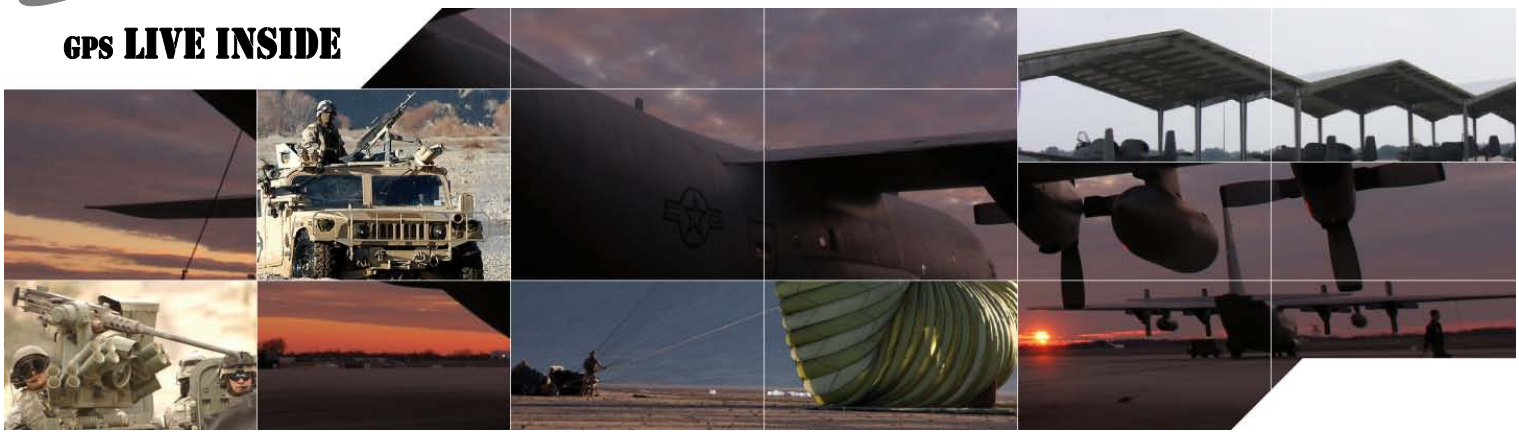
GPS Retransmission
Inside Military Ground Vehicles
White Paper

GPS SOURCE

GPS LIVE INSIDE



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Introduction

Global Positioning System (GPS) technology is increasingly being applied in many different military applications beyond navigation. Soldiers use GPS to enhance situational awareness on the battle field with systems such as Land Warrior, Blue Force Tracker, 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.

In all of the examples above and in many other GPS enabled military applications, it frequently becomes necessary for these GPS receivers to operate in locations where the GPS signals are normally not available. Many times, this environment is the inside of a military ground vehicle such as the M1165 HMMWV, M1126 Stryker, GMV-S, or MRAP. This white paper will discuss how GPS Retransmission can be an effective solution to the problem of GPS denied environments for *some* GPS enabled applications. Specifically, this paper will concentrate on GPS retransmission systems as they apply to military ground vehicles, including specific capabilities and requirements for these systems.

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 bay of a military maintenance facility
- In the final assembly stage of a military equipment manufacturer

Ground Vehicle Applications, Benefits, and Added Value

When GPS receivers, or specifically the receiver's antennas, are inside of vehicles (ie., DAGR mounted inside an MRAP) or buildings without a Line Of Sight (LOS) view of the GPS satellites, the receivers will not provide navigational or position information. Multipath or other errors in the received data, can lead to erroneously displayed information on the DAGR or commercial GPS receiver. The soldier or user may not be aware of this data error, leading to incorrect coordinates being called out for air support, medevac location, sniper position, or other position critical events. This limitation can impact many military GPS applications, even if location data inside of the denied environment is not a requirement.

For example, the receiver's or system's performance may be impacted in the following ways:

- When the receiver deploys from the vehicle, the "time to first fix" (TTFF) can vary significantly based on various conditions (worse case TTFF can be over 5 minutes).
- GPS receiver battery life while operating inside of the vehicle is significantly reduced due to the ongoing signal acquisition process.
- Lack of signal availability may preclude verification of system operation prior to deployment.
- Placement of DAGR on vehicle roof or through open door to acquire GPS signal, reduces survivability of crew against external threats.

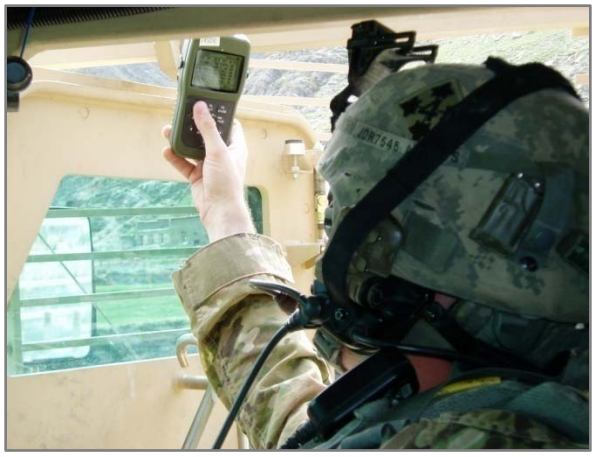

Figure 1. US Soldier Holding DAGR Through an Open Door to Acquire GPS Signal. Practices Such as This Dramatically Reduce Survivability Against a Range of Threats

With a GPS retransmission system installed in the crew compartment of a military ground vehicle and providing availability of the GPS signals in the otherwise denied environment, military applications benefit in the following ways:

- Situational Awareness (SA) maintained with valid location reporting even when inside of the vehicle, rather than reporting of "last known good" location, which would be the location *just prior to entering* the vehicle
- mounted soldiers can monitor position, route, and target location prior to dismount
- reduced time from dismount to initial breech on target location
- increased speed and accuracy of assault team, therefore improving survivability
- eliminated costly delay in Time To First position Fix (TTFF) when exiting the vehicle
- reduced GPS receiver battery consumption due to computationally intensive reacquisition process
- enabled radio frequency (RF) signal distribution system optimization within the small confines of a military ground vehicle with the elimination of coax cables, reduction in required active GPS antenna, improved mounting locations for GPS receivers, etc. - leading to improved reliability with fewer hardware failures
- a critical support to any soldier modernization program in which an individual soldier possesses active antenna or handheld GPS device.

Successful implementation of GPS retransmission systems within military ground vehicles are evident across a wide range of applications. It gives systems such as FBCB2 JV-5, DAGR, JTRS HMS, Garmin Foretrex, Tacticomp, Toughbook Computers, Laser Target Locator Modules (LTLM), and others the ability to receive a GPS signal wirelessly inside a vehicle. GPS retransmission systems are utilized in the Stryker vehicle in support of the Land Warrior ensemble. The system allows each soldier to receive a live GPS signal in his uniform mounted antenna. This guarantees FBCB2 tactical displays will accurately show position of the dismounted squad. Furthermore, the retransmission system ensures a "hot" GPS signal upon rapid dismount from the Stryker, eliminating time to first fix (TTFF).

The 4th Battalion of the 4th SBCT, 2nd Infantry Division was the first unit to deploy to a combat zone with a GPS retransmission system. 5th SBCT of the 2nd Infantry Division is currently deployed to Afghanistan in support of Operation Enduring Freedom with GPS retransmission system capability. 4th Battalion of the 5th Special Forces Group is slated to receive Land Warrior and GPS retransmission capability for their M1152, M1165, RG-31, and RG-33 vehicles in 2011. The 7th Special Forces Group deployed to Afghanistan in 2009, utilizes a GPS retransmission system aboard their M1152 HMMWV and MRAP vehicles to ensure situational awareness and improve survivability. The 75th Ranger Regiment is currently using GPS retransmission to support Operation Enduring Freedom in a range of tactical wheeled vehicles. GPS retransmission is combat proven and has received much praise from program representatives and the Warfighter, alike.

- "*It's made [the soldier] much more effective doing their job. It gives them a much more complete picture of the battlefield. Plus, it was an easy thing to integrate into the vehicle*" – Grant Ruhtzon, Program Manager, PM Land Warrior
- *"Land Warrior made 4-9 Infantry a more capable and lethal organization"* – COL Timothy Prior, J4, Special Operations Command-Central
- *"It's clear that the system is a force multiplier…"* – CPT Eric Adland, 2nd ID

GPS Retransmission System Architectures for Ground Vehicles

GPS retransmission systems, in their simplest form, include at a minimum the following elements:

- Active Antenna (Active meaning the antenna includes an integrated Low Noise Amplifier)
- Interconnecting Coaxial Cable(s)
- *Retransmission* Amplifier/Signal Conditioner
- Passive Retransmission Antenna

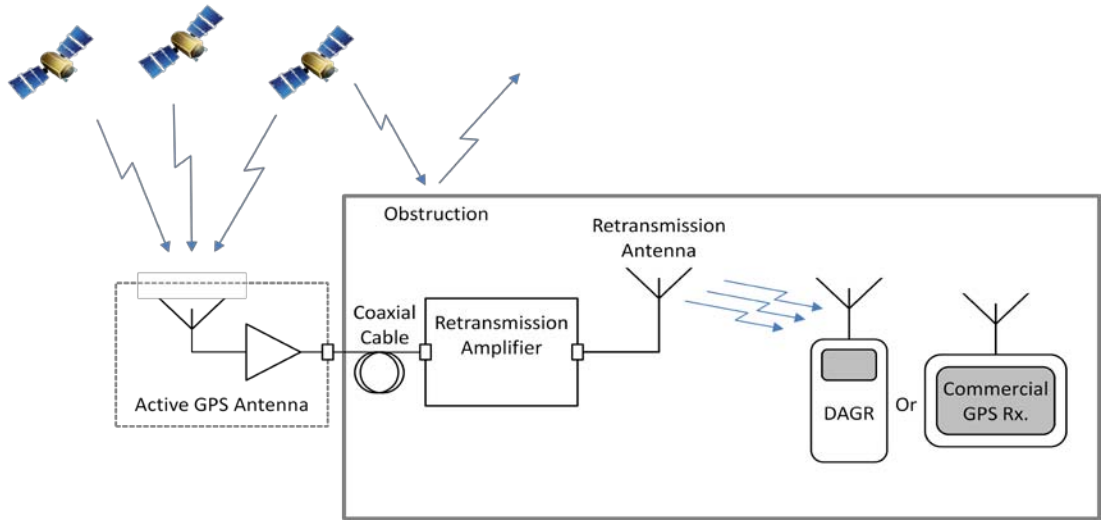

Figure 2. Basic GPS Retransmission System Architecture

In this system (Figure 2), the GPS satellite signals are received by the active receive antenna, amplified, and re-broadcast on the GPS frequency(s) by the retransmission antenna. Satellite signal delay through the GPS retransmission system is common. GPS receivers will calculate the position of the system's receive antenna, which is located outside and in view of the LOS signals. This limitation is not critical for the ground vehicle application described above, because the derived location is close enough to accomplish the intended function. Flexibility in systems architecture can be achieved with the incorporation of additional RF signal distribution hardware, such as a 1x4 splitter, exemplified in Figure 3, adding to the basic system in Figure 2.

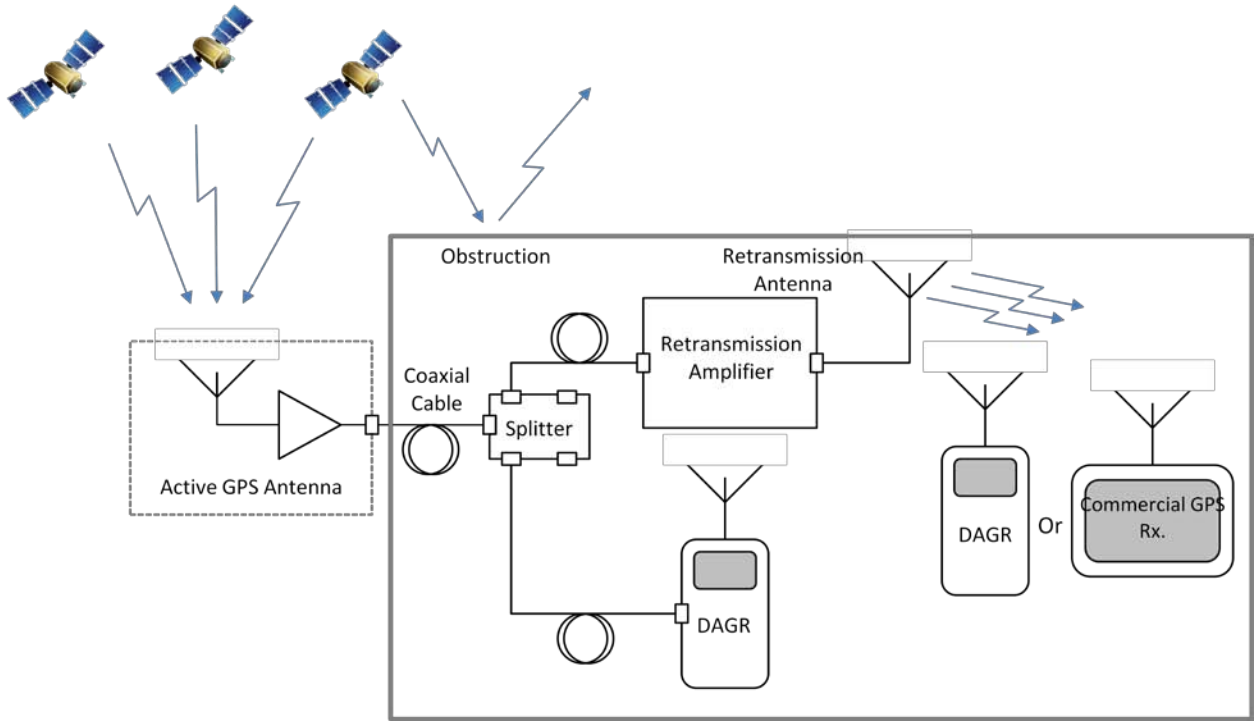

Figure 3. Basic GPS Retransmission System w/ Integrated RF Splitter

First generation GPS retransmission technology, as referenced in the previous figures, has been effective in many basic small vehicle applications, such as an M1165 HMMWV or Toyota technical obtained in theater. However, successful GPS retransmission in the confined, irregularly shaped cargo compartment of a larger military ground vehicle presents significant challenges. Controlled dynamic range for guaranteed performance of GPS application receivers constrains the retransmitted signal levels in the extended passenger compartment. If the retransmitted signal is beyond the dynamic range of the receiver, the GPS receiver may become saturated, resulting in failure to acquire GPS lock on the signals inside or immediately upon dismount from the vehicle.

An additional consideration must be taken for SAASM capable GPS receivers. If the retransmitted signal is too strong inside of the vehicle, this could trigger the Anti-Spoofing capability of the receiver, having an adverse effect on the performance of the receiver. Conversely, the signal may be so low as to preclude signal acquisition and GPS lock by the receiver while still inside the vehicle. The same risks exist in smaller tactical wheeled vehicles as well. These risks can be mitigated through the implementation of a more advanced GPS retransmission system containing multiple passive GPS retransmission antennas inside the vehicle, exemplified in Figure 4.

A second generation GPS retransmission system, or “smart” GPS retransmission system, may include the following elements:

- Active Antenna
- Interconnecting Coaxial Cable(s)
- Radio Frequency Signal Splitter
- Retransmission Amplifier/Signal Conditioner LRU
- Passive Retransmission Antenna(s)
- Output Power Control (signal conditioning)
- BIT and Fault Isolation Capabilities
- Oscillation Detection.

An advanced retransmission system has the capability to improve the logistics footprint of the system and easily control the effective radiated power (ERP). Most importantly, the output power level is visual (and NVG compatible), offering a visual check to the Warfighter, maintenance officer, or engineer supporting the unit. More robust passive antennas, included in a system such as this, offer a more optimized signal pattern. This gives the integrator a greater ability to optimize the retransmission system specifically for the intended application.

A second generation retransmission system capable of offering these capabilities is the GPS Source *Echo II* LRU. Exemplified in Figure 4, the Echo II offers a single GPS signal input and 4 RF outputs, allowing multiple GPS enabled systems to function as required with output power control, BIT, and fault isolation. A system can be designed with the Echo II LRU utilizing one or many passive antennas. The added features brought forth by a next generation LRU, such as Echo II, offer an improved level of control to the Warfighter, ensuring signal availability within the vehicle and confidence that dead zones caused by oscillation will be mitigated. All military and commercial GPS receivers are compatible with the Echo II enabled retransmission system, including DAGR, JTRS HMS, JV5 Tablet, TactiComp, and other GPS enabled communication and navigation devices.

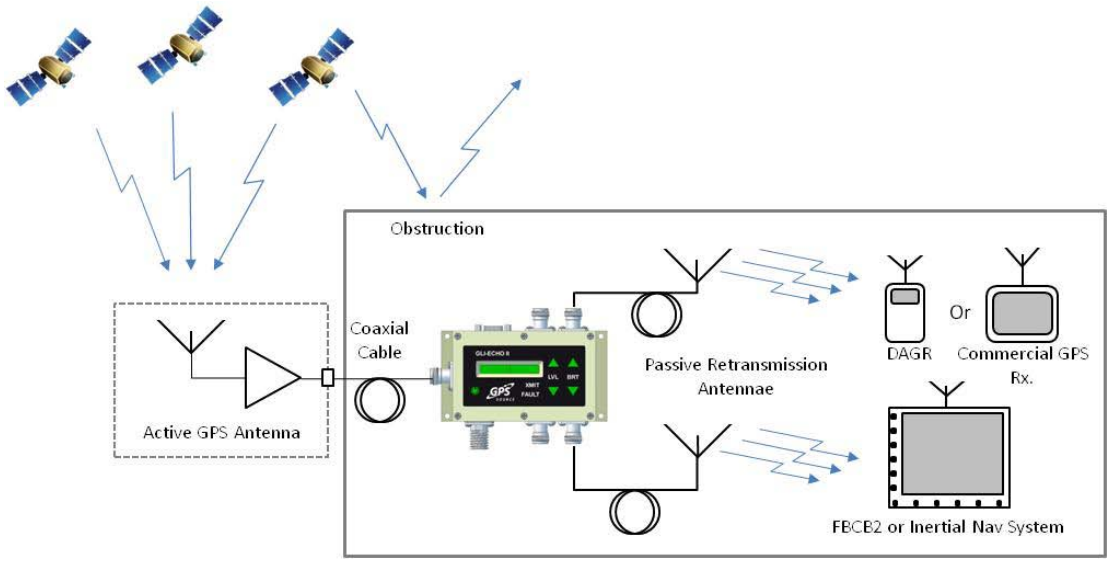

Figure 4. GPS Retransmission System With Echo II LRU

Figure 5. The *Echo II* LRU

For example, the long, narrow dimensions of an RG-33 MRAP crew compartment, taken together with the rapid $1/R^2$ signal propagation losses and limited dynamic range of application GPS receivers, typically dictates that multiple retransmission antennas will be required for complete, uniform coverage. Fewer antennas than appropriate would require a higher ERP from the retransmission antenna, potentially resulting in saturation of the receivers located in the vicinity of a transmit antenna. The saturated receiver would likely cause a slow or delayed reacquisition of the LOS signals upon deployment from the vehicle. This would result in excessive TTFF and compromised situational awareness. As mentioned previously, another concern for excessive signal strength is the potential for triggering the Anti-Spoofing functionality of SAASM capable military GPS receivers, which would further degrade the receiver's performance. The higher ERP also extends the range of the re-transmitted signals unnecessarily, which in turn extends the zone of potential interference with other GPS operations outside of the vehicle when doors are opened. In this example, oscillation detection and output power control mitigate these issues. They dictate the required power output by the retransmission system to establish a clean GPS signal within the confines of the vehicle, without oscillation or excess radiated power. In the event a fault is detected, the automatic fault isolation would provide a code to the maintenance crew, indicating the reason for the fault. This fault detection/troubleshooting feature reduces repair down time and improves mission readiness rates.

In a large ground vehicle, such as the MRAP II class Force Protection *Cougar*, shown in Figure 6, a dual repeater system is the ideal solution to provide 100% GPS signal coverage throughout the crew compartment. With a GPS Source *Echo II* LRU connected to an exterior GPS active antenna, dual passive active antennas will offer complete coverage for all Warfighters within the crew compartment. One passive retransmission antenna is placed in the forward crew compartment above the windshield, facing rearward. The second antenna is placed in the rear left corner, facing inward. The Echo II offers L1/L2 output power control, BIT, and fault isolation capabilities with signal coverage throughout the entire crew compartment of a larger ground vehicle such as an M1126 Stryker, RG-33, MaxxPro, or M2A3 Bradley. The vehicle crew compartment has a large volume and the dual antenna system coupled with the *Echo II* would offer the best option for GPS signal coverage. It reduces the potential for oscillation and minimizes areas with no signal coverage. The *Echo II* dual passive antenna solution can run from 28V vehicle power and/or BA5590 lithium battery.

Figure 6. Interior of the Force Protection Cougar MRAP Vehicle

Similarly, in a smaller tactical wheeled vehicle such as an HMMWV, JLTV, or ASV, the Echo II LRU is mounted to the C4I rack and a single passive retransmit antenna is mounted on the A-pillar facing inward toward the vehicle. This offers complete signal coverage for the vehicle occupants and any GPS enabled systems inside the vehicle. Removal of coax cables to GPS enabled equipment, such as the DAGR, eliminates the ability for a Warfighter to step on the cable, breaking connection and damaging the receiver. Operational tempo is improved as the Warfighter will not need to wait for the delay in TTFF once exiting the vehicle. The survivability feature of the vehicle is maximized as doors and hatches can remain closed, because direct access to satellite LOS is not required when the Echo II enabled retransmission system is functioning. Situational awareness for the Warfighter has been optimized. A retransmission system installed with the Echo II LRU will enable applications such as DAGR, TactiComp, JV5 Tablet, JTRS HMS, and other applications with embedded or expandable GPS antennas.

Permanent vs. Temporary Install

Currently available GPS retransmission systems include both permanently installed as well as temporarily installed systems. For example, GPS Source is providing components for permanently installed systems for the Stryker of the U.S. Army's 2nd Infantry Division and M1165, RG-31, and RG-33's of 5th Special Forces Group. Similarly, GPS Source provides hardware to the 75th Ranger Regiment in the form of man-portable kits, immediately available for install to any ground vehicle or aircraft in the theater of war. The following are a few of the advantages and disadvantages for temporary install vs. permanently installed systems.

Temporary Installed Systems:

GPS retransmission systems in kit form are typically far less expensive to develop and procure. Kit systems are rapidly deployable and immediately available to the Warfighter, requiring limited systems engineering. GPS retransmission kits can be used on multiple vehicle *and* aircraft platforms without significant integration activities; however, the system will not be optimized for any single vehicle.

Examples of primary applications for kits are military Airborne units who may deploy from an aircraft and require GPS retransmission aboard vehicles acquired in the field. Units seeking an immediate solution to GPS denied locations in theater are also prime candidates for a GPS retransmission kit where optimization for a single vehicle is a lower priority than maintaining operational tempo. GPS Source provides a line of man–portable GPS retransmission kits, GPS LIVE INSIDE, or GLI, which offer an immediate solution to GPS denied vehicle applications. GLI kits are installed in the field by the Warfighter or supporting maintenance or CLS organizations. They are available with single or dual retransmit antenna capability for vehicles large or small.

Figure 7. GPS Source's GLI Line of GPS Retransmission Kits

Permanent Installed Systems

Permanent installed GPS retransmission systems offer an improved level of optimization for ground vehicle applications and make sense when working with the original equipment manufacturer or primary vehicle operator. A permanent system (versus their kit counterpart) is more reliable, because points of failure, such as coaxial cables, power cables and connectors are not utilized. Systems can be specifically engineered for vehicle applications to ensure 100% vehicle coverage of the GPS signal. This improves performance of the system and significantly increases mission readiness. When installed on a permanent basis, the system is fully verified and validated on the specific vehicle application. Units or manufacturers seeking a long term solution to GPS denied environments inside military ground vehicles are likely candidates for a permanently installed solution.

GPS Source Contact Information

If you have any questions related to the information contained within the white paper, or for more information related to GPS Retransmission, GPS Source products and specifications, or quotations, please contact:

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