GNSS and GPS Timing Reference

Edward Powers

Global Positioning System

Timing Representative

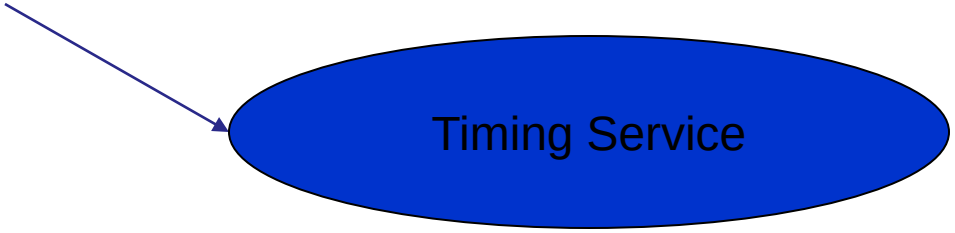
ICG 2015

Boulder Colorado, USA

GNSS Timekeeping Function

- Navigation Timekeeping:
  GPS Time is critical for navigation mission, needed for satellite clock synchronization determination/ prediction and internal satellite clock synchronization not intended for timing applications.

- UTC Timekeeping:
  not critical for navigation, but needed to provide UTC timing services (time dissemination) to support communication systems, banking, power grid management, etc…

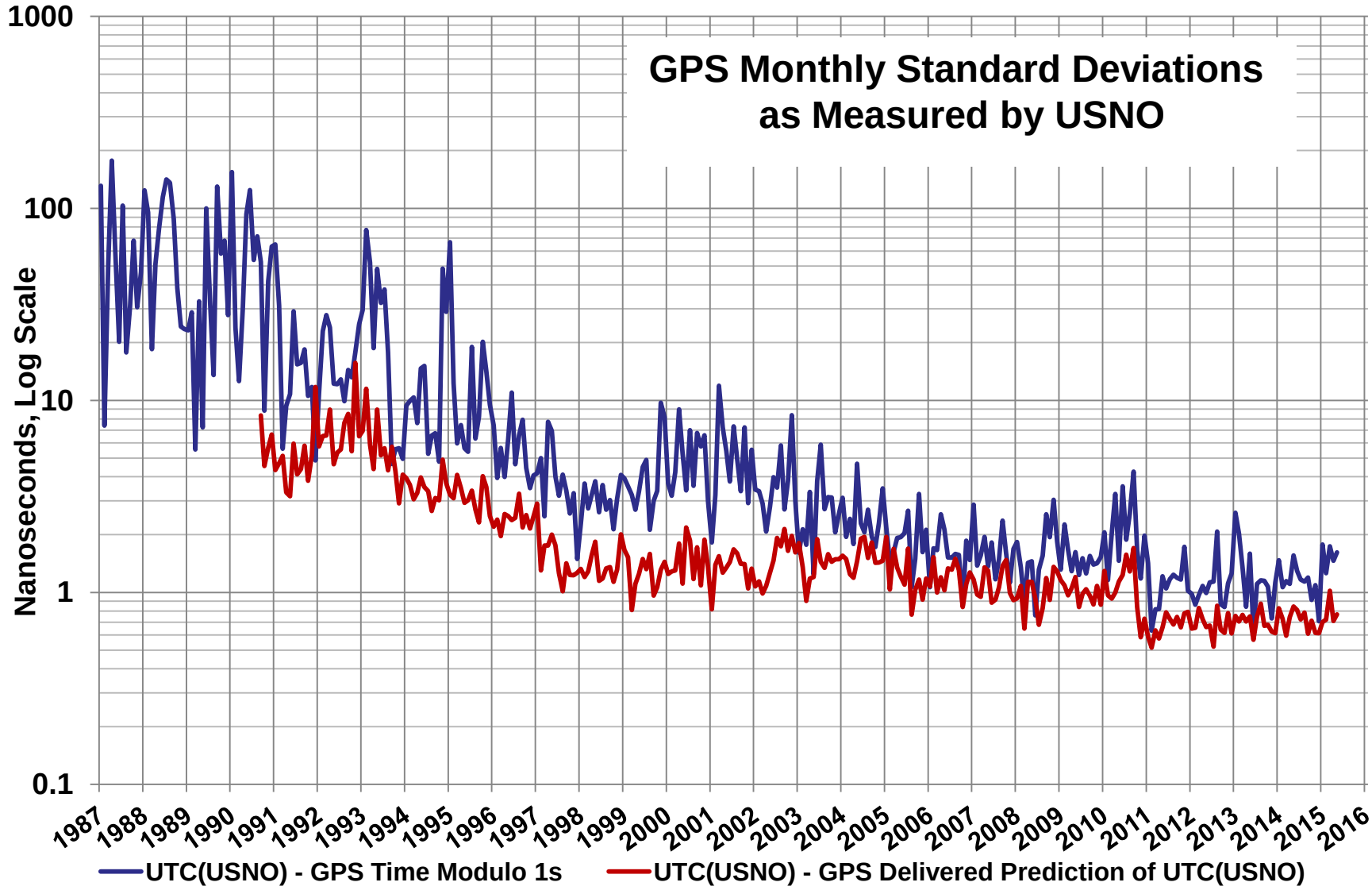


GPS Navigation Time and UTC Time Dissemination Service

- The GPS Internal Navigation Time Scale “GPS Time” is formed by creating a virtual “paper clock” through the weighed average of most GPS satellite and ground station clocks. GPS Time is slowly adjusted to maintain alignment with UTC(USNO) modulo leap second offsets with a time constant of several days. GPS time is used as the reference for the GPS satellite clock correction message that is critical for user navigation solution. Each nanosecond of relative satellite clock synchronization error can add one foot of ranging error (1 ns = 1 foot).

- The GPS Timing receiver applies the UTC corrections message contained in the GPS sub-frame 4, page 18, to produce UTC time traceable to UTC(USNO). This allows the GPS timing user access to the international accepted legal definition of UTC time needed to support many applications. Modernized CNAV and MNAV navigation messages have improved versions of the UTC correction (MT-33). (> 2 ns since 1997)

GPS Monthly Standard Deviations as Measured by USNO



GNSS Navigation Time Scale Interoperability

GPS CNAV Modernized GGTO Message

From GPS IS-200G 2015 will broadcast

- 30.3.3.8 Message Type 35 GPS/GNSS Time Offset. Message type 35, Figure 30-8, contains the GPS/Global Navigation Satellite System (GNSS) Time Offset (GGTO) parameters. The contents of message type 35 are defined below. The validity period of the GGTO shall be 1 day as a minimum.

- 30.3.3.8.1 GPS/GNSS Time Offset Parameter Content. Message Type 35 provides SV clock correction parameters (ref. Section 30.3.3.2) and also, shall contain the parameters related to correlating GPS time with other GNSS time. Bits 155 through 157 of message type 35 shall identify the other GPS like navigation system to which the offset data applies. The three bits are defined as follows;

000 = no data available,

001 = Galileo,

010 = GLONASS,

011 through 111 = reserved for other Global systems such as BeiDou.

GPS/GNSS Time Offset in Modernized Message Type 35

Table 30-XI. GPS/GNSS Time Offset Parameters					
Parameter		No. of Bits**	Scale Factor (LSB)	Effective Range***	Units
A_{0GGTO}	Bias coefficient of GPS time scale relative to GNSS time scale	16*	2^{-35}		seconds
A_{1GGTO}	Drift coefficient of GPS time scale relative to GNSS time scale	13*	2^{-51}		sec/sec
A_{2GGTO}	Drift rate correction coefficient of GPS time scale relative to GNSS time scale	7*	2^{-68}		sec/sec^2
t_{GGTO}	Time data reference Time of Week	16	2^{4}	604,784	seconds
WN_{GGTO}	Time data reference Week Number	13	2^{0}		weeks
GNSS ID	GNSS Type ID	3			see text

* Parameters so indicated shall be two's complement with the sign bit (+ or -) occupying the MSB;
** See Figure 30-8 for complete bit allocation;
*** Unless otherwise indicated in this column, effective range is the maximum range attainable with indicated bit allocation and scale factor.

From GLONASS ICD 5.1 2008 English translation

- GLONASS-M satellite transmitted GPS - correction to GPS time relative to GLONASS time (or difference between these time scales) which shall be not more 30 ns ( ).

- Word τGPS is correction to GPS time relative to GLONASS time. TGPS – TGL = ΔT + τGPS , where ΔT is integer part, and τGPS is fractional part of the difference between the system time scales expressed in seconds.

- Note. The integer part ΔT is determined from GPS navigation message in user receiver (1);

- 00 - C parameter relayed from control segment, GPS parameter relayed from control segment;
- 01 - C parameter relayed from control segment, GPS parameter calculated onboard the GLONASS-M satellite;
- 10 - C parameter calculated on-board the GLONASS-M satellite, GPS parameter relayed from control segment;
- 11 - C parameter calculated on-board the GLONASS-M satellite, GPS parameter calculated on-board the GLONASS-M satellite.

From Galileo ICD SIS issue 1 reversion 1

5.1.8. GPS to Galileo System Time Conversion and Parameters

The difference between the Galileo and the GPS time scales is given by the equation below.

$\Delta tSystems = tGalileo - tGPS = A0G + A1G\,[TOW - t0G + 604800 \cdot ((WN - WN0G)\bmod 64)]$ (s) Eq. 21 with:

- *A0G* constant term of the offset Δ*tsystems*
- *A1G* rate of change of the offset Δ*tsystems*
- *t0G* reference time for GGTO data
- *tGalileo* GST time (s)
- *tGPS* GPS time(s)
- *WN* GST Week Number
- *WN0G* Week Number of the GPS/Galileo Time Offset reference

The GGTO parameters are formatted according to the values in Table 70.

China Published BeiDou GGTO Plans from 2012 published draft ICD

- Time parameters relative to GPS time (A0GPS, A1GPS)
- Time parameters relative to Galileo time (A0Gal, A1Gal)
- Time parameters relative to GLONASS time (A0GLO, A1GLO)
- Listed in Page 1 – 6, subframe 2

GNSS to GPS Time Scale Offset (GGTO)

- With visibility of signals from multiple satellites from two or more Provider systems, a GNSS user receiver can autonomously determine system time differences. We anticipate that in almost all use cases the user receiver will estimate the GGTO time differences as an additional parameter (*fifth unknown*).
- The main purpose of GGTO message is for navigation when only a few signals from two or more systems are first available, i.e., GNSS user operating with limited view of the sky, such as urban canyon users, or to provide an initial seed value to aid the user receiver GNSS estimation process.

Recommendation

- ✓ *To enhance the ability for the Providers to produce accurate GGTO messages and to allow for extended validity period up to one day, the Providers should maintain a stable navigation time scale, referenced to UTC modulo whole second difference. The level of alignment of the Provider's navigation time scale to UTC should be documented in published system level interface documents and performance specifications. The level of alignment should be as good as practicable but completely up to the Provider to set the tolerances.*
- ✓ *The Provider using multi-GNSS reference station receivers can compute the GGTO value(s) independently of the other Providers. The exact definition of each Provider's GGTO message(s) should be documented in published system level interface documents and performance specifications.*