

Advantages of Using Satellite-Based Global Positioning System (GPS) Receivers in The Russia–Ukraine Armed Conflict

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Received: 24 July 2026; **Accepted:** 20 August 2026; **Published:** 15 September 2026

Abstract: This article analyzes the main advantages of using Global Positioning System (GPS/GNSS) receivers in modern armed conflicts, with particular focus on the Russia-Ukraine military confrontation. The role of GPS technology in precision-guided weapon systems (HIMARS, M982 Excalibur, JDAM), reconnaissance unmanned aerial vehicles (UAVs), and force coordination and command processes is examined. The article also provides a general overview of GPS signal vulnerabilities and contemporary approaches to mitigating them. The research is based on open-source international military-technical analyses and academic literature.

Keywords: GPS, GNSS, satellite navigation, precision-guided munitions, unmanned aerial vehicle, circular error probable (CEP), electronic warfare, Russia-Ukraine conflict, military technology.

Introduction: Global Navigation Satellite Systems (GNSS), including the Global Positioning System (GPS) developed by the United States, have become an integral technological component not only of civilian applications but also of the military domain over recent decades. Analyses of contemporary armed conflicts demonstrate that the capability to determine geographical positions accurately in real time has fundamentally transformed the nature and methods of modern warfare. The armed conflict between Russia and Ukraine, in turn, has become a large-scale operational setting that demonstrates in practice the significance of GPS technology in contemporary combat operations.

In this conflict, GPS signals underpin nearly all aspects of modern combat operations, ranging from the control of intelligence, surveillance, and reconnaissance (ISR) drones and the guidance of precision-guided munitions to the synchronization of mobile communication systems and the coordination of military forces. The purpose of this article is to systematically analyze and scientifically synthesize the key advantages of using GPS receivers in contemporary

armed conflicts, with particular reference to the Russia–Ukraine conflict.

1. Development and General Characteristics of GPS/GNSS Systems in the Military Domain. The GPS was originally developed by the U.S. Department of Defense for military purposes and enables the geographical coordinates of any location on the Earth's surface to be determined with a high degree of accuracy using satellite signals. Modern military GPS systems provide armed forces with unprecedented capabilities in terms of positioning accuracy, operational coordination, and intelligence support. Although initially intended primarily for aircraft navigation and the guidance of precision-guided weapons, GNSS technology is now also employed for drone navigation and control, coordination of geographically dispersed military units, synchronization of communication networks, and enhancement of the accuracy of long-range strikes.

This, in turn, demonstrates the substantial qualitative expansion of the role of satellite navigation in contemporary armed conflicts compared with the 1991 Gulf War, when it was still regarded as a relatively new

technology. Whereas the United States and its allies effectively held a monopoly on satellite-enabled precision capabilities at that time, several countries today operate their own GNSS constellations, including Russia's GLONASS and China's BeiDou. As a result, precision-guided weapon technologies have become increasingly accessible to a broader range of states.

The historical development of GPS technology for military applications began in the early 1970s under the U.S. Department of Defense, with the system initially intended primarily to support strategic nuclear forces and long-range aviation. Over time, declining costs and the miniaturization of GPS technology made it possible to integrate satellite navigation capabilities into virtually all types of military platforms, ranging from equipment carried by individual soldiers to naval vessels.

From a technical perspective, the GPS is based on a constellation designed around at least 24 operational satellites distributed across six orbital planes, providing sufficient satellite visibility for positioning at virtually any location on Earth. By receiving signals from at least four satellites, a GPS receiver can calculate its three-dimensional position—latitude, longitude, and altitude—as well as determine precise time.

Receivers designed for military applications generally employ more secure and encrypted signals than standard civilian receivers, including the P(Y)-code and M-code used by the U.S. military. These protected signals provide authorized military users with enhanced security and greater resilience against unauthorized signal manipulation, including spoofing attacks.

2. Employment of GPS-Guided Precision Weapon Systems in the Russia–Ukraine Conflict. One of the most prominent advantages of GPS technology demonstrated in the Russia–Ukraine conflict is the high effectiveness of precision-guided weapon systems. A notable example is the High Mobility Artillery Rocket System (HIMARS) employed by the Ukrainian Armed Forces. The M31A1 Guided Multiple Launch Rocket System (GMLRS) munition uses an inertial navigation system aided by GPS guidance, enabling it to achieve a Circular Error Probable (CEP) of approximately 8–10 meters at ranges of up to 84 kilometers. This level of precision has made HIMARS one of the most effective deep-strike capabilities provided to Ukrainian forces, enabling high-value targets such as ammunition depots, command posts, and logistics hubs to be engaged with a very limited number of precision-guided munitions.

Similarly, the 155 mm M982 Excalibur precision-guided artillery projectile employs an integrated GPS/INS

guidance system and can achieve a Circular Error Probable (CEP) of less than 10 meters, compared with approximately 270 meters for conventional unguided artillery projectiles at maximum range. Conventional artillery projectiles equipped with the Precision Guidance Kit (PGK) can likewise use GPS-based guidance to correct their ballistic trajectory and achieve a CEP of less than 50 meters. Such levels of accuracy can substantially reduce ammunition expenditure, limit collateral damage to civilian infrastructure, and enhance overall operational effectiveness.

More broadly, the historical development of GPS/INS-guided weapon systems demonstrates that, during Operations Enduring Freedom and Iraqi Freedom in 2001–2003, more than half of the bombs employed were already precision-guided munitions. This indicates that GPS-enabled precision technology had become widely established in military practice well before the Russia–Ukraine conflict. Modern Joint Direct Attack Munition (JDAM) systems can achieve a Circular Error Probable (CEP) of approximately 5 meters when GPS guidance is available, compared with roughly 30 meters when operating solely on inertial navigation in a GPS-denied environment. This difference clearly illustrates the substantial contribution of GPS signals to the accuracy of precision-guided munitions.

3. Significance of GPS Technology for Unmanned Aerial Vehicles (UAVs) and Intelligence, Surveillance, and Reconnaissance Systems. The Russia–Ukraine conflict has significantly increased the role of unmanned aerial vehicles (UAVs) in contemporary combat operations, with many of these systems relying directly on GPS signals for navigation. Intelligence, surveillance, and reconnaissance (ISR) drones transmit real-time video feeds and other intelligence data, enabling military units to identify and locate targets more accurately and coordinate their operations more effectively. In particular, when commercial satellite communication systems such as Starlink are employed, video feeds obtained from reconnaissance drones can be transmitted directly to artillery units, enabling them to observe the effects of fire in real time and make necessary adjustments based on battlefield conditions.

GPS-based precision positioning also enhances the ability of strike UAVs to engage tanks, defensive positions, and other strategically significant targets with a high degree of accuracy. This capability facilitates the effective application of asymmetric warfare principles, whereby smaller and comparatively inexpensive unmanned systems can be employed to counter the capabilities of a more powerful adversary. Such an approach not only enhances combat effectiveness but also substantially reduces the risk of exposing military personnel directly to hostile fire and

other battlefield threats.

It should also be emphasized that the navigational accuracy of UAVs plays an important role in artillery and mortar fire adjustment. GPS coordinates obtained by reconnaissance UAVs can be transmitted directly to artillery fire-control systems, allowing firing parameters to be calculated automatically. Compared with conventional methods based on manual calculations, this approach can significantly shorten the time required to engage a target.

4. Advantages in Troop Coordination, Situational Awareness, and Logistics. The military advantages of GPS technology are not limited to precision-guided weapons. Modern GNSS systems enable the effective coordination of geographically dispersed military units, naval vessels, and aircraft across extensive operational areas and in complex terrain. Real-time knowledge of the precise location of each military unit or combat platform enables commanders to accelerate decision-making processes, reduce the risk of engagements between friendly forces (“friendly fire” incidents), and maintain integrated command and control over military operations.

Furthermore, GPS-based time synchronization is essential for the stable operation of modern digital communication networks. GNSS signals provide not only positioning information but also highly precise timing data, enabling various communication, command, and control systems to operate in a synchronized manner. From a logistical perspective, GPS plays an important role in optimizing transportation and supply routes, tracking the real-time location of transport assets, and monitoring the continuity of supply chains, thereby enhancing the overall efficiency of combat logistics.

From the perspective of situational awareness, the integration of GPS data with Geographic Information Systems (GIS) makes it possible to create a continuously updated digital representation of the battlefield for commanders in real time. Such digital battlefield maps allow the locations of friendly forces and identified adversary forces to be visualized within a unified operational picture, significantly improving the speed and quality of tactical decision-making. This capability, in turn, constitutes one of the practical foundations of the modern “digital battlefield” concept.

5. Vulnerabilities of GPS Technology and General Approaches to Mitigating Them. To provide an objective assessment of the aforementioned advantages of GPS technology, its vulnerabilities must also be taken into consideration. Because satellite signals received at the Earth’s surface are relatively

weak, they can be disrupted through intentional interference (jamming) or manipulated through the transmission of counterfeit signals (spoofing). The extensive use of electronic warfare capabilities during the Russia–Ukraine conflict has demonstrated that systems dependent on GPS signals may experience reduced effectiveness under certain operational conditions.

At the same time, modern military systems employ a range of technical solutions to mitigate these vulnerabilities. These include inertial navigation systems (INS), which allow navigation to continue when GPS signals become unavailable; encrypted navigation signals; multi-frequency receivers; and the capability to use alternative GNSS constellations, including GLONASS, Galileo, and BeiDou. Such hybrid navigation approaches enhance the overall resilience and reliability of positioning systems and help maintain continuity of positioning and navigation in degraded or contested GNSS environments.

The overall development trajectory of precision-guided weapons indicates that modern systems are increasingly adopting multi-sensor guidance architectures that integrate GPS/INS with infrared and laser-based technologies. Such an approach makes it possible to maintain a relatively high degree of accuracy even when GPS signals are temporarily unavailable or disrupted. In conclusion, the vulnerabilities of GPS do not diminish its strategic significance; rather, they underscore the need for the next stage of technological development—the creation of resilient, multi-source navigation systems capable of operating effectively in contested signal environments.

6. Impact of Precision-Guided Navigation on Operational and Strategic Effectiveness. Whereas conventional unguided artillery systems may require dozens or even hundreds of projectiles to achieve the desired effect on a target, GPS-enabled precision-guided systems can potentially achieve the intended result with a single munition or a limited number of munitions. This, in turn, substantially reduces the logistical burden associated with combat sustainment, as fewer munitions need to be transported to the front, stored, and handled.

Furthermore, real-time operational analysis indicates that the employment of precision-guided weapons can shorten the interval between target detection, engagement, and assessment of the resulting effects—the so-called “sensor-to-shooter” cycle. Real-time positional information enabled by GPS allows military commanders to adapt more rapidly to changing battlefield conditions and respond more effectively to adversary maneuvers. Consequently, GPS technology

serves not only as a tactical enabler but also as an important force multiplier that can enhance the overall combat effectiveness of armed forces at the operational and strategic levels.

7. International Experience: A Comparative Analysis from the 1991 Gulf War to the Present. To objectively assess the military significance of GPS technology, it is appropriate to examine its development from a historical perspective. During the 1991 Gulf War, coalition forces employed GPS technology to enhance navigation and support the precise engagement of high-value targets while seeking to minimize collateral damage. At that time, however, GPS was still a relatively new technology and was employed on a comparatively limited scale. In the contemporary Russia–Ukraine conflict, by contrast, GPS technology is no longer an isolated or selectively employed capability; rather, it has become an integral component of a wide range of modern military systems—from UAVs and artillery systems to communication networks and transportation and logistics management.

This comparative analysis clearly demonstrates that the role of GPS technology in modern warfare has undergone a fundamental transformation in both scope and function. It has evolved from a specialized military-technical capability into a system-enabling infrastructure element underpinning the operation of contemporary armed forces. This transformation, in turn, highlights the growing importance of further research into the broader integration of GPS technology and the enhancement of its resilience and reliability in contested operational environments.

CONCLUSION

The findings of the analysis indicate that satellite-based positioning and navigation technology (GPS/GNSS) has become a system-enabling element of modern combat operations in the Russia–Ukraine armed conflict. Its principal advantages are manifested in several key areas. First, the high accuracy of precision-guided weapon systems, including HIMARS, Excalibur, and JDAM, with CEP values of approximately 10 meters or less under appropriate conditions, enables reduced ammunition expenditure and helps limit collateral damage compared with conventional unguided weapons. Second, the effective navigation of intelligence, surveillance, reconnaissance, and strike UAVs expands the operational possibilities of asymmetric warfare. Third, GPS significantly enhances operational effectiveness through improved force coordination, precise time synchronization, and more efficient logistics.

At the same time, the susceptibility of GPS signals to disruption or manipulation through electronic warfare

measures must be recognized as an important vulnerability. Future research should therefore focus on the development of resilient, multi-source navigation systems capable of maintaining reliable positioning under degraded or contested signal conditions, as well as on an objective assessment of the broader military and strategic significance of GPS technology.

The overall analysis demonstrates that GPS/GNSS technology is not merely an isolated or secondary capability in contemporary armed conflicts; rather, it constitutes a fundamental infrastructure element that connects multiple levels of military operations, ranging from individual weapon platforms to strategic command and control. Consequently, a comprehensive examination of the advantages and limitations of GPS technology is of considerable scientific relevance not only to military and technical studies but also to the fields of security policy and strategic studies. Future research in this area should also examine the integration of GPS technology with artificial intelligence-based autonomous systems and the development of alternative positioning, navigation, and timing solutions capable of operating effectively in GPS-denied environments.

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