

Testing The Precision Lightweight GPS Receiver

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Innovative field testing techniques are employed at Holloman Air Force Base to help the Global Positioning System (GPS) NAVSTAR Joint Program Office (JPO) test the Precision Lightweight GPS Receiver (PLGR). Characterizing the PLGR's accuracy in dynamic environments is of prime importance but testing also prescribes the evaluation of its ability to receive differential GPS corrections, real time, and its Electronic Counter Counter Measures.

To meet these goals, the 46th Test Group provides the C-12 cargo aircraft for flight testing, an instrumented test van for mobile testing, the High Speed Test Track for high velocity testing, a UH-1 helicopter for rotor blade modulation testing, and special PC laptops for ground troop testing. All of these test capabilities utilize Holloman's well instrumented test environments with thousands of surveyed sites validated by the Defense Mapping Agency.

This paper will emphasize the testing techniques that are helping to define Test & Evaluation methodologies for the changing world where Global Positioning with NAVSTAR is becoming a reality.

WHAT IS A PLGR?

PLGR is an acronym for the Precision Lightweight Global Positioning System (GPS) Receiver. It is a hand-held,

self-contained GPS satellite signal receiver used to derive positions, velocities and time. The military is currently reviewing the initial production deliveries of PLGR before proceeding to full rate production. PLGR is revolutionizing the way we navigate in the world. The Military needs PLGRs to be operationally fielded quickly, so a large scale characterization effort is underway, DoD wide, to assess PLGR's unique assets and uncover any operational defects.

The flexibility of PLGR for use in ground vehicles, ships or aircraft is one of its assets, but its best attribute is its low cost and high performance. PLGR has been designed to acquire and interpret the GPS Satellite data while taking into account such things as: the rollover of the GPS week number, satellites that are low on the horizon (5-10 degrees), and working while the "selective availability" mode is active. It boasts an anti-spoofing and anti-jamming capability, as well as the ability to receive differential GPS corrections. Through the use of high density computer chips it gives its user the ability to select one of four different coordinate systems, one of 60 different datums and one of many different types of measurement units. PLGR also has numerous other talents and it is receiving a lot of well deserved publicity for jobs that it can do well.

WHO IS TESTING PLGR?

Jointly, the Army, Navy, and Air Force is combined into a matrix of testing headed up by the GPS JPO at the Space and Missile Systems Center at Los Angeles Air Force Base, California. Together, the team will test, analyze, fix, and test again to maximize our knowledge about PLGR.

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Based on a presentation at PLANS '94

0885/8985/94 \$4.00 © 1994 IEEE

The 46th Test Group, Guidance Test Squadron (GTS), is the Responsible Test Organization (RTO) for the Joint Services GPS user equipment testing. During 1993 and 1994, its T&E mission includes PLGR evaluations.

WHY IS PLGR TESTED?

The 46th GTS' role is to learn about PLGR in field testing in support of the military's production decision. This includes learning how PLGR reacts to differing power levels of various jamming signals and spoofing types, how easily PLGR is implemented into a differential GPS data link scheme, and how effective performance can be with various antennas in static and dynamic scenarios.

WHERE IS PLGR TESTED?

The 46th GTS, part of the Air Force Materiel Command, has been known since 1967 as the Central Inertial Guidance Test Facility, or CIGTF. CIGTF is located on the north part of Holloman Air Force Base, adjacent to the eastern edge of White Sands Missile Range in southern New Mexico. Located in a very stable desert basin, it provides a geologically quiet environment. There are well over two thousand surveyed sites in the immediate area due to the fact that the transcontinental traverse (the Defense Mapping Agency's base reference grid lines) runs through the Range. Along van routes, there are at least nine first order survey sites with distance accuracies of 1 part in 100,000.

Mountain peaks surround the desert floor and become a unique CIGTF asset. They tower from 500 feet to 4,000 feet above the desert basin and give aerial views of incoming aircraft. Directional antennae can supply the RF jamming and spoofing capabilities for various tests. Many test beds can be monitored from these lofty perches which are situated within thousands of square miles of government-controlled air space. This setting provides plenty of room for flight tests, van tests, and troop tests.

The High Speed Rocket Sled Track offers the Test and Evaluation community a tool that bridges the gap between a controlled laboratory environment and real world missile flights. The Test Track is like an outdoor laboratory. It has been very carefully surveyed by the Defense Mapping Agency and boasts superior first order bench marks. The test sled is constrained to follow the track by slippers that curve around the rails. Therefore elevation and crosstrack, as well as downtrack positions are known quantities for all tests. A unique interrupter blade system permits accurate three dimensional position and velocity reference values. Rocket sled testing provides the only reliable and repeatable means of obtaining azimuth accuracy for boost and terminal guidance systems. For the PLGR system, the sled track becomes a mechanism for testing the effects of high speed, high acceleration, and the change in high acceleration.

WHEN IS PLGR TESTED?

The need to quickly identify PLGR's characteristics produces significant time constraints on all the test agencies. PLGR units were delivered to CIGTF in the latter part of September 1993. The first data results are due to the GPS JPO by January 15, 1994 for an In-Progress/Process Review, giving the 46th GTS 3.5 months of Test and Evaluation time. More evaluations are due in February and March, 1994. Added to this calendar schedule is the further requirement that PLGR requires some testing time during periods of Y-code (specially encrypted military) transmissions. The military is aware that Y-code satellite emanations affect the civilian users, dropping their expected accuracies to plus or minus 100 meters, and access to the DoD Y-code are sparingly granted. Adjacent non-Y-code authorized test projects at CIGTF suffer from the affects of Y-code periods, so the PLGR team tries to coordinate their activities with as many other projects as possible.

The Y-code test days are rare windows of opportunity. They require coordination between the RF broadcasting crew, the test vehicle crew, the Satellite Reference Station personnel, and the CIRIS (Completely Integrated Reference Instrumentation System) experts. All efforts are coordinated with a strict time schedule that tells the participants when set events will occur. Each day is planned with the same set of organized events, so that the testers can gain familiarity with

In Static Mode	➡	Helicopter Test
In Static Mode	➡	Troop Test
In Low Dynamic Mode	➡	Van Test
In Med Dynamic Mode	➡	Flight Test
In High Dynamic Mode	➡	Sled Test

Fig. 1. PLGR Test Beds at CIGTF

the proceedings as the days go by. So, whether the test day is on the ground, in a ground vehicle, or on the aircraft, the progression of events is meant to stay the same (refer to Figure 1). Murphy's law, however, will manage to step in and provide unexpected variations. Coordination between the groups is critical, so when all else fails, the encrypted radio messages will flow between the groups as new start times are defined.

HOW IS PLGR TESTED?

The navigation accuracies from PLGR will be tested in five scenarios: troops that hand carry the sets on the ground, troops

that operate the sets in helicopters, van tests where the sets are rack mounted, C-12 aircraft tests where the sets are mounted in racks, and High Speed Sled Track tests where the sets are mounted (see Figure 1). In each of these cases, instructions are given to the PLGRs by the use of a menu input, and the data is recorded by various computers and recording devices.

Each test setting has its own reference system geared to that test. These references involve:

- surveyed bench markers
- CIRIS, which is a non-spoofable Reference information system
- a Rockwell-Collins keyed 3-A GPS receiver in use with the DGPS reference
- a Rockwell-Collins unkeyed 3-A receiver in use with the DGPS reference
- a spectrum analyzer monitoring selected frequencies.

The spectrum analyzer has its own data acquisition system, and is used to monitor and record jamming and spoofing power levels.

In each test bed, the PLGR is given at least four minutes of normal operating time to ensure that it is in good operational condition. Then a special scenario is used to test a critical parameter. Nine different test conditions are rotated and each are tested and evaluated four times for repeatability:

An environmentally clear run

A Jam #1 signal is broadcast

A Jam #2 signal is broadcast

A Jam #3 signal is broadcast

A Jam #4 signal is broadcast

A Spoof #1 signal is broadcast

A Spoof #2 signal is broadcast

A Spoof #3 signal is broadcast

A Spoof #4 signal is broadcast

For each of these tests, the goal is to gather data on various power levels being received by the PLGR units. Figures 2 and 3 depict how the data will be presented and assembled. The

Desired Testing Results	Very Low Level Power	Low Level Power	Med Level Power	High Level Power
Best Jam #1 Navigation Error	results	results	results	results
Better Jam #2 Navigation Error	results	results	results	results
Good Jam #3 Navigation Error	results	results	results	results
OK Jam #4 Navigation Error	results	results	results	results

Fig. 2. Jamming Data Chart

Desired Testing Results	Very Low Power Diff	Low Power Diff	Med Power Diff	High Power Diff
Best Spoof #1 Navigation Error	results	results	results	results
Better Spoof #2 Navigation Error	results	results	results	results
Good Spoof #3 Navigation Error	results	results	results	results
OK Spoof #4 Navigation Error	results	results	results	results

Fig. 3. Spoofing Data Chart

actual data is classified in nature, and could not be presented here, but the charts show how the data can be organized into meaningful categories.

The Jamming Chart will contrast sharply with the Spoofing Chart in the way in which the data is interpreted. This is due to the inherent nature of the data.

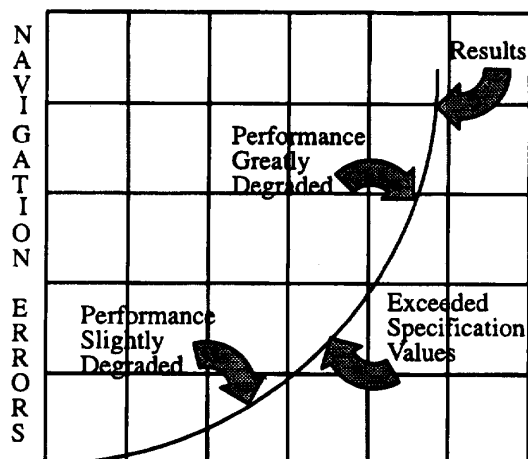


Fig. 4. Desired Information for a Jam Test

HOW IS PLGR EVALUATED?

It is also useful to present the data in plot form showing the various effective power levels which challenge PLGR's capability to keep operating with good navigation solutions (see Figures 4 and 5).

Evaluation criteria for data discrimination between jamming and spoofing are presented below (see Figure 6). Depicted are the major parameters which must be taken into account, collectively, to correctly assign the observed results to the correct cause.

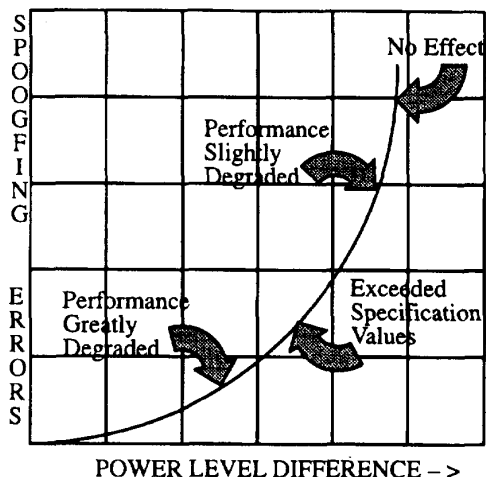


Fig. 5. Desired Information for a Spoof Test

	PDOP value	FOM number	SAT geom	Ephemeris lag	Known disturbance	Multi-path	Higher than expected power	Bit Error increase	Nav solution worse
Clear	OK	OK	OK	No	No	No	No	No	No
Jam	OK	OK	OK	No	No	No	Yes	Yes	Yes
Spoof	OK	OK	OK	No	No	No	Yes	No	Yes

Fig. 6. PLGR Comparisons

Finally the results will be combined into an accuracy chart which will be reported to the GPS JPO PLGR office (see Figure 7).

Some of the constraints encountered by the 46th GTS while testing PLGR in 1993 included:

Sharing test beds with other projects

A constrained time schedule & only 6 PLGRs



Barbara Cosentino has worked as a Physicist for five years earning the award "Most Outstanding Woman in Science and Engineering Field" at White Sands Missile Range from the U.S. Army for work on IHAWK, MLRS, Patriot, and Big Crow. She has worked at Holloman Air Force Base in New Mexico for ten years as an Operations Research Analyst on inertial guidance and navigation accuracy projects such as Small Missile, Advanced Guidance Technology, Trident, Peacekeeper, Lance, and PLGR. She enjoys spending time with her six children and four grandchildren.

	Troops	Van	Plane	Sled	UH-1
Clear					
Jam 1	[ACCURACY	DATA]	
Jam 2					
Jam 3					
Jam 4					
Spoof 1					
Spoof 2					
Spoof 3					
Spoof 4					

Fig. 7. PLGR Accuracy Results

We also have to balance Y-code time spans with non-Y-code times.

SUMMARY OF PLGR TESTING

In field testing, we are trying to match the right type of test with the appropriate test bed to create the right balance between cost effectiveness and sound data evaluations. The collected data has to be carefully evaluated to be useful to the GPS JPO. To access the right information from PLGR, the testing has to be carefully planned, designed, coordinated and documented. Holloman Air Force Base is a good place to test the PLGRs because of the availability of test beds, the unique characteristics of the test area and the 46th GTS/CIGTF's long experience in precision testing and evaluation.

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