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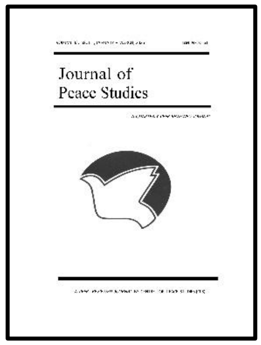

Weaponisation of Outer Space: Legal Gaps Strategic Risks and the Future of Global Security

Umesh Kadam, Independent Legal Consultant & Visiting Professor, Symbiosis Law School, Pune.

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Weaponisation of Outer Space: Legal Gaps, Strategic Risks and the Future of Global Security

Umesh Kadam*

Abstract

Since the early phases of space exploration, military ambitions have remained integral to national space programmes. Today, after nearly seven decades of sustained activity in outer space, serious initiatives are underway to deploy weapons in space and to develop terrestrial capabilities designed to target space-based assets. Such developments carry significant implications for safety and security not only in outer space and on celestial bodies, but also in airspace and on Earth's surface, and for global peace and stability more broadly. This article examines the existing legal regime governing military activities in outer space, provides an overview of ongoing attempts to weaponise space, and analyses the potential consequences of testing and deploying weapons in outer space. It underscores the urgent need for strengthened diplomatic and legal measures to preserve peace in outer space as a peaceful domain. Any military conflict in outer space that disrupts the critical space infrastructure essential for civilian applications would have disastrous consequences for the heavily digitalised lives of people. Such conflict could also generate cascading instability, heightening global insecurity and increasing the risk of widespread societal disruption.

Keywords: Anti-satellite weapons, ballistic missile defence, celestial bodies, nuclear weapons, outer space, peace and security, satellites, space debris, space weapons, weaponisation of outer space.

1. Introduction

Man's venture into outer space is one of the most remarkable scientific and technological achievements of the twentieth century. This endeavour was largely driven by military imperatives,

* *Umesh Kadam, Independent Legal Consultant & Visiting Professor, Symbiosis Law School, Pune.*

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particularly during the Cold War, when the United States and the Union of Soviet Socialist Republics (USSR) engaged in an intense arms race centred on the development of ballistic missile technology in the aftermath of the Second World War. Germany's earlier success in developing rocket technology during the 1930s significantly inspired both powers to pursue similar technological capabilities. The US and the USSR recognised the strategic potential of rocket systems and accordingly sought to utilise this technology to launch objects into outer space.[1]

These efforts culminated on 4 October 1957, when the Soviet Union successfully launched Sputnik 1, the world's first artificial satellite. Nearly three months later, on 31 January 1958, the US responded by launching Explorer 1, thereby marking the beginning of sustained space exploration by both superpowers. The ideological rivalry between these two global powers, rooted in the hostility that emerged immediately after the Second World War, thus became a defining feature of the Cold War and extended into competition for supremacy in outer space. From the outset of space exploration, military ambitions became a central driving force behind national space programmes.

Although the initial race to place objects in outer space was mainly motivated by strategic and security considerations, it also facilitated the development of many civilian applications during the formative years of space exploration, including meteorology, satellite communications, global positioning systems, and remote sensing technologies. Over time, such applications have evolved into essential components of modern life and have become indispensable to the functioning of contemporary societies.

However, what is alarming is that recent developments have raised significant concerns about the increasing militarisation of outer space. Several states are actively pursuing capabilities such as anti-satellite systems, anti-terrestrial strike technologies, and ballistic missile defence mechanisms designed for use in, through, or from outer space. These systems vary in their configuration, with some intended for deployment directly in outer space, others based on terrestrial platforms, and still others designed as hybrid systems operating across both domains. Any military conflict in outer space with the potential to disrupt the critical infrastructure supporting vital civilian and commercial applications would have catastrophic consequences for modern life, which remains heavily dependent on technology. Accordingly, such disruptions could undermine essential services, including communications, navigation, and disaster management systems, thereby affecting global economic and social stability.

2. The emergence of space law

The international law existing at the dawn of the space age was inadequate to address the new challenges arising from humanity's venture into outer space, particularly in maintaining order and preventing confrontation in this emerging domain. Recognising both this legal gap and the potential dangers of an uncontrolled arms race in outer space, the US and the Soviet Union – the only space powers at the time – supported the adoption of basic normative principles for space activities in the early 1960s. Accordingly, in December 1961, the United Nations General Assembly (UNGA) adopted a resolution to promote international cooperation in the peaceful uses of outer space.[2] It was followed by another resolution in 1963 titled "Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space,"[3] thereby marking the start of a new chapter in international law – 'Space Law'. Since the principles contained in the 1963 resolution were recommendatory rather than legally binding, most UN member states, including the US and USSR, supported their further elaboration into binding treaty obligations.

As a result, in 1967, the "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies" – commonly known as the Outer Space Treaty - was adopted.[4] This accord is regarded as the foundational instrument of international space law and was subsequently supplemented by several additional agreements: the "Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (Rescue Agreement) in 1968[5]; the Convention on International Liability for Damage Caused by Space Objects (Liability Convention) in 1972[6]; the Convention on Registration of Objects Launched into Outer Space (Registration Convention) in 1975;[7] and the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Treaty) in 1979.[8] Apart from the Outer Space Treaty and the Moon Treaty, these subsequent agreements do not directly address the militarisation of outer space. The adoption of five major treaties relating to space activities in outer space within a relatively short period of 12 years demonstrates the urgency perceived by the states, particularly the US and the Soviet Union, to establish norms, given the increasing space activities and the potential for facing unforeseen challenges, such as, rescuing astronauts stranded in outer space or landing in hostile countries, or liability for damage caused by spacecraft accidents. These treaties have since been supplemented by customary space law, which has developed from state practice and the accompanying *opinio juris* since the 1950s.

One of the most significant achievements of these developments, especially the Outer Space Treaty, was the prohibition on placing nuclear weapons or any other weapons of mass destruction in outer space and on celestial bodies. As of 1 January 2026, the Outer Space Treaty has 118 States Parties and 23 signatories,[9] including all major spacefaring nations. This prohibition arose against the backdrop of rapidly expanding space activities and widespread concern that outer space might be used not only for peaceful exploration but also to advance the strategic and security interests of rival superpowers. As such, from the very early on, the US and the Soviet Union, then only space powers, recognised the grave danger of weapons-equipped satellites, both nuclear and otherwise, orbiting above their territories and those of their allies. In this context, the Outer Space Treaty can be considered a key arms-control treaty of the twentieth century, establishing several fundamental principles of space law, many of which have been elaborated in subsequent agreements.

Two key articles of the Outer Space Treaty are particularly relevant to military activities in outer space: Articles III and IV. Article III requires the states to conduct space activities, including the exploration of the Moon and other celestial bodies, in accordance with international law, including the UN Charter, with due regard for the maintenance of international peace and security and the promotion of international cooperation and understanding. This provision is largely declaratory in nature, affirming that general principles of international law and the UN Charter apply to outer space. Its broadly framed language, however, has often been interpreted as expressing normative aspirations rather than imposing precise operational obligations.

In contrast, Article IV is more specific and directly applicable to military activities. It prohibits the placement in orbit around Earth of any objects carrying nuclear weapons or other weapons of mass destruction, as well as the stationing of such weapons in outer space by any other means. Since the prohibition applies specifically to nuclear weapons and other weapons of mass destruction, it may be inferred that outer space has been only partially de-weaponised, which is a condition sometimes described by scholars as 'partial demilitarisation'.[10] The second paragraph of Article IV specifically addresses celestial bodies, requiring states to use them exclusively for peaceful purposes. It prohibits the "establishment of military bases, installations and fortifications, testing of any type of weapons, and conducting military manoeuvres on celestial bodies." The deployment of military personnel and equipment for peaceful activities on celestial bodies is exempt from these prohibitions. Therefore, Article IV not only de-weaponises celestial bodies but also fully demilitarises them. Article IV employs both a generic and an enumerative approach to demilitarising celestial bodies. Article 3 of the Moon Treaty reaffirms these provisions insofar as celestial bodies are concerned. Notably, the terms 'nuclear weapons' and 'weapons of mass destruction' have not been defined by the Outer Space Treaty. This omission raises an important interpretive question: whether the term 'nuclear weapon', as used in Article IV, should automatically be considered synonymous with a weapon of mass destruction. In other words, would a weapon that utilises nuclear energy for its operation but does not cause mass destruction fall within the scope of Article IV? For instance, emerging technologies such as nuclear-pumped laser systems could theoretically be deployed aboard satellites to destroy individual targets in airspace, outer space, or on Earth's surface without causing widespread devastation.[11]

This article argues that the treaty prohibits only those nuclear weapons capable of causing mass destruction. In this context, the interpretive principle *noscitur a sociis*, widely recognised in domestic legal systems, is relevant. As noted by McNair, this rule also applies to treaty interpretation,[12] contending that when words with analogous meanings are grouped together, they should be interpreted in relation to each other in such a way that the context of the associated terms restricts the meaning of a more general term.[13] The phrase 'any other kinds' in Article IV suggests that nuclear weapons were regarded as inherently belonging to the broader category of weapons of mass destruction. Had the provision been framed as 'nuclear weapons or weapons of mass destruction', or 'nuclear weapons and weapons of mass destruction', a different interpretive outcome might have been possible. Further support for this interpretation may be drawn from the historical context in which the treaty was drafted. At the time of its conclusion in 1967, nuclear weapons were understood exclusively as weapons capable of causing mass destruction. McNair observes that, where ambiguity exists, treaty terms should generally be interpreted according to their meaning at the time of drafting.[14] On this basis, it is reasonable to conclude that Article IV prohibits the placement in orbit or stationing in outer space of weapons of mass destruction, including nuclear weapons that produce catastrophic effects.

However, this interpretation raises an additional question: why did the drafters single out nuclear weapons from the broader category of weapons of mass destruction? One plausible explanation is that nuclear weapons were considered the most destructive and strategically destabilising among such weapons, warranting explicit mention. Notably, international law has yet to establish a universally accepted definition of a weapon of mass destruction. The term is generally understood to refer to weapons capable of causing large-scale destruction of property and widespread harm to human populations. However, concerns persist that the concept may remain controversial and subject to evolving interpretations.[15] Some scholars have suggested that a weapon could be considered a weapon of mass destruction if its destructive impact is catastrophic.[16] They do not include conventional weapons whose lethal mechanism employs gunpowder or other explosives, and conventional components. In contrast, unconventional weapons such as nuclear, biological, bacteriological, and chemical weapons may be regarded as weapons of mass destruction.[17] The United States military has endorsed this view, but has clarified that such weapons do not include means of transporting or propelling them where these are separable and divisible from the weapon.[18]

3. Interpretation of 'peaceful' purposes under space law

As seen earlier, the Outer Space Treaty requires state parties to use outer space for peaceful purposes. Both the preamble and Article III oblige states to conduct space activities in the interest of maintaining international peace and security and promoting international cooperation. Accordingly, space activities are expected to be carried out for 'peaceful' purposes, a principle also emphasised in the 1963 General Assembly resolution that established the legal principles governing space activities.

However, Article IV introduces an important distinction by explicitly requiring that celestial bodies be used 'exclusively' for peaceful purposes. This means that activities in outer space would be 'peaceful', whereas activities on celestial bodies must be 'exclusively peaceful'. The first paragraph of Article IV prohibits the placement of objects carrying nuclear weapons and other weapons of mass destruction in orbit around the Earth, whereas its second paragraph prohibits all forms of military activity on celestial bodies. This difference raises an important interpretive question: did the drafters intend to permit certain military activities in outer space while prohibiting all military activities on celestial bodies?

One interpretation, based on the ordinary meaning of the term 'peaceful', equates peaceful with non-military. Under this view, any activity serving a military purpose – whether offensive, defensive, aggressive, or non-aggressive – would be excluded from outer space. An alternative interpretation, historically supported by the United States and several other states, construes 'peaceful' as 'non-aggressive', thereby allowing defensive military activities.[19] In contrast, the Soviet Union maintained that 'peaceful' should be interpreted as synonymous with 'non-military'.[20] During the early years of the Outer Space Treaty, it was widely observed that the concept of peace had traditionally been contrasted with war, and that 'peaceful' had therefore been understood to mean 'non-military'. [21] Some Western scholars also supported this interpretation in the early phase of space exploration.[22] The interpretation of 'peaceful' as 'non-aggressive' has been justified on pragmatic grounds, particularly the argument that it preserves strategic flexibility for states in the absence of effective verification mechanisms.[23] However, scholars such as Bin Cheng have argued that equating 'peaceful' with 'non-aggressive' leads to illogical and potentially unreasonable consequences,[24] as it weakens the normative constraints intended by the treaty framework.

However, despite these debates, nearly six decades of state practice indicate that the prevailing interpretation of 'peaceful' has evolved toward the meaning of 'non-aggressive'. Thus, almost all spacefaring states today believe that the obligation under Article IV of the Outer Space Treaty to use outer space for 'peaceful' purposes does not prevent them from deploying military satellites for communication, navigation, ocean surveillance, geodesy, and reconnaissance. Similarly, states pursuing advanced space capabilities appear to operate on the assumption that, provided they do not station weapons of mass destruction in outer space or on celestial bodies, they remain legally entitled to develop, possess, deploy, and potentially use other types of weapons in or from outer space. Against this background, it is pertinent to consider the types of weapons contemplated for use in or from outer space.

4. Space weapons

The term 'space weapons' has not been formally defined in international law. This article aligns with the definition which considers these as objects or devices that are capable of (a) causing damage, destruction, or otherwise rendering useless objects located in outer space or on celestial bodies from outer space or celestial bodies; (b) causing damage, destruction, or otherwise rendering useless objects located in airspace, the seas, or on the terrestrial Earth from outer space or celestial bodies; and (c) causing damage, destruction, or otherwise rendering useless objects located in outer space or on celestial bodies from airspace, the seas, or the terrestrial Earth. Accordingly, such weapons may be broadly classified into space-to-space, space-to-Earth, and Earth-to-space weapons. It should be noted that some states do not classify Earth-to-space weapons as 'space weapons',[25] thereby creating divergence in conceptual definitions among states.

Focused discussion on the development of space weapons began in the early 1980s. On 23 March 1983, President Ronald Reagan delivered a widely cited speech announcing the initiation of a major space defence programme.[26] This initiative was subsequently designated as the 'Strategic Defence Initiative' (SDI) by the United States administration, while the media popularly referred to it as 'Star Wars'. As discussed in later sections, several significant technological and strategic developments have occurred since that time regarding the development of space weapons. Apart from the traditional space powers, namely the United States and Russia, several other countries now harbour ambitions to develop space weapon technologies. An outline of various space weapon technologies currently being developed by leading spacefaring states is provided below.

4.1. Kinetic energy weapons

A kinetic energy weapon produces destructive force through the physical impact of a solid or explosive substance directed at a target and released from a launching device. Such weapons may take the form of direct-ascent systems, that is, weapons located on the terrestrial Earth but designed to destroy targets in outer space. A direct-ascent anti-satellite (ASAT) weapon typically consists of an interceptor mounted on a missile and launched toward the target satellite. In some configurations, the interceptor may release a cloud of pellets to increase the likelihood of collision with the target before interception. These systems are generally considered more effective against satellites in low-Earth orbit (LEO) due to range limitations.[27]

Another category of kinetic energy ASAT weapons is the co-orbital system, which refers to weapons mounted on a space platform or satellite launched into the same orbit as the target satellite. Such systems are designed to approach the target and release explosive devices aimed at disabling or destroying it. They may also employ unguided clouds of pellets or homing interceptors released shortly before impact.[28] It is widely believed that co-orbital ASAT systems offer the advantage of concealment, thereby providing the targeted satellite with limited warning before attack.[29]

During the 1970s, the United States actively pursued the development of a miniature homing vehicle (MHV) programme intended for anti-satellite applications. The objective of this programme was to produce a small satellite interceptor capable of being launched from air or ground platforms and guided toward its target through long-wave infrared homing systems.[30] Parallel to the development of anti-satellite kinetic energy weapons, research into ballistic missile defence technologies intensified during the 1980s. In February 1987, it was reported that the Strategic Defence Initiative Organisation was nearing the development of a cost-effective space-based kinetic kill vehicle capable of destroying intercontinental ballistic missiles during their boost phase.[31]

The United States conducted its first sea-based anti-satellite kinetic-energy test in 2008, destroying one of its defunct satellites.[32] China had previously tested an ASAT kinetic-energy device in 2007 and began exploring ballistic missile defence technologies around the same time.[33] In March 2019, India reportedly conducted a successful test of a kinetic anti-satellite weapon known as 'Shakti'.[34] During this test, India utilised a ballistic missile defence interceptor developed by the Defence Research and Development Organisation as a kinetic anti-satellite missile.[35]

The Soviet Union had also been engaged in developing anti-satellite capabilities, most likely involving kinetic energy technologies, from the early days of space exploration. These developments were partly undertaken in response to American anti-satellite programmes of the 1960s and 1970s.[36] Soviet research focused primarily on co-orbital technologies, whereas the United States concentrated more heavily on direct-ascent systems.[37] Following the dissolution of the Soviet Union, Russia inherited its predecessor's space programme and subsequently diversified its anti-satellite weapons research, while continuing to maintain interest in kinetic energy technologies for space applications.[38] It is widely believed that Russia conducted several direct-ascent ASAT tests during the 2010s and that such testing activities have reportedly continued into the present decade.[39] In November 2021, Russia reportedly conducted a direct-ascent anti-satellite kinetic energy missile test.[40]

Another kinetic energy weapon system under consideration involves space-to-Earth applications. Under this concept, a pair of satellites would be placed in low-Earth orbit, with one carrying multiple tungsten rods measuring approximately 20 feet in length and 1 foot in diameter, coated with heat-resistant materials. The second satellite would provide targeting and communication support.[41] Upon receiving instructions from ground-based command systems, the targeting satellite would guide the weapon satellite to release a rod directed toward a terrestrial target.[42] The released rod would descend at extremely high velocity, reportedly reaching speeds of approximately 36,000 feet per second, enabling it to destroy targets even when deeply buried underground.[43] The destructive effect would result solely from kinetic impact, not from explosive force. Such systems rely primarily on gravitational acceleration and mass to achieve destructive capability.[44] It is widely believed that such weapons would be difficult to intercept due to their extreme speed and could prove advantageous in attacking heavily fortified targets,[45] including missile silos, hardened aircraft shelters, deep underground bunkers, naval vessels, bridges, and critical infrastructure installations.[46]

4.2. Electromagnetic railgun

An electromagnetic railgun is a specialised form of kinetic energy weapon. When it was first conceived in the early 1980s, it was expected to fire projectiles at velocities exceeding 10 km/second, with ranges surpassing 1000 km, at a rate of 60 shots per second.[47] Such guns were being developed not only for use in outer space but also for terrestrial applications, including the seas. Their ultrahigh speed is believed to result from electromagnetic thrust. They were designed for use in long-range strikes, strategic air defence, and ballistic missile defence.[48] Their mechanism involves mass acceleration that ejects small homing hit-to-kill projectiles with kinetic non-nuclear impact.[49]

During the early 1980s, the US Department of Defence considered employing electromagnetic railguns as defensive systems against Soviet hunter-killer satellites.[50] In August 1988, the US Air Force reportedly acquired three electromagnetic railguns capable of intercepting missiles during their mid-course phase. These systems were designed to fire small guided projectiles weighing approximately 2 kilograms at velocities of 2-3 km per second.[51] Recent technological developments suggest renewed interest among major powers. In February 2024, reports suggested that China had successfully tested an electromagnetic railgun.[52] In October 2022, it was reported that India was working on an electromagnetic railgun.[53] Although there is no evidence to suggest that the Soviet Union had begun developing electromagnetic railguns, Russia is reported to have successfully developed the technology to produce them.[54]

The European Defence Agency, part of the European Commission, announced in September 2023 that it had initiated a comprehensive feasibility study to assess the use of the electromagnetic railgun as a long-range artillery system.[55] The device is expected to be developed between 2024 and 2028.[56] Although it is currently being considered for integration into terrestrial and naval platforms by countries developing such guns, once developed, their deployment in space may not pose a significant technological challenge.

4.3. Killer satellites

The Soviet Union started its anti-satellite weapons programme during the 1960s. During this period, emphasis was placed on developing Kamikaze-style 'killer' or 'hunter-killer' satellites designed to approach a target satellite and detonate in close proximity, thereby disabling or destroying it.[57] The destructive mechanism typically relied on chemical, non-nuclear explosive payloads.[58]

In most tests carried out during the Soviet era, these interceptor satellites successfully engaged target satellites at orbital altitudes ranging from 200 to 2000 km.[59] Following the dissolution of the Soviet Union, Russia continued these programmes, incorporating additional capabilities related to both anti-satellite and anti-missile technologies.[60] However, it was kept secret until 2009, when Russia disclosed elements of its programme to the international community, partly in response to ASAT weapons tests by China and the US in 2007 and 2008, respectively.[61]

Technological developments have also led to the emergence of smaller satellites, known as 'micro-satellites', which have potential dual-use capabilities.[62] These devices are not inherently designed as weapons and are designed for peaceful purposes, such as satellite refuelling. However, it has been suggested that such systems could be modified to function as 'space mines' by equipping them with explosive payloads or impact mechanisms that can damage or destroy targeted satellites.[63]

Reports suggest that in 2020, Russian satellites conducted tests involving the ejection of sub-satellites or secondary objects into orbit.[64] These systems are widely believed to fall within the operational category of hunter-killer satellites. Similarly, the American programme known as Global Protection Against Limited Strikes – 'Brilliant Pebbles' – may also be classified within the broader category of killer satellite technologies, as it envisages a distributed network of small autonomous satellites capable of intercepting and destroying hostile targets.

4.4. Directed energy weapons

Directed energy weapons consist of concentrated beams of electromagnetic energy designed to damage objects or disable technological systems. These weapons typically include high-intensity lasers and particle beam systems capable of transmitting focused energy from a source to a distant target.[65] These primarily include laser, maser, and particle beam technologies.

Laser beams are produced by exciting atoms or molecules, which then emit coherent electromagnetic radiation. [66] The US declassified certain reports on space-based laser technologies in March 1982, thereby providing early insight into the feasibility of such systems. Russia inherited the USSR's laser research programmes initiated during the 1970s, and reports indicate that Soviet scientists had been developing powerful laser systems as early as 1978, capable of damaging satellites at altitudes approaching 40,000 km.[67] China's laser development efforts are believed to have begun during the 1960s, with research activities conducted under the supervision of national scientific institutions, including the Chinese Academy of Sciences and defence-oriented technological agencies.[68]

Various materials and media can be utilised to generate laser beams, including solid-state, gas-based, liquid, dye-based, gas-dynamic, and chemical systems.[69] The resulting high-energy beam has attracted considerable interest among military planners due to its capacity to deliver concentrated energy over extended distances. When sufficient energy is transmitted to a target, the resulting thermal or structural stress may damage, disable, or destroy the target system.[70]

Two principal mechanisms of damage have been widely studied. The first is known as the 'melt-through kill mechanism', whereby sustained thermal energy causes structural melting and failure of the target satellite.[71] The second, referred to as the 'impulse loading mechanism', involves the generation of shock waves within the target structure, leading to rupture of the outer casing.[72] Such rupture typically occurs when intense heat causes the surface material to vaporise, thereby generating internal pressure and shock effects analogous to mechanical impact.[73]

Different categories of laser systems have been proposed for specialised operational roles. For example, excimer and X-ray laser systems are considered particularly suitable for generating high-intensity shock effects capable of damaging missile structures.[74] Free-electron lasers, including hydrogen fluoride and deuterium fluoride systems operating in continuous-wave modes, are regarded as suitable for sustained targeting operations designed to burn through protective surfaces.[75]

The US has increasingly focused on X-ray laser technologies due to their perceived efficiency and potential strategic applications. According to United States defence officials and Congressional assessments, technological breakthroughs involving the generation of high-energy X-rays from nuclear detonations were considered to hold significant potential for countering hostile missile threats.[76] Reports from 1986 indicated that nuclear-powered X-ray laser systems formed a key component of the Strategic Defence Initiative programme.[77]

Particle beam weapons have many similarities to laser weapons. To generate a particle beam, either electrically charged or neutral particles are required.[78] The kinetic energy of these particles is increased by an electromagnetic device known as an accelerator, which provides 'pushes' to the particles, producing a high-energy beam.[79] Typically, particle beam systems require integrated power supplies, energy storage units, targeting sensors, and precision aiming mechanisms.[80] A sufficiently intense particle beam can transmit large amounts of energy to a target, potentially melting metallic structures or damaging sensitive electronic components.[81] The destructive mechanisms associated with particle beam systems include thermal effects, the generation of X-rays and electric currents, structural rupture due to internal pressure, and the triggering of explosive reactions within targeted systems.[82]

High-powered microwave amplification by stimulated emission of radiation (maser) weapons are similar to laser weapons. They can be used to disrupt a satellite's electronics, corrupt data stored in memory, cause processors to restart, and, at higher power levels, inflict permanent damage on electrical circuits and processors.[83] This weapon may utilise a satellite's antennas as an entry point, or attempt to infiltrate through small seams or gaps around electrical connections and shielding.[84]

Recent developments highlight continuing advances in directed energy technologies. The Russian anti-satellite laser weapon system 'Peresvet', capable of blinding all reconnaissance satellite systems of potential adversaries in orbits of up to 1500 km, was commissioned in 2022.[85] A new Russian anti-satellite laser weapon is reported to have been tested in February 2024.[86] What is alarming about this test is that the proposed weapon requires a nuclear detonation in outer space.[87] China has made substantial advancements in directed energy weapons technology.[88] According to US intelligence reports, China has operational ground-based laser weapons capable of blinding optical sensors or damaging satellites.[89] China has also researched high-altitude nuclear detonations to disable constellations of hostile satellites.[90] It remains uncertain whether this was intended to create a directed-energy weapon or an electromagnetic pulse. Nonetheless, a study conducted in July 2024 found that China has developed lasers mounted on submarines capable of destroying hostile satellites if China's security is threatened.[91]

Other states have also demonstrated interest in directed energy technologies. In July 2019, France was reported to be considering launching a constellation of small satellites equipped with laser weapons to counter potential threats to its space assets.[92] India conducted tests of ground-based directed-energy weapons for both ballistic missile defence and ASAT purposes, according to a 2012 monograph published by the Defence Research and Development Organisation.[93] In 2019, the Head of the Defence Space Research Organisation announced that India was developing directed-energy, laser, electromagnetic pulse, and orbital weapons.[94] In 2023, it was reported that India had already developed some of these weapons.[95]

4.5. Electromagnetic pulse weapons

Serious research into the effects of electromagnetic pulse (EMP) for potential weapon applications began in the 1970s. A high-altitude nuclear detonation produces gamma radiation that travels toward Earth's surface. During this process, the gamma rays interact with molecules in the upper atmosphere,[96] resulting in the release of large numbers of electrons. These electrons are accelerated and deflected by Earth's magnetic field, creating an extensive electromagnetic disturbance capable of generating a powerful pulse across wide geographic areas.[97]

The pulse effect was studied in the United States during the late 1970s, and its potential as a weapon was suggested, although not developed at that time. An electromagnetic pulse can (a) devastate satellites, (b) disrupt telecommunications, and (c) destroy a satellite's communication system.[98] The effects of electromagnetic pulses include data corruption on memory chips, processor resets, and short circuits that can cause permanent damage to satellite components.[99] If a nuclear detonation generates an electromagnetic pulse, it would instantly affect satellites in its vicinity. At the same time, it would create a high-radiation environment that would accelerate component degradation in all unshielded satellites within the affected orbital zone.[100]

In the 1970s, the Soviet Union carried out nuclear detonations at high altitude above the Sary Shagan radar system, presumably to investigate and study the effects of electromagnetic nuclear pulses on electronic components.[101] Since those days, the US and Russia have made significant progress in developing electromagnetic pulse technology for military use. In February 2024, the US government confirmed that Russia is developing a new ASAT capability in the form of a nuclear weapon in space and that it is creating a nuclear-powered electronic warfare satellite.[102]

4.6. Radio-frequency weapons

Radio-frequency weapons constitute a category of electronic warfare systems designed to disrupt or disable adversary technologies by exploiting the electromagnetic spectrum.[103] Thus, a satellite's ability to perform its functions is temporarily interrupted without causing any physical damage, as long as the target remains engaged. Attacks using radio-frequency weapons may disrupt the operation of space-based radar and the reception of signals by service users and customers on Earth, the satellite itself, or the ground station of a space system.[104] They may also involve spoofing, which tricks a receiver into believing a fake signal created by the attacker is the genuine signal it expects to receive.[105] The main targets are the Global Navigation Satellite System (GNSS), the GPS, and communication satellites.[106] It is believed that jamming and spoofing are already occurring.[107]

Efforts to develop electronic weapons, such as radio-frequency weapons, often overlap with other similar projects that can broadly be categorised as directed energy weapons. Since these projects are highly classified, it is difficult to determine precisely when they began. However, there is a strong possibility that, since the 1980s, efforts have been focused on developing radio-frequency weapons. The US intelligence claimed in 1985 that the Soviet Union was exploring radio-frequency technology for weapon applications.[108] It is claimed that China is already using radio-frequency weapons to disrupt GPS in the Indo-Pacific region.[109] However, so far, its targets have been civilian aircraft in flight. Russia has also been accused of causing interference with the GPS in Poland, Scandinavia, and the Baltic states, alongside Ukraine.[110]

Today, GNSS interference has become quite prevalent. One reason is that devices capable of causing such interference are easily available in many countries. Reports indicate that interference with GNSS signals occurs regularly across the South China Sea, the Middle East—especially Iraq, Syria, and Armenia—and in the Eastern Mediterranean, covering Lebanon, Cyprus, Turkey, and Israel.[111] It is also believed that countries in Europe, especially Finland, Latvia, Lithuania, Poland, and Romania, occasionally experience GNSS interference.[112] It is thought that Iran is significantly engaged in radio-frequency warfare. It has been claimed that its GNSS spoofing abilities caused the downing of a United States drone in 2011.[113] Many commercial and private aircraft are routinely affected by such warfare, causing them to deviate from their course when flying near Iran.[114] At the same time, Israel is said to have used spoofing in the Middle East in the course of its recent armed conflict with Hamas.[115]

5. Possible consequences of space weaponisation

Since space infrastructure is closely integrated with terrestrial military infrastructure, any attack on space assets is likely to provoke armed conflict on Earth. Such actions would also increase distrust and hostility among nations, particularly if reconnaissance satellites were neutralised, thereby hindering verification and monitoring capabilities. Beyond military applications, outer space supports a wide range of civilian functions. Any military confrontation in outer space would not only pose a significant threat to the national security of states but would also disrupt the day-to-day lives of civilians who rely heavily on satellite-based services. These services include health-care systems, agriculture, shipping, aviation, finance, banking, information and communication technology, and related sectors. Moreover, disruption to meteorological satellites would adversely affect disaster forecasting and management capabilities. The collapse of banking and financial systems could lead to social unrest and severe economic disruption. Consequently, confrontation in outer space could spiral out of control, leading to global instability, insecurity, and public disorder.

Space weaponisation is directly correlated with the generation of space debris, which poses a serious threat to the safety of space missions. Outer space is already heavily congested with space debris, mainly produced by non-operational satellites. As of 16 January 2026, there are approximately 45,000 space debris objects larger than 10 cm, 1.2 million between 1 cm and 10 cm, and 140 million from 1 mm to 1 cm.[116] Space debris as small as 1 mm can disable a satellite's subsystems, while pieces around 1 cm can penetrate shielding and destroy an operational satellite due to high impact speeds, which often exceed 25,000 km/h.[117]

The 2007 Chinese test of a direct-ascent anti-satellite (ASAT) capability generated more than 2,500 pieces of trackable debris, increasing the number of man-made objects in orbit by approximately 20 per cent and raising the likelihood of orbital collisions by nearly 37 per cent.[118] It is also estimated that this test produced approximately 150,000 non-trackable debris fragments.[119] It has been argued that if such debris were to damage another state's space assets, China could bear liability for the resulting damage under the provisions of the Liability Convention.[120] India's test of a similar capability generated several hundred debris fragments, despite assertions by Indian authorities that the test was conducted in low-Earth orbit at an altitude of approximately 300 km, specifically to minimise long-term debris generation and prevent damage to satellites operating in higher orbits.[121]

It is inevitable that any anti-satellite weapon test, let alone the actual use of weapons, will produce significant space debris. Aside from anti-satellite weapons testing, if these weapons are actually used against satellites, the amount of space debris will multiply many times over, making any meaningful use of outer space almost impossible for generations to come. A rapid rise in space debris could trigger a chain reaction of collisions, causing even more debris to accumulate and spread. This is known as the Kessler Syndrome, a phenomenon in which the amount of junk in orbit around Earth reaches a point where it generates more and more space debris, causing major hurdles for satellites, astronauts, and mission planners.[122] Any conflict involving attacks on space assets would be as serious and catastrophic as a nuclear attack. It is estimated that a 10 KT nuclear explosion may cause damage up to a distance of about 5 km from ground zero.[123] Whereas, the impact of using anti-satellite weapons and debris created by such use would know no geographical limits – it will spread indiscriminately to much wider areas. Like a nuclear explosion, their effects will be experienced by future generations.

Recognising the potential dangers of space debris, the United Nations Committee on the Peaceful Uses of Outer Space adopted the Space Debris Mitigation Guidelines in 2010.[124] However, these are not legally binding on states and lack an effective enforcement mechanism. It is necessary to further articulate the guidelines and transform them into a binding treaty on space debris mitigation.

6. Concluding remarks

The foregoing survey of military activities in outer space demonstrates that the weaponisation of space is accelerating rapidly. Dependence on military space infrastructure is so significant that any interference, let alone an attack, on such space assets could result in devastating consequences. Besides, a large number of civilian satellites have become crucial for delivering a wide range of essential services. Any disruption to space infrastructure would cripple civilian life. The vital role of civilian and military space assets has propelled the advancement of space weapons. The three main players in this field are the United States, Russia, and China. Currently, a draft treaty jointly sponsored by China and Russia on space weaponisation, titled 'Treaty on Prevention of Placement of Weapons in Outer Space and of the Threat or Use of Force Against Outer Space Objects' (PPWT), has been pending in the Conference on Disarmament since June 2014.[125125] UN Doc. CD/ 1985.

The United States and its allies are staunchly opposing the draft. The increasing geopolitical tensions have led the three primary space powers to believe that conflict in space is probably unavoidable and within technological reach. As shown in the survey above, new capabilities to destroy or disable space infrastructure, as well as terrestrial infrastructure from space, are now a reality. The current space law does not prohibit developing and deploying weapons in outer space as long as they are not weapons of mass destruction. To prevent the catastrophic consequences of testing and using space weapons, major space powers must agree to adopt further legal measures to restrict or ban such weapons in the interest of maintaining international peace and security. ■

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