Anti-Satellite Weapons and Ballistic Missile Defense: the Siamese Twins?

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The 'weaponisation' of space is often interpreted to mean the placement or use of weapons in orbit around the Earth. Although at present there may be no actual weapons stationed in space, there are components of weapons (tracking, monitoring and targeting satellites) and many other military-related systems positioned there. The military of many states (and especially the US) are becoming increasingly dependent on satellites for communication, global positioning, surveillance, photoreconnaissance, weather observation, command and control, drone operations, etc. Military operations around the globe are dependent on and managed through satellites. However, these satellites are difficult to defend and therefore vulnerable to Anti-Satellite (ASAT) systems being developed and tested by nations with a major space capacity (such as China, US, Russia and India). Therefore, a major arms race in space is developing as the lack of trust and international cooperation means that the actions of one state are often seen in the worst possible light by another and then used as reasons for accelerating their own military space programs.

A treaty to prevent the development and positioning of ASATs would obviously benefit the majority of space-faring nations. However, a major problem arises when it comes to identifying what a space weapon is because determining the true intent and ability of some space systems is very difficult and many satellites have more than one function and maybe used for military and commercial purposes. Thus coming up with a definition for a space weapon and for an assessment of the extent of the development and deployment of aggressive space systems is difficult. The major space power states (the US, Russia, China and India) are known to have ongoing space weapons or ASAT programs and have clearly demonstrated to each other that they have the capability to deploy them. A variety of ASAT weapons have been or are being developed and many of these have a dual use capability for Ballistic Missile Defense (BMD), making it difficult to determine whether a space-based object is a weapon or not. This is becoming more of an issue as an increasing number of states become dependent on vulnerable space technologies.

1. Military Space Budgets

Space research, development and deployment does not come cheap and the arms race in outer space will be fuelled by significant amounts of money. Exact figures are difficult to obtain for all nations involved but the 2020 military appropriations approved by US Congress included $40 million for Space Force operations and maintenance. In addition, Air Force Secretary Barbara Barrett has requested the transfer to the Space Force of $9.3 billion from Air Force space related weapons systems and operations[1], $1.4 billion from weapons system sustainment, $275 million from major command support, $26.3 million from education and training and $95 million from headquarters spending. Barrett also said that the personnel costs associated with all these programs also will also

1 "Trump signs defense bill establishing U.S. Space Force: What comes next" from Since News, December 2019 - http://science.fabiola.uk/space/trump-signs-defense-bill-establishing-u-s-space-force-what-comes-next/

be transferred. This is just the start however and the US President will be asking for a Space Force budget of $15.4 billion for 2021[2].

China's government has made conquering space a key strategic priority, and *Space Foundation*[3] reports that the nation's reported space budget is $8 billion - second only to the US. There is no official budgetary information on Russia's military space program but according to "*Defense News*"[4] governmental open sources and financial data from the state space corporation *Roscosmos* provide an estimate of $1 billion for Russian annual spending on the development of its military satellites, launch vehicles and launches. In addition, spending on the Russian space navigation system GLONASS was $437 million in 2019 and the military launch site Plesetsk costs at least $100 million annually – which brings the total costs of the Russian military space program to about $1.6 billion.

India has allocated nearly $1.8 billion for its *Department of Space* operations for 2020-21[5] (a 7.5% increase over the previous year). France is set to spend $780 million on its own military space force,[6] and Japan has set aside around $470 million for improving outer space capabilities.[7] The UK is a minor player in comparison but has still earmarked $37.25 million for its military space programme involving the development of mini-satellites. These are perhaps the major spenders on military space programmes but others are following.

So, a total of around $27.5 billion is being spent annually on an arms race in outer space. If a global agreement on PAROS and a culture of cooperation and sharing could be achieved then this money could become available for activities that would benefit humanity, rather than add to the likelihood of a space war and the accompanying devastating effects to the Earth below.

2. Anti-Satellite Weapons

Some ASAT projects are being resurrected from previously abandoned projects, some are at the research and development stage and others have already been tested and are operational. Table 1 illustrates the different anti-satellite weapons currently in development or being investigated.

The Trump administration's "*2019 Missile Defense Review*" (MDR)[8] emphasises the importance of systems that tackle missiles in their boost-phase - before the re-entry vehicles separate from the main missile. This type of system is seen as increasing the likelihood of successful interception.

In particular, the *MDR* recommends exploring two boost-phase intercept options that would also have ASAT possibilities. These are an F-35 fighter plane armed with a kinetic interceptor and a compact high-energy laser on an unmanned drone.

However, there are significant operational and technical challenges associated with boost-phase defense. These were highlighted by the *American Physical Society* in 2003[9] and two pre-

2 "Trump seeks $15.4 billion for US Space Force in 2021 budget" by Sandra Erwin, Space News, February 2020 - https://spacenews.com/trump-seeks-15-4-billion-for-u-s-space-force-in-2021-budget/

3 "The Space Report", Space Foundation - https://www.spacefoundation.org/

4 "Russia is behind in military space capabilities, but that only drives its appetite" by Pavel Luzin, Defense News, April, 2020 - https://www.defensenews.com/opinion/commentary/2020/04/02/russia-is-behind-in-military-space-capabilities-but-that-only-drives-its-appetite/

5 "Budget 2019: FM hikes Dept of Space Outlay, pushes for commercialisation", Business Standard, January 2020 - https://www.business-standard.com/budget/article/budget-2019-fm-hikes-dept-of-space-outlay-pushes-for-commercialisation-119070500973_1.html

6 "France is Launching a 'Space Force' With Weaponised Satellites" by Hanneke Weitering, space.com, August 2019 - https://www.space.com/france-military-space-force.html

7 "Japan defense budget hits new high with focus on space, cyberspace", Kyodo News, December 2019 - https://english.kyodonews.net/news/2019/12/c26eceaf0bde-japan-defense-budget-hits-new-high-with-focus-on-space-cyberspace.html

8 "2019 Missile Defese Review", *US Department of Defense*, January 2019 - https://media.defense.gov/2019/Jan/17/2002080666/-1/-1/1/2019-MISSILE-DEFENSE-REVIEW.PDF

9 "Report of the American Physical

Table 1 - Types of space weapons

	Technology	Status	Comments
Signal Jammers	Radio Frequency generators used to disrupt communications	Systems have been in use for some time.	Effects are reversible.
Directed Energy Weapons (DEW)	Microwaves, disrupt or disable	Satellite jamming systems are operational. Electro-magnetic pulse systems are under investigation.	Satellite communication jammers have been deployed a number of times. EM pulses for use against drones - could possibly damage warhead deployment or targeting.
	Laser, particle beams, disable, destroy	Ground based lasers have been developed, air-borne laser projects were shelved but are now being renewed.	Low powered lasers to temporarily blind satellites have been tested. High powered lasers would be needed to destroy missiles/satellites.
Kinetic Energy Weapons (KEW)	Missiles/ collision / intercept devices	Tested and available for ASAT and BMD use.	Basis of existing intercept strategy.
Co-orbiting satellite	Moves close-in to the target and either disrupts it, hits it, or explodes near it.	Tested and being tested by US, Russia and China.	Could also be used for inspecting or repairing satellites or capturing space debris. Possibly not favoured for missile defense

vious boost-phase interception technologies - the '*Airborne Laser*' and the '*Kinetic Energy Interceptor*' - were cancelled and another - the '*Space Based Laser*' - was shelved for various operational, technical, and cost reasons.

It is informative to look a little closer at the different forms of ASAT technology shown in Table 1 to assess possible joint ASAT-BMD applications.

2.1 RF Jamming

In March 2020 the US Space Force officially received its first space weapon - a ground-based satellite communications Radio Frequency (RF) jamming system[10]. Satellites have demonstrated their importance to the military since the 1991 Gulf War, often called the first "*Space War*", and since then attempts have been made to jam satellite signals on a number of occasions by a number of states, including Iraq, Iran and Libya. Disrupting satellite signals would affect the ability of the military to communicate, to command and control distributed systems and to identify and home-in on targets.

It is not obvious how RF jamming might assist in BMD – unless they can disrupt all of the on-board electronics. The missiles are targeted prior to launch and once on

Society Study Group on Boost-Phase Intercept Systems for National Missile Defense: Scientific and Technical Issues" by D.K. Barton, R. Falcone, D. Kleppner, F.K. Lamb, M.K. Lau, H.L. Lynch, D. Moncton, D. Montague, D.E. Mosher, W. Priedhorsky, M. Tigner, and D.R. Vaughan, *Rev. Mod. Phys*. 76, S1, October, 2004 - https://journals.aps.org/rmp/pdf/10.1103/RevModPhys.76.S1

10 "U.S. Space Force gets first offensive weapon, a satellite jammer" by Ed Adamczyk, *Defense News*, March16, 2020 - https://www.upi.com/Defense-News/2020/03/16/US-Space-Force-gets-first-offensive-weapon-a-satellite-jammer/7891584383839/ accessed March 30, 2020

their trajectory do not need to communicate with a central control.

2.2 Directed Energy Weapons

These include laser, microwave and particle beam technologies that damage target with highly focused beams or pulses of energy. They can be deployed against personnel, missiles, vehicles, drones and space objects.

2.2.1 Microwaves

The U.S. is developing directed-energy weapons and railguns (that use electromagnetic force to launch high velocity projectiles) to counter ballistic missiles, hypersonic cruise missiles, and hypersonic glide vehicles. Some of these systems are planned for deployment for missile defense in the mid to late-2020s and also have obvious applications as ASAT weapons.

For example, the *Counter-electronics High Power Microwave Advanced Missile Project* (CHAMP), is an air-launched weapon used to disable or damage electronic systems by a burst of electromagnetic energy - an *ElectroMagnetic Pulse* (EMP). The idea is to develop it as a warhead to be deployed on a cruise missile launched from a B-52 aircraft.[11] However, it is unclear just how effective and useful the system might be – and if there are any advantages of using microwave energy rather than any other kind of weapon for missile defense purposes.

It was recently reported that Turkey had deployed a DEW system called *Alka*[12], equipped with lasers and microwave systems to destroy or disable drones and aircraft. It is claimed that *Alka* is equipped with radar and electro-optical systems that can track multiple targets, although it is not clear whether it can be used as an ASAT device. However, it may be on the way there.

2.2.2 Ground-based Lasers

Lasers can be used to help target ASAT weapons or BMD interceptors or as weapons themselves. The USAF *Starfire Optical Range* in New Mexico uses lasers to help measure atmospheric distortion and obtain a clearer image of objects in space. China's *Anhui Institute of Optics and Fine Mechanics* also uses lasers to track satellites.

A number of states (including the U.S., Russia, China, India, Germany, Turkey and Iran) are developing or deploying high-energy lasers to be used to blind satellites or as anti-aircraft/anti-drone land or sea-based weapons.

In 1997, the US attempted to fire a high-powered (over 1 megawatt) laser beam from its *Mid-Infrared Advanced Chemical Laser* (MIRACL) in New Mexico at a USAF satellite. MIRACL illuminated the satellite but then failed. However a second lower powered, 30-watt, laser was then used and temporarily blinded the satellites sensors.[13] This demonstrated that just a few seconds of exposure from a low-powered laser can dazzle (disrupt) space-based sensors and a medium-powered laser could permanently blind imaging satellites.

China also used a laser to illuminate and track US reconnaissance satellites as they passed over China in August and September 2006. The satellites suffered no temporary or permanent damage[14], despite reports to

11 "CHAMP: America's EMP Missile that might be able to fry North Koea's Nukes – or start World War III" by Dave Majumdar, *The National Interest*, December, 2017 - https://nationalinterest.org/blog/the-buzz/champ-americas-emp-missile-might-be-able-fry-north-koreas-23610

12 "Turkey's Roketsan

13 "Laser of 30 Watts Blinded Satellite 300 Miles High," by John Donnelly, *Defense Week*, December 1997, p. 1 and reported in „Pentagon beams over military laser test" by Chris Plante, *CNN.com*. *Associated Press* and *Reuters*, October, 1997 https://web.archive.org/web/20071230052044/http://www.cnn.com/US/9710/20/pentagon.laser/

14 "Coming in 2021: A laser weapon for fighter jets" by Valerie Insinna, *Defense News*, November 2017 - https://www.defensenews.com/air/2017/11/07/coming-in-2021-a-laser-weapon-for-fighter-jets/; "Russia's Beriev seeks to patent airborne carrier for laser weapon" by Piotr Butowski, Jane's International Defence Review, March, 2020 - https://www.janes.com/article/94798/russia-s-beriev-seeks-to-patent-airborne-carrier-for-laser-weapon; "China has not attacked US satellites says DoD" by Martin Sieff, *UPI*, October, 2006 - https://www.spacedaily.com/reports/China_Has_Not_Attacked_US_Satellites_Says_DoD_999.

the contrary.[15]

In January 2020 it was reported that Israel is beginning tests on a ground-based laser system to intercept drones, rockets and anti-tank missiles.[16] Apparently, electric-source lasers have been able to overcome atmospheric effects and have enabled a beam to be precisely focused on a long-range target. The system is now being designed to complement Israel's *Iron Dome* missile defense system and could possibly be developed into an ASAT system.

2.2.3 Air-Borne Lasers

An Air-Borne Laser (ABL) has been considered as a possible key component of ballistic missile defense for some time. The US, Russia and China all have on-going airborne laser weapon programmes.[17] Some have origins in a possible use for long range missile defense but they are mostly now focussed on fighter plane-based systems for use against drones and surface-to-air or air-to-air weapons, although they could also be used as ASAT weapons.

The original US plan was for an aircraft, armed with a high-powered laser to be used to disable ballistic missiles during the initial boost phase of their flight. A long-range missile would burn out at a height of 200kms or more, whereas the ABL would fly at an altitude of about 13kms, therefore if the ABL was to be able to target satellites, it would have to be able to direct the laser upwards.

The original ABL concept consisted of a modified Boeing 747 carrying a powerful, megawatt class chemical oxygen iodine laser (COIL). The missile would be disabled by the laser dwelling on the missile body long enough for the heat to damage it sufficiently to cause the warhead to fall short of its target.

In 2011, after spending over $5bn on the project in ten years, the US Department of Defense cancelled the programme. The idea did not prove to be feasible because, in order to disable a missile, the aircraft would have to get very close to the target, making it vulnerable to attack. However, it was considered that the concept of an ABL laser missile defense system had been proven. The Pentagon is now investigating building the laser technology onto unmanned drones that can loiter near or move quickly towards a target in order to shoot down a missile during the launch phase. Such a situation would require less power and the use of drones would mean that there is no danger to onboard pilots. It is not clear whether such a weapon would also be to damage satellites in low-earth orbit, at a height of 2,000kms, unless the drones or the laser could also be carried to a much higher altitude by another vehicle - such as a space plane.

2.2.4 Space-Based DEW

The US Defense Department seems to have abandoned one of the most ambitious research goals – a space-based neutral-particle-beam generator to destroy the electronics in missiles (and satellites)[18]. However, the funding is being directed instead toward fundamental research on high powered lasers.

The original US Space-Based Laser (SBL) programme was shelved in 2012, the SBL program office was closed and the integrated flight experiment was cancelled. However, the 2019 MDR established that the Pentagon is again developing high energy laser evaluation programmes and demonstrators to investigate the possibility of space-based interception

15 "Bachmann's claim that China 'blinded' U.S. satellites" by Glenn Kessler, *Washington Post*, October, 2011 - https://www.washingtonpost.com/blogs/fact-checker/post/bachmanns-claim-that-china-blinded-us-satellites/2011/10/03/gIQAHvm7IL_blog.html

16 "Lifting the Veil of Israel's Classified Laser Weapon Program" from *Defense Update*, January 2020 - https://defense-update.com/20200108_hel_israel.html

17 "China is Developing an Airborne Laser Weapon" by Michael Peck, *The National Interest*, January 2020 - https://nationalinterest.org/blog/buzz/china-developing-airborne-laser-weapon-113546;

18 "Pentagon Shelves Neutral Particle Beam Research" by Patrick Tucker, *Defense One*, September, 2019 - https://www.defenseone.com/technology/2019/09/pentagon-shelves-neutral-particle-beam-research/159643/

capable of boost-phase defense. If this is shown to be possible, then they would also be available as ASAT weapons.

However, a major problem with any form of space-based interception is that a ridiculously large number of satellites would be needed to ensure global coverage, at a cost of hundreds of billions of dollars. The Pentagon believes that costs can be reduced by using new commercially available technology but there are currently no concrete proposals for actual implementation.

2.3 Co-orbiting Satellites

The US, China and Russia have all tested the manoeuvring of satellites in orbit, enabling small satellites to rendezvous with others placed in Low Earth Orbit (LEO) or Geostationary Earth Orbit (GEO). Such manoeuvring has many possible applications, including the inspection, repair or refuelling of space objects, the removal of space debris and ASAT activity. However, it is not clear how it might be useful for missile defense purposes except as a possible counter measure for space-based BMD systems. A useful overview of space rendezvous operations can be found in the 2015 *Space Review* article by Brian Weedon.[19] He points out that the increase in autonomous rendezvous and proximity activity by small satellites are creating new challenges and "increased opportunities for misperceptions, mishaps, and mistakes."

There has been one recent connection with missile defence. In December 2019 the Russians released a satellite designated Cosmos 2543 from another satellite, Cosmos 2542, launched the previous month. This action aroused interest and then suspicion when they both altered their orbits to match the orbit of a classified U.S. reconnaissance satellite. Cosmos 2543 was later accused of firing a projectile close to another Russian satellite[20]. This kind of operation was also a problem in 2004 when the U.S. Missile Defence Agency were planning to launch a Near Field Infrared Experiment (NFIRE) - an experimental satellite designed to pick out a missile from its exhaust plume to improve the targeting of interceptors[21]. NFIRE was also to carry a sensor platform, aka a 'kill vehicle', which would be fired from the satellite to get as close as possible to its target. Although the Pentagon insisted that the term "kill vehicle" referred to a category of space vehicles, rather than its function on the test, there was huge controversy, with Russia accusing the U.S. of breaking "a long-held taboo" and launching "the first weapon into the global commons of outer space." The kill vehicle was removed from the test and replaced it with a laser communications payload and NFIRE was retired in 2015.

2.4 Kinetic Energy Weapons (KEW)

BMD and ASAT KEW systems envisage the use of weapons that operate by intercepting targets – and destroying them either by force of the direct collision or with the help of an explosive warhead. These kinetic kill weapons can be launched from the ground or from space. Although these are the type of system that offers spectacular and visible results, a major disadvantage is that they produce vast amounts of space debris which can be a significant problem for all space-faring nations.

2.5 Space-based BMD

For a space-based missile defense system, kill vehicles would be placed in LEO. If a missile launch is detected, then a kill vehicle close to the launch site would accelerate out of orbit and home-

19 "Dancing in the dark redux: Recent Russian rendezvous and proximity operations in space" by Brian Weedon, The Space Review, October 2015 - https://www.thespacereview.com/article/2839/1

20 "Russia conducts space-based anti-satellite weapon test" by U.S. Space Command Public Affairs Office, July 23, 2020 - https://www.spacecom.mil/MEDIA/NEWS-ARTICLES/Article/2285098/russia-conducts-space-based-anti-satellite-weapons-test/

21 "Near Field Infrared Experiment" from Wikipedia, accessed July 2020 - https://en.wikipedia.org/wiki/Near_Field_Infrared_Experiment

in on the missile.

Whether a kill vehicle designed for missile defense could be used to attack satellites as well, depends on the type of sensors it carries, the amount of fuel for manoeuvring it has available, and the length of time it is designed to operate for. It may take a few minutes to reach a missile during its boost phase but perhaps an hour and more energy to reach GEO. However, these capabilities could be included in a kill vehicle to enable it to operate as an effective high-altitude ASAT. Target satellites could be tracked accurately from the ground and, on launch, the interceptor's sensors could guide it to its target as it would a missile. As the sensors on an interceptor are primarily for detecting missile plumes during boost phase, they might not be suitable for detecting a satellite, but there are lightweight sensors that could be used.

However, a major negative point is that because there is little time to attack a missile during its boost phase, kill vehicles would need to be stationed close together over potential target areas and, as they would be in LEO, they would move with respect to their target areas on the ground and so, as stated above, many other kill vehicles would need to be in orbit to ensure a full coverage. Although this would ensure that there were more than enough kill vehicles in place to destroy hundreds of military satellite targets, the whole operation is likely to be prohibitively expensive.

The MDR does recommend a study of the possibility of a space-based interceptor capability, although it seems that the Trump administration favours beginning research and development as soon as possible - before preliminary studies have been made.

2.6 Ground-based BMD

The US, China, Russia and India have all tested ground-based BMD systems for use as ASATS.

In 2008, in *Operation Burnt Frost*, the U.S. shot down one of its own satellites with a *Standard Missile-3* (SM-3) launched from *USS Lake Erie*, part of the US ship-based *Aegis Ballistic Missile Defense* (BMD) system[22]. This was viewed by many, and Russia and China in particular, as a way for the U.S. to demonstrate its ASAT capability. This seems likely to be the case as it was carried out just over a year after China conducted a similar ASAT operation in 2007, shooting down one of its weather satellites with a solid fuel missile launched from, or near, the *Xiching Satellite Launch Centre*[23].

Also in 2018, Russia conducted a test of its ground launched *Nudol* ASAT system from a mobile launcher in *Plesetsk Cosmodrome*.[24] A further test of the system was carried out in April 2020[25] and a year previously, in March 2019, India launched a modified ABM missile interceptor (*Prithvi Defence Vehicle Mark-II*) in an operation codenamed *Mission Shakti* to destroy a satellite in LEO.[26] All three states use mobile systems, whether ship or truck-based, which enables them to threaten more satellites than they could reach with a fixed system.

As mentioned above, the 2019 MDR also includes plans to turn the SM-3 interceptor missile and the F-35 jet fighter into a BMD system and a potential ASAT weapon. A similar air borne ASAT test had been demonstrated previously by the US as long ago as 1985, when a *Solwind* satellite was destroyed by a ASM-135 ASAT missile launched from a F-15A *Eagle* aircraft.[27]

22 "U.S. Satellite Shootdown: the Inside Story" by James Oberg, *IEEE Spectrum*, August, 2008 - https://spectrum.ieee.org/aerospace/satellites/us-satellite-shootdown-the-inside-story

23 "2007 Chinese Anti-Satellite Test Fact Sheet" by Brian Weedon, *Secure World Foundation*, 2012 - https://swfound.org/media/205391/chinese_asat_fact_sheet_updated_2012.pdf

24 "Russia's ASAT development takes aim at LEO assets" by Sean O'Connor, *Jane's Intelligence Review*, 2018 - https://www.janes.com/images/assets/591/81591/Russias_ASAT_development_takes_aim_at_LEO_assets_v2.pdf

25 "Russia tests anti-satellite missile and the US Space Force is not happy" by Chelsea Gohd, *Space.com,* April 2020 - https://www.space.com/russia-anti-satellite-missile-test-2020.html

26 „Narendra Modi announces success of Mission Shakti, India's anti-satellite missile capability", *The Hindu*. *PTI.* 27 March 2019 - https://www.thehindu.com/news/national/narendra-modi-announces-success-of-mission-shakti-indias-anti-satellite-missile-capability/article26651731.ece

27 "ASM-135 ASAT", Wikipedia - https://en.wikipedia.org/wiki/ASM-135_ASAT

2.7 Space Drones and Planes

Other forms of spacecraft, still in the experimental stage, could be assigned an ASAT role. The US Orbital Test Vehicle (OTV) X-37B is an unmanned reusable spacecraft which is boosted into space by a launch vehicle and re-enters the atmosphere to land as a space-plane. According to the X-37B fact sheet,[28] "The primary objectives of the X-37B are twofold: reusable spacecraft technologies for America's future in space and operating experiments which can be returned to, and examined, on Earth."

Originally a NASA project, it was transferred to the Department of Defense in 2004 and its maiden launch was in April 2010 - when it spent 224 days in space. Its purpose and capabilities are secret but Colonel Andre Lovett, vice-commander of the US Air Force 45th Space Wing, commented: "This launch helps ensure that our warfighters will be provided the capabilities they need in the future."[29] It appears to be being developed to linger for extended periods in space which may also enable it to be used for BMD purposes. The fifth mission was launched on 7th September 2017 and landed on 27th October 2019 having spent 780 days in orbit.

In 2015 Subrata Ghoshroy pointed out that the X-37b is likely to be a move to weaponize space and to conduct tests for hypersonic weapons. [30]

2.7.1 Hypersonic Spacecraft

The Boeing X-51 is another unmanned space drone, this time an experimental scramjet (supersonic combusting ramjet) aircraft for hypersonic flight. Its first powered hypersonic flight was made on 26 May 2010. It is often referred to as the X-51 *Waverider*, as it takes advantage of the compression lift produced by its own shock wave.

The Falcon (Force Application and Launch from Continental United States) is a DARPA and USAF project to develop a rapid-strike Hypersonic Weapon System (HWS). Current research under the FALCON program is centred on the X-41 Common Aero Vehicle (CAV), an aerial platform for hypersonic Intercontinental Ballistic Missiles (ICBMs) and cruise missiles. The prototype Hypersonic Technology Vehicle 2 (HTV-2) first flew on 22 April 2010; the second test flew 11 August 2011 - both ended prematurely.

Russia and China also have hypersonic missile programs. Russia has started trials of its Zircon hypersonic missile which will be able to fly five to six times faster than the speed of sound. China too has held several tests of its DF-ZF hypersonic glide vehicle.

2.7.2 Spaceplanes

The idea of a plane that can take off from earth, fly into space and return to the Earth and land has been pursued by a number of states, for either high speed transport or military purposes. The Soviet Union, the UK, France, the ESA, Japan, Germany, China and India have all considered designs of rocket assisted space planes at one time or another and at least the US, ESA, Russia, China and India are still developing the idea. In fact, in May 2017 DARPA announced that Boeing had been selected to develop its XS-1 experimental military space-plane project. The aim was to develop the XS-1 as a reusable military space plane but in January 2020 the program was effectively ended when Boeing withdrew from the project.

3. ASAT-BMD Duality

As shown above, ASAT and BMD systems are difficult to separate[31] and, as the for-

28 "X-37b Orbital Test Vehicle", U.S. Air Force, published September 1st 2018 - https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104539/x-37b-orbital-test-vehicle/

29 "US spacecraft sparks arms race concerns" by Xin Dingling, China Daily, 24th April 2010 - http://www.chinadaily.com.cn/world/2010-04/24/content_9770149.htm

30 "The X-37b: Backdoor weaponization of space?" by Subrata Ghoshroy, Bulletin of the Atomic Scientists, Volume 71, Issue 3, 2015

31 See also, for example: "Technical Demarcations for ASAT and BMD Systems." by A. Carter, in: Jasani B (Ed.) *Peaceful and Non-Peaceful Uses of Space*,

mer Office of Technology Assessment of the US Congress noted:

"There is a strong relationship between ASAT and BMD technologies and the technical, political, and diplomatic actions taken in one sphere will almost certainly affect the other."[32]

This applies particularly to the BMD mid-flight interception of nuclear warheads. It is not easy to draw a dividing line, as satellites and missile warheads share some similarities and can therefore be attacked by the same systems. The following general points should be emphasised.

3.1. It is easier to intercept satellites than ballistic missiles.

Satellites follow known and easily predictable orbits that can be measured accurately if there is sufficient time. The trajectory and position of warheads, however, can only be determined at the moment of a nuclear attack. The crest of an ICBM trajectory is at altitudes higher than 1000 km, and the speeds in this area are only slightly below those of earth orbits. The task of destroying satellites in low orbits by directly ascending missiles is possible from the ground with non-nuclear BMD interceptors. The number of satellite targets is also small compared to the number of missiles and warheads in the event of a massive launch of intercontinental ballistic missiles. The interception of warheads and missiles is much more time-critical than that of satellites due to the surprise effect and the short time span of attack. For instance, a laser used in an ASAT role would have more time to irradiate the target than in a BMD mission. The requirements for BMD are therefore significantly higher than for ASAT: the time pressure is greater, there are more targets which are more resistant. However, an ineffective BMD system can still be a powerful ASAT weapon.

3.2 Space-based BMD systems are vulnerable to ASAT weapons.

Since BMD systems are also effective ASAT weapons (at least for LEO), they also threaten the space-based BMD systems of other parties. Even simple destruction mechanisms (e.g. sand or nails in orbit, space mines, nuclear explosions) could make sensitive parts of BMD platforms inoperable. Those who are capable and ready to attack with ballistic missiles could improve their chances of success by simultaneously attacking defense components in space. During an attack with kinetic kill vehicles or lasers, a BMD platform cannot fulfill its task of intercepting missiles. Both of these factors and the short warning time involved are strong and destabilising drivers for a preemptive strike. Finally, BMD systems could also be used to defend against attacking ASAT weapons, providing that the destruction mechanism provides enough time to react. There would be no advance warning time for laser weapons, however.

3.3 ASAT and BMD duality causes problems for BMD arms control.

Conversely, without BMD arms control, a ban on the use of ASATs becomes merely a symbolic act - as a missile defense system has an inherent potential to destroy satellites. As long as BMD capabilities for altitudes of a few hundred kilometers are permitted, a complete ban on ASAT capability is questionable. Thus, ASAT and BMD arms control complement each other.[33]

Taylor & Francis,.pp. 107-127, 1991; and "The Lethal Paradox: The ASAT-SDI Link." by J. Tirman and P. Didisheim, in: Tirman J (Ed*) Empty Promise: The Growing Case Against Star Wars*. Boston: Union of Concerned Scientists, 1986; "Implications of anti-satellite weapons for ABM issues." by D.M. Kerr, in: Jasani B (Ed) *Space Weapons – The Arms Control Dilemma*. London/ Philadelphia, 1984.

32 See "*Anti-satellite weapons, countermeasures, and arms control*". Office of Technology Assessment report OTA-ISC-281, US Congress, 1985, p. 25.

33 "Is a space weapons ban feasible? Thoughts on technology and verification of arms control in space", by Regina Hagen and Jürgen Scheffran, *UNIDIR Disarmament Forum* 1/2003: 42-51, 2003 and "Dual-Use in a New Security Environment – The Case of Missiles and Space" by Jürgen Scheffran, *INESAP Information Bulletin*, No. 26: pp 48-53, June, 2006.

How problematic the ASAT-BMD duality is, ultimately depends on the criteria for security and the requirements for verification. What constitutes a significant ASAT or BMD capacity must be clarified in the context of the security requirements.[34] For high missile and satellite numbers, an overlap between ASAT and BMD is less critical than at low numbers because individual damage events are less significant.[35] The definition of a threshold between significant and non-significant overlaps also depends on whether there is a multilateral negotiation context, in which asymmetries between states can be very large. An ASAT capability, which would correspond to a BMD capability against a few warheads, could not significantly impair the deterrence ability of the two major nuclear powers, but could affect smaller nuclear powers such as China, India, Israel or Pakistan.

Further problems are created by the fact that BMD systems cannot only intercept ballistic missiles, but also space rockets that launch satellites into orbit. Therefore, a global BMD system could theoretically block all others from accessing space, whether for satellites, ASAT or BMD components. The result would be complete space dominance.

4. Conclusion

A major difficulty in determining the intention behind the deployment of some space objects lies in their 'dual-use' potential. They may be primarily for civil use but also used by the military (e.g. photoreconnaissance, environmental monitoring, weather satellites, etc.) or they may be military satellites positioned as part of a missile defense system but also able to be used as ASATs. Some indication of the potential use of a space object is shown by its orbit. Satellites in GEO at an altitude of around 36,000kms remain stationary over one particular point on the Earth and have been traditionally used for communication purposes. They are also used by the military for early warning, missile defense satellites and intelligence gathering (interception and spying).

Satellites occupying a LEO, at altitudes between 500kms and 2,000km and with orbital periods of 128 minutes or less, have tracks that sweep out large areas of the Earth over short periods of time. The much lower altitudes offer the opportunity of faster communication and commercial companies are now deploying large numbers of mini-satellites in LEO to give fast and continuous global coverage. In May 2019, 60 satellites were launched by a single SpaceX[36] rocket in the first of a 12,000-satellite network for global 5G coverage. This network may eventually grow by an additional 30,000[37] and other companies are also participating. LEO orbits are also used by the military for reconnaissance and surveillance purposes as they can give a wide coverage in a short time.

Satellites in Highly Elliptical Orbits (HEO) maximise their viewing times over high latitudes because they move more slowly in the high-altitude parts of their orbit than in in the low-altitude parts. These are useful orbits for weather and environmental monitoring by civil and military interests and missile early warning and tracking.

The problems associated with dual-use mean that, to lower international tension we need more international openness on the purpose and function of space objects. There is are international agreements on the publication of launch data but more information is needed to allay any suspicions concerning the purpose and role of the space objects being placed in orbit.

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