# Changing the Deterrence Paradigm: Leveraging Space to Mitigate Nuclear Risks

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**Abstract**

The US nuclear enterprise is in need of modernization in order to remain an effective deterrent while President Trump has called for strengthening and expanding nuclear capability. Making use of space-based technology to intercept and destroy nuclear missiles entering the space domain is a feasible alternative near-term solution that can change the existing paradigm of deterrence while increasing US security. Specifically, the US should invest in a global, defensive, space-based, additive directed energy grid to co-target nuclear and antisatellite (ASAT) threats. While executing this course of action will strengthen America's strategic advantage, multiple higher order effects and limitations exist that warrant policy maker consideration. This article explores these issues.

## Introduction

Strategic deterrence and nuclear capability are at the forefront of America's national security and a high priorities to the new Presidential Administration. President Trump has tweeted the following: "The United States must greatly strengthen and expand its nuclear capability until such time as the world comes to its senses regarding nukes"[1]. While this frames the associated concept of deterrence to nuclear weapons, it can be linked to the future of the subject in a broader sense as well. The question becomes: do we march forward with revitalizing our time tested model of nuclear deterrence through the nuclear triad, or do we consider alternate methods of accomplishing strategic deterrence in the interest of the United States and its allies? Nuclear modernization and maintenance is already built into the Department of Defense (DOD) budget and nuclear weapons have been the cornerstone of deterrence for nearly 60 years. However, should it continue to be our only strategic deterrence option?

With emerging technologies and scientific breakthroughs, space offers a unique and valuable frontier that the United States can advantageously explore for defense and deterrence. These technologies open up an entirely new realm of possibilities for national defense, industry, and the overall geopolitical environment in which we live. Space defense can change deterrence at the national and global levels. Moreover, current and future space capabilities are key terrain to war fighters and policy makers alike - assuring the ultimate high ground for our national objectives is truly critical.

In order to maintain a strong deterrence posture, the US should invest in a global, defensive, space-based, additive directed energy grid to co-target nuclear and ASAT threats. Executing this course of action (COA) will maintain the US's Strategic advantage while changing the deterrence paradigm. This piece advocates for this initiative and will cover topic background, a thorough discussion of the COA, second and third order effects of it, constraints, and concluding remarks.

## **Background**

### *Deterrence and Geo-political Climate*

Since the days of the Cold War, nuclear warfare with other nuclear nations has been a significant threat to the United States. The United States and the Union of Soviet Socialist Republics (USSR) were the first two nations to develop nuclear weapons and immediately recognized that there is essentially no defense for these weapons of mass destruction (WMDs). This led to the ongoing challenge of keeping the other side from using them.

In the 1960s, an analyst at Hudson Institute coined the acronym "MAD", which stands for mutually assured destruction, in describing the outcome of two nations engaging in nuclear warfare.[2] Since that time, we have relied on our own nuclear weapons in order to dissuade other nuclear nations from using their WMDs against the United States. If an adversary launched a nuclear weapon at the United States, we would respond by reciprocating in kind. This would result in two severely demolished nations—a devastating scenario so awful that no near-peer nation would even make threats of launching a nuclear weapon. This has been our nuclear deterrence paradigm up until today. It centers on the doctrine of proportional response and retaliation with a second-strike capability.

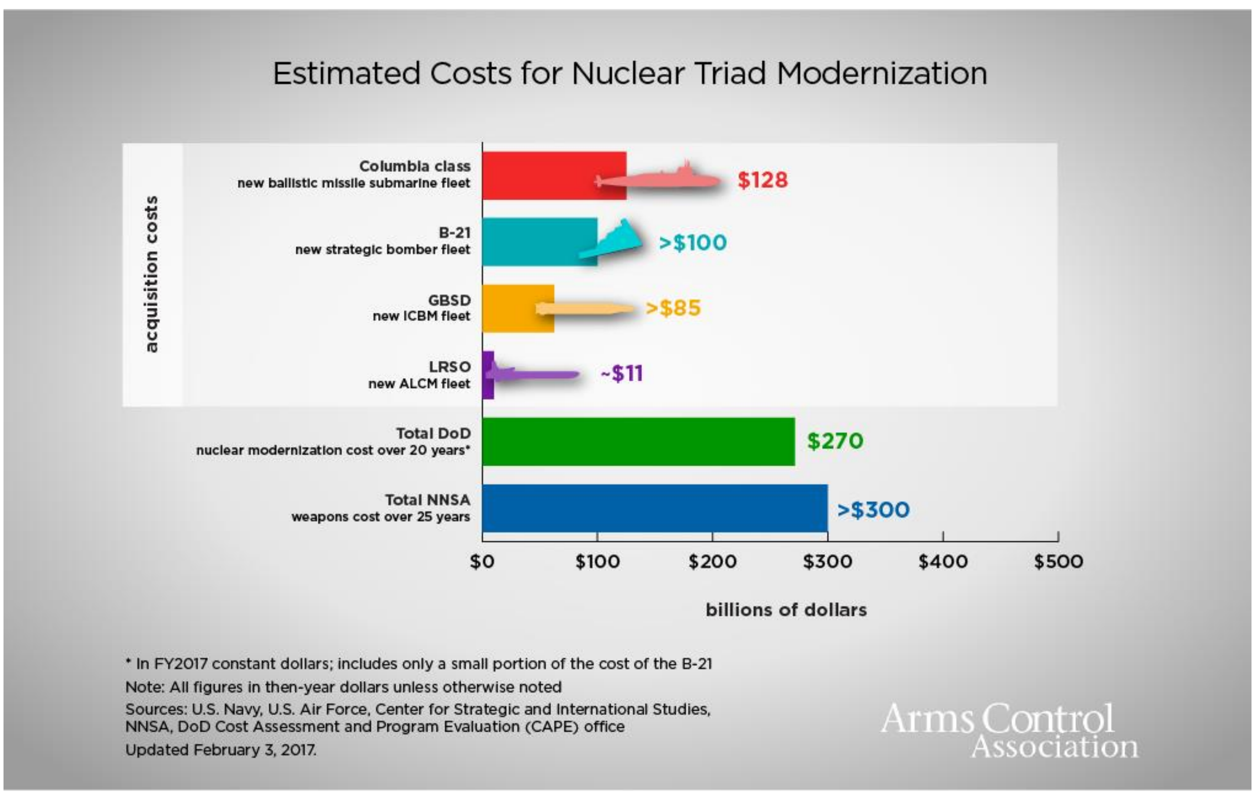
We as the United States think that the MAD deterrence model has worked so far, but can never know for sure until it fails. We have even less confidence that this paradigm would stand up against rogue nations. It also fails to protect anyone from an accidental launch or unauthorized launch by a renegade operator. Furthermore, if a terrorist organization ever came into possession of a nuclear weapon, it would not hesitate to use this capability. Extremists would happily die as martyrs if they could launch a nuclear weapon at the United States. For these reasons, mutually assured destruction proves to be both outdated and ineffective. It cannot remain the sole, permanent model for nuclear deterrence.

The geo-political situation has evolved over the past 30 years to include other countries with a nuclear capability. US allies sought and gained the technology as well as other countries that the US is not allies with, such as China. More importantly, other nations, namely North Korea and Iran, are aggressively seeking nuclear Intercontinental Ballistic Missile (ICBM) technology. Whereas once the system of nuclear deterrence and mutually assured destruction applied to two actors, now multiple countries in different regions are involved. Mutually assured destruction is still the main deterrent; however, the predictability of other nations cannot be calculated. Nations such as Iran and North Korea have already proven a disregard for the United Nations and will present a clear and present danger to the US once they are successful in their endeavors. Furthermore, regional instability between Pakistan and India can lead to nuclear weapon use that could draw other nations into a war. In such a geo-political environment, the United States must further evolve in order to ensure its national security rather than leave it to a complacent perception of deterrence by mutually assured destruction.

*Aging Nuclear Assets*

This nuclear deterrence, MAD, paradigm relies upon an adequate and reliable nuclear arsenal. Unfortunately, this is in question as every leg of the US' nuclear triad is aging. The ground based leg of the triad, the Minuteman III ICBM, was fielded in 1970. There are approximately 416 deployed Minuteman III ICBMs which cost an estimated $2.6 billion annually to maintain. The Minuteman III is expected to be phased out and replaced beginning in

2030. The 14 Ohio-class ballistic missile submarines represent the sea leg of the nuclear triad. The first of these was fielded in 1981, and is expected to be phased out starting in 2027. The air leg of the triad, the B-52H Stratofortress and B-2 Spirit strategic bombers, need replacement as well. The B-52H was fielded in 1961 with a current end-of-service date in the 2040s. The B-2 stealth bomber was fielded in 1997 but is expected to retire in 2058. All three legs of the triad have modernization plans. The Ground Based Strategic Deterrent will replace the Minuteman III; the Columbia-class ballistic missile submarine will replace the Ohio-class; and the B-21 Raider will replace the B-52H as a dual-use long range strike bomber. All told, the cost of this modernization is estimated by to be around $1T over 30 years. The cost breakdown of this modernization is outlined in the graphic below[3].



*Space Law*

While space provides an attractive alternative to policy makers as a domain in which to field a strategic deterrent, the US must consider current space agreements and international norms. The 1967 Outer Space Treaty is the foundational document for international attitudes and postures toward space. Article IV of the Outer Space Treaty specifically bans placing nuclear, or other WMDs in orbit around Earth. Additionally, this article prohibits military bases, fortifications, and weapons testing on celestial bodies. Aside from banning WMDs and militarization of celestial bodies, the primary result of the 1967 Outer Space Treaty is the establishment of outer space as a global commons for the open use and benefit of all mankind. Global commons are the domains that no one person or nation controls but which all individuals and nations can utilize. Because of this global commons status, and the ban on nuclear weapons, the prevention of any weaponization of space has become an international norm[4]. This sentiment stems from the massive benefits of the space industry, as well as the potential catastrophe of its destruction. For example, the Global Positioning System (GPS), is used across the globe as a public good for everything from navigation, to banking, cellular phone operations, and much more[5]. Destroying the GPS system would destroy the US economy. Despite the understood benefits of space, and sentiment to keep it conflict free, nations are pursuing weapons for use in the domain because these capabilities represent a clear and present danger.

*Antisatellite Weapons (ASATs)*

Another key consideration for policy makers is the role of the most common weapon being developed for the space domain, ASATs. ASAT development has a long history dating back to the 1950s with the USSR and the US. However, more interesting are the recent developments. Recognizing that space is the “soft ribs” of the US due to the US’ dependence on space assets, China began pursuing ASAT technology. In 2007, China successfully destroyed one of their own aging satellites in low Earth orbit with a kinetic kill vehicle launched from the ground. This stunned the international community, including the US, but since then China has conducted multiple tests including a 2014 test of a "non-destructive" ASAT[6]. Russia has also demonstrated a renewed interest in ASAT technology. In 2016, Russia successfully tested its Nudol ASAT for the fifth time[7].

These tests have all used direct ascent ASAT technology where the ASAT is launched from a ballistic missile to place the kill-vehicle on an intercept trajectory with the orbital target. However, co-orbital ASAT systems have also been tested where the ASAT is placed into orbit and maneuvers toward a target to intercept/destroy or within range to disable the target through other means. Co-orbital ASATs are generally more expensive and sophisticated, but a potential future co-orbital ASAT threat is the miniaturization of satellites and the emergence of cubesatellites (cubesats). Cubesats are small, cheap, and simple satellites that can be easily designed, built, and launched. High-schools and universities have placed cubesats in orbit. Due to their size, these cubesats are incredibly difficult to track in space. And due to their price, even rogue nations such as North Korea could weaponize cubesats technology to impose their will on others[8]. Indeed, ASATs are not only a threat to US assets, but the global commons of space as well.

## Course of Action

The course of action recommended by this work incorporates both space miniaturization and distributed systems design. We propose a global, distributed multi-node satellite grid, situated in a variety of orbits, each capable of hosting a low-power directed energy beam payload, for global space-domain superiority. The power of each beam will be such that, by itself, it will be incapable of producing a kinetic effect, suitable for a smaller spacecraft platform. However, the co-targeting of multiple such beams, on the same object, would raise the incident power to a destructive level, allowing the total system to exert destructive effects.

In less than a decade, space miniaturization technology has come so far that students at a high-school level of education are today capable of designing, integrating, launching, and operating cubesat systems[9]. Some university-designed systems boast sophisticated maneuvering and navigation capabilities[10] and are capable of advanced military-relevant mission sets[11]. Though systems centered on smaller spacecraft may not be as reliable, these development efforts prove that the technology is both mature and accessible.

This additive directed energy system would target any projectile that breaks into the space domain around the world, whether an ICBM, standoff submarine launched ballistic missile (SLBM) or direct-ascent ASAT weapon. It would therefore directly target the ICBM leg of the nuclear triad, and would be proportionally less effective against either a close-range SLBM or the bomber aircraft-released nuclear weapon.

By nature, this system would be highly distributed. It is anticipated that several dozen spacecraft will be required to achieve system global reach, particularly since co-targeting by multiple spacecraft will be required to achieve kinetic effects. However, distributed or disaggregated systems are intrinsically less vulnerable. Defined as "the dispersion of space-based missions, functions or sensors across multiple systems spanning one or more orbital plane, platform, host or domain"[12], a disaggregated system offers a natural resiliency and survivability. Since the capability is exerted through a larger number of redundant component parts, multiple component satellites can be lost before total system failure. There are many challenges to consider in the move toward small-satellite disaggregation, including architecture integration, ground system operations, mission assurance and others. However, these are dwarfed by the benefits: such systems are resilient by nature. A distributed systems architecture serves to eliminate the United States' dependence on finite centers of gravity (COGs) of space power; with multiple systems in play, the payoff for an attack against the overall system lessens.

Such a platform would, by nature, be multi-purpose as well. The push toward multi-sensor space platforms is well under way; a global small spacecraft system in Low Earth Orbit (LEO), such as that proposed here, could also carry sensors for global Wi-Fi, protected communications, LEO position-navigation-timing (PNT) or global missile launch detection. Such combined mission sets would help to reduce the overall cost of the system, which is currently estimated to be of the same order as the modernization of the ICBM leg of America's nuclear triad. Fielding such a system would render ICBMs and other nuclear launch systems that require space as a medium within which to transit highly susceptible to failure, redirecting worldwide nuclear spending from a "triad" concept to a "diad" concept, consisting of SLBMs and aircraft-based nuclear weapons. For several countries around the world, e.g. Pakistan, Iran and North Korea, this negates their nuclear delivery capability completely.

Finally, the theory of graduated deterrence is centered on "active" defensive measures complementing the threat of force. One of the key factors for successful deterrence is the criteria of "proportionality, reciprocity and coercive credibility". The more superior a nation's available instruments to inflict harm, the larger costs for non-compliance it may credibly impose[13]. Dissuasion of enemy escalation is accomplished through the threat of progressive retaliation, ultimately discouraging the enemy from an initial action[14]. Nuclear deterrence theory makes good use of graduated deterrence, dating back to Robert McNamara and the Cold War[15] and attacks against this space system would follow a similar principle[16]. Though each directed energy platform is not capable of an offensive strike against the ground or even a target in flight, it is able to defend itself against either ASAT attacks or space-to-space attacks by leveraging that directed energy capability. Combined with the fact that US space policy makes clear that any hostile act in space will be considered an act of war,[17] this allows for a credible defense and dissuasion of enemy aggression against this system.

## **Second Order Effects**

### *Change in Nuclear Posture Worldwide*

Employing this defensive grid of lasers dramatically changes the nuclear posture worldwide for all countries employing ICBMs, both for launching them and for defending against our own. The concept of shooting down any missile that enters the space domain limits the employment of ICBM weaponry, restricting any countries using them to theater or regional tactics only. There is no point to launching ordinance to strike targets if the ordinance can never reach the destination. Adversaries no longer have the ability to make long range strikes, but the grid and its capabilities have to become common knowledge. Without demonstrating the ability to defeat ICBMs, the potential for launch still exists.

Ultimately, the resulting ineffectiveness of ICBMs reduces the nuclear triad by eliminating that leg, simultaneously rendering adversary ICBMs useless. Any attempt to launch would be intercepted with destruction of the weapon followed by political and/or military response depending on the nature of the attack. Robert Art’s Four Functions of Force talks about offensive and defensive postures relating them both to deterrence; the US must be able and ready to answer back[18].

In the vein of retaliatory strikes, if another nation desired to construct a defensive grid of their own, the potential for an arms race exists relative to the system. Though not desirable, it is not necessarily a negative to the argument; adversary development of defensive grids can fill holes in potential gaps of our system and it creates transparency with those nations, a genuine example of how this is purely defensive weapon. If another country develops the same method of defense, the two grids would be opposing, necessitating a self-defense capability in addition to its global defense role. In Forrest Morgan's Deterrence and First-Strike Stability in Space, he states that we must make "space systems more resilient and defendable, thereby demonstrating tangible capabilities to deny potential adversaries the benefits of space"[19]. While this does not necessarily mean striking down another country's defensive grid, it would be a good idea to be protected against that threat and ready to do it in case a situation did warrant that retaliatory strike. Having coverage provided by the US and any other able countries, ICBMs will be destroyed long before they can cause harm.

*Shift in Nuclear Threat: Global → Regional*

The possibility exists that the system of satellites may not be able to strike with enough speed or precision to knock out short ranged ICBMs, which means that nuclear conflict would still remain a problem at the theater or even regional levels. If the laser is capable enough, bordering nuclear countries' interests shift to deal with each other, such as the proximity of India and Pakistan, both neighbors to China. Ideally, each country would work toward resolving any dispute at their own level, unable to affect the rest of the world without the reach. As a better example, North Korea's propensity to attract attention to its launches would force China and Russia to act, now the main potential targets for close-proximity strike, while US satellite protection extends to Japan. China and Russia might also build a grid to combat this new, exclusive problem, but that would again be beneficial in enhancing global nuclear defense from space. In all cases, each country must shift their focus to handle nuclear threats from neighbors only, changing their defensive postures, incredibly significant for China as they have the most nuclear neighbors. For the US, currently regionally unthreatened with hostile nuclear neighbors, SLBMs still pose the biggest problem for strikes on American soil.

*Cyber Vulnerability*

As with any technology, there is always a threat of cyber-attack against the defensive grid with the potential to hijack it. To help combat these concerns, the fractionated power and numerous distributed satellites of the grid act as a defense. The entire system can survive attacks on individual nodes as well as maintaining the capability to independently target itself. In the event any satellite is destroyed or rendered inoperable, there is a replenishment cycle in place that would restock the constellation every five years or as necessary, restoring lost satellites and updating technology as it develops. In the event of a cyber-attack, the fractionated power prevents any one device from being able to do any kind of catastrophic damage commanded from any outside source and allows other satellites to be operational. The distributed nature of this satellite network would also be applicable to other space based systems, such as GPS, missile warning or secure communications. Incorporating the same defensive strategy into other systems makes them more resilient to any kind of attack.

## **Third Order Effects**

*Highly Distributed Architecture*

Implementing this novel space infrastructure will introduce and encourage greater distribution in the US space architecture, reducing the threat of high-reward attacks against vulnerable US space centers of gravity. Both China and Russia have developed antisatellite missiles that are capable of knocking out US space assets in any orbit, and both adversaries have acknowledged US dependence on space to project global power. The Air Force Space

Command (AFSPC) Commander's Strategic intent is filled with emphasis on increasing "Resilience Capacity", and one of the key tenants of space system resiliency defined by the Office of the Secretary of Defense - Policy is "distribution"[20]. More resilient, distributed space systems not only secure US advantage in the space domain, but they encourage their own kind of deterrence[21]. If an adversary is unable to degrade a capability due to its high resilience, that adversary is less likely to attack that particular asset. Due to the grid's co-targeting requirement, it is, by nature, distributed into many nodes. In order to achieve a cooperative constellation in multiple orbits of the size necessary to have global, redundant coverage, new technologies and methods will need to be implemented. The development of these technologies and methods will allow the Air Force to more easily field systems with a higher Resilience Capacity than the systems we use today.

*Advantages to Industry*

Space technology is a $330 billion, US-dominated industry[22]. Technological advances from the development and implementation of this network will benefit the US economy and strengthen international ties. Advances in communication technology will advance cubesat infrastructures and make larger constellations of smaller satellites more achievable. Smaller satellites equate to more affordable satellites and launches, which will further encourage the growth of the commercial space industry. This system will also encourage the commercial space industry by ensuring freedom of navigation in space. Policing the space domain will decrease the likelihood for mishaps and interference with large-investment commercial space assets, providing less risk for commercial investors. The liberalism theory of international security indicates that an increase in international trade due to this boon in the space industry will strengthen ties with our allies and stabilize relationships with adversaries.

### *Encouraging Nuclear Disarmament*

As relationships with our adversaries stabilize and approach trust, the most important effect of this defensive space grid will be to set the stage for further nuclear disarmament. As legs of the nuclear triad become less and less effective, the public's support to spend in order to maintain that leg will decrease. America's National Security Strategy has been geared toward putting political pressure on other nations to move toward shrinking nuclear arsenals. The external pressure combined with the loss of internal support should begin to wear at our adversaries' will to maintain those programs. Adversaries who do not rely on public opinion in order to fund their programs will be slower to the table, but eventually, they will be forced to note the economic toll that antiquated programs are taking on their budgets for little-to-no strategic gain.

## **Constraints**

Any course of action must fit within the constraints of its environment. The primary constraints inhibiting the launch of a space based defensive grid are cost, time, treaties, and the geopolitical climate. While each of these constraints will shape how the program is developed and employed, they do not derail its implementation.

### *Cost*

In an ever more fiscally conscious environment, cost of any new defense program will be of paramount concern. "With rising interest rates and expected increases in the Federal debt, at some point in the next ten years, annual interest payments are on pace to exceed the US defense budget"[23]. In order to remain a viable course of action, the space based defensive energy grid must keep program costs to a minimum. The small size and large number of required satellites to implement the grid will allow the utilization of mass production. Drawing from the civilian sector, we find a correlating system model in Oneweb. Oneweb is currently working to provide worldwide wireless internet by employing a global constellation of small low cost low earth orbit satellites. Using the Oneweb model of mass production, 900 satellites could be manufactured with 720 being launched into orbit for approximately $3.5 billion[24]. While a large sum of money, this only represents one percent of current budget estimates to modernize the nuclear triad[25]. Additionally, the cost of deploying the satellite grid could be decreased further by utilizing the satellite for multiple purposes such as communications, surveillance, or even commercial applications. Pursuing the space based directed energy grid would posture the Air Force to better cope with future budgetary constraints.

*Time*

The time required to field a new system must also be accounted for when considering the future posture of the Air Force. The public is acutely aware of program delays with weapons systems such as the F-35[26]. Program delays can cost crucial public support for new systems. Furthermore, in order to provide a viable alternative to the modernization of the nuclear triad, the space based defensive grid must ready to field in a similar timeline of 20 years or less[27]. Traditionally it has required an average of 7.5 years to develop and launch a satellite, with an additional 2-3 years for subsequent satellites[28]. However, using Oneweb's model of mass production and launch of small satellites a complete deployment of the system could be expected closer to 4 years with a proper acquisition process[29]. The space based directed energy grid would require time to develop and employ; however, using existing technology as the foundation for the grid, and borrowing lessons learned from commercial enterprises, the grid could be operational in less than half the time require to modernize the nuclear triad.

### *Treaties*

No discussion of a space based system would be complete without addressing the constraints placed on space by treaties and international norms. International law prohibits the placement of WMDs in space, preserves free exploration and use by all states, and holds states liable for damage caused by their space objects[30]. Additionally, toward the end of 2000 the United Nations voted on a resolution called “Prevention of Outer Space Arms Race”; however, the United States and two other nations abstained[31]. The implementation of the space based defensive grid would abide by international law. The Outer Space Treaty defines WMDs as nuclear, biological, chemical, or radiological. The implementation of a directed energy grid would not violate any of these categories. Furthermore, the directed energy grid would not deny the free exploration of space by any state. In fact, through its ability to protect against ASAT threats, the grid would protect the free exploration of space. Finally, so long as the orbits of the satellite constellation were maintained, and any damage to other satellites caused by use of the system were recouped to the owning nation, the liability clause of the Outer Space Treaty would be upheld. Therefore, implementation of a space based directed energy grid would not violate any international agreements the US has entered.

### *Geopolitical Climate*

A final constraint that must be accounted for while implementing a space based directed energy grid is the current geopolitical climate. There is a great deal of international concern about the possibility of a space arms race[32]. The United Nations (UN) resolution “Prevention of Outer Space Arms Race” was adopted by a recorded vote of 163 in favor to none against, with 3 abstentions[33]. This represents a very real international concern regarding the weaponization of space. The possibility of sanctions or trade restrictions should the US move forward with the grid is very real. The space industry, which relies heavily on exports, would be a prime target for such economic actions. The short term influx of defense spending would offset the cost of any such actions to the US economy; however, increased defense spending alone would not recoup the losses incumbent with major sanctions. This highlights the importance of how the program is sold to the international community. Highlighting the system as a global good, coupled with well-publicized national policy for system use, will be paramount in easing international discomfort. Some states will never accept what they will surely see as a US hegemony in space; however, proper policy and prudent implementation could win over the majority of the international community, and save the US from the economic ramifications of international sanctions.

## **Conclusion**

Over the past 25 years the world has witnessed a sweeping reduction in nuclear stockpiles. The United States and Russia have both worked to reduce their arsenals by nearly five-fold[34]. Despite this trend, the United States Department of Defense is still forecasted to spend more than $350 billion updating its nuclear triad over the next 20 years[35].

Space based nuclear defenses stand to modernize a decades-old model of mutually assured destruction and reduce the need for such costly nuclear modernization efforts. Should these defenses prove to be capable of defending against ICBM threats, the future effectiveness of ICBMs is expected to be greatly reduced. Thereby, reducing the incentive for powers such as the United States and Russia to allocate resources to their modernization.

The ripple effects caused by deploying a space-based nuclear defense system would be felt world-wide for years to come. Following the decrease in global nuclear threats attained by reducing ICBM effectiveness, nation-states would be encouraged to turn their attention to deterring regional nuclear powers. Additionally, an initial step towards space-based deterrence by the United States could spur similar developments by like-minded powers. These developments could lead to global partnerships dedicated to enhancing nuclear deterrence capabilities rather than relying on the assets of a single country.

Space-based defenses such as the directed energy grid laid out in this work come with multiple constraining factors. Cost, time, global, and the geopolitical climate must all be considered when contemplating such a drastic change in deterrence strategy. Fortunately, current mass production efforts in the commercial space sector have already shown that similar space assets can be produced in both a timely, and cost-efficient manner. Additionally, despite potential misgivings, the production and deployment of these assets would maintain adherence to the Outer Space Treaty agreed upon by the United States.

The United States is approaching a crossroads regarding nuclear strategy. A choice to maintain the current policy of mutually assured destruction holds the entire globe at risk of disastrous nuclear effects. The alternative, deploying a space based nuclear and ASAT defense system, offers the world the opportunity move away from its dependence on nuclear weapons. Whatever the choice, it will have global ramifications for decades to come.

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[1] CBS News. "Aides scramble to clarify Trump's abrupt tweet about nukes" *Foreign Policy*, (23 December 2016): http://www.cbsnews.com/news/president-elect-donald- trump-nuclear-weapons-tweet-aides-scramble-to-clarify/

[2] Robert Jervis, “The Dustbin of History: Mutually Assured Destruction,” *Foreign Policy*, (9 November 2009): http://foreignpolicy.com/2009/11/09/the-dustbin-of-history-mutual-assured-destruction

3 Reif, Kingston, "Fact Sheets & Briefs." US Nuclear Modernization Programs, *Arms Control Association*. August 15, 2016, https://www.armscontrol.org/factsheets/USNuclearModernization

4 Moreland, Scott "Introduction: A Comprehensive Approach." In *Conflict and Cooperation in the Global Commons: A Comprehensive Approach for International Security*, pages 1-20, 2012, http://www.jstor.org/stable/j.ctt2tt578.7

5 "GPS: The Global Positioning System." GPS.gov, accessed February 07, 2017, http://www.gps.gov/

6 Gruss, Mike. "US State Department: China Tested Anti-satellite Weapon." *SpaceNews.com*, January 30, 2015, http://spacenews.com/41413us-state-department-china-tested-anti-satellite-weapon/.

7 Wood, L. Todd. "Russia tests anti-satellite weapon." *The Washington Times*, Decmber 21, 2016, http://www.washingtontimes.com/news/2016/dec/21/russia-tests-anti-satellite-weapon-pl-19-nudol/

8 Nayak, Michael, "Cubesat proximity operations: The natural evolution of defensive space control into a deterrence initiative." *The Space Review*, CubeSat proximity operations: The natural evolution of defensive space control into a deterrence initiative, January 18, 2016, http://www.thespacereview.com/article/2902/1

[9] Niederstrasser, C., A. Hassan, J. Hermle, A. Kemp, A. McGlothlin, D. Samant, and J. Stein (2009), TJ3Sat–The First Satellite Developed and Operated by High School Students.

[10] Moore, G., W. Holemans, A. Huang, J. Lee, M. McMullen, J. White, R. Twiggs, B. Malphrus, N. Fite, and D. Klumpar (2010), 3D Printing and MEMS Propulsion for the RAMPART 2U CubeSat, in *Small Satellite Conference*, Logan, UT, USA.; Davis, S. (2011), Construction of a CubeSat Using Additive Manufacturing, *SAE*, *2011-01-25;* Longmier, B. (2014), The CubeSat Ambipolar Thruster: Earth Escape in a 3U CubeSat, in *Interplanetary Small Satellite conference*, Jet Propulsion Laboratory, Pasadena, CA

[11] Harris, K., M. McGarvey, H. Y. Chang, M. Ryle, T. Ruscitti, B. Udrea, and M. Nayak (2013), Application for RSO Automated Proximity Analysis and IMAging (ARAPAIMA): Development of a Nanosat-based Space Situational Awareness Mission, *Proc. 2013 Small Satell. Conf.*, (SSC13-WK6), 1–19.; Nayak, M., J. Beck, and B. Udrea (2013), Real-time attitude commanding to detect coverage gaps and generate high resolution point clouds for RSO shape characterization

with a laser rangefinder, in *Aerospace Conference, 2013 IEEE*, pp. 1–14; Udrea, B. et al. (2013), Mission Design and Concept of Operations of a 6U CubeSat Mission for Proximity Operations and RSO Imaging, in *Proceedings of the 5th International Conference on Spacecraft Formation Flying Missions and Technologies*, pp. 1–15, Munich, Germany

[12] Air Force Space Command White Paper (n.d.), Resiliency and Disaggregated Space Architectures

[13] Jentleson, B. A., and C. . Whytock (2005), Who Won Libya, *Int. Secur.*, *30*(3), Winter 2005/06: 47–86

[14] Shelling, T. (1966), *Arms and Influence*, Yale University Press, New Haven, CT

[15] Powell, R. (1999), *In the Shadow of Power: States and Strategies in International Politics*, Princeton University Press, Princeton, NJ

[16] Nayak, "Cubesat proximity operations"

[17] Frey, A. E. (2008), Defense of US Space Assets: A Legal Perspective, *Air Sp. Power J.*, *Winter*.

[18] Art, Robert. "'The Four Functions of Force." Art, Robert J. and Robert Jervis: International Politics: Enduring Concepts and Contemporary Issues, 11th edn. Pearson, 2012 pg 164-171.

[19] Morgan, Forrest E. "Deterrence and First-Strike Stability in Space: A Preliminary Assessment." Rand Corporation. 2010.

[20] Office of the Assistant Secretary of Defense for Homeland Defense and Global Security. "Space Domain Mission Assurance: A Resilience Taxonomy, A White Paper." September 2015, https://fas.org/man/eprint/resilience.pdf; Headquarters Air Force Space Command. "AFSPC Commander's 2016 Strategic Intent." Peterson Air Force Base, Colorado. May 6, 2016. http://www.afspc.af.mil/Portals/3/Commander%20Documents/AFSPC%20Commander's %2020 16%20Strategic%20Intent.pdf?ver=2016-05-09-094135-810

[21] Nayak, "Cubesat proximity operations"

[22] Messier, D. (2015). "Global Space Economy Grew 9 percent to $330 Billion Last Year." *Parabolic Arc News*. Retrieved from http://www.parabolicarc.com/2015/07/10/global-space-economy-grew-9-percent-330-billion-year

[23] Garver, R. (2014, January 8). "Here's the Giant Shoe About to Drop on the Economy." Retrieved February 07, 2017, from http://www.thefiscaltimes.com/Articles/2014/01/08/Rising-interest-rates-will-slam-Federal-Budget

[24] De Selding, P. B. (2016, July 06). “One year after kickoff, OneWeb says its 700-satellite constellation is on schedule.” Retrieved February 07, 2017, from http://spacenews.com/one-year-after-kickoff-oneweb-says-its-700-satellite-constellation-is-on-schedule/

[25] Torbati, Y. (2016, September 26). “Cost of modernizing US nuclear weapons to fall to next president.” Retrieved February 07, 2017, from http://www.reuters.com/article/us-usa-nuclear-future-idUSKCN11W2IW

[26] Tucker, P. (2017, January 11). “Pentagon Tester: F-35 Program Rushing Tests, Delays Still Likely.” Retrieved February 07, 2017, from http://www.defenseone.com/technology/2017/01/pentagon-inspector-f-35-program-rushing-testing-delays-still-likely/134531/

[27] Torbati, “Cost of modernizing”

[28] Davis, L. A., & Filip, L. (2014). “How Long Does It Take to Develop and Launch Government Satellite Systems?” (Rep. No. ATR-2015-00535). Aerospace.

[29] De Selding, “One Year after kickoff”

[30] United NationsOffice for Outer Space Affairs. (n.d.). Retrieved February 07, 2017, from http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html

[31] Shah, A. (2007, January 21). “Militarization and Weaponization of Outer Space.” Retrieved February 07, 2017, from http://www.globalissues.org/article/69/militarization-and-weaponization-of-outer-space

[32] Ibid

[33] Ibid

[34] Kristensen, Hans. “Trimming Nuclear Excess.” Federation of American Scientists. December 2012.

[35] Reif, Kingston. “US Nuclear Modernization Programs.” Arms Control Association. 2016.