USNO GPS Time Transfer

The U.S. Naval Observatory (USNO) monitors the timing of the GPS to provide a reliable and stable coordinated time reference for the satellite navigation system. The USNO provides two modes of operation to monitor the GPS: the Standard Positioning Service (SPS) and the Precise Positioning Service (PPS). The USNO SPS consists of a coarse acquisition (C/A) code, single channel timing receiver and the processed data are available on the USNO GPS timing data website **http://tycho.usno.navy.mil/gps_datafiles.html**.

SATELLITE CLOCKS

Each Block II/IIA satellite contains two cesium (Cs) and two rubidium (Rb) atomic clocks. Each Block IIR satellite contains three Rb atomic clocks.

GPS TIME INFORMATION

GPS time is given by its **Composite Clock (CC)**. The CC or "paper" clock consists of all **Monitor Station** and satellite operational frequency standards. The system was previously referenced to one of the Monitor Station's operational frequency standards and switched from one station to another as needed. The GPS epoch is 0000 UT (midnight) on January 6, 1980. GPS time is not adjusted and therefore is offset from UTC by an integer number of seconds, due to the insertion of **leap seconds**. The number remains constant until the next leap second occurs. This offset is also given in the navigation (NAV) message and your receiver should apply the correction automatically. As of January 1, 1999, GPS time is ahead of UTC by thirteen (13) seconds.

In addition to the leap seconds, there are additional corrections given in the NAV message. The system time, in turn, is referenced to the **Master Clock (MC)** at the USNO and steered to UTC(USNO) from which system time will not deviate by more than one microsecond (PPS requirement). The exact difference is contained in the NAV message in the form of two constants, A0 and A1, giving the time difference and rate of system time against UTC(USNO,MC). UTC(USNO) itself is kept very close to the international benchmark **UTC as maintained by the BIPM**. **A direct reference to UTC(USNO,MC)** can be made

automatically by most timing receivers. These receivers can be commanded to take the two constants, A0 and A1, from the NAV message for a linear extrapolation to the USNO MC. These constants are updated with the uploads on the basis of USNO PPS monitor information. By means of the information given in the NAV message, and stated in the 1996 Federal Radionavigation Plan (FRP), the SPS user can obtain a time transfer accuracy to UTC(USNO) within 340 nanoseconds (ns) (95 percent) and the PPS user can obtain a time transfer accuracy to UTC(USNO) within 200 ns (95 percent). Decisions to change operational modes of GPS to include degrading GPS accuracy to civil users will be made by the National Command Authorities (NCA).

GPS TIME STEERING

GPS time is automatically steered to UTC(USNO) on a daily basis to keep system time within one microsecond of UTC(USNO), but during the last several years has been within a few hundred nanoseconds. The rate of steer being applied is +/-1.0E-19 seconds per second squared.

USNO TIME TRANSFER DATA

The USNO monitors the timing of the GPS satellites using two types of operation: SPS and PPS. The SPS time differences published by the USNO for the GPS represent the difference between the USNO MC and the GPS CC as recovered from individual satellites and permit a user to increase the precision of timing obtained by monitoring any of these satellites. The SPS time differences are available on the USNO Time Service web site at **http://tycho.usno.navy.mil/gps_datafiles.html**.

All GPS satellites are monitored at USNO, collecting time transfer data for a track period of 780 seconds duration. The individual satellite values published are the result of a linear solution referring to the midpoint of the track period. The 13-minute track period was chosen in order to receive the entire NAV message transmitted every 12.5 minutes that includes the latest ionospheric and UTC information. The individual values are an estimate of the **difference between the USNO MC and the GPS CC (GPS time)** via the individual satellite. The RMS of

the 13-minute solutions ranges between 2 to 20 nanoseconds Block II without **Selective Availability (SA).** When SA was implemented on the Block II constellation, the RMS ranged from 20 to 100 nanoseconds.

The actual performance of GPS time transfers can be seen in these files:

- The last seven days of processed USNO GPS SPS data are available in
  - UNIX compressed or PC zipped format.
  - The data format explanation can be found here.

- The last seven days of processed USNO GPS SPS data in CGGTTS format are available in
  - UNIX compressed or PC zipped format.
  - The data format explanation can be found here.

Daily overall values for the entire constellation are an estimate of the difference between the USNO MC and the GPS CC. These values represent a 2-day filtered linear solution and computed for zero hours UT of the second day and published daily for the preceding day. The RMS of the residuals for the **entire constellation** when SA is not implemented is around 4 to 10 nanoseconds. When SA was implemented, the RMS of the residuals ranged from 40 to 60 nanoseconds for the entire constellation.

TIME TRANSFER TECHNIQUES

Common-view is the use of specially arranged, simultaneous view measurements, that maximize satellite elevation angles between pairs of stations. This accurate method of time transfer includes the participation of approximately 50 international laboratories. Development of the common-view schedules has been the responsibility of the Bureau des Poids et Mesures (BIPM), in Sèvres, France since July 1986. The USNO's current operational GPS SPS receiver is a multi-channel receiver and does not utilize a tracking schedule. However, the Eastern North America common view schedule is located here. We should note that the common-view method extracts a price with a single-channel receiver. It requires a strict adherence to exactly the same simultaneous observations at both locations, a requirement which is not easy to fulfill except at measurement laboratories. The use of common-view will work if the SA does not include the degradation of the ephemerides, but will be even less robust than if SA was not applied.

The method to link the USNO MC to several remote sites is the **Precise Time Reference Station (PTRS)**. Since the common-view requires a strict adherence, we use a smoothing method of all satellite observations for the operational transfer of time to our PTRS. A filtered linear solution, based on all 13-minute satellite observations, allows an estimate of the available precision and is much less sensitive to the slow bias changes in the observation of individual satellites. This procedure has become known as the "melting-pot". The melting-pot method is probably slightly less accurate than the common-view, but is more robust and allows a definitive measure of uncertainty derived from all observations. Since the implementation of SA and a full constellation, approximately 90 satellite observations over a two day period, averaging over all satellite observations for the two day period with a stable clock still allows a very good precision of the filtered mean with great reliability.

REFERENCES:

- *Time Transfer via GPS at USNO, Miranian and Klepczynski, ION GPS-91 proceed.*
- *Time Service Information Bulletin, 16 March 1992*
- *1996 Federal Radionavigation Plan (FRP)*
- *Introduction to Robust Statistics and Data Filtering, Dr. G.M.R. Winkler, USNO 17 May 1993*

US Naval Observatory Home Page

What Time Is It? USNO Time Service Home Page

GPS Home Page at USNO