Abstract submission to IEEE National Telesystems Conference 1994

Title: USING THE GLOBAL POSITIONING SYSTEM FOR EARTH ORBITER AND DEEP SPACE TRACKING

Authors: Stephen M. Lichten, Bruce J. Haines, Lawrence E. Young, Charles Dunn, Jeff Srinivasan, Dennis Sweeney, Sumita Nandi, and Don Spitzmesser

Jet Propulsion Laboratory, California Institute of Technology
Mail Stop 238/600
4800 Oak Grove Drive
Pasadena, California 91109

phone: **818-354-1614** fax: **818-393-4965** email: s]@cobra.jpl.nasa.gov

Abstract

The Global Positioning System (GPS) can play a major role in supporting orbit and trajectory determination for spacecraft in a wide range of applications, including low-Earth, high-Earth, and even deep space (interplanetary) tracking. This paper summarizes recent results demonstrating these unique and far-ranging applications of GPS.

Summary

The U. S. Global Positioning System (GPS) was originally conceived as a navigation and positioning system for military applications. GPS can provide instantaneous knowledge of position to better than 10 meters for military users equipped with an appropriate receiver. However the civilian surveying and space science communities have also begun to utilize GPS for many applications which are considerably more demanding in absolute accuracy than the original military applications. While most civilian users' real-time determination of position and velocity directly from GPS is somewhat degraded due to various restrictions and encryptions placed on the GPS transmissions, filtering and differential estimation strategies enable extremely precise position and velocity fixes to be made from GPS in a post-processing mode where the time delay for the solution may range from minutes to days. This paper focuses on the contribution of GPS tracking data to orbit and trajectory determination of space. vehicles in a wide range of applications, including low-Earth remote sensing satellites, high-Earth orbiters, and even spacecraft traveling through interplanetary Space..

Recent results from the highly successful Topex/POSEIDON GPS flight demonstration show that a satellite in low-altitude (1336 km) Earth orbit can be tracked to a radial accuracy of better than 3 cm (10-15 cm in the other components) with a high-quality flight GPS receiver. The Topex/POSEIDON oceanography mission originally had a 13 cm goal for radial orbit accuracy. The GPS results surpassed that goal, and even rivaled the other operational tracking systems used for Topex - satellite laser ranging and the French DORIS system. To achieve such high accuracy orbit determination, the flight GPS data are combined with GPS data from a global ground network of about 15 sites, evenly spaced around the world. The total turnaround time for data collection and for orbit determination can be as low as a few hours, but is more. typically several days. For Topex (and other low-Earth satellites carrying GPS flight receivers), the. GPS antenna is directed away from the Earth up towards the. high-altitude (20000 km) GPS satellites. GPS visibility is excellent from such low-altitude satellites, with typically - 9 GPS satellites tracked simultaneously from an antenna with hemispherical field of view. Future low-Earth missions are anticipated in the late 1990s where positioning accuracy will be improved to the cm-level in all three dimensions due to various improvements in the flight and ground GPS tracking systems. The most demanding of these missions in terms of measurement accuracy will be using GPS signals for extremely precise measurement of atmospheric conditions and of the Earth's gravity field.

Several less conventional applications of GPS have been studied at the Jet Propulsion Laboratory recently, specifically for tracking spacecraft at much higher altitude or even in deep space. It is these applications which this paper will emphasize. Above - 3000 km altitude, visibility of GPS satellites from an upward looking antenna on a satellite (such as used on Topex) falls off rapidly, due in part to the typically hemispherical (180°) field of view of such antennas. At even higher altitudes, such as geosynchronous altitude, an average of less than 2 GPS can be simultaneously tracked at any given time, but at such high altitudes even this is possible only if the GPS flight antenna is pointed "down" to look past the Earth and track GPS on the opposite side. There are a number of operational complications with the "down-looking" tracking geometry. Nonetheless, analyses show that geosynchronous orbit accuracies in the 50 m range could in principle be achieved (20 m with SA decryption capability). Orbit recovery after a maneuver, however, would require about 4 hrs of data (24 hrs without SA decryption) for a geosynchronous orbiter.

An alternative to the "down-looking" GPS approach is GPS-like tracking (GLT), also referred to as "inverted GPS" in some papers. GLT utilizes a beacon on the user spacecraft and this beacon is tracked in ground GPS receivers along with actual GPS signals. Covariance analyses have been done for several high-Earth orbiters, including one geosynchronous case, which seem to indicate that 5-m quality orbits could be determined for a GLT system where the GPS-like beacon has a footprint to cover the Earth. An experiment is presently being conducted at JPL to track several TDRS orbiters with this technique. For TDRS, the small footprint near White Sands, New Mexico puts a constraint on the orbit accuracy one could expect, since the ground network will be relatively small. The available signal from TDRS which is being tracked in the ground GPS receivers is the Ku-band carrier phase. To recover the longitude orbit component, some ranging information is needed. The plan is to utilize a small amount of White Sands 2-way range data which is collected routinely to provide a coarse check on the TDRS orbit. At the present time, GPS receivers on a rooftop at JPL have detected and tracked TDRS carrier phase from two TDRS orbiters during initial tests. The experiment is expected to be carried out in January or February 1994, with results anticipated within a few months after that. The goal is to demonstrate 50-m orbit accuracy. The use of GPS receivers in a small ground network offers attractive features for a geosynchronous operational tracking system, including the possibility of automated orbit production in near-real time and simplicity in maintenance of the network.

The application of GPS tracking to deep space (interplanetary) tracking has two different facets which are being studied at JPL. One is an extension of the GLT technique for tracking high-Earth satellites. With appropriate system design, deep space probes could send suitable signals towards Earth which could be detected and tracked in ground GPS receivers. Since the ground GPS receivers are part of a global network, they provide a built in and extremely accurate calibration for clock parameters and geophysical parameters necessary for precise trajectory determination, such as ground station coordinates, Earth orientation, and atmospheric delays. In some cases, it will only be possible to track the interplanetary spacecraft with the large deep space network antennas (which are as large as 70 m in diameter). For those situations, nearby co-location of a GPS ground receiver offers most of the advantages of GLT since the geophysical parameters derived from GPS can still be used to calibrate the deep space radiometric data. Time transfer with GPS is more complicated, however. Even if the GPS receiver and the deep space antennas are running off the same clock (a hydrogen maser standard), electronic and cable delays must be calibrated. A GPS calibration and tracking system is presently nearing readiness for implementation at NASA's deep space network. Sample results obtained over the past year will be presented to show the capability of the planned GPS tracking system for providing geodetic, atmospheric, and clock calibrations.