GPS: THE LOGICAL TOOL FOR PRECISION TRACKING IN SPACE

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ABSTRACT

As we develop more space vehicles, a pressing requirement emerges to provide precision tracking information. This need for exact time and space-position information (TSPI) persists whether developing and testing space weapons or locating the precise position of intelligence-gathering satellites. Because this is a worldwide tracking requirement, the use of conventional tracking techniques such as radar is precluded. Fortunately the Global Positioning System (GPS) is now in place and can provide the tracking information required. GPS offers two techniques for tracking space vehicles. A GPS receiver can be installed on the vehicle to determine the position that is then relayed to a ground terminal, or a GPS frequency translator can be used to compute the vehicle position at the master groundsite. Since both techniques have been proven satisfactory, the specific tracking requirement determines the method selected.

For the flight tests of the Exoatmospheric Reentry-Vehicle Interceptor Subsystem (ERIS), the GPS frequency translator technique is used. A GPS frequency translator is installed on the target (a reentry-vehicle launched on a Minuteman from Vandenberg), and a translator is also installed on the ERIS, which is launched from Meck Island in the Kwajalein Atoll. The GPS frequency translator approach was chosen for these tests for a variety of reasons, the most important of which were the limited instrumentation space on the target and interceptor, the extreme dynamics of the interceptor, the tracking accuracy required, and the range at which the operation must be tracked.

For the tracking of orbiting satellites, a GPS receiver can be flown on the satellite with its derived position information continuously stored. This data can then be dumped as the satellite passes over a selected groundsite.

Keywords: Global Positioning System (GPS), time and space-position information (TSPI), frequency translator, translator processing system (TPS).

THE TRACKING REQUIREMENT IN SPACE

Precision tracking of cooperative targets in space is primarily required for both test and evaluation and reconnaissance. For test and evaluation, weapons such as ballistic missiles and kinetic energy space weapons must be tracked to evaluate their guidance systems. The targets these weapons seek must also be tracked to measure miss distance of the weapon to verify its performance. As we have seen from the recent Persian gulf conflict, satellite surveillance of the battlefield is extremely important, and for satellite information to be of value, precise position of the satellite is mandatory while it gathers information. There are undoubtedly many more examples of cooperative space vehicle tracking, but this paper is concerned only with orbiting satellites and kinetic energy weapons employed against space vehicles. These two requirements imply precise tracking over long ranges anywhere in terrestrial space.

WHY GPS IS SELECTED

Although the Global Positioning System (GPS) was developed for navigational purposes, it is ideally suited for terrestrial space tracking. The GPS satellite constellation is in place and provides precise position information anywhere around the world. All that is required is a GPS receiver or a GPS frequency translator on the vehicle. With the GPS receiver, precise position is computed onboard the vehicle and retransmitted in realtime or stored for later transmission to a master groundsite. When the GPS frequency translator is used, the satellite signals are received at L-band and retransmitted at S-band to a translator processing system (TPS). The precise vehicle position is then determined, either aboard a space station or at a master groundsite. Both GPS receiver-based instrumentation systems and GPS frequency translator tracking systems have been proven to be very effective.

LIMITATIONS OF GPS AT EXTREME ALTITUDES

Although we have postulated the use of GPS for tracking in space, this is impossible at extreme altitudes above the earth; that is why we have spoken only of terrestrial space. The GPS satellite constellation orbits at about 11,000 miles above the earth's surface (semisynchronous orbit). The directional antennas on the satellites are focused to cover the surface of the earth, so the beamwidth of transmitted L-band signals is such that it subtends an arc of about 6,900 nautical miles at a range of about 14,400 nautical miles. This implies a beamwidth of approximately 27 degrees. The actual beamwidth of the L1 satellite antennas is about 28.6 degrees. The GPS constellation consists of 18 satellites all beaming their signals at the earth. There is a critical altitude above the earth, however, at which signals from four satellites cannot be received simultaneously. Therefore, the use of GPS in space is limited to altitudes below about 1,000 miles above the earth. GPS is entirely satisfactory, however, for tracking ballistic missiles, ballistic missile interceptors, and low-altitude orbital satellites. So as long as we limit ourselves to tracking in terrestrial space below the 1,000-mile altitude, we have selected an effective technique.

RECENT USE OF GPS IN SPACE

GPS has, in fact, been proven as a successful space tracking technique in two Department of Defense weapon system test and evaluation programs. These are the U.S. Navy's Trident ballistic missile program and the Strategic Defense Initiative's exoatmospheric reentry-vehicle interceptor subsystem (ERIS), a ground-launched kinetic energy weapon. For the Trident program a GPS frequency translator-based tracking system is used to track the missile in portions of its ballistic flight in space to gather precision trajectory data for guidance system evaluation. In the ERIS program GPS frequency translator tracking systems are used to track both the reentry-vehicle target, launched on a Minuteman missile from Vandenberg Air Force Base in California, and the ERIS, launched from Meek Island in the Kwajalein Atoll. The precision GPS tracking data is used to evaluate the effectiveness of the ERIS weapon system.

THE FUTURE OF GPS TRACKING IN SPACE

The two programs just described used relatively large GPS frequency translators on the vehicles being tracked. The position data was derived in large ground-based translator processing systems. A typical 40-cubic-inch translator is shown in Figure 1, while Figure 2 shows the large, complex TPS used on the ERIS program. With the advancement of technology, it is now feasible to reduce the size of the GPS frequency translator to 10 cubic inches or less (see Figure 3), and the TPS to a single rack-mounted chassis (see Figure 4). With these possibilities a whole new world of GPS space tracking techniques is now available. Small weapons such as those proposed for Brilliant Pebbles could easily contain a miniature GPS frequency translator, and a small TPS installed in an orbiting vehicle could derive the position of the small weapon and temporarily store it until convenient to dump its data to a groundsite. For orbiting surveillance satellites, a GPS receiver could be flown in the satellite and stored with the surveillance sensor data until convenient to transmit the data to a ground station.

CONCLUSIONS

With the entire GPS satellite constellation almost entirely in place, GPS is ready to be extensively used for test and evaluation. It has already been demonstrated successfully on major programs, and as the hardware developed by the Range Applications Joint Program Office (RAJPO) becomes available, we will see much more use of GPS on the test and training ranges. It is logical, therefore, that GPS be extensively used for precision tracking in space.

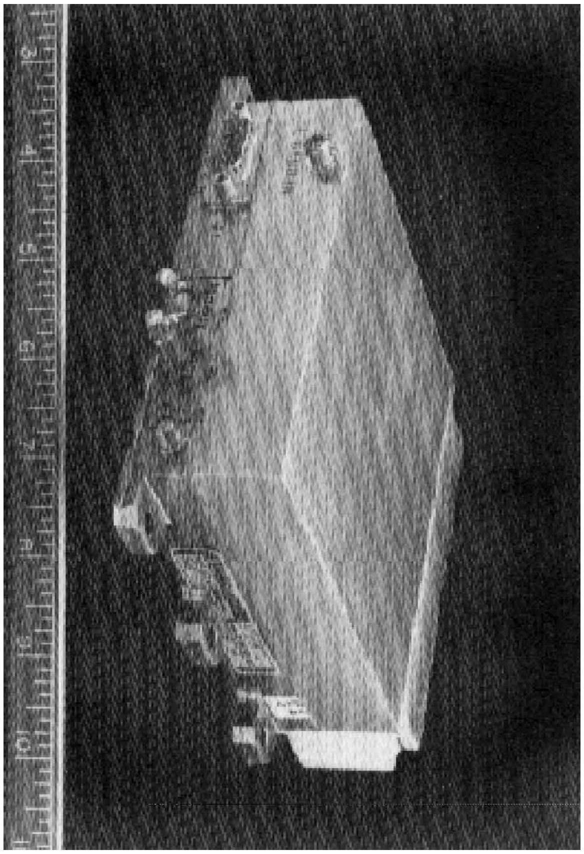

Figure 1. The ERIS 40-Cubic-Inch Translator

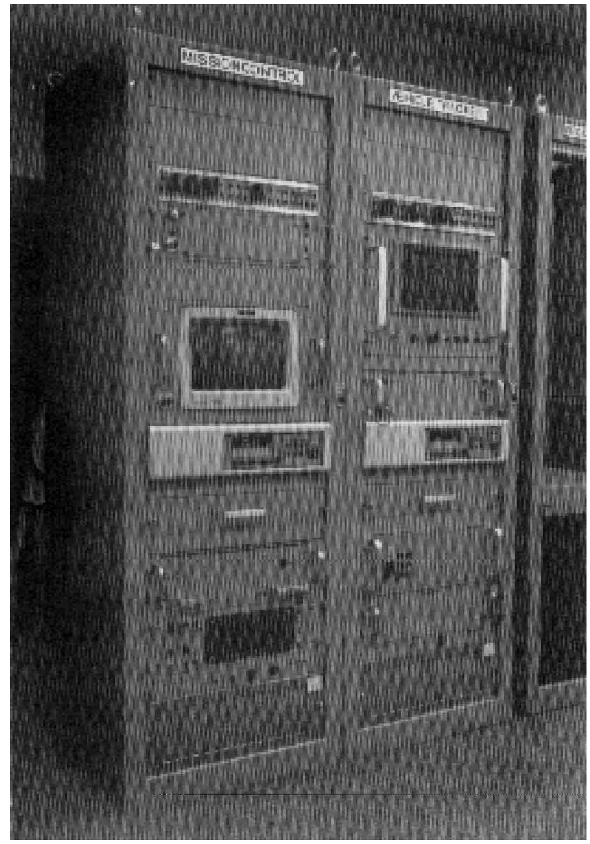

Figure 2. Translator Processing System Single-Vehicle Tracker

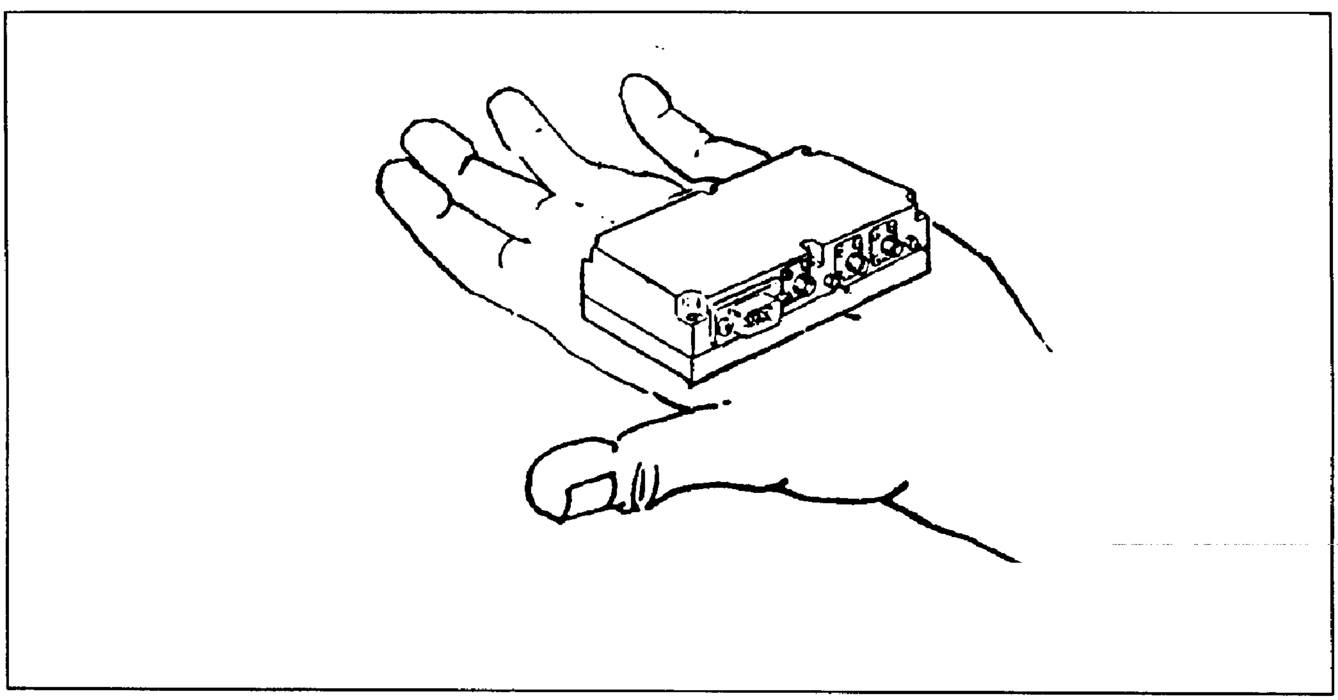

Figure 3. The Miniaturized GPS Frequency Translator (Artist's Conception)

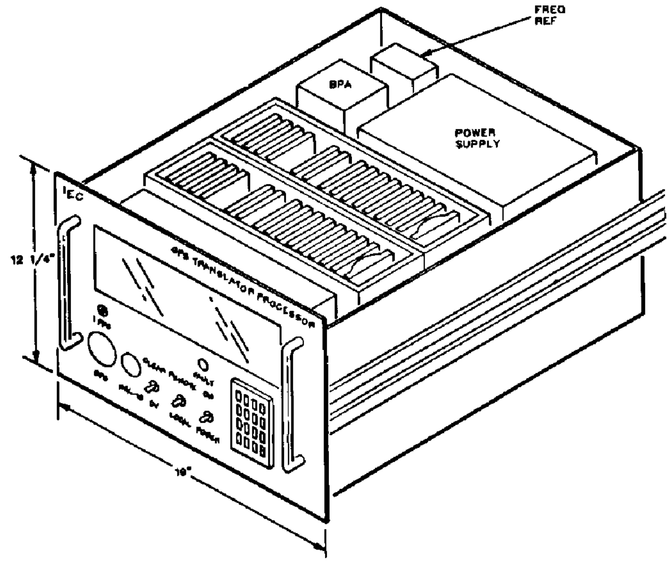

Figure 4. GPS Translator Processor (Artist's Conception)