GNSS Time Reference

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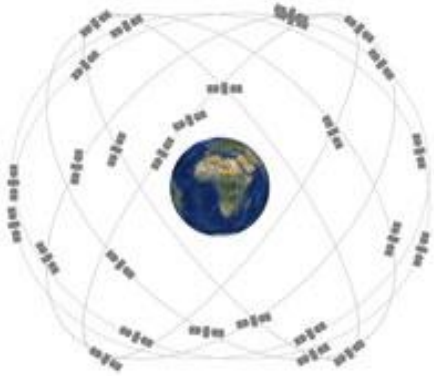
Agenda

- Status of constellation
- Time references
- Reliability and accuracy
- Conclusion



The status of the four Global constellations

THE GNSS NETWORKS

The Status of Constellations

Constellation	GPS	GLONASS	BEIDOU	GALILEO
Status	Operational	Operational	Partial Operation	Partial Operation
Satellites	31 (24 available 95% of the time)	28 (24 required for global coverage)	20 (35 planned, 27 for full coverage	10 (30 planned for global coverage)
Frequency	L1 1575.42 MHz L2 1227.60 MHz	G1 1602 MHz G2 1246 MHz	B1 1561 MHz B2 1207 MHz	E1 1575.42 MHz E6 1278.75 MHz
Coding	CDMA	FDMA	CDMA	CDMA
Performance Standard *(Published)*	C/A code ~ 5-10m (95%)	SP Signal ~4-7m (95%)	Public Signal 25m (95%)	Open Service ~15m (95%)
Modernization Plan	Modernization SV (as of Nov 2013) GPS-IIR-M (with L2CS) GPS IIF (w/ L2CS & L5)	Modernization plan add CDMA & triple frequency	Global FOC (Phase III) by 2020	Full Operational Capability (FOC) by 2020

TIME REFERENCE

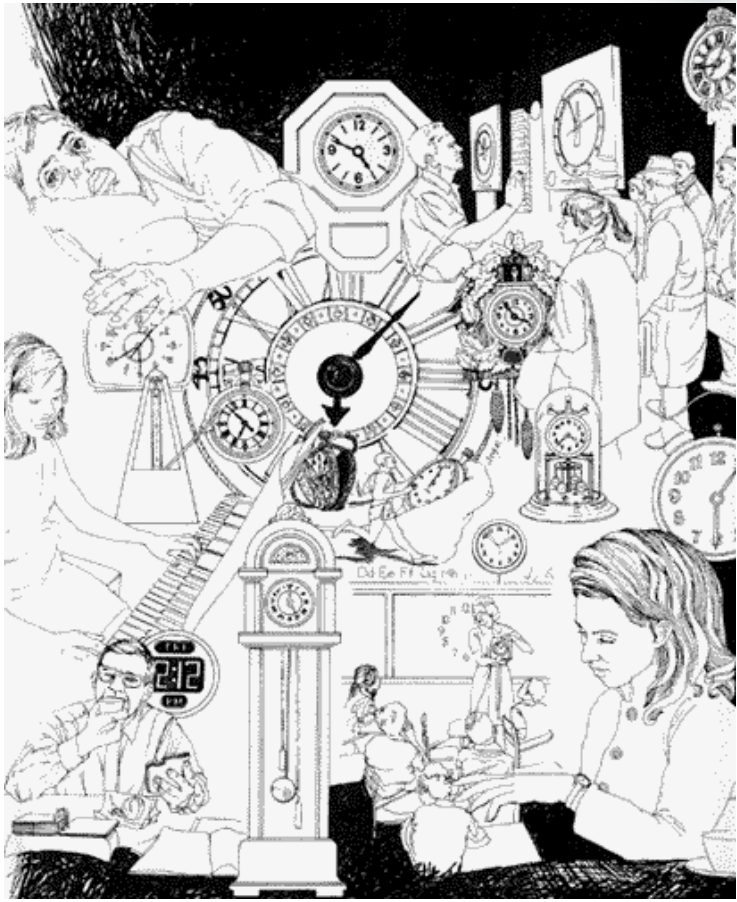


Photo: www.nist.gov

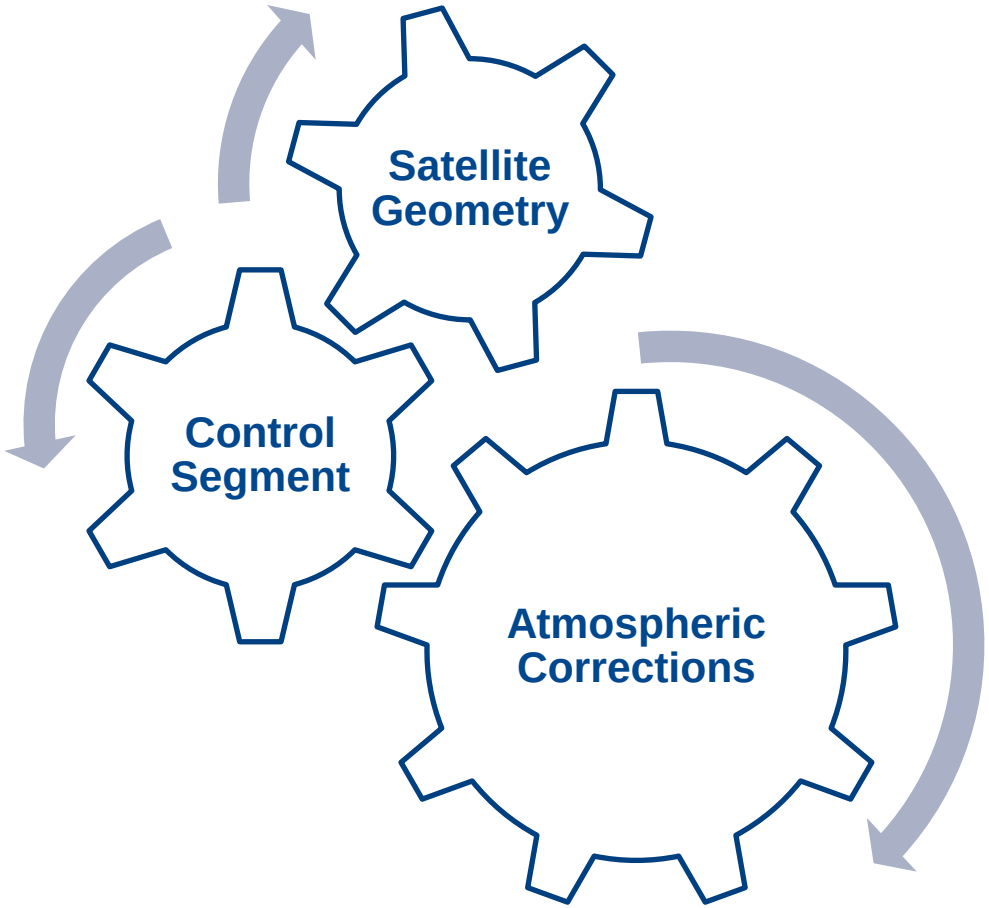
GNSS Time Formats

Constellation	GPS	GLONASS	BEIDOU	GALILEO
Launch	First launch 1978 Fully operational 1995	First launch 1982 Fully operational 2011	First launch 2000 Fully operational 2020	First launch 2011 Fully operational 2020
Constellation Time Format	**GPS Time** Continuous timescale, starting on Jan 6, 1980	**GLONASS Time**	**BeiDou Time** Continuous timescale, starting on Jan 1, 2006	**Galileo Time,** Continuous timescale, starting on Aug 22, 1999
Standard Time Format	UTC (USNO)	UTC (SU)	UTC (NTSC)	TAI
Relation with UTC	UTC = GPS ± Leap Second	GLONASS Time = UTC (SU) + 3 hours	BDT = UTC (NTSC)	UTC = GST + ΔSeconds
Relation with other GNSS	No conversion to other GNSS system **New message type-35** in ICD version G. For time offset only for GLO and GAL	Currently no conversion to other GNSS systems	Other GNSS time can be derived from Beidou	Other GNSS time can be derived from Galileo

PERFORMANCE

Position & Time Accuracy

Factors affecting GNSS accuracy



There are a few things that effect GNSS position and timing accuracy. Significant are:

- Better Geometry yields a better survey position
- Accuracy and maintenance of uploaded ephemeris, almanac, clock bias, and frequency bias
- Atmospheric corrections

GPS vs. GLONASS

Satellite Geometry

- Constellation geometry gives GPS an advantage over GLONASS
- GLONASS has better constellation geometry on higher (polar) latitudes

Control Segment

- GPS has 19 Control stations in 14 countries
- GLONASS has Control stations in the former Soviet Union territory and Brazil

Atmospheric Corrections

- GPS transmits ionospheric corrections
- GLONASS does not transmit any ionospheric corrections

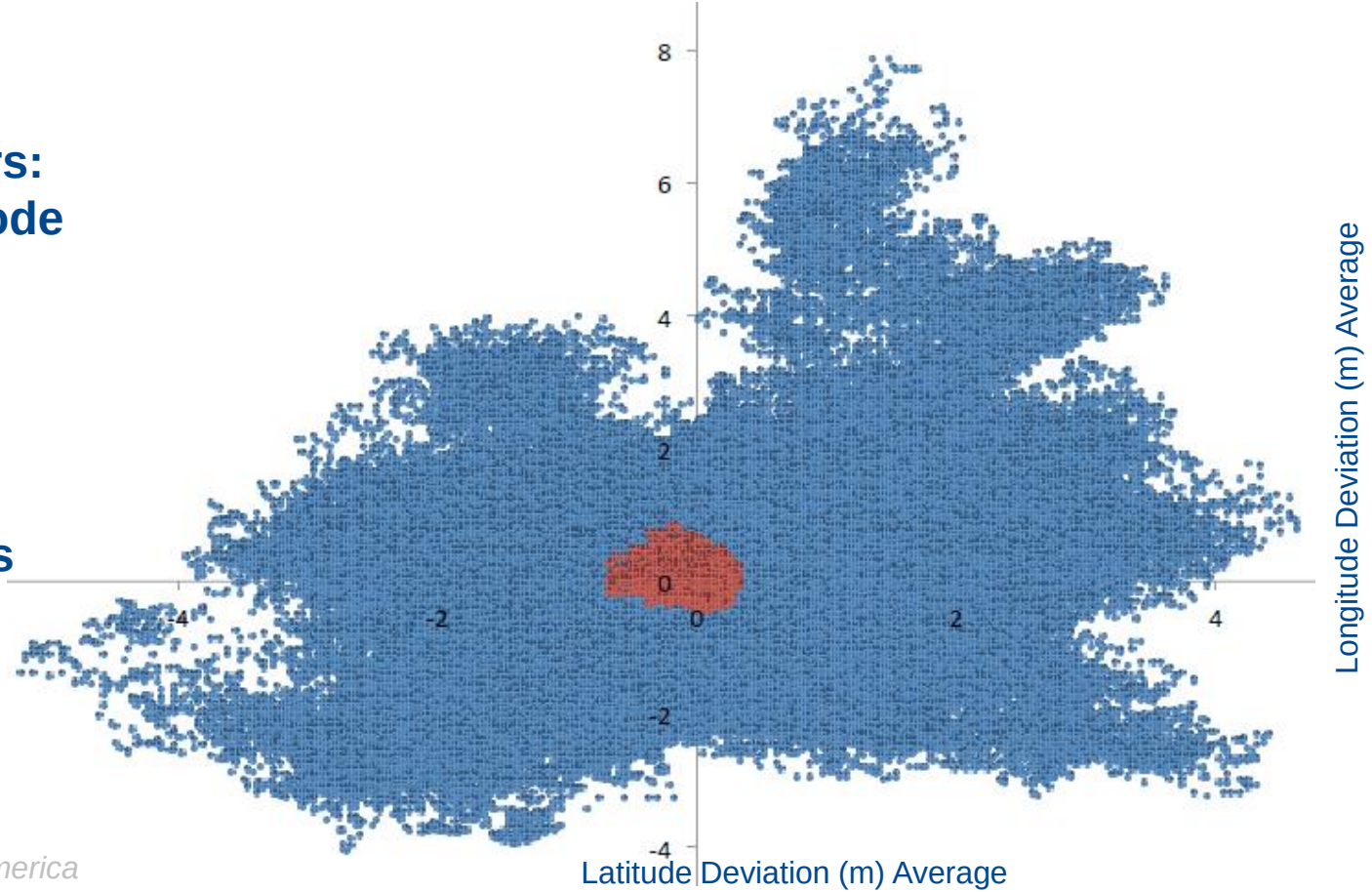
The GPS constellation provides better position & timing accuracy than GLONASS.

GLONASS accuracy can be improved by using GPS satellites in computations

GPS vs GLONASS Position Precision

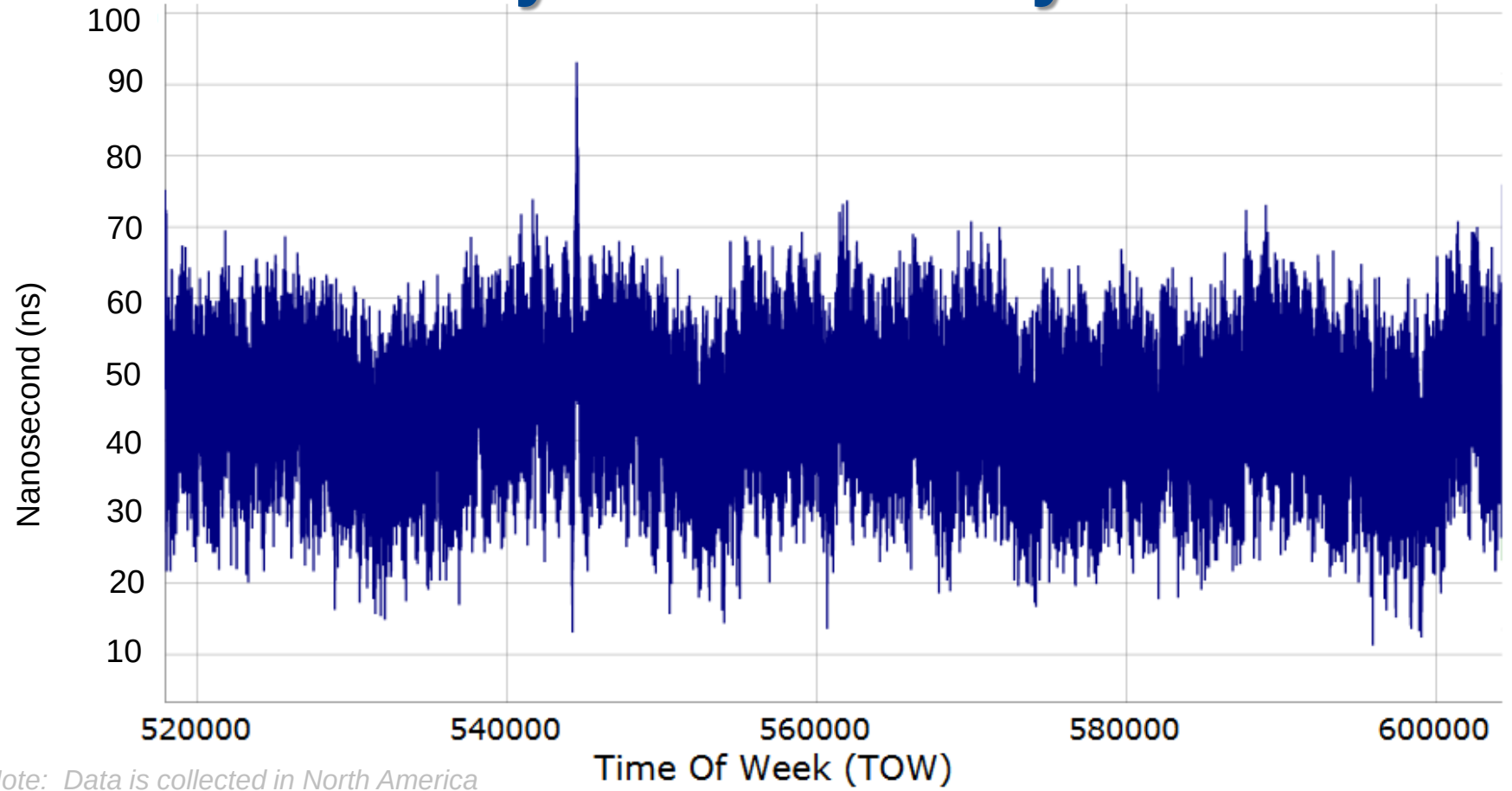
This is a 48-hours data of two receivers: one in GPS-only mode other in GLONASS-only mode.

The blue area is GLONASS position fixes and red area is GPS position fixes.



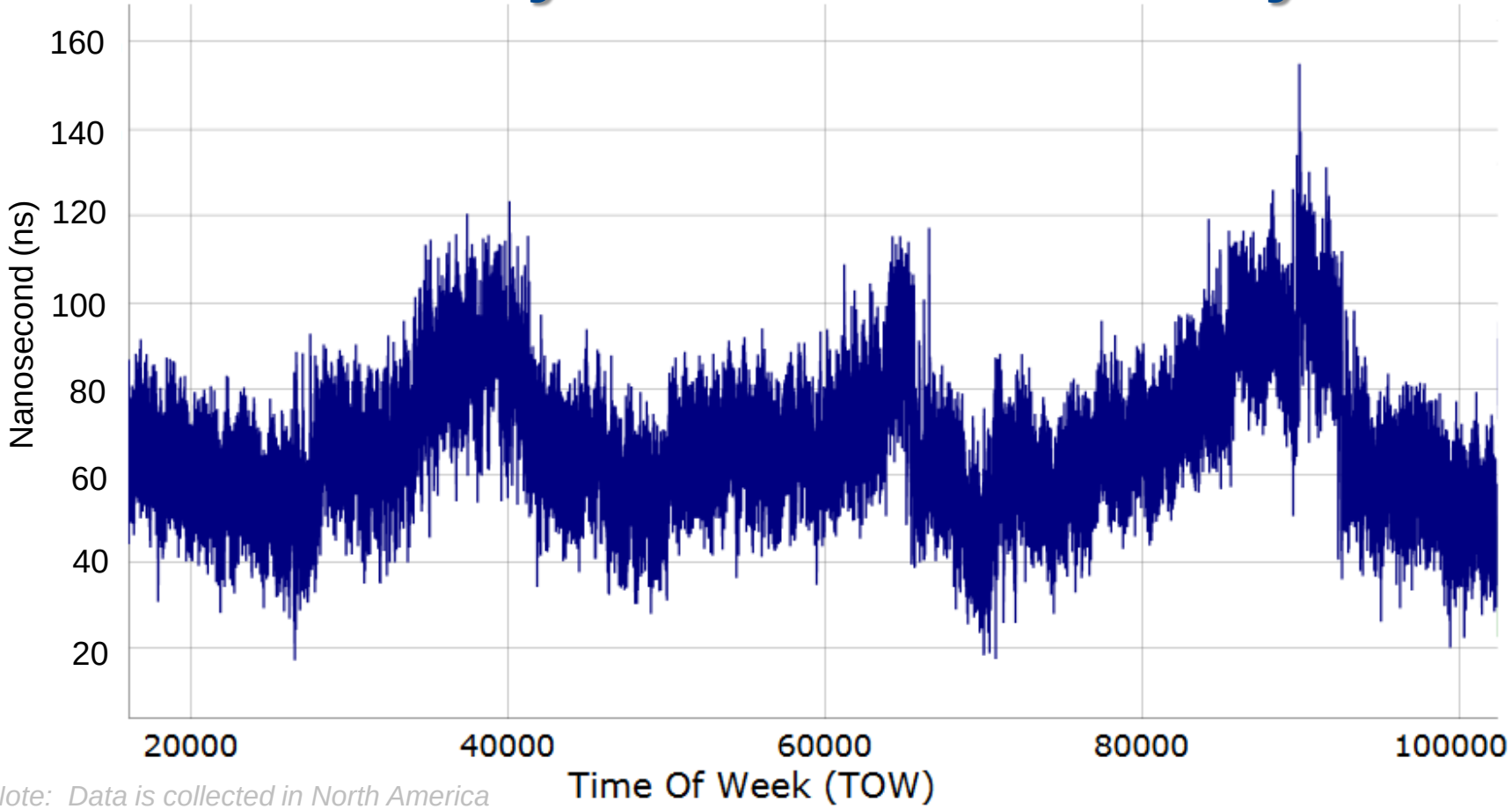
Note: Data is collected in North America

PPS Accuracy with GPS only



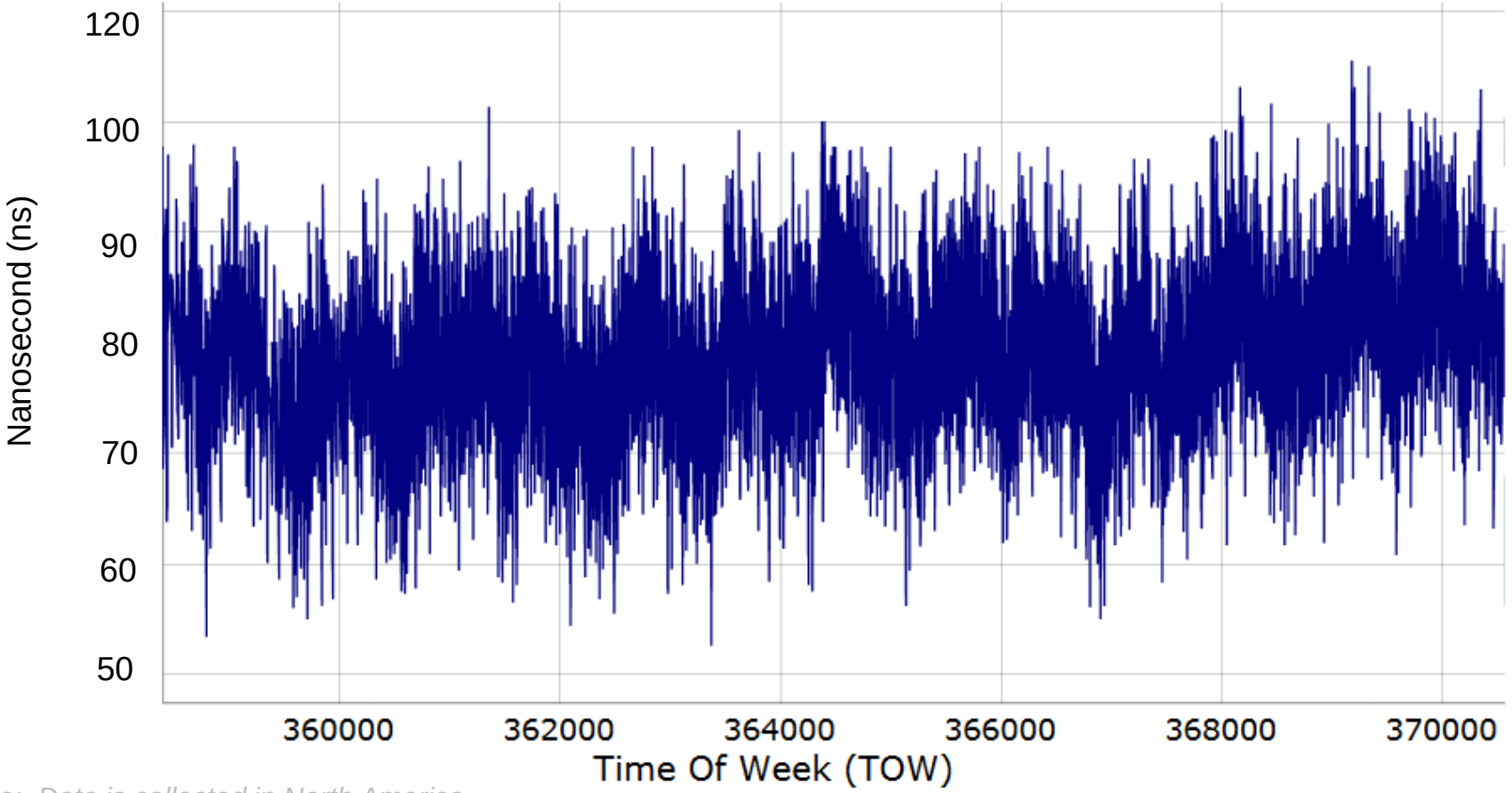
Note: Data is collected in North America

PPS Accuracy with GLONASS only



Note: Data is collected in North America

PPS Accuracy with GPS & GLONASS



Note: Data is collected in North America

Conclusion

- Position accuracy translates into time accuracy
- GPS control segments maintain very tight tolerances and, due to additional control segments, GPS currently provides the most reliable and accurate worldwide coverage
- Adding GPS satellites to any timing solution (GLONASS/Beidou) will improve the accuracy of the time reference