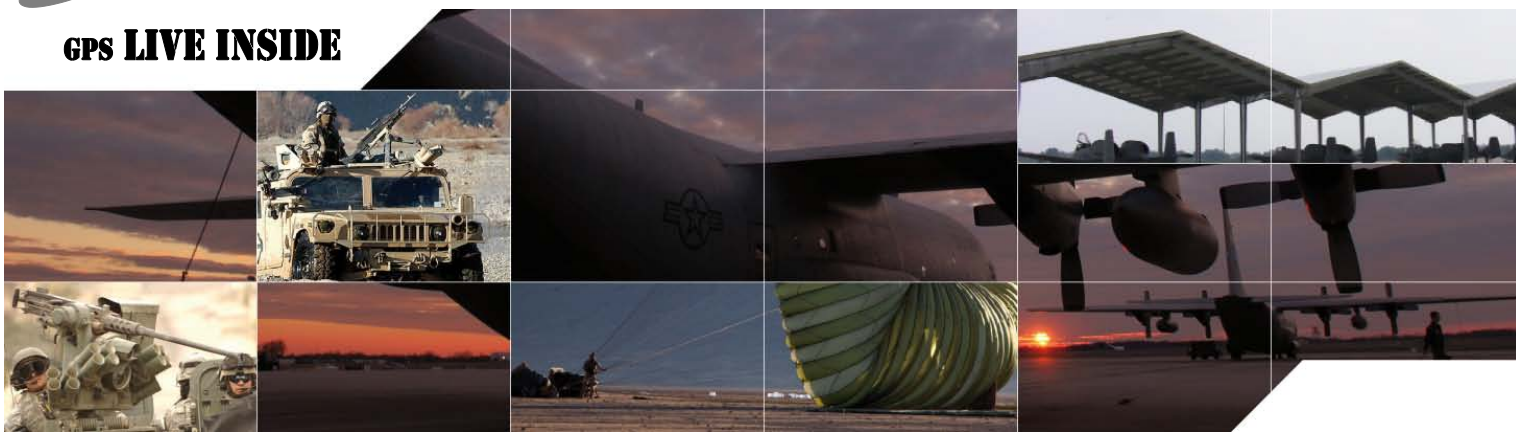
# White Paper – GPS Retransmission for GPS Guided Munitions Delivery

GPS SOURCE

GPS LIVE INSIDE



Brian Paul

October 2010

## 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. GPS applications are utilized for precision aerial resupply via the Joint Precision Airdrop System (JPADS) to guide ammunition, medical supplies, or food to units operating on the ground. 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. GPS provides accurate target position information to smart weapons deployed from aircraft or ground based platforms, improving accuracy and lethality of these weapons systems.

GPS retransmission systems have successfully been utilized in combat since 2004 to provide live wireless signals to commercial and military GPS receivers inside volumes where a clear view of the sky is unavailable. Successful examples include military free fall (MFF), precision aerial resupply (JPADS), air and ground assault, and ground vehicle patrols (DAGR, Land Warrior). GPS retransmission systems have been successfully employed on a range of platforms, including C-130, C-17, CH-47, MH-60, HMMWV, Stryker, Bradley, and more.

This white paper will discuss how GPS Retransmission can be a very cost effective solution to the problem of GPS denied environments for delivery of GPS guided munitions from aircraft weapons bays, under-wing munitions pylons, or artillery & mortar tubes.

## What is GPS Retransmission?

GPS Retransmission, or GPS Repeating, is the art of making the live GPS signals available to handheld or mobile GPS applications at locations where the signals are otherwise not available or experience limited, unreliable availability. Proven applications include the following:

- In the crew compartment of a military vehicle,
- In the cargo or weapons 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,
- In the wet-well or maintenance deck of a naval ship.

## Applications, Benefits, and Added Value

When GPS receivers, or specifically the receiver's antennas, are inside of vehicles (aircraft, land vehicles, boats, etc.) or buildings without a Line Of Sight (LOS) view of the GPS satellites, the receivers will not reliably provide position, navigation, or timing (PNT) information. 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 or aircraft, the "time to first fix" (TTFF) can vary significantly based on various conditions (TTFF can be over 5 minutes worst case)
- GPS receiver battery life while operating inside of the vehicle is significantly reduced due to the computationally intensive signal acquisition process
- Lack of signal availability may preclude verification of system operation prior to deployment
- Targeting or landing zone updates are not immediately recognized by the GPS application due to ongoing satellite acquisition process.

With a GPS retransmission system installed and providing availability of the GPS signals in the otherwise denied environment, the applications may benefit in the following ways:

- In the weapons bay of a military aircraft, the GPS retransmission system:
  - Enables acquisition and verification of weapons guidance payload prior to release
  - Ensures confirmation of weapon systems guidance system status prior to release
  - Simplified installation of weapons to aircraft eliminating GPS umbilical connection
  - Increased reliability of aircraft weapons pylons due to elimination of umbilical connection

- In the cargo compartment of a military aircraft, the GPS retransmission system:
  - Enables acquisition and verification of cargo payload receivers prior to air drop (JPADS)
  - Eliminates TTFF, enabling payload guidance receivers to generate steering commands immediately upon exiting A/C
  - Enables verification of position, velocity, and elevation of airborne soldier GPS prior to the jump

- In the crew compartment of a typical military vehicle, the GPS retransmission system:
  - Maintains SA 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
  - Eliminates costly delay in Time To First position Fix (TTFF) when exiting the vehicle
  - Reduces GPS receiver battery consumption due to computationally intensive reacquisition process

- In the garage or hangar bay of a military maintenance facility and in the final assembly stage of a military equipment manufacturer, the GPS retransmission system:
  - Eliminates requirement to perform maintenance outside of protective shelter, potentially exposing the asset and personnel to hostile fire
  - Allows 100% system functional test, including the application's receive antenna system
  - Maintains "Hot" GPS Ephemeris enabling immediate taxi for A/C on alert status

## GPS Retransmission System Architectures

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 (or repeat antenna)

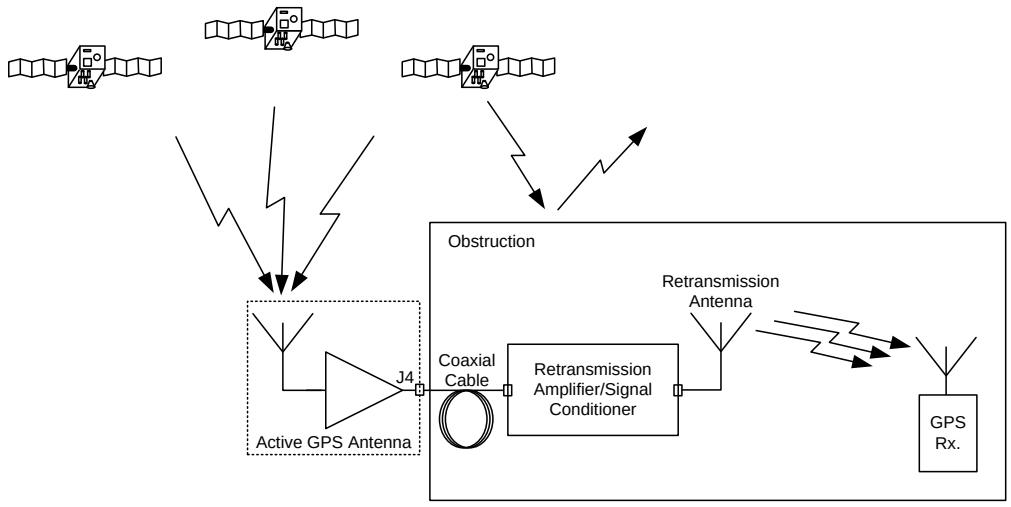



**Figure 1. Simple GPS Retransmission System**

In this system, the GPS satellite signals are received by the active (receive) antenna, amplified and conditioned by the retransmission amplifier, and re-broadcast on the GPS frequency(s) by the retransmission antenna. Because the signal delay through the GPS retransmission system is common for each satellite once the signals are received by the exterior antenna, GPS receivers operating in the retransmitted signal environment will generate a location, not at their actual position inside of the hangar, vehicle, or aircraft, but rather they will calculate the position for the system's receive antenna that is located outside in view of the LOS signals. This limitation, however, is not critical for the applications described above, as the derived location is close enough to accomplish the intended function.

In the application of a GPS retransmission system repeating a wireless GPS signal to munitions stored in an aircraft's enclosed weapons bay, the system utilizes the aircraft's existing active GPS antenna to receive a signal from the satellites. The signal is transferred through an RF splitter to the passive, or repeat antenna, and received by the munitions' active antenna, thereby providing a live GPS signal to the weapon. This process creates an efficient manner for installation of munitions onto the aircraft by the weapons technician. Similarly, this system provides a more robust and efficient manner of transferring GPS data to munitions prior to separation. The guided munitions utilize their active antenna to receive a "hot" position signal and do not require a separate MIL-STD-1760 compliant GPS umbilical to provide this positional information then switch over to the antenna post-separation. Most importantly, during separation the weapon seamlessly transitions from repeat GPS signal to organic signals by keeping the ephemeris, within the weapon's GPS receiver, active. A transition from the umbilical signal to the munitions antenna is unnecessary, removing the burden from firmware or electromechanical switch within the weapon. Figure 2 graphically depicts the concept of GPS retransmission systems for use with GPS guided munitions deployment.

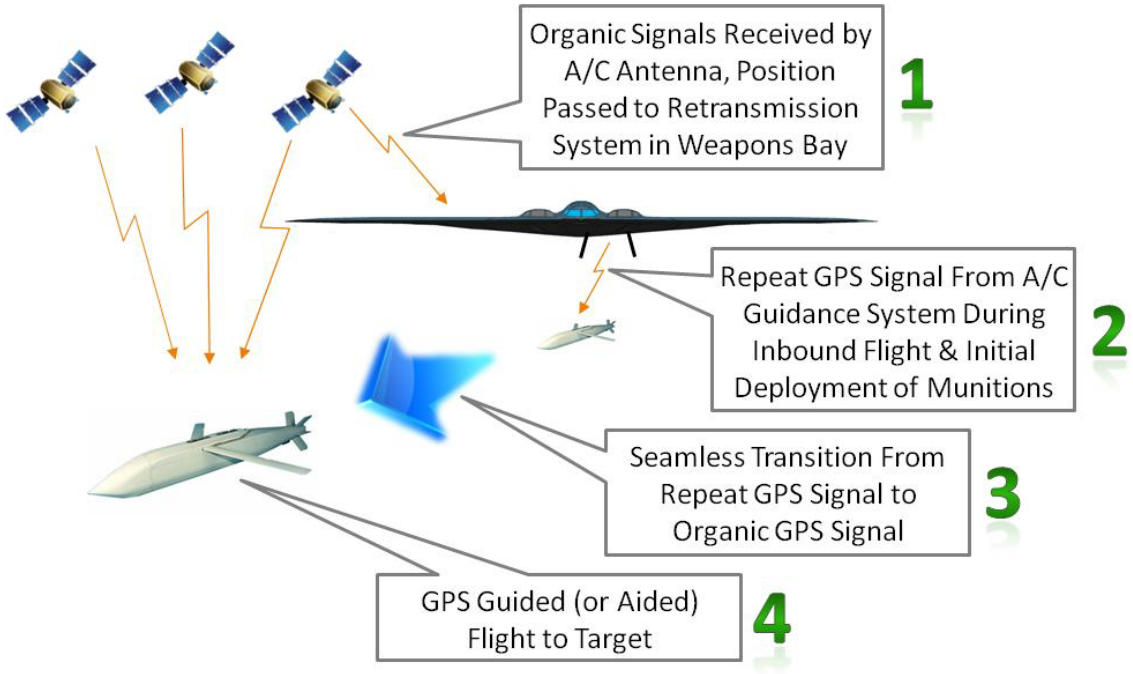



**Figure 2. GPS Retransmission System Function in Aircraft Deployed Munitions**

Within the aircraft weapons bay, the repeated GPS signal can be tailored to meet the requirements of different aircraft or weapons configurations. The signal power can be tailored to ranges of a few inches to ranges of 12 ft, depending on the application and requirements. Similarly, one or multiple repeat antennas, or near field antenna couplers, may be utilized in the system design to provide maximum GPS signal coverage for the weapons bay while eliminating the potential for the signal to propagate beyond the intended area of coverage. For example, a GBU-15 Air-to-Surface GPS guided weapon houses the guidance system and GPS antennas in the forward portion of the weapon. Alternatively, the JDAM GPS guided weapon houses the guidance system and GPS antennas at the rear of the system, with one of the GPS antennas facing rearward mounted to the tail section of the weapon, shown in Figure 3. When loaded aboard an F-35 weapons bay, for example, the GPS retransmission system must be designed in a manner to provide GPS signal coverage for both types of munitions and may require two repeat antennas if both weapons were to be loaded onto the aircraft, simultaneously, for a mission.

This configuration requirement would also hold true with munitions systems loaded onto an aircraft's wing pylon or underbelly where a clear view of the sky may not always be available. A repeated GPS signal extending 12 to 24 inches from the passive antenna or near field antenna coupler will provide a GPS signal to the munitions to ensure immediate organic positional information upon separation.

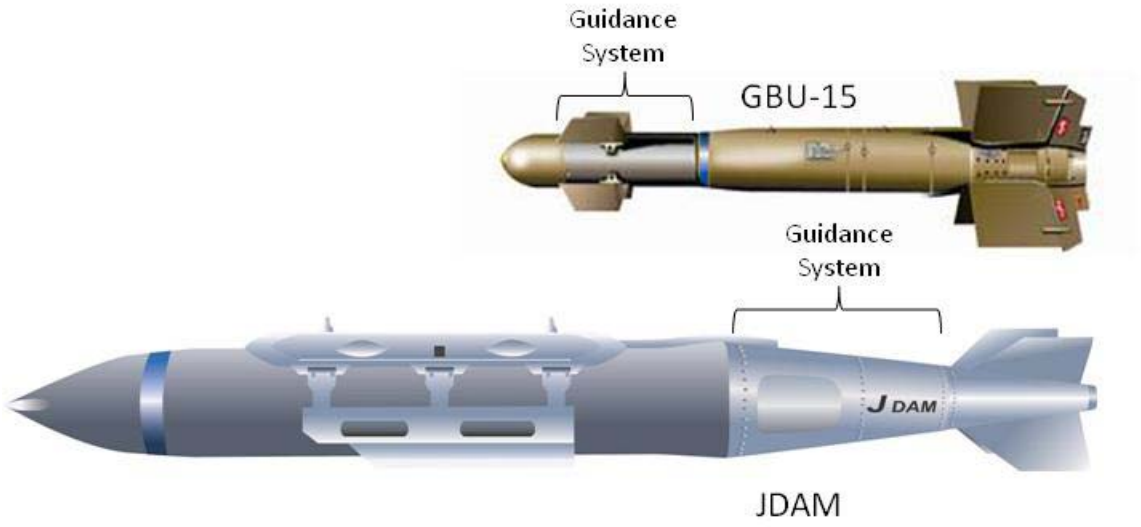



Figure 3. GPS Guided Weapons Utilized by US Military Branches

Figure 4 demonstrates a typical weapons installation aboard the F-35 during qualification testing, emphasizing the requirement for consideration of the diversity of weapons systems and their antenna locations relative to the weapons bay.

Figure 4. F-35 Loaded With Different Types of Munitions

## Performance Requirements & Expectations

The state-of-the-art for GPS retransmission systems is such that certain levels of performance and quality are to be expected for any application. The following are the minimum performance criteria that absolutely should apply for a permanently installed solution where the system is optimized for installation on the particular aircraft.

- Optimized Signal Coverage – Optimized GPS signal coverage of the weapons bay can be accomplished given the proper antenna system design and installation.
- 100% Compatibility – 100% compatibility is an absolutely reasonable requirement for GPS retransmission systems. If designed correctly, and appropriate methods are employed to address other system deficiencies – such as excessively high ERP or antenna system techniques to address multipath, GPS retransmission systems should be 100% compatible with any military or civilian GPS receiver utilized by any weapons systems, eliminating the requirement for non-recurring engineering of the stores management software to support GPS data transfer which may be specific to each weapon type.
- Appropriate Signal Level – GPS retransmission systems should be design to provide and maintain, regardless of variations within the GPS signal source, a precise GPS signal level within the coverage area that ensures GPS signal availability within the normal operating range of GPS Receivers.
- Continuous GPS Lock During Separation – Prolonged loss of GPS signal availability by the application receiver should not be observed, the GPS retransmission system should enable a seamless transition to the organic GPS satellite signals.
- High Signal Quality – The GPS retransmission system should be designed so as to maintain the GPS retransmitted signal quality. The Signal-to-Noise ratio of the retransmitted signal should not be degraded more than 3dB with respect to the LOS signal quality available outside of the aircraft.
- Design & Manufacturing Quality – With any aircraft system, a GPS retransmission system should demonstrate compliance to the following US military standards:
  - Electrical Power Service Conditions — MIL-STD-704
  - EMI/EMC — MIL-STD-461
  - Environmental Conditions — MIL-STD-810
  - Human Factors & Personnel Safety — MIL-STD-1472
  - General Safety — MIL-STD-882
  - Software Development Process Quality — RTCA DO-178B, MIL-STD-498
  - Construction
    - Materials, Processes, Parts — MIL-E-5400, MIL-STD-1568, MIL-STD-587
    - Finish & Color — AFSC DH2-2 DN 2A2, MIL-E-5400
    - Soldering — IPC/EIA J-STD-001, Class 3, IPC-A-610, Class 3
    - PWB — IPC-2221, IPC-2222, IPC-6011, IPC-6012, Class 3
    - Interconnecting Wiring — MIL-HDBK-454

## 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:


Brian Paul

Defense Business Development Manager

+011 719.565.8589

Email: bpaul@gpssource.com

Website: www.gpssource.com