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CASE STUDY OF GPS RETRANSMISSION IN MILITARY GROUND VEHICLES

Mr. Brian Paul
Defense Business Development Manager
GPS Source, Inc.
Pueblo West, CO

ABSTRACT

Global Positioning System (GPS) technology has seen increased use in many different military applications worldwide, beyond navigation. The Warfighter uses GPS to enhance Situational Awareness on the battle field with systems such as Land Warrior, Blue Force Tracker, TIGR, and various electronic mission planning tools in locations where the GPS signals are normally not available. For example, this includes the inside of a HMMWV, Stryker, or MRAP.

GPS retransmission, or the art of repeating a live GPS signal, has evolved into a technically advanced solution to provide GPS signals to the Warfighter mounted inside ground vehicles, protecting themselves from sniper and IED threats, while providing mobility and Situational Awareness from vehicle mounted communication & navigation systems. The objective of this technical paper is to communicate a relevant understanding of how this technology is being embraced by the Warfighter to accomplish their mission safer and more efficiently and to open dialogue on how vehicle integration can improve capability of onboard systems.

INTRODUCTION

Global Positioning System (GPS) technology has radically evolved as a go-to technology for all aspects of modern combat. From guidance of smart weapons and parachute navigation aids, to supplying a timing reference for frequency-hopping spread spectrum communications equipment, GPS has seen an increased use in many different military applications worldwide, beyond navigation. The Warfighter uses GPS to enhance Situational Awareness on the battle field with systems such as Land Warrior, Blue Force Tracker, PARANAVSYS, and various electronic mission planning tools. GPS applications for Airborne Soldiers provide guidance to the drop zone in night or inclement weather operations. In the case of Joint Precision Airdrop Systems (JPADS), GPS guidance receivers provide navigation and steering commands to guide the payload to the drop zone. GPS enabled asset tracking may provide current position and status of high value assets, such as VIPs, nuclear weapons, etc. In training applications, GPS technology may be used to track the participating assets, scoring the exercise and enabling a far more instructive de-brief.

This paper shall define the value proposition of GPS retransmission as it applies to use in military ground vehicles and discuss recent applications in which the Warfighter has benefited from GPS retransmission. Finally, this paper intends to present key capabilities and safety features any GPS retransmission system should offer to ensure the Warfighter may accomplish his mission safely, effectively, and efficiently.

WHAT IS GPS RETRANSMISSION?

GPS retransmission, or GPS repeating, is the art of making the live GPS signal available to handheld or mobile GPS applications at locations where the signal is not otherwise available. Proven applications include the following:

- In the crew compartment of a military vehicle,
- In the cargo compartment of a military aircraft,
- In the garage or hangar of a maintenance facility,
- In the final assembly stage of a heavy equipment manufacturer,
- In a laboratory of a GPS application developer, and
- In the wet well of a naval ship

GPS retransmission does not alter or digitize the information carried on the GPS frequencies, 1227.60 MHz and 1575.42 MHz, respectively. Rather, GPS retransmission provides a throughput of the weak RF energy transmitted by the GPS satellite constellation and repeats the RF energy on the same frequencies through a simple network of RF signal

distribution equipment. In its basic form, a GPS retransmission system may be realized with only an active (receive) GPS antenna, coaxial cabling, RF splitter and/or amplifier, and passive (repeat) antenna(s). A sample GPS retransmission system is demonstrated in Figure 1.

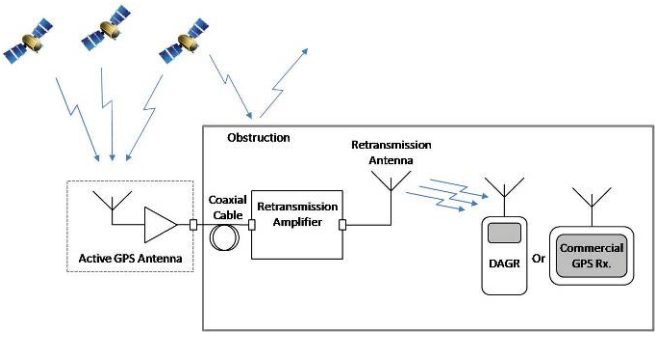

Figure 1. GPS Retransmission System Diagram

GROUND VEHICLE APPLICATIONS & BENEFITS

The threats of Improvised Explosive Devices (IED) and sniper fire in theaters of operation, such as Iraq and Afghanistan, has forced the development and fielding of large ballistic and blast protected vehicles such as MRAP, M-ATV, and the Up-Armored HMMWV. Infantry forces wisely choose to execute large portions of their missions mounted inside vehicles, such as these. Ceramic appliqué, RHA steel, and composite ballistic glass, common materials used in the construction of these vehicles and successfully protecting our Warfighter's from these threats, has proven to be a difficult medium to pass weak RF energy, such as the GPS signals. As a result, when "buttoned up," achieving maximum protection from the IED and sniper threats inside MRAP, HMMWV, and M-ATV, GPS signals must be brought into the crew compartment of these vehicles through wired means. Wired connections to equipment such as the Defense Advanced GPS Receiver (DAGR), however, can lead to issues such as poor reliability, obstructions during integration, or impediments to egress and in-vehicle movement. As such, GPS retransmission has become a viable and efficient manner in which to provide wireless GPS signals to the Warfighter operating in these conditions.

Further, the Warfighter has benefited from a decade of military specific C4I equipment development, phenomenal hardware linking each Soldier and Marine into a network of data and voice communications that identifies his position and status on the battlefield for his peers and commanders. Situational Awareness has been dramatically improved through the development of tools such as wideband and software driven tactical radios, GPS receivers, Blue Force Tracker, UAVs, and many others. Dozens of individual items are available to the Warfighter to improve communications and Situational Awareness today that benefit from use of the GPS frequencies, for positional information, timing, and synchronization purposes. The fog of war has been significantly reduced for the Warfighter and battlefield leadership through C4I technology development over the past decade.

However, the Warfighter expects to leverage these technologies whether on foot or mounted inside an MRAP. The loss of a GPS satellite connection inside a vehicle environment not only results in reduced situational awareness, but potentially compromises accurate position reporting by invalid location information (i.e. reporting of last known good location before entering a military vehicle). The lack of available GPS signals inside his vehicle provides a perplexing issue, but one easily solved through the incorporation of a GPS retransmission system.

GPS retransmission provides a wireless GPS signal inside the crew compartment of a military vehicle to systems such as the AN/PRC-117G tactical radio, GPS receivers such as DAGR and Magellan Triton, AN/GVS-5 laser range finder, Nett Warrior Soldier Ensemble, Toughbook laptop computers, FBCB2, and many others.

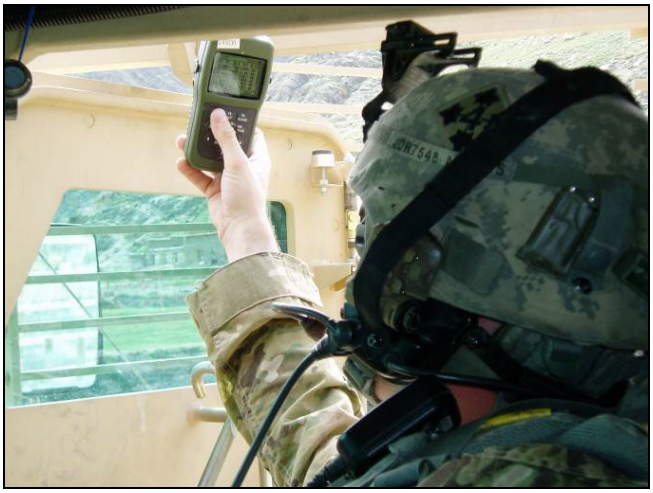

Figure 2. Soldier Holding a DAGR Out The Door of His MRAP to Get a GPS Signal

With a wireless GPS signal repeated inside the crew compartment of a military ground vehicle, the Warfighter will experience the following benefits:

- Improves Situational Awareness and valid location reporting while under armor,
- Reduced time from dismount to initial breach on the target location,
- Increased speed and accuracy of an assault team thereby improving survivability,
- Eliminated Time-To-First-Fix (TTFF) of GPS receivers upon dismount,

- Reduced battery consumption on GPS enabled devices,
- Enabled frequency-hopping spread spectrum enabled radios to ensure COMSEC features are functioning, and
- Reduced weight during systems integration efforts on ground vehicle platforms by eliminating coaxial cables and excess batteries.

GPS retransmission eliminates the need for the Warfighter to hold his DAGR out the door or place it in the cupola or hatch of his vehicle to receive a signal, making him susceptible to external threats.

As stated by a US Army 7th Special Forces Group (Airborne) Company Commander, integration of GPS retransmission technology, "will allow soldiers to remain oriented on the battlefield, reduce time from the exit of vehicles to initial breach, and aid in ensuring the right structure is targeted. The GPS [retransmission] systems will increase speed and accuracy, thus increasing survivability."

WARFIGHTER EXPECTATIONS FOR GPS RETRANSMISSION SOLUTIONS

It is critical that any GPS retransmission system employed by the Warfighter meet a basic list of expectations. Although simple and straightforward, GPS retransmission systems offered in today's marketplace have fallen short of this list of expectations. This author submits that this list of expectations, especially those relating to safety, should never be compromised and should be considered a minimum list of criteria that the Warfighter should demand from any GPS retransmission solution.

Below is the list of expectations any GPS retransmission solution should meet:

1. The Warfighter should expect 100% signal availability to all GPS receivers regardless of payload quantity or complexity in the aircraft or ground vehicle.
2. The Warfighter should expect 100% compatibility with all military and commercial grade GPS receivers, regardless of brand or manufacturer.
3. The Warfighter should receive a continuous GPS signal on his GPS receiver through deployment or egress from the vehicle.
4. The Warfighter should expect a highly reliable system, able to withstand the demanding environments in which he operates.
5. Finally, the Warfighter should expect zero interference with onboard vehicle electronics or handheld equipment and zero interference with other GPS operations in the vicinity of the mission.

Critical Safety Features in GPS Retransmission

In order to meet the *expectations* of the Warfighter for any GPS retransmission systems fielded to a military ground vehicle, a simple set of key *safety features* should be incorporated to ensure safe and effective operation of GPS and electronic equipment.

First, any GPS retransmission system should offer manual power control features, providing the operator the ability to tune the effective radiated power (ERP) specific to the vehicle application. This control enables a single GPS retransmission system to be optimized for any vehicle (or aircraft) application, large or small, and significantly eliminates the potential for harmful interference with other vehicle electronics. A single ERP level is not appropriate for all vehicle applications.

Second, automatic power control features should be included in the GPS retransmission system hardware to ensure the manually set power level is maintained throughout the duration of the mission. RF energy can be affected by variables such as ambient temperature and electronic emissions. Changes in these environmental factors may have an impact on the GPS retransmission system, especially if it is operating at a threshold level near a transition point, such as an excessively high ERP or inappropriately installed equipment. Automatic power control is a feature within the GPS retransmission system that ensures these factors do not cause an increase in ERP, thus causing harmful interference or oscillation. Automatic power control and manual power control features work complimentary to one another to provide the Warfighter with a highly reliable and smart GPS retransmission system that is optimized to the specific vehicle, but enable use across a range of applications.

Third, oscillation detection and mitigation features are paramount to any GPS retransmission system, ensuring that harmful interference events are detected and mitigated immediately. Oscillation events can occur due to poorly installed or improperly operated GPS retransmission systems or due to excessive ERP from the passive antenna. An oscillation detection feature identifies these events and provides a fault code indication to the operator. The oscillation mitigation feature should automatically begin eliminating the oscillation event by turning down the output power to a level conducive to the application, effectively eliminating the interference. Should the GPS retransmission system fail to effectively mitigate the event, it should take action to power down, completely eliminating the oscillation event and ensuring the safety of the crew. Oscillation detection and mitigation may be the most effective and critical safety feature available in GPS retransmission systems today.

Finally, GPS retransmission systems should offer the Warfighter fault isolation capability, enabling the operator to quickly and efficiently identify an issue in the system and

related course of action. Fault isolation should provide the operator with a simple notification, such as a fault light, or similar indication of the issue, along with a code to identify the nature of the issue. Fault isolation ensures the operator can quickly restore the GPS retransmission system to good health, enabling mission success.

A result of GPS retransmission systems implemented without key safety features was exemplified in June 2010 at Yuma Proving Grounds (YPG) when a US Army Special Operations Command unit installed an unapproved GPS retransmission system to a US Army CASA-212 aircraft to support training operations.[3] Prior to takeoff, the flight crew realized their flight deck GPS receiver was jammed. After troubleshooting, the crew identified the GPS retransmission system installed in the cargo area as the cause, emitting RF energy well in excess of appropriate levels and thus causing oscillation of the L1 GPS frequency, effectively jamming L1 GPS signals for hundreds of meters around the aircraft. If this event had occurred mid-flight, the flight crew would have been flying blind and potentially jamming the GPS receivers of aircraft around the airfield making a very dangerous situation for many operators. Although extreme, this example could occur in the military ground vehicle environment as well, causing harmful interference for systems, both onboard the vehicle, and in the surrounding environment, reducing situational awareness and the ability to communicate on the battlefield.

Implementation of a GPS retransmission system with oscillation detection and automatic mitigation features would have prevented this event and maintained an important level of safety for everyone involved in the mission.

This list of Warfighter expectations and the related safety features that ensure compliance to these expectations are critical for any GPS retransmission system implemented in a military application. Appropriately engineered and integrated, a GPS retransmission system can safely provide unparalleled Situational Awareness and value to the Warfighter by enabling his multitude of GPS enabled devices during his mission, but protected from external threats.

CASE STUDIES OF IMPLEMENTATION

GPS retransmission solutions have been employed by US forces in theater since 2004 to provide improved Situational Awareness and survivability. Applications have included fixed wing aircraft supporting precision aerial resupply and military free fall insertion, rotorcraft supporting airborne assault and troop transport, infrastructure applications including aircraft hangars, revetments, and tactical operations centers, and naval ships to support deployment of aquatic and airborne craft such as LCAC, AAV, and fighter jet maintenance.

This paper shall focus on the application of GPS retransmission systems integrated to military ground vehicles. Numerous active duty units and their applications have been identified in the ground vehicle space and have been proven through use in combat, adding value to the Warfighter.

Stryker IAV and Land Warrior

In 2004, PM Soldier Warrior (PM SWAR) and prime contractor General Dynamics identified a major gap in evaluation of the US Army's Land Warrior soldier modernization ensemble. The objective of the Land Warrior Program, as defined by programmatic documents, was to use a combination of commercial, off-the-shelf technology (COTS) and current-issue military gear and equipment designed to integrate small arms with high-tech equipment, provide communications and command and control at the infantry soldier level, and look at the individual infantry soldier as a complete unit rather than as a segment of a larger force.[1] A major focus area for the Land Warrior Program was to place a GPS antenna on the soldier, effectively identifying him on the battlefield by operational leadership.

During operations with the use of Land Warrior, program leadership quickly realized that the ensemble lost GPS lock as soon as the Soldier entered a vehicle, whether it was a Stryker or CH-47. Without GPS lock, the Land Warrior system reported the Soldier's last known good location, despite the fact that the Soldier, and his team, may be rapidly moving multiple kilometers away via ground vehicle. In such cases, bad information at the command level is far worse than no information. Erroneous information related to the team's location may lead to improper medevac location, threats of friendly indirect fires, and general confusion, resulting in poor decision making.

A result of this discovery was the conclusion by the program leadership that a GPS retransmission system must accompany the vehicle integration kit for the ensemble such that a soldier would maintain GPS lock, even while located inside an armored vehicle. The Program approached GPS Source to assist in identifying a solution to this GPS lock issue. A rugged mobile repeater product was identified for integration to the Stryker IAV to provide a wireless L1 GPS signal to soldiers located in the crew compartment. Testing revealed that the system effectively provided each soldier with a signal to maintain ephemeris data in the receiver to facilitate positional calculations and accurate reporting to FBCB2 and other mapping tools. The program included the system in their vehicle integration kit bill of materials and was subsequently fielded to all units training and deploying with the very successful Land Warrior ensemble.

Since 2004, multiple battalions within the US Army's 4th and 5th Stryker Brigade Combat Teams have deployed to

Iraq and Afghanistan with Land Warrior and the GPS retransmission product.

Most recently, a battalion within the 5th Special Forces Group (Airborne) prepared to deploy to Afghanistan with Land Warrior and their fleet of Ground Mobility Vehicle (GMV), M-ATV, and MRAP vehicles. The GPS retransmission system was, again, integrated to the fleet to support mounted operations with Land Warrior and ensure accurate and timely position reporting. The GPS retransmission system was integrated to the 5SFG vehicles in conjunction with an amplified splitter to eliminate the need for multiple active antennas on the roof of the vehicle. A single antenna provided signals of up to 4 wired and numerous wireless GPS enabled devices inside the vehicles. Fortunately, the integration team was able to incorporate the GPS retransmission system hardware during integration of other key systems components to efficiently design the RF signal distribution system for more than the GPS retransmission system. This included a hard wire coax connection to DAGR and tactical radios for redundancy.

Figure 3. US Army Unit Fielding Land Warrior

Feedback from operations utilizing the GPS retransmission systems in conjuction with Land Warrior in recent years has been positive. Soldiers report growing use of the GPS retransmission system beyond the intent of the Land Warrior program. Vehicle commanders have utilized the wireless GPS signal to facilitate mounted mission planning and pre-mission briefings on tablet computers. Additionally, Soldiers form Land Warrior equipped units have leveraged the GPS signal from the GPS retransmission system to provide synchronization data modulated on the GPS frequencies to enable frequency-hopping spread spectrum (FHSS) man pack radios inside vehicles. Transitioning from inside the vehicles to the ground during dismounted operations is seamless with the GPS retransmission system installed, the Land Warrior system transitions from the repeated signal inside the vehicle to the organic satellite signals without issue or error.

US Army Special Operations Command Units

Beyond the use of Land Warrior by 5th Special Forces Group (Airborne), a number of US Army Special Operations Command (USASOC) subordinate organizations have successfully implemented GPS retransmission systems to fulfill mission needs on the ground.

Companies within 7th Special Forces Group (Airborne) have implemented GPS retransmission systems to aircraft and ground vehicles in order to monitor position, routes, and target location during mission transport. 7SFG's use of GPS retransmission ensured Soldiers inside the vehicles, protected from key external threats, were able to utilize GPS systems to their maximum extent, including GoBook and ToughBook laptop computers leveraging FalconView mapping software, commercial Garmin and Magellan GPS receivers, and DAGR military GPS receivers. Company leadership wanted to ensure Soldiers left the vehicles oriented on the target location, especially during night operations, thereby increasing speed and accuracy during assault operations and improving survivability.

Similar to 7SFG's implementation to GMV, Stryker, and Bradley IFV vehicles, other USASOC organizations have implemented GPS retransmission systems to ground vehicles to facilitate the use of GPS enabled equipment during operations inside the protection of armored vehicles. One organization implemented a GPS retransmission product to the Pandur family of vehicles. The intent of this integration effort was to enable military and COTS GPS equipment wirelessly, during the mission. Unlike Land Warrior equipment, the vast majority of GPS equipment, when not locked on to the GPS satellite constellation, will not report a position. This organizations intent was to eliminate scenarios where team members might be left without accurate positional information during the course of their mission.

Recent upgrades within USASOC have brought GPS retransmission technology to the forefront, with the implementation of GPS Source's GLI-ECHO II L1/L2 GPS retransmission controller. The world's first *smart repeater*, the GLI-ECHO II offers USASOC a full complement of the previously identified safety features for air and ground operations. Installed in place of earlier GPS retransmission models, along with a lightweight passive antenna, the GLI-ECHO II provides output power control, fault isolation, oscillation detection & mitigation features previously unavailable in GPS retransmission systems on the market. These features dramatically simplify the Warfighter interaction with the system, eliminating any RF engineering and link budget calculations for installation.

Installed in a Pandur in a matter of minutes, the USASOC operator must simply press the power button and adjust the

output power level on the device faceplate to Level 3. Health status is immediately provided to the Operator, including specific fault codes. Any single band or dual band GPS capable device will immediately receive a wireless GPS signal inside the vehicle. Designed as a kit, the operator can easily remove the GPS retransmission hardware from the vehicle after the mission is complete and install to a different ground vehicle or aircraft immediately, adjusting the output power specific to that application.

Another USASOC organization who successfully implemented GPS retransmission solutions to military ground vehicles is the US Army's 75th Ranger Regiment. Tasked with airborne, air assault, and direct action raids and infiltrations, the Rangers required a GPS retransmission solution in kit form that could quickly be installed to a range of ground vehicle applications from a commercial Toyota pickup truck to a large MRAP, such as an RG-33. Demonstrating the use of the GLI-ECHO II system, the Rangers have successfully operated GPS retransmission systems onboard a wide range of ground vehicle applications in combat since 2008.

75th Ranger ground vehicle implementation of GPS retransmission systems includes Stryker, HMMWV, GMV, Toyota Hilux, and MRAP (RG-31 and RG-33).

Figure 4. GPS Source's GLI-ECHO II GPS Retransmission Controller

Canadian Land Force Command

In late 2009, the Canadian Army recognized a need for GPS signal coverage inside military ground vehicles to enable a wide range of fielded systems requiring L1 & L2 GPS signals. As the Canadian Army modernizes its communications and Situational Awareness-focused equipment, many soldiers are issued GPS enabled devices. GPS enabled systems fielded in the Canadian Army include tactical radios, DAGR GPS receivers, and commercial GPS receivers used by Soldiers inside vehicles. It was immediately obvious to the Canadian Army and Department of National Defense that it would not be feasible to provide a wired signal to each and every soldier to enable their equipment while mounted, an alternative solution had to be identified. The focus application was the Canadian Army LAV III fleet.

The managing organization for GPS systems implemented within the Department of National Defense identified the GLI-ECHO II GPS retransmission controller for use onboard the LAV III fleet. Offering output power control to both wired and wireless devices, the GLI-ECHO II would be integrated to the vehicles with a single passive antenna eliminating time-to-first-fix (TTFF) when soldiers dismount from the vehicles and dramatically reducing integration burden for current and future RF systems. Retrofit of the fleet will begin in FY12.

Figure 5. Canadian Army LAV-III

VALUE OF INTEGRATION

This paper has presented numerous real-world instances of recent GPS retransmission integration to ground vehicle applications, both in kitted form, as well as permanent installation. GPS retransmission offers wide value to infantry units operating in wheeled and tracked vehicles. In addition, GPS retransmission continues to grow in applications well beyond ground vehicles, with military operators gaining the benefits in rotorcraft, fixed wing aircraft, ships, tactical operations centers (TOC), and hangars.

As described in the above case studies, GPS retransmission enables the Warfighter to maintain Situational Awareness with valid location reporting even while operating within the safe confines of a military ground vehicle. This enables the Warfighter to be more efficient in accomplishing his mission by monitoring his position, route, and target location during movement and convoy operations. This especially becomes important operating at night or from the crew compartment of an armored vehicle where visual observations may not be made.

Further, GPS retransmission solutions eliminate the time-to-first-fix issue, which can span critical minutes, as the GPS receiver re-acquires almanac and ephemeris data after exit from the vehicle. This issue becomes critical when making a quick dismount from the vehicle, either in defensive posture or during a planned assault. Understanding the Warfighter's

position upon dismount is a critical piece of information during night operations and austere environments when targets may be camouflaged or unfamiliar. This value is emphasized by a company commander from 7th Special Forces Group, "GPS re-radiating systems will allow soldiers to remain oriented on the battlefield, reduce time from the exit of vehicles to initial breach, and aid in ensuring the right structure is targeted. The GPS re-radiating systems will increase speed and accuracy, thus increasing survivability."

Beyond these immediate benefits to the Warfighter, the integration of a GPS retransmission system to military ground vehicles provides secondary value as well. The use of "wireless" solutions inside vehicles enables the integration team to eliminate unnecessary coax cables which add weight and potential for interference with the soldier and his equipment during egress. The use of DAGR, for example, is improved when a GPS retransmission system is implemented, as the bulky and troublesome cabling can be removed to alleviate this major complaint from the Warfighter: tangling of weapons and equipment on tactical vests during egress. GPS retransmission eliminates this risk by removing the cable passing across the door or windshield.

Additionally, reliability of RF signal distribution systems is dramatically improved with the reduction of RF connectors in the system. The natural shock and vibration loads incurred inside a military ground vehicle over its life are not conducive to sensitive connections such as these and every connector and cable eliminated in the system offers overall reliability improvement.

As technology evolves and new equipment, such as the Joint Tactical Radio System (JTRS), is fielded, the use of a GPS retransmission system makes integration to the existing fleet a simpler undertaking. Tactical radio systems requiring the accurate timing information modulated on the GPS frequencies do not require a wired connection. This enables a simplified integration effort or enables the use of man-pack radios carried onto the vehicle by the Warfighter.

The reduction of GPS active antennas on the roof of ground vehicles can be achieved with an appropriately integrated GPS retransmission system. Although weight is not an issue with antennas, typically, interference issues between antennas can be prevalent in this day and age of increased communications on the battlefield. In one case study of a US Marine Corps vehicle, five GPS active antennas were integrated to the vehicle. This is excessive and progresses beyond the concept of redundancy. A primary complaint from the Marines operating the vehicle was a lack of space to stow personal items during missions, such as rucksacks, mortar base plates, rations, and spare ammunition, as the antennas were located throughout the roof of the vehicle taking up valuable stowage space. Reality suggests that Marines will bring their spare ammunition along to the fight, eliminating the functionality of the GPS active antenna if it is covered up or damaged.

Following this concept, GPS retransmission devices can be utilized as a "GPS Hub," distributing a conditioned and reliable GPS signal, both wireless and wired, to any GPS enabled device integrated to the military ground vehicle. GPS antennas can be reduced to a single unit, wireless L1/L2 signals can be distributed to handheld systems, wired coax or serial data (NMEA-0182 or GPS-STD-153) can be provided to TACNAV, tactical radios, C4I computers, or other devices inside the vehicle, providing systems integrators with a low cost an straight forward means to provide position, navigation, and timing (PNT) information to any device within the vehicle. Most importantly, SAASM capability can be distributed throughout the vehicle without the integration of GB-GRAM cards to multiple devices, further reducing cost, integration, and security burdens.

In many cases, incorporation of multiple antennas or sub-systems within the vehicle is a result of the way the defense industry operates. Multiple Program Offices are independently integrating C4ISR systems to the vehicles in a vacuum, or with independent budgets. GPS retransmission systems not only enable on board systems during missions, but enable Program Offices and design houses within the defense community to find a means to distribute GPS signals efficiently and effectively to the mounted Warfighter. This makes GPS retransmission an important and enabling subsystem to be considered early in the vehicle development process. Alternatively, case studies have shown that post-production integration is feasible, and many of the value propositions of GPS retransmission can still be achieved.

GPS retransmission products, such as the GLI-ECHO II, will continue to revolutionize the military ground vehicle community, providing safe, efficient, and low cost means to distribute GPS signals and PNT data to an ever growing number of communications and situational awareness products implemented today. Numerous applications have proven the benefit of GPS retransmission, it is this author's recommendation that these GPS retransmission solutions continue to improve the efficiency of the missions successfully undertaken by our brave Warfighters.

REFERENCES

[1] U.S. Army Budget Request Documents FY08 (page 4). US Army Office of Financial Management.

[2] GPS Source Product Information. www.gpssource.com

[3] USASOC Safety Bulletin 01-10. June 2010