 24 May, 2016, https://www.nytimes.com/2018/07/28/world/americas/china-latin-america.html

87. *Challenges to Security in Space*, Defense Intelligence Agency (DIA), Washington D.C., 2019, p. 20, https://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Space_Threat_V14_020119_sm.pdf

88. Ibid.

89. "ISRO Telemetry, Tracking and Command Network (ISRTRAC): Supports Astrosat Mission", accessed 16 October, 2019, https://www.isro.gov.in/isro-telemetry-tracking-and-command-network-istrac-supports-astrosat-mission

90. Ibid

91. Chandrashekar, "Space, War & Security – A Strategy for India", p. 2

92. See for more on this of ISRO's year wise launch at, "Department of Space, Indian Space Research Organisation", https://www.isro.gov.in/press-releases/2018

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