Space weapons, fiction or reality

Report 3 of 3: Non-Kinetic ASAT

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On June 18, 2018, US President Trump announced at the National Space Council, "We are going to have the Space Force." This announcement provided extra attention in the media about space weapons. In Report 1 of a series of three, an overview of Co-Orbital ASAT was given on the current situation in America, Russia and China. The second report has addressed Direct Ascent ASAT. This final report on the subject deals with non-kinetic ASAT.

Preface. An increasing number of countries and commercial parties is making use of space for things like observation (meteorology, intelligence, exploration), communication, navigation and science. These matters are no longer reserved for the great powers. The increasing use and reliance on space-based assets for national security purposes has led to an increasing number of countries committed to defending those assets. What applies on earth also applies in space: ensuring that you can use your own space resources while ensuring that the opponent (no longer) cannot. Then you have *Space Superiority*. In order to achieve that, you need to know what is present in space and what is happening: *Space Situational Awareness*. Countries that understand the need for this are therefore developing counterspace activities and techniques. Defensive counterspace helps you protect your own resources while offensive counterspace must prevent your opponent from using his space resources. Offensive counterspace includes anti-satellite weapons (ASAT). This group of weapons can be used to decrease the opponent's space capabilities by applying disruption, deception, denial, degradation or even destruction of the three system elements of space assets: the satellite, the ground station and/or the communication between them. ASAT weapons can be divided into five types, which are addressed in the underlying reports. The three last mentioned weapons below, collectively referred to as Non-Kinetic ASAT, are discussed in this report.

- Co-orbital (CO). Kinetic weapons brought into space by missiles and waiting for them to be guided to a target.
- Direct Ascent (DA). The use of rocket-launched interceptors that directly destroy a target with kinetic energy (collision or warhead).
- Directed Energy (DE). Weapons using concentrated energy (laser, particle or microwave beams) to reduce or stop the operation of a target.
- Electronic Warfare (EW). Weapons that use radio frequency energy to disrupt connections between system elements.
- Cyber Warfare (CW). Weapons that use software and networking techniques to compromise or disrupt computer networks, or even destroy computer systems.

Non-Kinetic ASAT. A non-kinetic Anti-Satellite (NK-ASAT) weapon is here understood to mean a weapon that does not use a surface-to-air, air-to-space or sea-launched missile to kinetically destroy satellites with an interceptor by collision or a nearby conventional explosion.

The nuclear option

The Americans and Russians have developed ASATs since the late 1950s. The first generation of ASATs were non-nuclear or nuclear-charged ballistic missiles. The non-nuclear-charged ballistic

missile had to hit the satellite directly or destroy nearby satellites by flying bomb shards. In the case of nuclear-charged missiles, the satellite had to be destroyed by the effects of a nuclear detonation.

America initially developed and tested exo-atmospheric nuclear (1kT) ASATs. On July 9, 1962, the Americans (Starfish Prime exercise) launched a 1.4 MT nuclear weapon from Johnson Island on a Titan missile, which detonated at 400 km altitude. The flash of light was visible all the way to Hawaii. A target was expected to be destroyed by the thermal shock wave, X-rays, or other radiation or electromagnetic effects. After the nuclear detonation, energetic beta particles followed the earth's magnetic field and illuminated the sky. Electrons formed a radiation belt around the Earth. At that time, there was not yet a clear picture of what exactly could happen regarding the composition and strength of this radiation belt. Nor was it known what negative effects this radiation belt could have for other (including its own) satellites. It soon became apparent that three satellites in low Earth orbit had become inoperative. In the months that followed, at least six more satellites were destroyed by the radiation belt due to the solar panels and/or electronic components being damaged by the radiation. The first commercial satellite, Telstar, and the English satellite Ariel-1 were also damaged. The Soviet Union also tested nuclear-charged rockets in space with comparable results.

The electromagnetic pulse (EMP) released after a nuclear explosion posed major problems for the researchers. The magnetic field of the EMP induces voltage in electric circuits. Both the occurring voltage and the associated current can cause (heat) damage in electrical wiring. Wires and components can be protected against EMP by placing them in a grounded environment (hardening), but antennas, for example, cannot.

Space-based nuclear ASAT are e.g. nuclear-pumped ASATs. These weapons use a nuclear explosion in space to generate X-rays, neutrons, gamma rays, or other radiation from the electromagnetic spectrum and direct them to the target satellite. These are single-shot weapons because the nuclear explosion also destroys the weapon. However, these types of weapons are also a threat to Earth's population, when used or with accidental accidents, due to the potential for radioactive debris to fall to Earth. These weapons have only been studied theoretically.

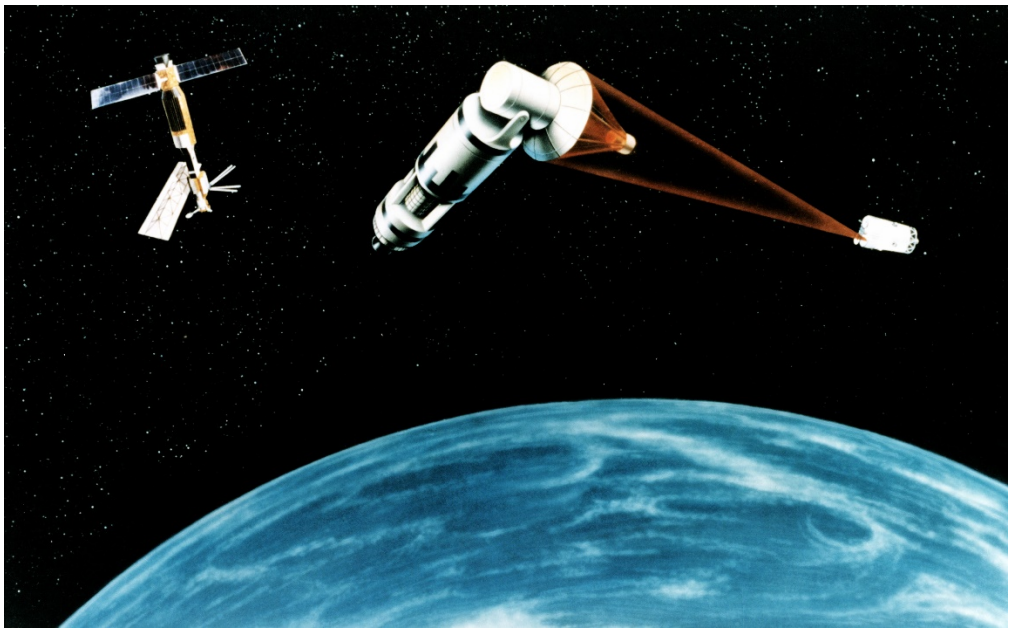
Thor 278 nuclear-charged missile at Johnston Island Program 437, 1964-1966 launch site [USAF]

Starfish Prime detonation. [driverlayer.com]

Conclusion. After the unforeseen effects of the EMP, America and the Soviet Union have stopped the nuclear option for ASAT. Moreover, the Comprehensive Test Ban Treaty has banned the detonation of a nuclear weapon in space since 1996. Much research has been/is being conducted into the possibilities of hardening (protecting) electronic devices against a multitude of radiation. Due to ever better hardening techniques, EMP is now seen as a possible future option.

Directed Energy (DE) ASAT

A Directed Energy Weapon (DEW) is a weapon system that inflicts damage to a target by covering that target with bundled energy such as laser, microwave, or particle beams. A DEW can be used against people, equipment, and more specifically against satellites, making it a DE-ASAT.



Artistic depiction of a Space Laser Satellite Defense System. [USAF]

Laser

Lasers have long been used against targets in space and are often part of specific weapon programs. A laser is a light source capable of producing a narrow beam of light with coherent, monochromatic and directional light. For example, low-power lasers are used for precise distance measurement, but also for dazzling sensors on satellites. It has been shown that commercially available low power lasers can have an effect on satellite sensors. America, China and Russia are known to conduct research (and tests in ABM tests) on medium to high power lasers in the context of anti-satellite weapons. Reportedly, there are many more countries researching militarily usable laser systems, but that is difficult to prove.

Low power lasers can be used to temporarily or permanently blind mission-critical satellite sensors. Attacking a satellite with a laser from Earth calls for features such as high beam quality, adaptive optics (continuously adjustable mirrors that compensate for turbulence in the atmosphere), and advanced control on laser beam alignment. These technologies are very complex and expensive, but feasible for highly industrialized countries. A laser beam is also only effective against a satellite sensor if it is possible to aim this beam within the field of view of the sensor.

In order to blind more than the sensors of a satellite and thus inflict structural damage, the weapon system must also have a high power (100+ kW) in addition to the aforementioned properties. All over

the world intensive work is being done on high power lasers for all kinds of applications. However, before military operational applications with high power lasers become commonplace, many problems remain to be solved. Current laser weapon systems are too heavy (power) to blind sensors and too light to structurally damage satellites. Chemical lasers are the only systems capable of producing megawatts of power, but the fuel to be used is highly toxic and these lasers must be powered by an external power source. Electrically powered semiconductor lasers are easy to make and easier to use, but can (not yet) provide sufficient power. The research and development of adaptive optics mainly takes place in America, Canada, China, India, Japan and Russia.

Artistic depiction of a Space Based Laser Satellite Defense System.
[digitaltrends.com]

America

Most DEW laser systems are developed for defense against (ballistic) missiles but have inherent ASAT capabilities. Examples in America are the Mid-Infrared Advanced Chemical Laser (MIRACL) for the United States Navy and the Boeing YAL-1 Airborne Laser Test Bed (ALTB) for the Air Force. The MIRACL is a Chemical Deuterium Fluoride Laser that became operational in 1980. This laser can produce a 1 MW undamped wave of light for 70 seconds. Originally intended to be placed on ships to protect against anti- ship cruise missiles, this laser was also tested against ballistic missiles and, in 1997, as ASAT against an old American satellite (MSTI-3).
The ALTB Chemical Oxygen Iodine Laser successfully destroyed ballistic missile targets in 2010. The program was discontinued in 2011 (cost $ 5 billion). Some ALTB technologies are being reused in new military systems. The High Energy Liquid Laser Area Defense System (HELLADS) developed by DARPA has successfully demonstrated use up to 150 kW against a wide variety of targets. Of course, new systems are being developed in America, but the details are kept secret and are hidden in various budget lines. For example, in 2016, Boeing Directed Energy and Strategic Systems was awarded a $ 275 million indefinite-delivery/indefinite-quantity contract for “research, engineering, and program management to advance scientific and technical knowledge of ground-based space-superiority capabilities and technology, and then apply and transition that knowledge to achieve Air Force and national goals”.

MIRACL Mid-Infrared Advanced Chemical Laser Beam Director [Wikipedia]

YAL-1 Airborne Laser Test Bed with the mirror visible in the nose [US-MDA]

Russia

Russia has a great deal of academic knowledge in the field of directed energy physics and has traditionally developed all kinds of military laser applications. This includes, for example, aircraft and ground-based laser systems for attacking mission-critical sensors and components in satellites.

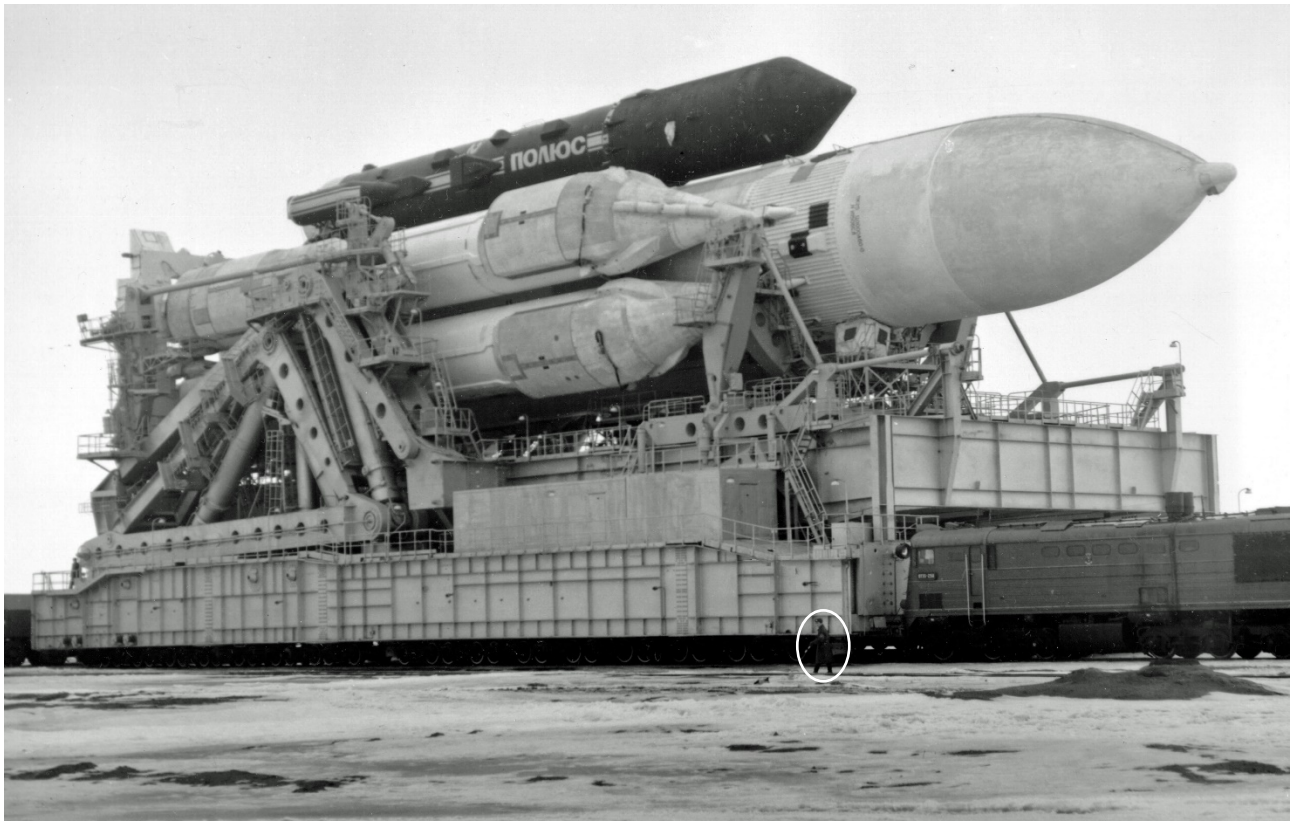
During the eighties, the Soviet Union started a development program for placing a high-power laser on a modified Il-76 transport aircraft (Beriev A-60). The laser was installed in the cargo hold with an opening on top of the aircraft. In this way, the Skif-DM laser system was tested. After the first plane was lost in a fire, a second plane continued testing. Reportedly, several successful tests (2009) have taken place before the program was discontinued in 2011 for financial reasons. However, the program already resumed in 2012. In April 2017, a representative from the Almaz-Antey design agency said they had been commissioned "to develop weapons that could interfere electronically with or achieve direct functional destruction of those elements deployed in orbit". This new system is called Sokol Echelon and will be equipped with the 1LK222 laser that differs from the Carbon Dioxide Laser from the 1980s. It would be installed on a brand new aircraft, according to news agency Tass. This could possibly be the new Tupolev PAK-DA strategic bomber. No data is available in the public domain for the 1LK222 laser system.

Beriev A-60 / Il-76 Airborne Laser Testbed [O.Ziminov RovSpotters Team]

Russia has a large number of (types of) operational laser distance measuring stations, the majority of which have the capacity to (temporarily) blind sensors on satellites. Nine laser stations are part of the global International Laser Ranging Service (ILRS). The ILRS network supports laser distance measurement for geodetic scientific work with satellites that have reflectors for this.

As early as the 1970s, the Soviet Union developed and tested a space-based high-power laser for ASAT missions. The test platform Skif-DM (Polius) was an exceptionally large and heavy spacecraft

(80 t) that could only be launched into space by the Energia space launch vehicle. This laser was lost in the last, failed launch of the Energia on May 11, 1987. It was later revealed that the Skif-DM was a 1 MW Carbon Dioxide Laser. No further similar launches took place and the program most likely ended when the Soviet Union ceased to exist in 1991. There is no evidence that Russia currently has the capability/technology, nor that it plans to develop any laser ASAT capability in space.



Skif-DM/Polius-Energia combination at the Baikonur launch center
[forum.kerbalspaceprogram.com]

China

China has been developing laser technology since the 1960s and makes no secret of its intensive efforts to develop laser weapons (program 640-3). The subsequent program 863 studied Free Electron Lasers and Chemical Oxygen Iodine Lasers that were tested around 1993. China openly tests laser weapons against aircraft and drones, for example, and markets them commercially. An example of an operational military laser on offer is the LW-30 exhibited at the Zhuhai Airshow in November 2018. Scientific researchers published in Chinese Optics magazine in 2013 that in 2005 China used a 50-100 kW ground-bound laser against a low-Earth orbit satellite (600 km) and in 2006 China was suspected of having laser-covered U.S. satellites. China is an active member of the ISLR service and has seven connected laser stations.

Chinese scientists publish a lot about air, sea and space bound lasers, but there is no evidence in the public domain that such lasers are actually being tested. Should China develop a space laser platform, it will be able to bring such a heavy platform (5-10 t) into space with their Long Mars-5 launcher.

High power microwave weapon

Microwave weapons can damage a target through transmission of microwave energy and have been the focus of the military since Starfish Prime. The weapons generate an intense wave of microwave energy strong enough to overload electrical circuits and induce large currents that disable or even melt electrical systems, temporarily or permanently. Two types of weapons are distinguished. One is the electromagnetic pulse bomb (e-bomb); the other is the so-called maser (microwave amplification by stimulated emission of radiation). Weapons range from low-power Active Denial Systems that heat the surface of the target (e.g. people's skin as a crowd control weapon) to high-power radar systems that can disable enemy electronics (e.g. from UAVs) remotely by penetrating through antennas.

Theoretically, the problem is under control, but a number of practical and technological hurdles still have to be overcome before the intended weapon can be used operationally as an ASAT. This includes sufficient transmitted power and high gain antenna technology. Bypassing the restrictions from the influence of the atmosphere (water droplets absorb microwaves) can be achieved by placing the weapon on a platform (satellite) in space.

Particle radiation

A Particle Beam Weapon (PBW) uses a high energy beam of charged or neutral atomic or subatomic particles to damage a target by disrupting the target's molecular or atomic structure. It is the least developed of the DEWs technologies and is known to receive the least funding. It is actually not a real DEW. Lasers and masers send electromagnetic energy to the target. A PBW brings kinetic energy to the target's atomic structure, so it is actually a hard- kill weapon.

Theoretically, the PBW is fully understood and experimented with on a small scale, scientifically. The practical implementation, getting enough energy on the target in a military conflict environment so that the target is disabled, is far from feasible. The U.S. Strategic Defense Initiative developed the theory/technology of the electrically neutral particle beam that should be placed on a space-based platform. A prototype of this weapon was successfully tested in 1989 on a four-minute sub-orbital flight before finally arriving at the Smithsonian Museum in Washington DC. For the time being, the PBW is not yet seen as a practical ASAT.

Artistic depiction of a Particle Beam Weapon [activistpost.com]

Conclusion. The three DEWs discussed here are the most famous. There are even more exotic weapons like the Laser-Induced Plasma Channel Weapon, Pulsed Energy Projectiles, or the Long-Range Accoustic Device Weapon, just to name a few. All these types of weapons have been reviewed, especially in America and Russia, or efforts have been made to develop and, if possible, test them. For the time being, for ASAT purposes, only laser weapons are eligible. We therefore see that a number of countries, not just America, China and Russia, are developing different types of laser weapons.

Electronic Warfare (EW) ASAT

Electronic warfare (EW) is defined as applying all possible processes to intercept, disrupt or make impossible the electronic data traffic of the enemy. In the context of EW-ASAT, we are talking, for example, about deliberately disturbing the enemy radio-frequency connections to and from a satellite. This is often referred to as 'jamming' the connections. Jamming the satellite with an interference signal is called jamming the 'uplink'; jamming of the ground station is called jamming the 'downlink'. Intercepting these up- and downlinks instead of jamming them can yield important information. EW capabilities and vulnerabilities are considered very sensitive information and therefore little is known in the public domain. Tests are generally done in special environments (Faraday cage) from which no information can escape. However, general theoretical knowledge about the possibilities of EW is available and that knowledge applies in full to data traffic between satellite and ground station v.v.

EW-ASAT is something that is not only reserved for America, China and Russia. Since a great deal of electronic data exchange takes place via satellite channels, countries that have a regional military significance are dealing with this because they know that their opponents are also doing it. Also the Netherlands. For example, 102 EOV Company of the Royal Netherlands Army is engaged in electronic warfare. The company is part of 103 ISTAR battalion, whose main task is to gather military intelligence. The company is engaged in the interception, eavesdropping, direction finding, investigation, analyzation and disturbing of radio communications and other types of radio broadcasts. However, the spoken word has long ceased to be the determining factor and the emphasis is increasingly shifting to interception of electronic signals that contain (technical) information. It is inconceivable that the Netherlands would carry out military missions without adding a component of EW.

Russian EW system [americanmilitaryforum.com]

Cyber Warfare (CW) ASAT

The boundary between EW-ASAT and CW-ASAT is vague and sometimes somewhat artificial. Also, various names that are used interchangeably sometimes create confusion: Information Warfare , Computer Network Operations, Deception Operations, Cyber Counterspace, Network Centric Warfare, Command & Control Warfare. New technologies that are being used make mention of Spectrum Warfare, which combines electronic and cyber warfare, and other technological applications to control the RF spectrum. They are low cost / high value operations that can have large asymmetric effects. Satellites for communication and data transfer play a crucial role in this. Not only the ever increasing technological progress, but also the wide proliferation thereof, is causing (commercial) electronic connections, cabled or not, to become more sensitive to intrusions (hacking) in networks. This includes the many wireless (WiFi) applications such as handheld computers, mobile phones and even remote-controlled (video) cameras, equipment and toys. All of these devices, if not properly secured, are ultimately potential entries in computer networks exploited by malicious parties for the purpose of controlling/taking over these networks. The (data) connection via satellites to link networks is of the utmost importance (most used) and is still often the weakest link. Military connections often run through specially secured satellites, but network connections of power plants and/or other utilities often have to deal with weak or unsecured commercial satellite connections and are inherently prone to intrusion.

Conclusion. EW-ASAT and CW-ASAT have been briefly discussed here because they are always part of a larger whole. You can take over the Command & Control of a satellite and thus let the satellite do what you want, or even switch it off without causing space debris. You can also listen in on the data stream and extract essential information from it. Or one can break into the data stream and thus gain access to a connected network. EW-ASAT and CW-ASAT can either replace conventional or complementary counterspace operations.

Network Centric Warfare [defensesystems.com]