Space systems and their role in modern warfare: the invisible weapon that decides conflicts

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In contemporary warfare scenarios, **Space** has become an essential operational domain, on par with land, sea, air, and cyber. The ability to exploit **data, products, and services (DPS)** from space platforms allows armed forces—both national and allied like NATO—to operate with greater precision, speed, and efficiency, reducing risks to personnel and equipment.

The impact is particularly evident in unmanned aerial systems (**UAS, Unmanned Aircraft Systems**), which critically depend on space services for navigation, communications, reconnaissance, and operational support. Understanding the **segments, capabilities, and vulnerabilities of space systems** is therefore fundamental not only for military planning but also for collective security in a world characterized by increasingly intense technological and geopolitical competition.

From deep space to modern warfare

During the **Cold War**, the United States and the Soviet Union were the driving forces of the space race, gaining enormous technological and military advantages. Today, the “space club” has expanded: **China, India, Europe, Japan**, and other nations possess advanced capabilities, while Russia and the USA continue to invest to maintain supremacy.

Space is no longer just a scientific or economic theater but a **strategic operational domain**. Surveillance satellites, communication systems, and navigation constellations play a central role in ensuring informational superiority and the ability to conduct integrated military operations on a global scale.

The four segments of a space system

A space system is not limited to the satellite orbiting above our heads: it is composed of four interconnected segments, each of which is essential to the functioning of the whole.

1. **Space Segment**: the satellite in orbit, equipped with sensors or mission equipment.
2. **Ground Segment**: the command and control stations that manage the satellite and its payload.
3. **User Segment**: the end users who receive and process the data (armed forces, civilian operators, etc.).
4. **Link Segment**: the radio links (uplink and downlink) that transmit data and commands.

The malfunction—or sabotage—of just one of these segments can compromise the entire system, making space both a strategic resource and a prime target.

The advantages and limitations of space services

The use of satellites entails a series of **operational advantages**: global coverage with reduced forces, information gathering without violating national borders, near real-time transmissions, and the ability to support expeditionary operations with light units.

However, there are also **limitations**: image resolution, revisit times, the influence of weather conditions, and transmission delays. Therefore, each mission requires careful planning based on the orbital characteristics of the satellites involved.

Typical orbits

- **LEO (Low Earth Orbit, 200–2,000 km)**: used for Earth observation, intelligence, scientific purposes, and the International Space Station.
- **MEO (Medium Earth Orbit, 2,000–36,000 km)**: hosts GNSS constellations like GPS and Galileo.
- **GEO (Geostationary Earth Orbit, 36,000 km)**: ideal geostationary orbit for communications and early warning.
- **HEO (Highly Elliptical Orbit, 200–40,000 km)**: provides prolonged coverage over high latitudes, useful for military communications.

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The six functional areas of military space capabilities

According to NATO classification, space activities can be divided into six major areas.

Positioning, Navigation, and Timing (PNT). Systems like GPS, Galileo, Glonass, and Beidou enable precise positioning, communication synchronization, and the use of precision-guided weapons. However, their weak signal makes them vulnerable to **jamming** and **spoofing**.

Intelligence, Surveillance, and Reconnaissance (ISR). Optical, infrared, or synthetic aperture radar satellites provide essential images and data for military planning, although with limitations related to resolution, weather conditions, and revisit times.

Meteorology and Oceanography (METOC). Satellite weather forecasts are crucial for military operations, particularly for UAS, which are sensitive to weather conditions. Solar activity can also affect communications and sensors.

Space Situational Awareness (SSA). Monitoring of space activities, collision prevention, debris tracking, and forecasting overflights of adversary satellites: essential tools for situational awareness.

Satellite Communications (SATCOM). Fundamental for command and control, especially for operations beyond the line of sight. They enable global transmissions but are subject to capacity limits and vulnerability to interference.

Shared Early Warning. Missile warning services based on satellite data, essential for the defense of allies and civilian populations.

UAS and Dependence on Space Services

Unmanned Aerial Vehicles today encompass a vast range, from commercial drones to complex long-range military systems. All, to varying degrees, depend on space services.

Satellite communications (SATCOM) are vital for beyond line of sight (BLOS) control. **PNT services** are indispensable for navigation, synchronization, and the use of guided munitions.

The increasing complexity of sensors on board UAS leads to an exponential demand for bandwidth, which satellites must meet with new constellations in lower orbits (LEO and MEO), the so-called **mega-constellations**. These systems promise greater transmission capacity, lower latency, and global coverage, but also open new scenarios of strategic competition.

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UAS connected via satellite communications - Copyright US JAPCC

Threats: From Jamming to Spoofing

The disruption of satellite links represents one of the most serious vulnerabilities for military operations. Two techniques are now well known and widely used:

- **Jamming**: involves sending a disruptive radio signal on the same frequency as the authentic signal, preventing the receiver from distinguishing the correct one.

- **Spoofing**: is a more sophisticated form, which involves generating a false signal that appears authentic, causing the target system to receive incorrect data.

Both techniques have already proven effective against commercial drones and pose a concrete threat to military systems as well.

Uplink and Downlink Jamming

In addition to generic interference, it is crucial to distinguish two particularly relevant operational variants.

Uplink Jamming. In this case, the disruption affects the communication path from the ground station to the satellite. The jammer must be within the satellite antenna's line of sight and transmit a very powerful disruptive signal. If effective, the satellite can no longer distinguish the legitimate command, and the entire operational flow is compromised. This type of attack is particularly dangerous because it affects the satellite's control capability, rendering it temporarily unusable.

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Uplink Jamming - Copyright US JAPCC

Downlink Jamming. Here the target is the signal descending from the satellite to the ground receiver or directly to a UAS. The jammer must be near the receiving antenna and transmit a disruptive signal that obscures the authentic one. This approach is simpler and less expensive because it requires less power than uplink jamming. However, it can have devastating effects, especially against UAS that rely on continuous links to receive critical data.

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Downlink Jamming - Copyright US JAPCC

These two forms of jamming clearly show how space systems are **vulnerable on both communication paths**: both the ascending and descending ones. For this reason, armed forces must anticipate redundancies, alternative lines, and systems protected against intentional interference.

The Influences of Space Weather

Not only human action but also natural phenomena can compromise satellite communications. Solar storms and geomagnetic activity can cause disturbances in GNSS and SATCOM signals, damaging electronic systems on board UAS and ground stations.

A sudden blackout due to a solar storm can have the same effect as a jamming attack, but without the possibility of attribution or preventive defense. This adds an additional level of complexity to the management of space-dependent military operations.

Conclusion

Space is now an essential **force multiplier** for military operations. No modern mission can be planned or conducted without the support of satellites for navigation, communication, surveillance, and early warning. However, this dependence also brings new vulnerabilities.

UAS, in particular, are closely tied to the availability of satellite services. Targeted attacks – from **jamming** to **spoofing**, and more specific forms like **uplink** and **downlink jamming** – can compromise critical missions, reduce operational effectiveness, and even cause the loss of assets.

The challenge for modern armed forces will therefore be twofold: on one hand, to fully exploit the opportunities offered by new satellite constellations and the integration of increasingly advanced space systems; on the other hand, to protect these same systems from interference, attacks, and natural phenomena that could turn the technological advantage into an Achilles' heel.

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