# Research on Military Application and Countermeasures of Starlink

Abstract: The U.S. SpaceX’s Starlink is the most representative and most rapidly developing LEO (LowEarth Orbit) satellite communication system. In the Russian-Ukrainian conflict, as an important way of connecting Ukraine’s wartime communication links, the Starlink system has even had a significant impact on war trends, which further validates the powerful military application potential of Starlink. Therefore, it is necessary to deeply research the technological development and corresponding countermeasures of the LEO satellite constellations represented by Starlink. Based on the introduction of the basic situation and advantages of Starlink, this paper analyzes the potential military application prospects of the system. In view of its impact on the future warfare of the U.S., this paper proposes countermeasures from four aspects: independently developing large-scale LEO satellite communication systems, accelerating research on lower-cost anti-LEO satellite technologies, carrying out research on countermeasures in unmanned combat scenarios, and speeding up research on cyber-attack countermeasure technologies.Keywords: LEO satellite communication; Starlink; military application; countermeasure

## 0 Introduction

In recent years, due to advantages such as wide coverage, high bandwidth, and low cost, Western major powers have been vigorously promoting the construction of LEO satellite internet communication systems. They are steadily establishing LEO (Low Earth Orbit) and MEO (Medium Earth Orbit) satellite communication systems to create a global integrated space-ground communication network, aiming to seize space resources early through first-mover advantages. Typical LEO satellite constellations include OneWeb, Iridium-Next, Telesat, and the Starlink system, among which Starlink, as a representative commercial LEO communication satellite system, is developing most rapidly. U.S. agencies like the Missile Defense Agency, the Department of Defense, and various military branches highly value the military application potential of the Starlink system. They have tested related functions of Starlink satellites in exercises such as "Northern Edge" and "Global Lightning." Concurrently, to overcome drone communication bottlenecks and shorten the kill chain time, the U.S. military has utilized the Starlink system to command and test drones. To further enhance U.S. military communication and reconnaissance/surveillance capabilities, SpaceX launched the "StarShield" plan based on Starlink in December 2022. The potent combination of the two will pose immeasurable potential security threats to other countries worldwide. Simultaneously, Starlink played a pivotal role in establishing stable wartime communication links for Ukraine during the Russian-Ukrainian conflict, attracting widespread international attention.

## 1 The Starlink LEO Constellation

### 1.1 Analysis of the Starlink System

The Starlink project is a LEO satellite internet initiative proposed by SpaceX in January 2015. It aims to provide global users with comprehensive coverage, high bandwidth, and low-latency international internet services by deploying massive small satellite constellations in near-Earth orbit. SpaceX plans to launch and operate 11,927 LEO broadband constellation satellites, including 4,409 Ku and Ka-band satellites and 7,518 V-band satellites. The entire Starlink plan is divided into three phases [1]. The first two phases involve a total of 4,425 satellites operating in the Ka and Ku bands. **Phase 1:** Deploy 1,584 satellites in 32 orbital planes at an altitude of 550 km and an inclination of 53°, with 50 satellites per plane, to achieve initial coverage. **Phase 2:** Deploy 2,825 satellites across four different orbital shells: 1,600 satellites in 32 planes at 1,110 km altitude and 53.8° inclination (50 per plane); 400 satellites in 8 planes at 1,130 km altitude and 74° inclination (50 per plane); 375 satellites in 5 planes at 1,275 km altitude and 81° inclination (75 per plane); 450 satellites in 6 planes at 1,325 km altitude and 70° inclination (75 per plane), ultimately achieving global networking. **Phase 3:** Deploy 7,518 satellites in orbits near 340 km altitude, further enhancing global networking performance.

The Starlink system primarily consists of three main components: ground user terminals, ground gateway stations, and the satellite network. Ground user terminals are the service endpoints of the Starlink system, used to receive satellite signals, and their terminal platforms support various forms like vehicle-mounted, airborne, and shipborne. Ground gateway stations include gateway earth stations and telemetry, tracking, and command (TT&C) stations. Gateway stations connect the terrestrial internet to the satellites, while TT&C stations send control commands to adjust the satellites' in-orbit operational attitude [4]. The satellite network is the communication foundation of the Starlink satellites, relying on the satellites to achieve data transmission for the Starlink system. This also makes Starlink more advantageous and unique compared to other communication systems.

## 1.2 Advantages and Military Applications of the Starlink System

### 1.2.1 Technical Advantages of the Starlink System

The technical advantages of the Starlink system can be summarized into the following three points.

(1) **Low launch cost and high launch speed.** This is primarily because the Starlink system utilizes multi-satellite launch ("one rocket, multiple satellites") technology and reusable rocket and spacecraft technology.

(2) **Compared to fiber-optic communication, Starlink satellites achieve comprehensive coverage with high communication rates and low latency, offering immense commercial value.** This mainly relies on the laser inter-satellite link (LISL) technology adopted by Starlink. This technology enables global internet coverage even without local ground gateway stations. Simultaneously, laser inter-satellite links reduce signal transmission time to only about 25 ms. Through link budget analysis, the maximum downlink data rate for a 1.0 m terminal is approximately 790 Mbit/s, and the maximum uplink data rate is approximately 378.8 Mbit/s.

(3) **Advantages of multiple coverage, multiple satellites visible to users, and resilience/survivability.** The large number of Starlink satellites, their high-dynamic motion, and global reach naturally provide resilience and survivability. Leveraging the above advantages, the Starlink system has gained significant attention in fields such as maritime and civil aviation.

### 1.2.2 Military Application Value of the Starlink System

The military application value of the Starlink system is mainly reflected in the following five points.

(1) Currently, geosynchronous orbit resources are nearing saturation, and competition for LEO/MEO orbital slots and frequency resources is intensifying. Especially after the completion of Starlink launches, only about 20% of LEO resources capable of accommodating 50,000 satellites will remain [7]. The Starlink system can assist the U.S. in "staking claims," monopolizing space resources, and gaining communication channel advantages on the battlefield, enabling real-time rapid dissemination and transmission of battlefield information, thereby enhancing U.S. military communication capabilities.

(2) Starlink satellites have positioning accuracy better than 1 meter and data transmission rates exceeding 100 Mbit/s. Their signal strength is over 10 times that of GPS and they possess stronger anti-jamming capabilities [7,8]. Combining the GPS receivers on Starlink satellites with existing GPS satellite signals could make it the U.S. preferred choice for "Assured Positioning, Navigation, and Timing" (APNT) in the future.

(3)Leveraging the advantages of numerous satellites, wide coverage, short revisit cycles, and high recognition rates, various military payloads can be mounted on Starlink satellites to conduct comprehensive, all-weather reconnaissance and surveillance missions, as well as tasks like missile warning and hypersonic weapon detection. Simultaneously, combined with the technical advantages of traditional U.S. reconnaissance and surveillance methods, Starlink will further enhance its military reconnaissance capabilities [9].

(4) Upon full completion, the Starlink system could build a large-bandwidth, high-rate global command and communication network covering the globe and involving various military service platforms for the U.S. military. Improvements in anti-jamming capability and positioning accuracy will further enhance lethality, enabling long-range precision strikes. Additionally, the advantages of numerous satellites and low per-satellite cost enhance the resilience of the U.S. space system.

(5)The Starlink system can effectively adapt to long-range drone combat scenarios, solving the problem of large path loss in communication links, and is conducive to the application of joint drone warfare modes, providing global and all-domain command and control capabilities for unmanned equipment.

## 2 Countermeasures Against the Starlink LEO Constellation

Judging from the current development and capabilities of China's satellite systems, for a considerable period, relying solely on satellite vs. satellite confrontation would place China at an absolute disadvantage in countering LEO constellations. Therefore, we should objectively recognize the current disadvantage. While comprehensively promoting the construction and development of the national satellite internet system, we should simultaneously conduct research on lower-cost anti-LEO satellite technologies, countermeasures tailored to the characteristics of unmanned warfare, and cyber-attack countermeasure methods.

### 2.1 Independently Develop and Construct Large-Scale LEO Satellite Communication Systems, Accelerate the Advancement of the National Satellite Internet

The Starlink LEO constellation has already shone brilliantly due to its unique advantages demonstrated in the Russian-Ukrainian conflict, and it will have profound impacts on future warfare patterns and the security of other nations. Future wars will inevitably be all-domain conflicts dominated by information chains, integrating land, sea, air, space, cyber, and electromagnetic dimensions. Space resources are limited; whoever occupies more space resources will have a greater say in directing the course of war [10]. Therefore, to safeguard national security and social development, it is necessary to accelerate the construction of large-scale LEO satellite constellations. Simultaneously, a large-scale satellite constellation simulation platform based on container cloud computing technology can be built to achieve a simulation method for large-scale, high-fidelity, time-efficient, and stable/reliable satellite constellation networks, providing functional and performance simulation verification services for future LEO satellite communication network confrontation tasks.

Currently, high-level national attention has spurred significant progress in civil satellite communications. We should seize this opportunity, strengthen civil-military integration, utilize civil systems to compensate for the deficiencies in the Chinese military's satellite communication capabilities, and promote the construction of the national satellite internet through civil-military collaboration to enhance systemic confrontation capabilities.

2.2 **Accelerate the Development of Lower-Cost Anti-LEO Satellite Technologies**

The rapid development of massive LEO satellite constellations by major foreign powers, represented by Starlink, has brought adverse impacts on China's national defense security and social stability. Therefore, there is an urgent need to develop lower-cost, faster-response anti-satellite (ASAT) technologies to further strengthen China's space power.

(1) Using missiles to conduct electromagnetic interference against satellite signals and kinetic strikes are currently the primary ASAT means. Co-orbital ASAT systems and directed-energy weapons (DEW) are two ASAT methods actively researched by various countries. According to information and feedback from military experts, Russia has long been committed to developing directed-energy ASAT weapons and may have completed prototype designs for particle beam weapons.

(2) Laser weapons, as ideal weapons for space warfare, are also a type of directed-energy weapon. High-energy laser weapons with deep magazines and fast response speeds can degrade or destroy certain functions of Starlink satellites, damaging a significant number of satellites within a certain timeframe. Several land-based laser weapon systems "capable of paralyzing satellite sensors" have been developed, and one such laser weapon was delivered to the Russian Air Force in 2018 [13].

(3) Rapid-response anti-communication ground terminal systems, as an adaptive jamming system against Starlink, can utilize advanced feature learning algorithms and new threat learning algorithms to classify intercepted signals. They can quickly generate characteristic information of jamming signals, using this as a basis for optimizing jamming waveforms and battlefield assessment, to effectively jam satellites.

2.3 **Research Countermeasures Against "Starlink"-Enabled Unmanned Warfare**

Long-range communication links for drones can lead to reduced signal-to-noise ratio (SNR) at the receiving end, increased system bit error rate (BER), and higher data packet loss probability.

Leveraging the advantages of Starlink satellites can improve system power, frequency efficiency, and system capacity while reducing attenuation and delay, ensuring the drone's operational radius as much as possible. Simultaneously, Starlink enables existing drone communication links to achieve multi-drone coordination, real-time battlefield situational awareness transmission, and intelligent decision-making. With its advantages of low cost, high density, and high resilience, it minimizes the probability of the satellite communication network being paralyzed by the enemy and maximizes battlefield survivability. Regarding unmanned warfare enabled by Starlink, measures should be taken from both enemy and friendly perspectives.

(1) **Against the Enemy:** First, through radar and electro-optical countermeasures, implement radar and electro-optical jamming against Starlink perception sensors, degrading or destroying their detection and perception capabilities to a certain extent and within a certain range, causing hallucinations or blinding. Second, to effectively interrupt relay communications, deploy jamming satellites on the directly connected Starlink satellite links. Third, jam the satellite-to-ground links to disrupt combat communication capabilities and interconnectivity, damaging inter-satellite collaborative detection and intelligent capabilities, as well as system reliability, effectiveness, and trustworthiness. Fourth, employ cyber-electronic warfare (CEW) to conduct attacks such as false situational awareness, false data, false battlefields, and false targets against Starlink, consuming its computing power and memory, delaying or misleading its cognitive capabilities.

(2) **For Ourselves:** Build a flexible and compatible standardized drone airborne system and ground command and control system. This enables single or multiple drones within a swarm or coordinated drone formation to execute different flight tasks, achieving more efficient command execution within the swarm or formation [16]. This enhances drone perception capabilities and combat effectiveness, further strengthening the operational flexibility and survivability of unmanned combat systems.

### 2.4 Identify Technical Weaknesses, Accelerate Research on Cyber-Attack Countermeasures

Cyber-attack methods, due to their advantages of low cost, strong concealment, and high deterrent effect, may become an important way to counter Starlink. From the three aspects of Starlink terminals, ground stations, and the supply chain, four feasible cyber-attack schemes are proposed.

(1) **Targeting Terminal Equipment:** Infiltrate terminal equipment, crack signature authentication to impersonate legitimate users, and send large amounts of false routing information or invalid information to satellites to consume satellite transmission bandwidth. This increases system overhead and delay, disrupts useful information transmission, achieving the effect of a Distributed Denial of Service (DDoS) attack.

(2) **Targeting Terminal Equipment:** Also, exploit the exposed nodes and open channels of Starlink to generate high-power false satellite signals, radiated to the terminal via a transmitting antenna to mask the real useful satellite signals. This jams the terminal, preventing it from normally receiving useful signals, leading to network disconnection or failure.

(3) **Targeting Ground Stations:** Infiltrate ground stations, implant trojan viruses during near-field

operations inside the station, or scan vulnerabilities in their internet access ports and then deliver cyber-attack data. Through these two methods, tamper with useful data and disrupt satellite operational control commands, thermally destroy critical components, or cause satellites to deviate from their predetermined orbits and collide.

(4) **Targeting the Supply Chain:** To improve Starlink production efficiency and reduce R&D costs, SpaceX is responsible for the independent R&D and production of core components such as antennas, Hall thrusters, and laser communication equipment. Other ground-based non-core components are provided by various suppliers and then assembled. If cybersecurity oversight by these enterprises during this process is inadequate, backdoors or vulnerabilities may be implanted, serving as entry points for subsequent cyber attacks.

3 **Conclusion**

The Starlink system has advantages such as low launch cost, low latency, wide coverage, and strong resilience/survivability. Its military application potential is immense, and it played an extremely critical role in the Russian-Ukrainian military conflict. It is bound to have a profound impact on the future U.S. Joint All-Domain Operations and combat systems, giving the U.S. future battlefield overwhelming advantages characterized by spatial three-dimensionality and high dimensionality. Currently, China should seize the opportunity. While paying attention to the technological development of Starlink, it must rapidly research countermeasures, comprehensively promote the construction of the national satellite internet, accelerate the development of lower-cost anti-LEO satellite technologies, conduct research on countermeasures against unmanned warfare enabled by Starlink, and simultaneously identify Starlink's technical weaknesses to accelerate research on cyber-attack countermeasure methods. This is of profound significance for building a "transparent" battlefield, winning future wars, and ensuring national security and social stability.