

GPS Timekeeping



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Two GPS Timekeeping Functions

1. Navigation

- orbit determination/prediction
- internal satellite clock synchronization
- not intended for timing applications.

2. Metrological

- provides traceability to UTC
- support communication systems, banking, power grid management, etc...



GPS Time Products

- **GPS System Time**
 - Internal navigation time scale.
 - Typically the internal navigation system time is only used as part of the navigation solution and is not considered a standard time product.

- **UTC Time** is obtained from GPS by subtracting an integral number of seconds and applying the fine UTC correction information contained in the broadcast navigation data.



Why do GNSS need clocks in space?

- Accuracy depends on precise knowledge of the timing differences between each GNSS satellite and its position in space
 - 1 ns is ~one foot (1/3 meter)
- GPS clock errors grow between satellite updates
 - Currently each GPS satellite is updated at least once per day resulting in errors of less than a few meters
- Better clocks combined with more rapid clock corrections could reduce future GPS system errors to a few decimeters

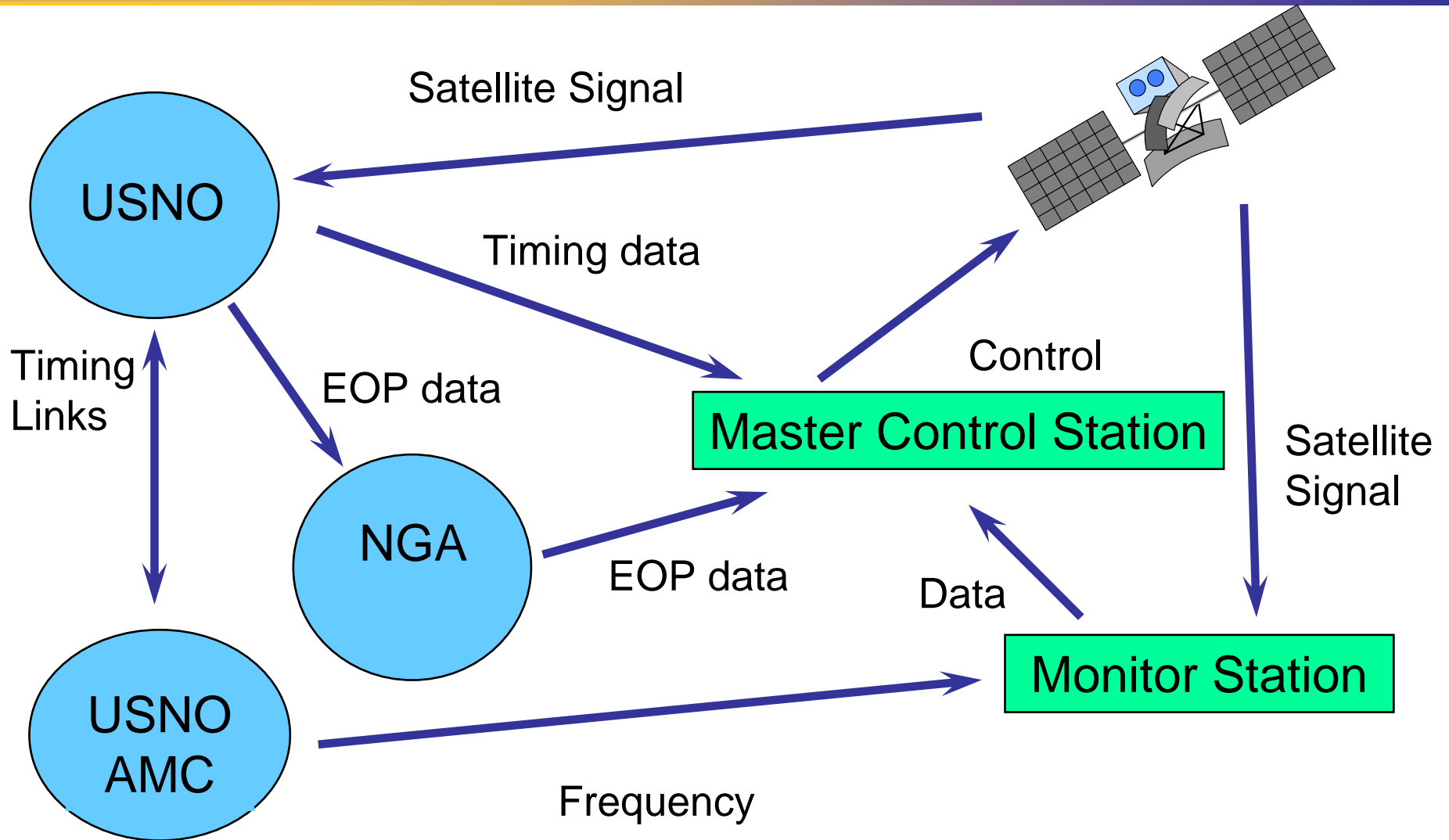


Steering GPS Time

- USNO continuously monitors GPS satellites to provide the GPS Master Control Station with observed differences between GPS Time and UTC(USNO)
- The Master Control Station Kalman Filter (MCSKF) generates its clock solutions using data from system clocks and steers to minimize UTC(USNO)-GPS
- The corrections to create both GPS Time and GPS's delivered prediction of UTC(USNO) are broadcast as part of the GPS navigation message which is applied within a users GPS receiver in a process that is transparent to the user.



USNO Contribution to GPS



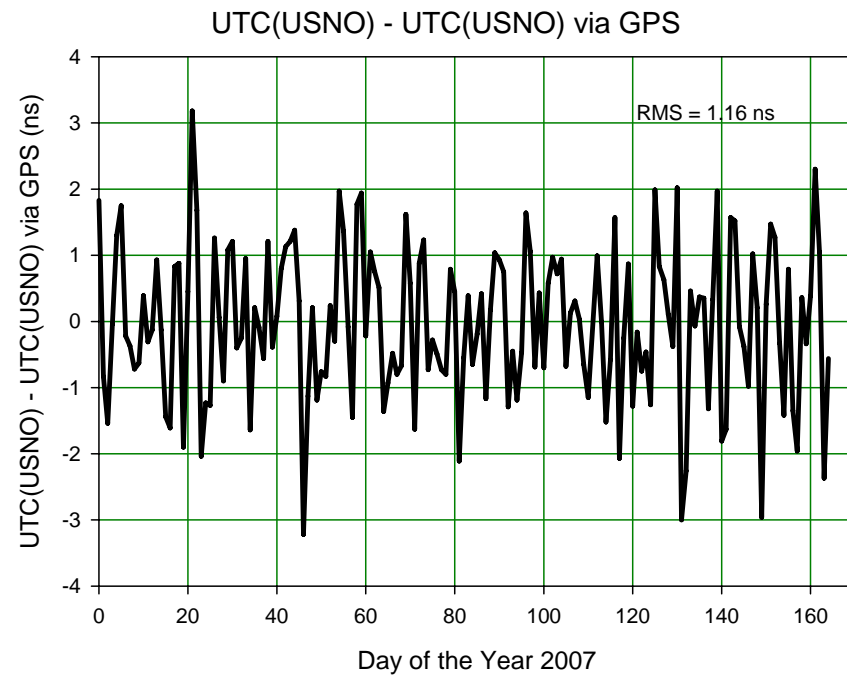
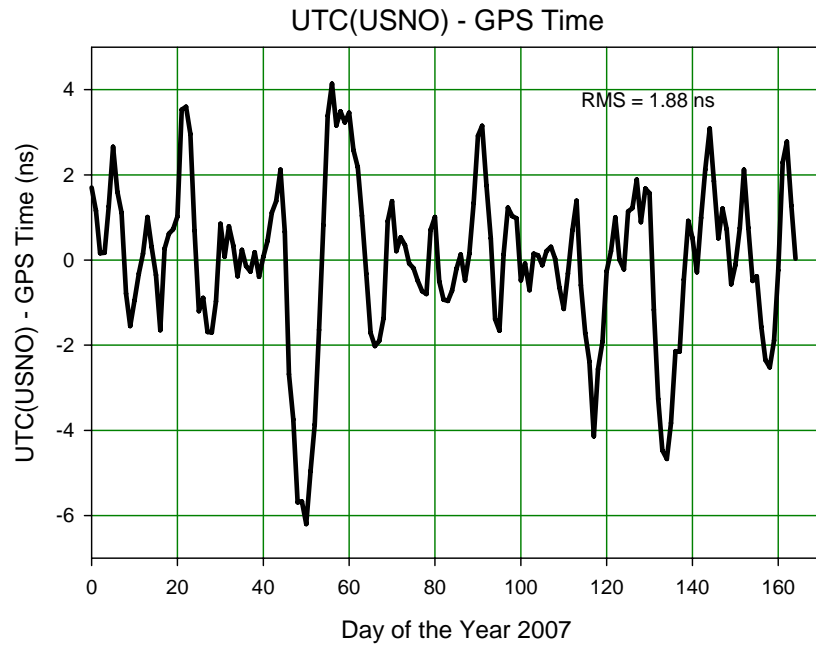


UTC/TAI Timing

- The International Bureau of Weights and Measures (BIPM) coordinates UTC/TAI timing through monthly reports (Circular T) which reports the timing error of contributing timing laboratories over the previous month relative to the UTC/TAI paper clock produced by the BIPM
- Contributing timing laboratories (like USNO) produce a local real time realization of UTC by steering its local realization of UTC/TAI time with a time constant of several months
- GPS Time is then steered to UTC(USNO) with a time constant of approximately one week
- The fine UTC correction broadcast by GPS is updated daily and has an effective time constant of only a few days.



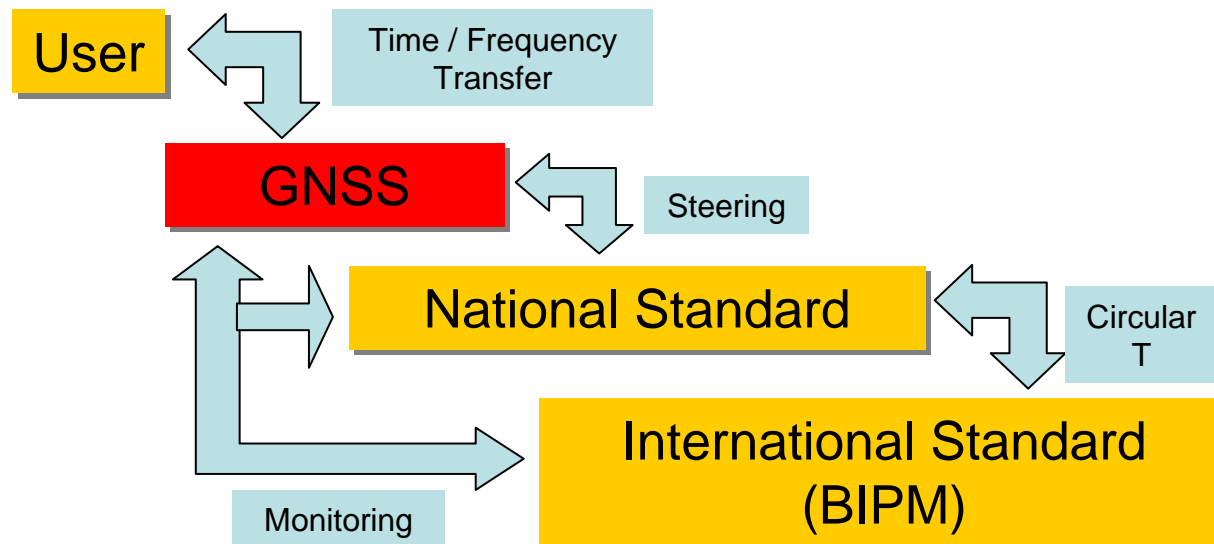
GPS Timing Products in 2007





Traceability

- International Organization for Standardization (ISO) *International Vocabulary of Basic and General Terms in Metrology*, traceability is defined as:
The property of a result of a measurement or the value of a standard whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties.
- The GPS delivered UTC timing service is directly traceable to UTC(USNO) via BIPM Circular T.
- Philosophy is that only a user should decide traceability issues because only that user knows the specifics of their system





Summary

- GPS provides the world a fully traceable UTC timing service
 - Supports communication systems (Cell Phone, telephone, etc...)
 - Power Grid (fault location, phase synchronization, etc...)
 - Banking/Financial transactions
- The GPS UTC Timing service is fully traceable to UTC
 - traceable through UTC(USNO)

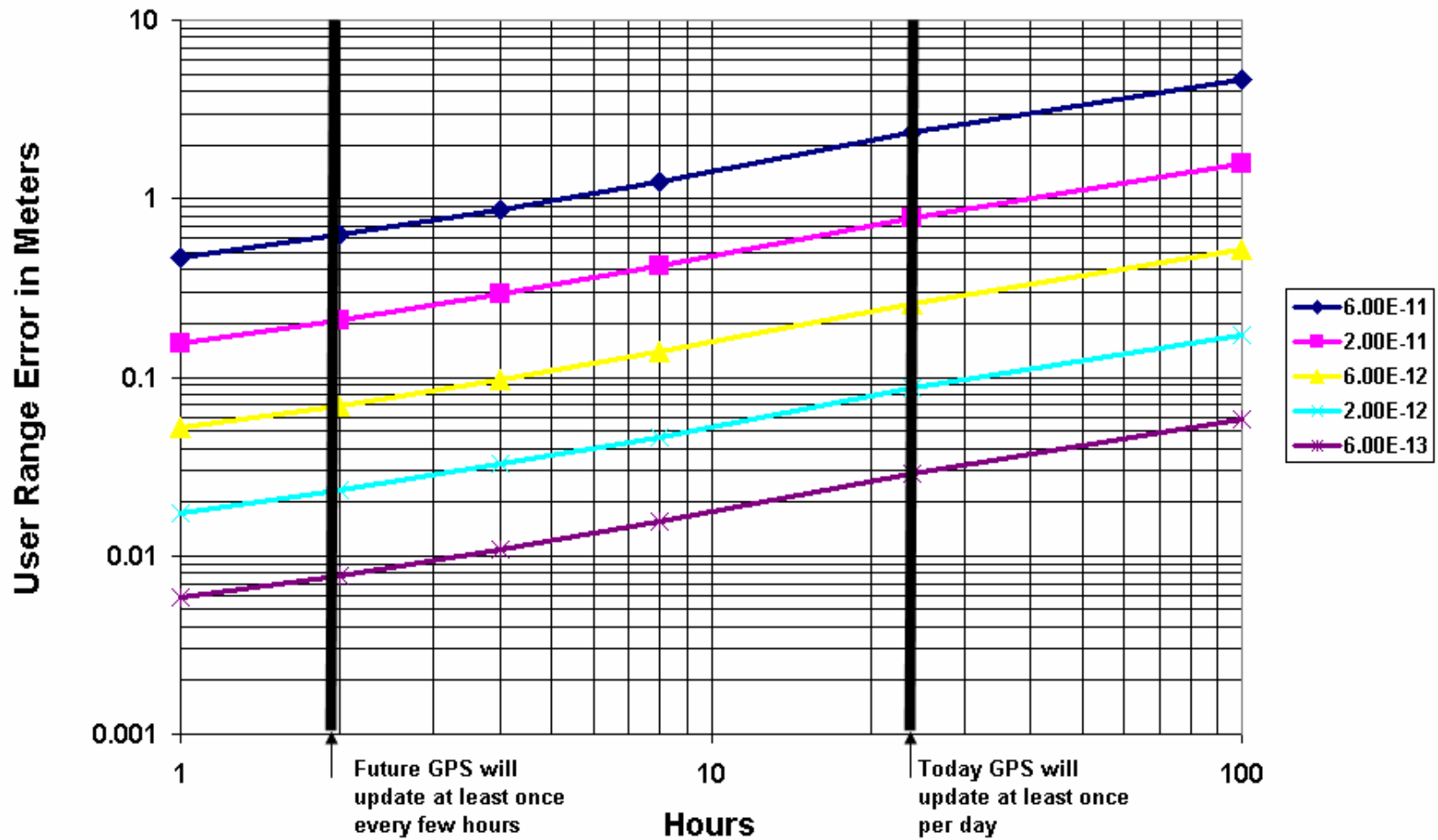


BACKUP



Clock Accuracies

GNSS Space Atomic relationship to update interval





GPS Time and UTC Timing Service

- GPS Time counts in weeks and seconds of a week from midnight of January 5/6, 1980 UTC
- Weeks begin at the Saturday/Sunday transition
- Weeks are counted using 10 bits and roll-over every 19.7 years (1024 weeks - Aug 22, 1999 was last GPS Time rollover)
- The time during the week is determined by counting the number of 1.5 second epochs since the beginning of the week
- The GPS UTC correction defines leap second offset and also contains the precise corrections to UTC(USNO), typically accurate to a few nanoseconds

BIPM Weights by Country

June 2007

