ABSTRACT  The Global Positioning System (GPS) has made significant contributions in range instrumentation. It was the prime tracking method for both realtime range safety and metric tracking for the Trident II. Because of its many advantages, GPS will become the primary source of time, space, and position information (TSPI) on the ranges. Many activities requiring precision TSPI have already committed to GPS and others are planning on the application of GPS in the future for use on the ranges. GPS is also an extremely accurate time source, with timing accuracies of 10 nanoseconds obtainable worldwide. The range interoperability problem is solvable through the use of GPS as the TSPI source. There is little doubt that GPS will become the standard TSPI source for all test and training ranges.

Although GPS was designed by the Air Force to be a precision radionavigation system, some of its most significant benefits have been in range instrumentation. It was first proposed by the Navy for metric track determination of the Trident I missile. Although first used for postflight trajectory determination for the Trident I, it has been adopted as the prime tracking method for realtime range safety in addition to the metric track for the Trident II. Because of the limited number of GPS satellites in orbit, the early flight tests had to be conducted at preselected times, but now GPS is close to reality. By using the current satellite constellation (seven useful satellites now in 0 orbit) and augmenting their coverage with pseudosatellites, successful flight test tracking operations can be conducted. More phase II satellites will be available soon (see figure 1, the current satellite launch schedule). Because of its many inherent advantages, GPS will become the primary source of time, space, and position information (TSPI) on the ranges. The Tri-Service Range Applications Program under the management of the Air Force AD/YI is producing a family of GPS hardware specifically designed for test and training range applications. This hardware includes single-channel C/A-code receivers for low-dynamic platforms, single- and dual-channel P-code multiplexing receivers for medium-dynamic platforms, multichannel P-code receivers for high-dynamic platforms, and IRU-aided receivers for ultra-high dynamic platforms. These units can be mounted in 5-inch-diameter pods with datalinks and encryption devices for wing tip installation on aircraft. In addition GPS frequency translator-based tracking systems are being developed for space vehicle and
ballistic missile tracking. These units and systems are currently under development; the program schedule is shown in figure 2.

By using GPS as their TSPI source, the ranges can overcome many of their current tracking deficiencies. The current range tracking systems have severe limitations as follows:

- Radars and other existing tracking techniques are limited in their geographic coverage because the tracking sites must be at presurveyed locations, while GPS may be used worldwide with no geographic limitation.

- Conventional tracking techniques are limited in the number of vehicles they can track simultaneously, while GPS enables any number of vehicles to be tracked at the same time.

- Conventional tracking techniques have historically used independent benchmarks so that all ranges did not have a common grid reference system, causing tracking difficulties as vehicles passed from range to range. Because GPS uses a worldwide standard reference system, vehicle tracking data can be easily interchanged among ranges.

Figure 1. Current Launch Schedules for the GPS Block II Satellites
The accuracy of radar target position data deteriorates with range, while GPS position data is more accurate than radar and does not deteriorate with range.

Conventional tracking facilities are very large and cumbersome and require presurveyed sites, while GPS tracking requires only small portable ground facilities, allowing it to be easily transported anywhere in the world.

Radar, which is generally not satisfactory for tracking ground targets, is not useful for tracking ground-air operational scenarios. GPS, however, provides high accuracy TSPI regardless of altitude.

A wide variety of activities requiring precision TSPI have already committed to GPS. Regardless of the operational scenario, GPS has been selected as the preferred source for TSPI as witnessed by the following activities:

- **Aircraft Flight Testing** - GPS will be adopted for aircraft flight testing on the Advanced Range Data System (ARDS) at the AFFTC Edwards and the MATS at NTC Pawtuxent River.
• SDI Testing - The exoatmospheric reentry vehicle interceptor (ERIS), SDI ground-launched kinetic energy weapon, will utilize GPS for precision-tracking and miss-distance measurement at USAKA, Kwajalein Missile Range.

• Ballistic Missiles - The U.S. Navy’s Trident II program utilizes GPS realtime tracking for range safety during submarine-launched Fleet Ballistic Missile tests at ESMC, Patrick Air Force Base, Florida. It will in the future utilize a similar system for Pacific operational tests at WSMC, Vandenberg Air Force Base, California.

• Space Testing - The SABIR, space-launched kinetic energy interceptor, will utilize GPS for precision developmental test tracking at USAKA, Kwajalein Missile Range.

• At Sea Testing/Training - GPS will be utilized for ship and aircraft tracking as part of the Extended Area Tracking System (EATS) at PMTC, Point Mugu, California, and the Gulf Range Drone Control Upgrade System (GRDCUS) at Tyndall Air Force Base, Florida.

• Electronic Combat Testing - The Electronic Weapons Test Evaluation System (EWTES) at NWC, China Lake, California, has selected GPS for precision vehicle tracking.

• Army Field Training - The Mobile Automated Field Instrumentation System (MAFIS) program at TCATA, Ft. Hood, Texas, has also selected GPS for TSPI of soldiers, land vehicles, and helicopters during battlefield training exercises.

• Both ESMC and WSMC are planning to convert to GPS translator-based tracking systems for range safety tracking in the future.

The preceding activities either have or have on order GPS TSPI systems. There are also a number of activities planning on the application of GPS in the future for their standard range safety and metric tracking systems of the future. These include the following:

• AD
• AFFTC
• AFWTF
• Air Defense Board
• Armor Board
• Aviation Board
• EPG
• ESMC
• Infantry Board
• NATC
• PMTC
• WSMC
• WSMR
• YPG
All of the activities listed above are either using GPS presently or are anticipating its use in the future. In all of the above cases we have been considering GPS as an extremely accurate source of position information. There is, however, another extremely valuable characteristic of GPS, which makes it particularly suited to range applications.

Because of the method in which GPS is implemented, not only does it provide precision X, Y, and H position coordinates, but it is an extremely accurate time source. Timing accuracies of 10 nanoseconds are obtainable worldwide. This means that on extremely large ranges where currently a flying clock is used to synchronize timing sources, a GPS receiver at each location would be a much more practical technique. This would be even more applicable to timing synchronization among ranges where long range tests such as when the cruise missile travels over many ranges during its flight test.

As more long range testing appears to be in future test plans, the question of range interoperability is starting to be considered by the higher echelons of range management. GPS used as the TSPI source makes the range interoperability problem solvable as it provides common grid system among the ranges as well as a common time reference. The IRIG has solved the telemetry range interoperability problems, but the question of independent datalinks presents a serious problem to range interoperability in the future.

There is no doubt that GPS will become the standard TSPI source for all test and training ranges.