Space Attack Technology Overview

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Abstract. With the development of aerospace technology, space security has become the focus of national attention, and space offensive and defensive technologies have become increasingly important. This article summarizes the attack methods of space satellites and aircraft. It focuses on analyzing three types of space attack technologies: kinetic energy attacks, directed energy attacks, and communication interference. In-depth analysis of anti-satellite missiles, common-orbit satellite interceptors, high-energy lasers, microwaves, particle beams, communication suppression, communication deception and other attack technologies, introduced the maturity and test situation of each technology, and sorted out for further development of space attack and defense technology research Several research directions.

1. Introduction
Space warfare is the use of space weapons to combat ground or space equipment. In order to seize space dominance, the United States, Russia, and other countries have set up space forces to carry out space offensive and defensive research and system construction [1-2]. On August 29, 2019, the U.S. Space Command was formally established. The functions of the newly established Space Command include protecting U.S. assets in space orbit, preventing other countries from destroying U.S. satellites, and monitoring and early warning of missile launches by other countries. On August 1, 2015, the formation of the Russian Air Force was completed, responsible for the unified management of the air, air defense and antimissile forces on duty, the launch and management of orbiting satellite cluster spacecraft, the missile strike early warning system and the space monitoring system.

According to the April 2019 report of the center for Strategic and International Studies of the United States, China has kinetic physics anti-satellites, non-kinetic physics anti-satellites, electronic anti-satellites and network anti-satellite weapons [2-3]. Iran has acquired the ability to blind US satellites with lasers. Israel, India, Egypt, Libya, Pakistan, Japan and European countries also have some anti-satellite capabilities.

The space attack system is the protagonist of future wars and the key to the battle for "space right." The existing space attack weapons mainly target satellites. Satellites occupy a vital position in the modern war system. Satellite navigation, reconnaissance imaging and information transmission has become one of the main means of strategic and tactical informatization.

2. Kinetic energy attack technology
Kinetic anti-satellite weapons kill target satellites by moving objects at high speed. Kinetic anti-satellite weapons usually use rocket propulsion or electromagnetic force to accelerate the warhead to a very high speed and destroy the target by direct collision. The high-energy explosive device carried by the warhead can also be used to explode near the target to generate dense metal fragments to destroy the target. Such
anti-satellite weapons mainly include: direct-rising anti-satellite missiles, common-orbit satellite interceptors, and autonomous active collision attackers. The key technologies of the kinetic energy attack space attack system mainly include non-cooperative target acquisition and tracking technology, autonomous guidance navigation and control technology, and warhead release technology.

Direct-lift anti-satellite missiles can be launched from ground, water (underwater), air, or space platforms. Ground-based and sea-based anti-satellite missiles are composed of kinetic energy killing interceptors, fairings and three-stage solid boosters. The kinetic energy killer interceptor is composed of a seeker, a guidance device, a communication device, a booster tank, an orbiting engine, an air-conditioning attitude control system, a propellant tank, a propellant attitude control system, a power source, and a killing device. During combat, the solid booster sends the kinetic energy killer interceptor into the space to intercept the orbit at a sufficient speed, and can be maneuvered to change orbits. By releasing the high-speed moving warhead as a whole or an explosion, the debris is directly collided and destroyed in earth orbit off the satellite achieves devastating killing of the target satellite.

The United States has developed equipment such as "standard-3" missiles with the help of its missile defense plan, and has the ability to conduct direct-rising kinetic energy attacks on low-orbit targets. U.S. Navy forecasts show that the system has a global coverage attack capability against satellites within a range of 500km altitude.

The Soviet Union began developing anti-satellite missiles in 1963. In 1985, a modified MiG 31 carrying an anti-satellite missile for testing successfully destroyed a low-Earth orbit satellite. In November 2015, Russia successfully tested the antimissile system, using “Nudol” ballistic missiles to destroy space objects. The anti-satellite missile was successfully tested again in December 2016. In December 2018, Russia successfully tested a nuclear-capable aircraft at a speed of 20 times the speed of a supersonic aircraft capable of entering space.

2.1. Common Orbit Anti-Satellite Interceptor

The common-orbit anti-satellite interceptor is to launch the anti-satellite interceptor to the same orbital height and height of the target satellite, and then gradually approach the target through orbital maneuver control, and finally intercept the target satellite, causing destructive damage to the target.

The former Soviet Union / Russian common-orbit anti-satellite was mainly launched into the orbit by the "Whirlwind" series of rockets. The combat altitude of the anti-satellite interceptors was 150 to 2000 kilometres and the combat response time was 90 minutes. On the latent orbit, once the combat command is received, it can complete the orbital maneuverer within 90 to 200 minutes, enter the target spacecraft orbit, and perform a kinetic energy fragmentation attack after reaching the target. The relative speed to approach the target is 40 to 400 m / s. The time to intercept the target satellite ranges from about 1 hour (intercept in the first orbit) to 3.8 hours (intercept in the second orbit).

The former Soviet Union began to develop ground-based common-orbit anti-satellite interceptors in 1963. It was announced in 1978 that it had reached the actual combat level and could attack satellites with an orbit altitude of less than 1,000 km. By June 1982, 20 interception tests had been conducted, with a success rate of 60%. Flight tests of target approach, identification and destruction, and tests of rapid launch, interception, and new guidance technologies are conducted which aimed at improving actual combat capabilities, with anti-satellite combat capabilities. In 1992, the Russian army acknowledged that it had two common-orbit anti-satellite weapons ready for combat.

At present, Russia has multiple common-orbit anti-satellite weapon system fixed launch pads, mainly concentrated at the Baikonur launch site and the Plesetsk space launch site, especially the Baikonur launch site. Test launch mission.

2.2. Active collision attacker

This type of space offensive system mainly refers to a space system that can autonomously meet a target, approach and meet kinetic energy collisions, such as the US "deep impact" spacecraft, to autonomously perform orbital maneuvers and destroy targets. Like other kinetic energy attack weapons, this offensive system can cause destructive damage to the target.
The United States conducted a comet "deep impact" test from January 2005 to July 2005. As shown in the figure below, the launched "deep impact" detector consists of an orbiter and an impact capsule. The impact capsule separated from the orbiter at a distance of 8.64 × 10^5 km from Comet Tempel-1, and flew toward the comet at a high speed of 3.7 × 10^4 km/h through autonomous guidance and navigation control. After flying for about 24 hours, it hit a comet nucleus with a diameter of less than 6 kilometers, and the error was better than 1 m. It was detected and analyzed after the orbiter hit.

Various technologies verified in this test, such as impact capsule release, autonomous guidance and control, can be used for the development and application of mother-child satellite attack weapons.

3. directed energy attack technology

Scientists define directed energy anti-satellite weapon as a weapon system which uses a high-energy beam to kill or destroy a target by launching a strong energy beam in a certain direction. Its outstanding feature is that it has a fast attack speed and can reach or approach the speed of light. The main research directions of anti-satellite weapons and anti-satellite weapons after kinetic energy anti-satellite weapons. Currently, there are three types of directional energy weapons under development in the world: high-energy laser beam anti-satellite weapons, high-energy particle beam anti-satellite weapons, and high-frequency microwave radio-frequency anti-satellite weapons. Both the United States and Russia have conducted a large number of successful ground-based directed energy anti-satellite tests, and are conducting research on space-based directed energy anti-satellite weapons.

3.1. High-energy laser technology

Ground-based (including land-based, sea-based, and air-based) laser anti-satellite weapons can accurately fire specific targeting points on low-orbit satellites and accumulate enough energy to disable key components on the satellite or be destroyed by thermal damage. When the laser and the optical sensor on the satellite work at the same wavelength, and the laser beam is located in the sensor site, the sensor may be temporarily blinded or completely destroyed due to saturation or thermal damage.

Simulation results show that when a 3MW ground-based laser is used to strike a satellite, it generates an energy density of about 250 W/cm² for a satellite with an orbital height of 300 km, which can almost directly melt the optical glass on the satellite; for satellites with an orbital height of 400 km, the energy density drops to 150 W/cm²; when the satellite has an orbit altitude of 1000 km, the energy density drops to about 25 W/cm², which can still destroy the performance of the optical detector.

Strong laser anti-satellite weapons can interfere with or destroy satellites in three ways: 1) jamming or blinding space-borne photoelectric sensors; 2) destroying satellite solar cells; 3) destroying satellite thermal control systems.

(1) Interfering or blinding the photoelectric sensor

Low-orbit reconnaissance and early warning satellites generally use infrared cameras and CCD cameras to detect ground infrared targets and visible light targets. The working bands of infrared cameras are usually 3-5um and 8-12um, and CCD cameras generally work in the visible light band. The use of pulsed CO_2 lasers or DF chemical lasers is an effective means to interfere with spaceborne infrared sensors; the use of pulsed Nd: YAG lasers is an effective way to interfere with spaceborne CCD cameras.

(2) Damage to the power supply system

Using lasers to destroy satellite solar panels is the most fundamental method of satellite confrontation. In space, the ambient temperature is around -170°-195°. The opening area of satellite solar panels is about 10 square meters. After the silicon photovoltaic cell sail board is irradiated with laser light, the local position rises sharply due to thermal effects. If the temperature rises to hundreds of degrees, the temperature impact speed will be exceeded and the material will be damaged.

(3) Countermeasure against satellite thermal control system

Laser destruction of satellite thermal control systems is also a possible satellite countermeasure. According to the current design of satellite thermal control, when the satellite is exposed to strong laser light, it will easily cause thermal management out-of-control phenomenon, which will cause some or all functions of the satellite to fail and lose its original combat effectiveness. Thermal control technology
is a key factor in the design of satellites. Normally, the absorption and re-radiation of solar radiation by
the satellite is balanced by reasonable control of the absorption and emissivity of surface materials.
Generally, the temperature inside the satellite must be kept within a narrow range to protect the
functional system. Thermally controlled surfaces that cause destructive temperature deviations sufficient
to alter their absorption and emissivity will cause satellite failure.

The key technologies of the high-energy laser space attack system mainly include the relatively
powerful chemical laser system technology, phase conjugate technology for optical path distortion
compensation, and uncooled optical system technology.

DARPA has implemented a series of plans for space-based laser weapons: 1) "Alpha of the Trinity",
which successfully verified the technical feasibility of orbital flight of a megawatt-class cylindrical
hydrogen fluoride chemical laser; 2) "large-scale optical demonstration experiment" (LoDE) program,
successfully verified the use of output wave detection technology coupled with adaptive optical system
to control and aim the laser beam; 3) "Large Advanced Mirror Project" (LAMP), successfully verified
the 4m diameter multifaceted suitable for use in space The feasibility of combining lightweight primary
mirrors; 4) The "Talon Gold" program, which aims to validate target capture, tracking and targeting
technology. Table.1 shows the performance parameters of US space-based laser system.

| Item                        | Parameters                      |
|-----------------------------|---------------------------------|
| Track height                | 1300km                          |
| Laser type                  | HF chemical laser or HF harmonic laser |
| Wavelength                  | 2.7μm or 1.3μm                  |
| Laser power                 | 12 MW                           |
| Overall star mass           | about 30 t                      |
| Primary mirror diameter     | 4 m                             |
| Killing distance            | 4000-5000 km                    |

At present, the power of the US Army's ground-based laser weapons can reach 10MW, and the power
of airborne lasers (ABL) can reach MW. Based on this estimate, ABL has the ability to perform laser
blinding or physical destruction attacks on low-orbit satellites; ground-based laser weapons can perform
destructive attacks on low-orbit satellites, and certain types of lasers already have practical application
capabilities. Russia has the capability to combat laser blinding or physical damage to low-orbit satellites.
It is also planned to develop a laser with a range of 40,000 kilometers to attack early warning satellites
in geosynchronous orbit.

3.2. High energy particle beam
Particle beam weapons use particle beam accelerators to accelerate electrons, protons, and ions
generated by the ion source to near the speed of light and gather them into a dense beam, and then emit
them to the target. Its main characteristics are strong penetration ability, fast speed, large energy, flexible
response, and ability to fight all weather. Potential military uses of particle beam weapons include: as
anti-satellite and anti-missile weapons and for identifying true and false targets. According to whether
the example is charged, particle beam weapons are divided into two types: charged particle beam
weapons and neutral particle beam weapons.

High-energy particle beam weapon systems mainly include: particle beam generating devices, energy
systems, early warning systems, target tracking and targeting systems, and command and control
systems. The high-energy particle beam generating device is the core part of the entire particle beam
weapon. It is used to generate high-energy particle beams and gather them into a narrow beam, which
has sufficient energy and sufficient strength.

The key technologies of high-energy particle beam weapons include: the overall technology of
particle beam weapons, ion accelerator technology, particle beam transmission technology and target
tracking and targeting technology. Among them, particle accelerators, stable transmission of particle
beams, and the destruction mechanism of particle beams are the focus of research on particle beam weapons.

Particle beam weapon is an advanced strategic defensive weapon program that is still in the principle or laboratory research stage, and its technology is extremely complicated. Although the United States and Russia have conducted 40 years of research and have achieved the technical results of artistic conception, there is still a long way to go before they can be used in actual combat, mainly as follows:

1. There is still 1 to 2 orders of magnitude in performance level. As a defensive ballistic missile or anti-satellite weapon, the energy of the particle beam must reach 250 mega electron volts, and the ground particle beam accelerator put into use in the 1990s has only 24 mega electron volts. The voltage and beam intensity of the neutral particle beam accelerator must be increased by two orders of magnitude and the pulse power must be increased by at least 3 orders of magnitude in order to buy sufficient defense missiles or anti-satellite weapons.

2. The equipment is bulky and bulky, which is difficult to use in actual combat. Calculated according to 250 mega-electron volts and an acceleration gradient of 10 mega-electron volts per meter. The length of the entire weapon system is at least 25 m. Considering energy and fuel, the total weight may be as much as 50 to 100 tons. How to make it smaller. Lighter is also a serious technical problem.

In view of the above and other technical issues, most of the particle beam weapon research programs in the United States have ceased since the 1990s. From the perspective of overall technology maturity, particle beam weapons are 15 to 20 years behind laser weapons, at least It will not be used as a combat weapon until 2025.

3.3. High-energy microwave

High-energy microwave (HPM) weapons are directed energy weapons that use directed high-energy microbeams to destroy enemy electronics and kill enemy personnel. It is characterized in that the microwave generated by a high-energy microwave source is transmitted through a high-gain directional antenna to form a high-power, energy-concentrated and directional microwave beam, making it a killing and destroying weapon.

The key technologies involved in space-based high-power microwave weapons mainly include pulse power source technology, high-power microwave source technology, high-power pulse switching technology, antenna technology, ultra-high bandwidth and ultra-short pulse technology.

The US-conceived space-based HPM system can be used to kill ground, air and space targets. It consists of a low-orbit satellite constellation that can direct ultra-wideband microwave energy to ground, air and space targets. Its role is to generate a high electric field in the range of tens to hundreds of meters of the target area, thereby destroying or damaging any electronic components.

Since the first high-power microwave source came out in 1973, after more than 30 years of development, high-power microwave weapons have been successfully used in tactical missiles. However, the microwave radiation source power required for its application to ground-based anti-satellite weapons is very high, and the technical difficulty is very large, so it is still in the early experimental stage.

In the "Air Force 2025", the U.S. military put forward the idea of "space-based high-power microwave bombs". These microwave bombs consist of tiny and lightweight satellites equipped with HPM generators to attack satellites in orbit. Because the beam of HPM weapons is relatively wide, the accuracy requirements for targeting are not as demanding as laser weapons. Micro-satellite satellites equipped with HPM can maneuver close to enemy satellties and emit short-range pulses to interfere with the normal operation of enemy satellites. In order to minimize the possibility of hitting neighboring satellites, this kind of bombs tend to be short-term operations and minimize the combat time. these HPM microsatellites can be launched into space by aircraft, space shuttle (TAV), small launch rockets, or small combat spacecraft in preparation for war operations, emergencies / wars, and deployed near a large number of enemy satellite systems. The explosion generator (ready-to-use weapon) will fire a precisely tuned calibration pulse to the target, rendering the enemy satellite system partially ineffective and capable of launching multiple attacks continuously for 60 days.
4. Communication interference technology

Communication interference refers to communication countermeasures that use radio interference equipment to emit appropriate interference electromagnetic waves to destroy and disrupt enemy radio communications. According to the nature of the interference, it can be divided into two categories: 1) Suppressive interference refers to the transmission of interference signals with the same frequency or frequency band as the enemy's communication based on the communication characteristics of the other party obtained by reconnaissance, causing the other party's call to be unclear or completely disturbed. The purpose of "submersion" is to interrupt the communication with the enemy and paralyze the command. 2) Deceptive interference, usually by transmitting an interference signal similar to the communication of the other party, making the communication party difficult to distinguish between fake and deceived. This method can sometimes cause to suppress the difficult goal of interference.

Divided into blocking interference and targeting interference according to the spectrum width: blocking interference, also known as blocking interference, is the interference to multiple or all channels in a frequency band at the same time. The interference bandwidth is equal to the working frequency range of the target signal, or it covers the target. Most of the operating frequency range of the signal. Aiming interference is divided into accurate aiming interference and semi-aiming interference, which refers to co-frequency interference formed by overlapping the frequency of the interference with the frequency of the signal. Generally, the interference whose interference coincides with the frequency of the target signal is higher than 75% is called accurate target interference. In targeting interference, according to the control and implementation, it can be further divided into forward interference, tracking interference, frequency-sweep search interference, intermittent interference, continuous interference, and single frequency interference.

According to the composition and working process of the satellite communication system, the combat object of the satellite communication countermeasure system as a means of implementing "soft killing" can have remote control telemetry command sub-system, uplink, downlink, satellite repeater and ground satellite communication equipment or network.

(1) Interference remote control telemetry command sub-system

In order to ensure the correct position and normal operation of the satellite in orbit, it is necessary to receive various remote control telemetry commands from the ground telemetry command sub-system and the monitoring management sub-system from time to time. Our satellite communication countermeasure reconnaissance equipment can interfere with the enemy's remote control telemetry system to achieve the interference effect.

(2) Interfering with uplink

Due to the characteristics of satellite communications, electronic attacks on the uplink of enemy satellite communications systems have become the focus of interference, which can affect many communication links at the same time. When interfering with the uplink, the interfering party must first intercept its communication signal, and then interfere with the satellite receiver to disrupt its entire communication process.

(3) Interfering with the downlink

Interfering with the downlink communication line is to perform reconnaissance on the signals transmitted by the satellite to the ground terminal and interfere with the ground receiving end, so as to achieve the purpose of disrupting its communication.

(4) Comprehensive confrontation

With the intensification of satellite communication countermeasures, satellite communication systems have adopted anti-interference technologies such as spread spectrum and confidential communication, so satellite communication interference must develop from a single interference technology to a comprehensive use of various interference technologies. For example, the mixed interference of the uplink and the downlink, that is, the simultaneous detection and interference of the uplink communication signal and the downlink communication signal, which will be a common interference method.
The US satellite communication jamming system has been equipped for application. Ground-based satellite "Communication Jamming System" (CCS) has been deployed in two air squadrons, which has the ability to interfere and block the communication links of high and low orbit satellites. Satellite Communication Countermeasure System (CCS) is a ground mobile system. The CCS system consists of an antenna, a transmitter and a receiver. It is assembled in a trailer and can move freely.

5. Summary
After years of development, the space offensive and defensive system has been basically established, and the technical route for space attack has been basically clarified. Ground- and space-based kinetic energy attack technology has been supported by most countries. Space kinetic energy attack technology is still in its infancy. The United States, Russia, and other countries are actively researching and developing; high-energy laser technology in directed energy attacks has undergone a large number of experiments and has preliminary operational capabilities. However, there are still many limitations. High-energy microwave and particle beam technology are currently at the laboratory level, and no engineering cases have been seen. Communication jamming technology is currently the most commonly used space offensive and defensive method. Major military forces in the world have deployed corresponding offensive and defensive systems. With the outbreak of aerospace technology, space offensive and defensive technologies will also enter a high-speed development stage, and more and more space attack methods will be applied to space loads.

Acknowledgments
This work was supported by Scientific Research and Development Fund Project of Hefei University(19ZR03ZDA), Talent Research Fund of Hefei University (18-19RC33).

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