Preparing for artillery operations in a GPS denied environment

By Capt. Neal MacDonald

Abstract
The Fires community is immensely dependent on the ability to determine accurate location and direction. From the laying of a howitzer, the emplacement of a counterbattery radar system, an occupation of a Patriot launcher, or to the fixing of a target grid, knowing where ‘here’ is becomes a vital portion of any activity. There is good reason why the first two of the Five Requirements for Accurate Fire are concerned with correctly determining position, be it friendly or enemy. Without this basis of precise location, being able to deliver indirect Fires becomes an exercise in futility. Notably, almost every piece of equipment in the artillery arsenal now relies on Global Positioning System (GPS) as the means for acquiring location, greatly improving functionality under ideal conditions but also increasing vulnerability in a contested operating environment. It therefore should be of concern to all artillerymen that potential adversaries are developing sophisticated technologies to deny, degrade, and disrupt our modern positioning, navigation and timing (PNT) capabilities. This necessitates a critical evaluation of how we train,
one of the increasingly portable GPS receivers at their disposal.

One such device is the Defense Advanced GPS Receiver (DAGR), which is distributed widely across U.S. and allied forces. It is a dual-frequency receiver, meaning that it can acquire both the L1 and L2 frequencies that the GPS constellation emits, supported by a Selective Availability Anti-Spoofing Module (SAASM) that allows the DAGR to be filled with cryptographic keys. When correctly encrypted and employed, the DAGR can provide a 95 percent horizontal Circular Error Probable of less than 6.7 meters. This high degree of accuracy drives the extensive use of the DAGR in the Fires community, not just as a manually controlled handheld device: it digitally provides location services to the M777A2 and M109A6 howitzers, the Improved Position and Azimuth Determining System-Global Positioning System, Patriot missile launcher system, and a variety of Fire Support devices. Additionally, other Fires systems utilize integrated GPS chipsets, such as the M119A3 howitzer with a Ground Based GPS Receiver Applications Module (Gb-GRAM) embedded in its hardware.

**Emerging threat**

Unfortunately, as we become increasingly dependent on these technological solutions to provide accurate location, the opportunity for this to be exploited against us also increases. Specifically, the reliance of United States Armed Forces upon GPS has become a major risk now that potential adversaries have identified it as a critical dependency, one that is vulnerable to attack. The threat to GPS-reliant systems is diverse: denial and deception of receivers, cyberattacks on the GPS infrastructure, and a variety of other means exist that are unambiguously designed to interrupt our ability to use and trust GPS data. The artillerymen and women of the past, however, still determined location and directional control without the crutch of modern technology, which should serve as inspiration to the current generation of Fires leaders who will be asked to adapt and overcome the challenges of the modern battlefield.

While specifics regarding the threat posed by potential adversaries quickly enter classified territory, there are several open-source examples of real-world use of GPS denial actions that can serve as vignettes. One event that is commonly used to demonstrate the impact of GPS jamming is an incident that occurred near Newark Airport several years ago. A commercial truck driver, seeking to avoid his boss monitoring his activities via his truck’s GPS tracking system, purchased and employed a small GPS jammer. Over the course of two years, his usage of the jammer resulted in Newark airport experiencing harmful interference to their ground and air-based GPS systems, and when the FCC finally tracked him down he was arrested, fined $31,875, and fired by his employer. A more startling employment of GPS interference occurred in the Black Sea in 2017, when multiple ships reported their GPS receivers erroneously showed their position as being on dry land and up to 200 km away from their actual locations afloat on the water. The reports were assessed by PNT experts to be clear indications of “spoofing” activities, whereby GPS signals are deliberately manipulated to result in an inaccurate location being reported to the user. In this instance, no lasting damage was done, but this could have easily resulted in ships running aground at night or in foul weather, and highlights the real-world presence of GPS spoofing.

**Planning to win**

Because of this growing threat, U.S. Armed Forces must prepare to continue operations in the event that GPS becomes unavailable. Relevant to direct support artillery units located in the BCTs, much of this planning will occur at the battalion level. As part of the military decision-making process, forces to operate in a GPS-denied environment.

**Overview of PNT usage**

The primary mechanism for acquiring PNT is the GPS, a satellite-based radio navigation system owned by the U.S. government. The first GPS satellites went into orbit in the 1980s, with the fully-operational 24 satellite constellation being achieved in 1993. With the advent of GPS, worldwide geolocation became a simple and accessible process, requiring nothing more than line of sight to at least four of the satellites. For the U.S. Army and other services this provided a massive technological advantage, as anywhere a unit went they were able to determine their location using

process (MDMP), planners should include decision points and commander's critical information requirements that address GPS denial. If forward-located units such as forward observers and unmanned aerial vehicles (UAVs) encounter and are able to report GPS interference, this could drive commanders' decisions to occupy different position areas for artillery (PAAs), modify survivability move criteria, or change fire orders to counteract the GPS jamming threat. This requires that staff planners be aware of both the potential enemy threat capabilities on the battlefield, as well as their friendly forces' vulnerabilities. Just a few examples of Wargaming Function impacts that occur in a GPS-denied environment are:

- **Mission Command.** Networks that rely on GPS-based timing for synchronization start to degrade, progressively falling more out of tolerance as the length of GPS denial continues.
- **Movement and Maneuver.** Use of Friendly Force Tracking devices are degraded, with unit icons becoming stale and systems inaccurately representing the current location of forces.
- **Fires.** Loss of Precision Guided Munition capabilities; Artillery pieces must be positioned and laid utilizing degraded and manual techniques.
- **Intelligence.** Collection assets such as UAVs are unable to navigate or locate targets.
- **Protection.** Increased casualties and fratricide due to lowered spatial awareness, decreased operational tempo, and inability to maintain common operating picture.
- **Sustainment.** Logistics convoys and Joint Precision Airdrop Systems are unable to reach intended destinations.

**Fighting through interference**

GPS-enabled methods will continue to be the primary means of occupation and other artillery operations for the foreseeable future. The speed, accuracy and all-weather availability of GPS provides a significant advantage over degraded methods. As previous articles in this journal have pointed out, the time required to emplace and fire U.S. Army howitzers is already a source of concern in a near-peer fight; incurring additional time on the firing point deriving location manually only exacerbates this issue. Therefore, while units must absolutely be prepared to execute these manual location-determining techniques, there are several techniques that may enable continued usage of GPS devices in a contested environment.

First and foremost, every military GPS receiver can and should be encrypted with crypto variable (CV) keys. The SAASM chip embedded in military receivers provides the ability for these devices, when filled properly with CV keys, to access the encrypted P(Y) code that is broadcast over the L1 and L2 bands from the GPS constellation. This not only makes the devices more accurate, but it significantly increases their ability to function in the presence of electromagnetic interference (EMI). Contrary to popular belief, the process of encrypting a SAASM-enabled GPS device does not change the classification level of the equipment. Unlike a filled radio, an encrypted DAGR remains unclassified. For these reasons and others, the DoD specifically instructs combat and combat support operations to utilize SAASM-enabled military receivers only, and will not field PNT systems that cannot be encrypted.

Second, thanks to the laws of physics, GPS jamming has many limitations which can be exploited. Like all jamming activities, it requires three elements: frequency, access and power. For GPS, the frequencies used are specific, unchangeable and publicly known: 1575.42 MHz for L1 and 1227.6 MHz for L2. There is not much that can be done to defend against this element of jamming other than avoiding unintentional interference from friendly systems, such as radars which operate in the same frequency region. Next, the power of a GPS jammer determines its range of effect; the more power, the farther its reach. This plays into the final element, in that a jammer must be located in a line-of-sight to the receiver, closed enough for its power to reach it. While the finer points of wave propagation are beyond the scope of this article, the basic way to defeat GPS jamming is therefore simple: if you can place enough mass between jammer and receiver, the signal cannot reach or access, and therefore affect, the device. Terrain features, armored vehicles, or even the human body can provide this masking between jammer and receiver, and so long as the receiver is able to still see four GPS satellites it has the potential to continue to function properly. One of the easiest ways to achieve this is by digging a small hole six to 12 inches in depth and width and placing the receiver inside. This hole provides lateral protection from terrestrial-based jammers while still allowing a clear view of the sky and the GPS constellation.

The most critical element of preparing to deal with GPS interference is exactly that: preparation. We must adequately ready our Soldiers through education, doctrine and training on GPS and EMI. There are opportunities to do so beginning with initial entry training and continuing onward through venues such as professional military education courses, unit collective training events, and combat training center (CTC) rotations. As there is no substitute for the real thing, this also includes establishing realistic training environments where Soldiers can directly observe the effects of GPS interference on their equipment and operations. The complications of conducting live GPS denial jamming at home station or the CTCs are currently being addressed through coordination between agencies including SMDC, USSTRATCOM, and the FAA, with the intent being to bal-
ance the disruption to civil activities while still providing effective training to the operational force. There are also materiel solutions in development that will aid in the replication of contested space environments, as well as a variety of publications and doctrinal resources regarding GPS degraded operations training available for reference. The key is to develop Soldiers to be able to recognize, react to, and fight through GPS interference, but also to know when to revert to manual location techniques.

**Manual techniques and doctrinal references**

While many of the techniques and procedures to determine location and direction without GPS-aided devices are no longer in regular use, they are as or more valid today than they were in years past due to the emergence of new threats. These techniques may have fallen out of common practice, yet there are still several doctrinal references regarding their usage and employment. For example, ATP 3-09.2 Artillery Survey Operations, published February 2016, describes the planning, execution and methodology of deliberate survey operations both with and without GPS. Similarly, ATP 3-09.50 The Field Artillery Cannon Battery, published May 2016, includes hasty survey operations techniques. In addition to these general references, every piece of Army equipment is issued with some form of reference or manual. These manuals often include considerations for operating in austere or degraded environments, and some specifically address GPS-denial.

In addition to doctrinal references, the U.S. Army Field Artillery School has published a Degraded Operations White Paper, which provides guidance on preparing and training for operations in a denied or degraded GPS environment. Of note, the white paper contains an exhaustive list of references for those interested in further study on degraded operations. For a more general perspective on operations in a denied, degraded and disrupted space operating environment (D3SOE), the U.S. Army Space and Missile Command / Army Strategic Command and the Joint Navigation Warfare Center have published several guides and best practices based on information gained from training, testing and operational experiences. The Center for Army Lessons Learned has also published a comprehensive handbook regarding D3SOE. These documents serve as a fundamental resource for units and leaders looking to train and prepare for operations in a contested or D3SOE environment.

**Closing remarks and recommendations**

There is no question that GPS provides enormous benefits to the warfighter and has revolutionized the way we shoot, move and communicate. Yet, almost counterintuitively, it is now more important than ever to be able to self-locate without such digital means. We must therefore prepare our artillery men and women to be experts in the usage of both the modern GPS-enabled systems and the manual techniques of the past. In order to do so, I recommend the following be implemented:

1. Reinstate training on degraded means of achieving position and azimuth control. This includes hands-on training with the techniques and associated equipment, classroom education on common survey and degraded techniques and the creation of realistic training scenarios in field exercises that challenge units to fight through a GPS-denied environment. The loss of the 13T MOS removed and reassigned many of the subject matter experts on this subject; leaders should seek out former 13Ts and leverage their experience to train their organization.

2. Update and clarify doctrinal references in support of GPS-degraded survey. While some manuals do cover hasty survey operations, the material is dated and often references equipment and resources that are hard to obtain (i.e., correction nomograms and world star charts). The Degraded Operations White Paper should be a major focus of training and field exercise planning, as it provides a modern and updated perspective on the topic.

3. Equip and outfit units to properly conduct hasty survey operations. For example, the M67 GLPS is an indispensable tool even when GPS is unavailable; there is still a clear operational requirement for it at the battery level. Removing the tools to conduct degraded position and azimuth determination from the inventory creates a substantial capabilities gap, unnecessarily blunting the resilience of the firing battery.

4. Integrate GPS interference training and D3SOE instruction across the Fires force. This could include: incorporating GPS denial jamming (or suitable replication) into unit collective training and field exercises, sending artillery Soldiers to the Army Space Cadre Basic Course, requesting home station training from SMDC G37, and including TTPs and battle drills for GPS interference in unit SOPs and Redbooks.

Regardless of the means, it is critical that we adequately prepare, outfit and enable our artillery forces to fight and win in an increasingly contested space environment.

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