



Report From the
U.S. Naval Observatory

Timing Session of the
Civil GPS Service Interface Committee (CGSIC)
September 16, 2013
Nashville, Tennessee



DoD Directive 4650.05 (2008) and 4650.07 (2012)



The Secretary of the Navy shall direct the U.S. Naval Observatory to:

- Develop and maintain the standards for Precise Time and Time Interval (PTTI) services, earth orientation parameters, and the celestial reference frame for the DoD Components
- Provide representation to PNT committees and working groups, as necessary
- Serve as the DoD PTTI Manager for all DoD systems

*Maintain the Master Clock for DoD and
US government PNT systems*



USNO Master Clocks



Master Clock Washington, DC

- 66 High Performance Cesiums
- 37 Cavity-Tuned Masers
- 4 Rubidium Fountains

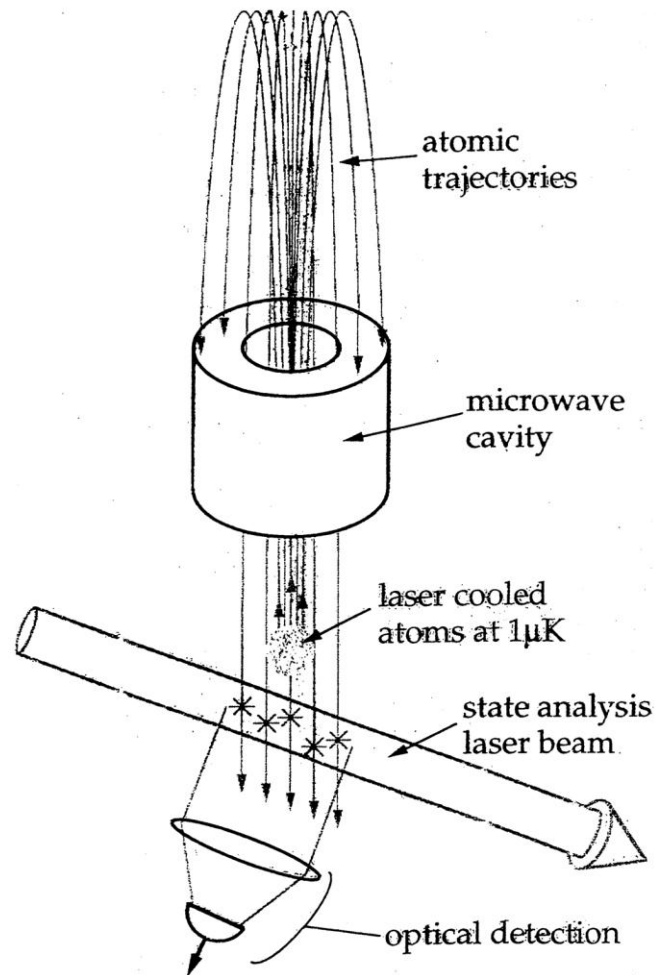


Alternate Master Clock Schriever AFB

- 12 High Performance Cesiums
- 4 Cavity-Tuned Hydrogen Masers

Rubidium Fountains

Full Operational Capability: FOC 27AUG13



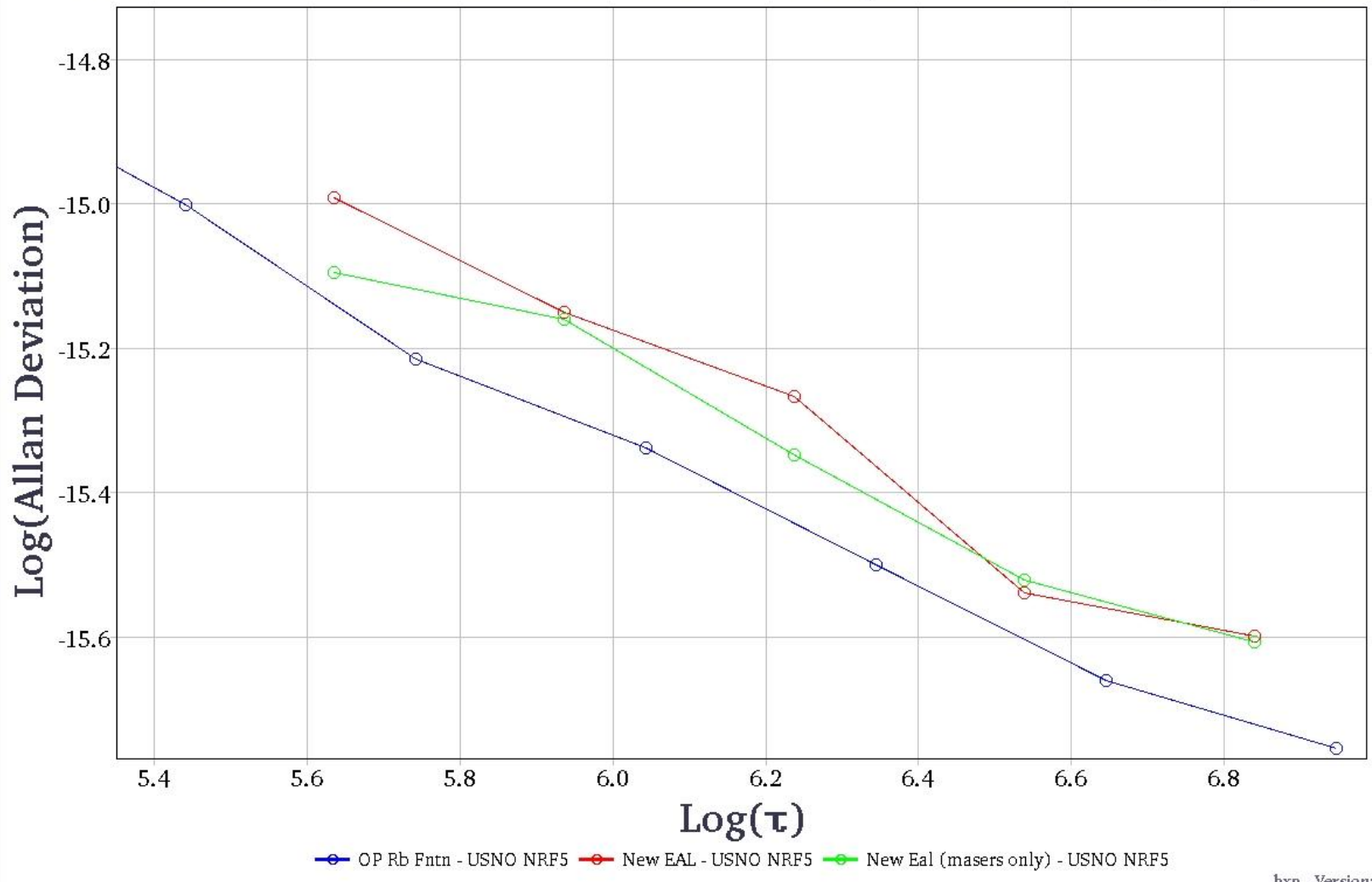
Source: Chris Ekstrom



the times they are a'changin ...



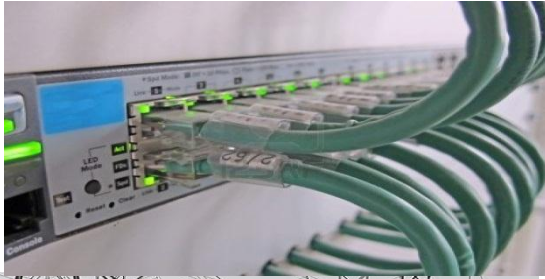
New EAL with and without Cesiums, and OP Ftn (PPP,NRF5)





GPS Time Transfer

GPS and USNO Provided Precise Time and Time Interval (PTTI) Support



Communications



Power Grid



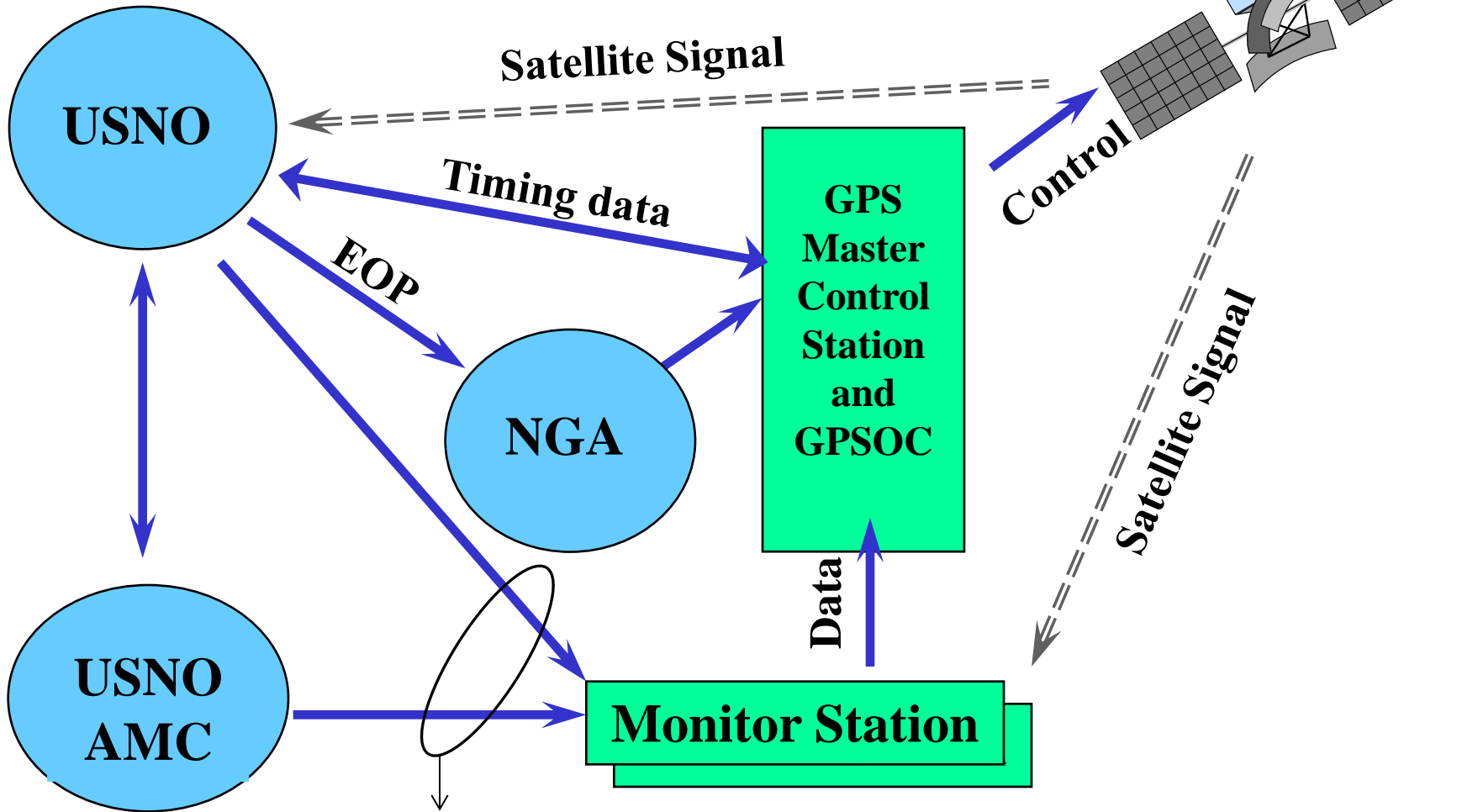
Banking



Scientific



USNO Contribution to GPS



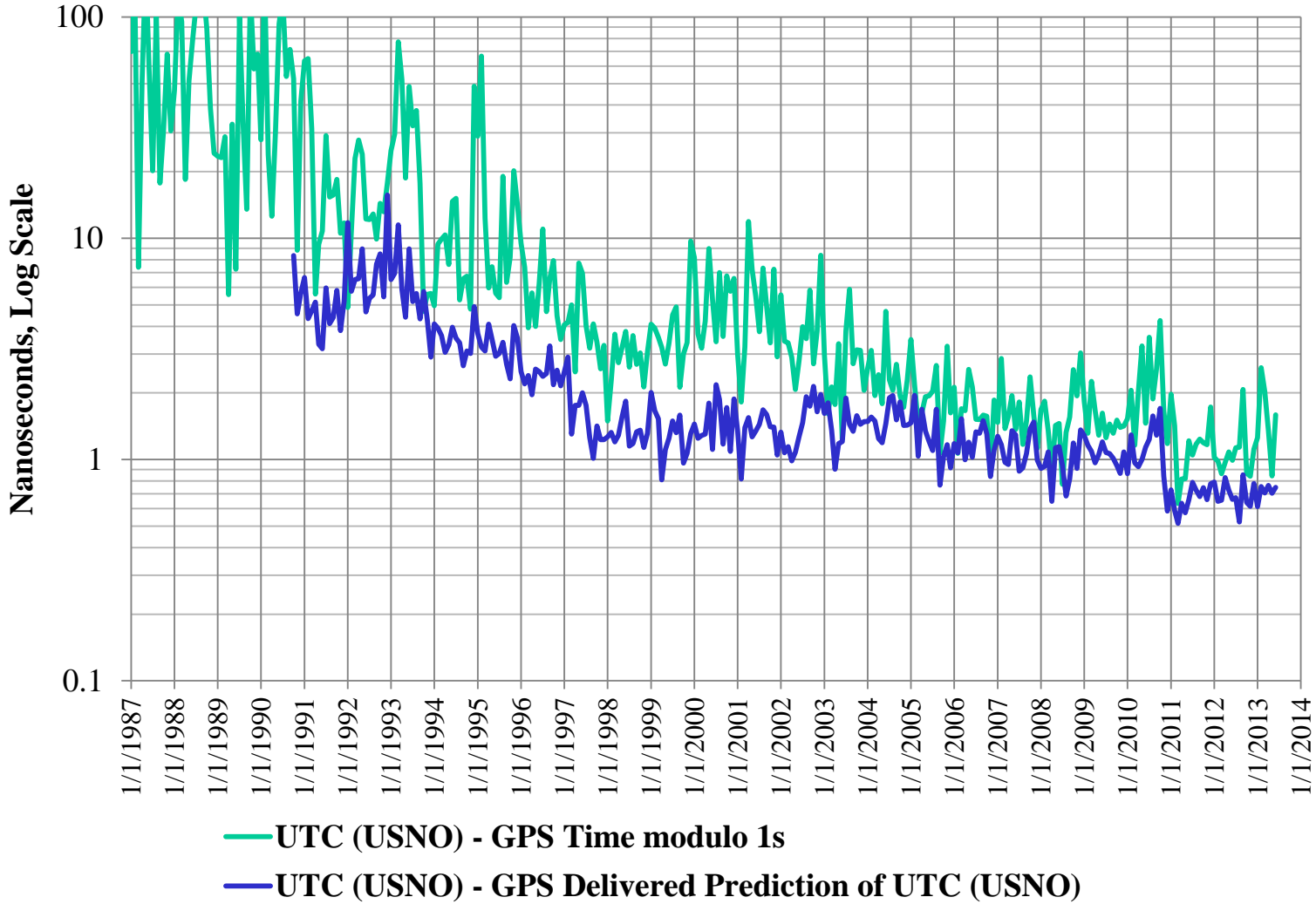
Time and Frequency Signals



GPS Timing Service Since 1987



GPS Monthly Standard Deviations as measured by USNO



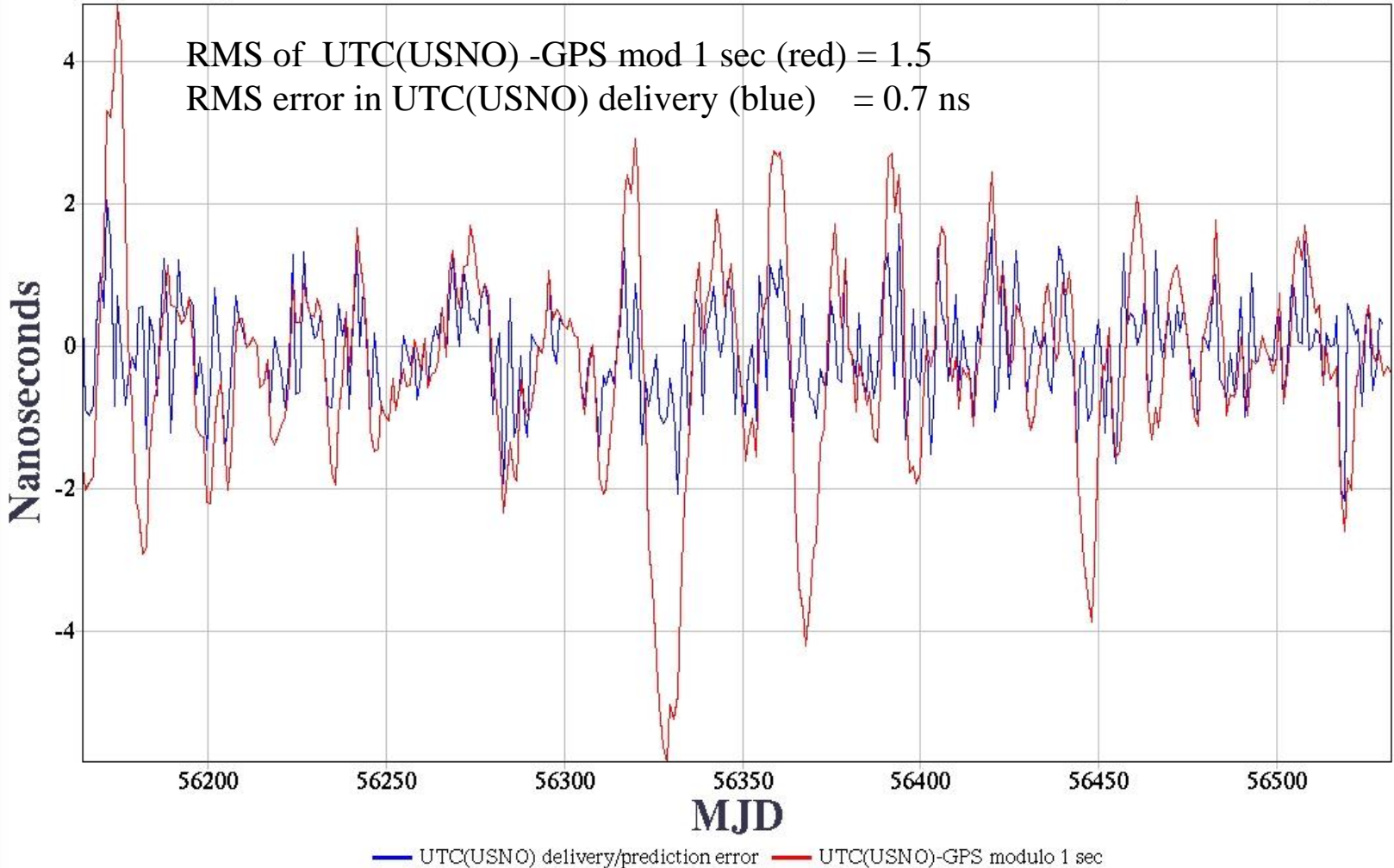


GPS Time Transfer Performance

8/26/12-8/26/13



Delivery of UTC(USNO) and GPS Time modulo 1s, daily averages last year

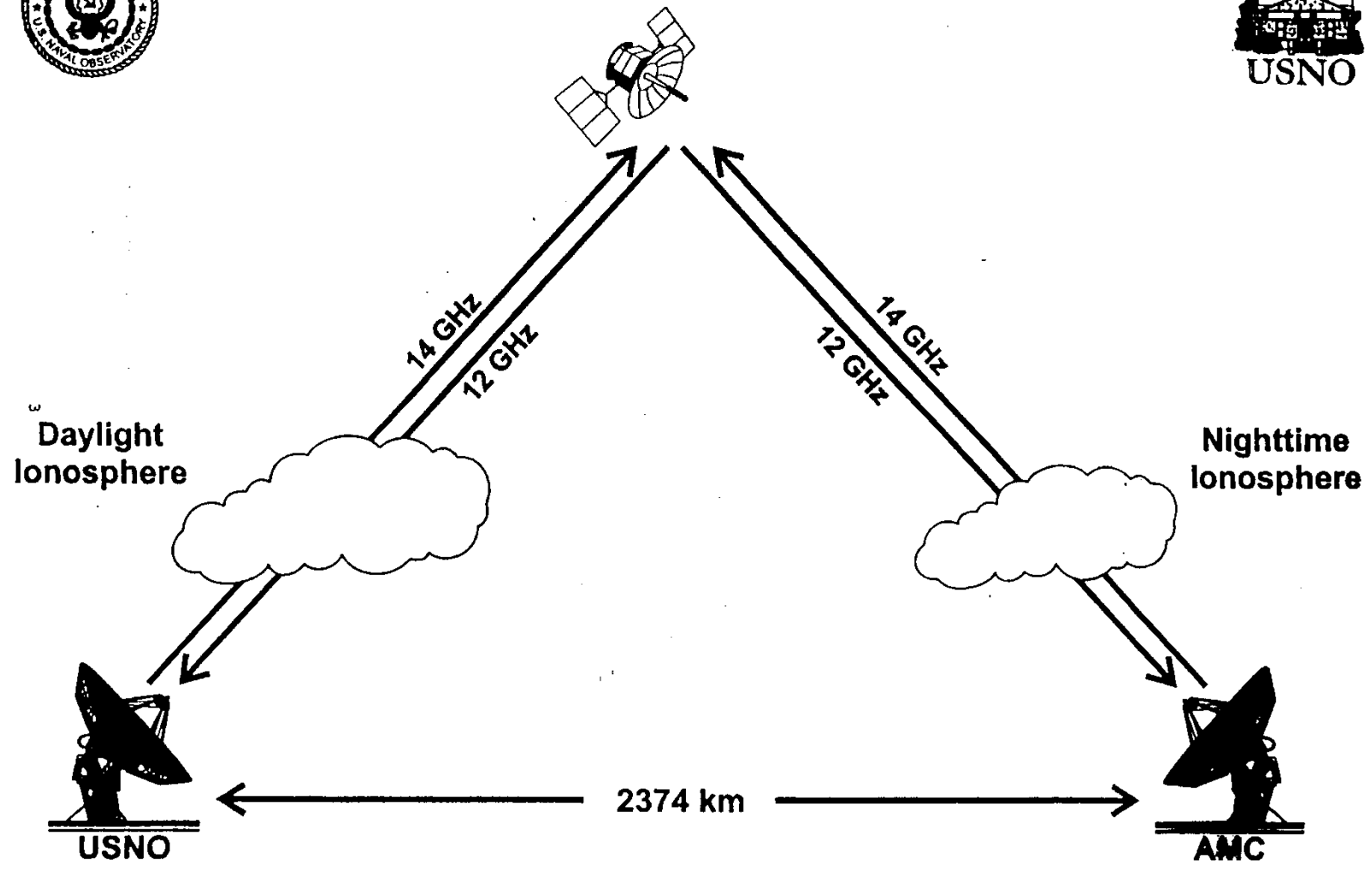




TWSTT Time Transfer



Two-Way Satellite Time Transfer





TWSTT at a Glance



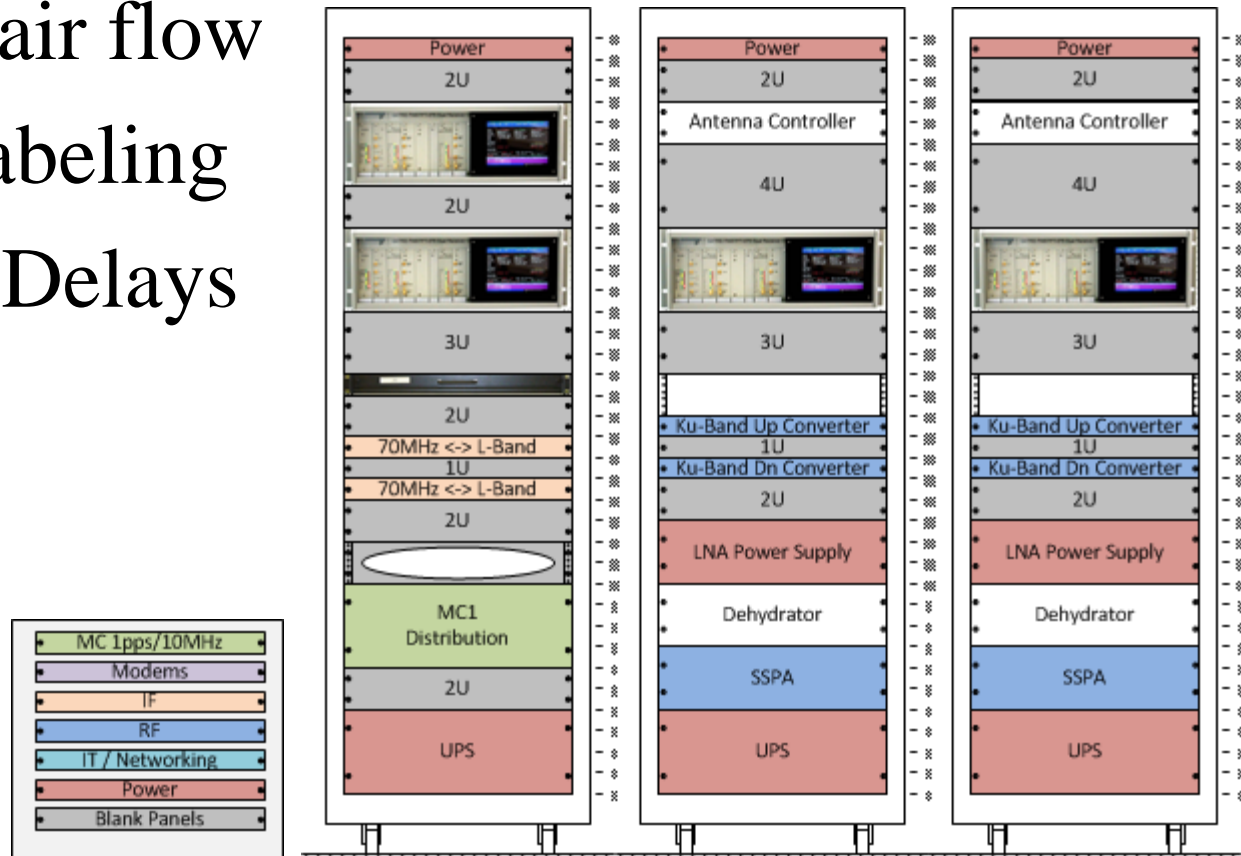
- Time at 1.0 nanosecond to specific users
 - Operational with NICT (Japan)
 - Supporting QZSS
 - Uses Hawaii (Kokee Park) for a hop
 - Cape Canaveral operations over extended range
 - Extensions to Pacific
- AMC time link rebuilt
 - Engineering for better and cheaper
 - Thermal Control, Impedance Matching,
 - Calibration requires frequent and expensive travel
- GPS PPP now used for USNO's link to BIPM
 - Sending data from two receivers for redundancy



Projects: Earth Station



- Replacing old equipment and cables
- Improving air flow
- Updated Labeling
- Measuring Delays

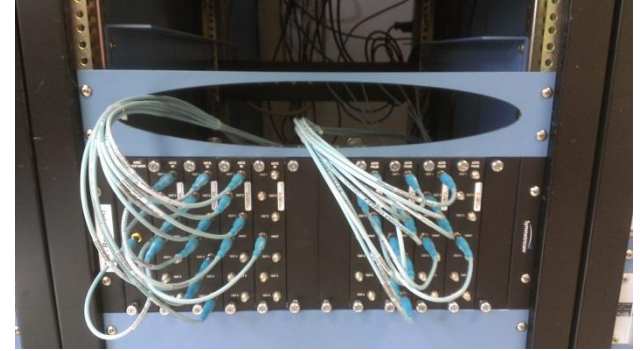




Projects: Earth Station

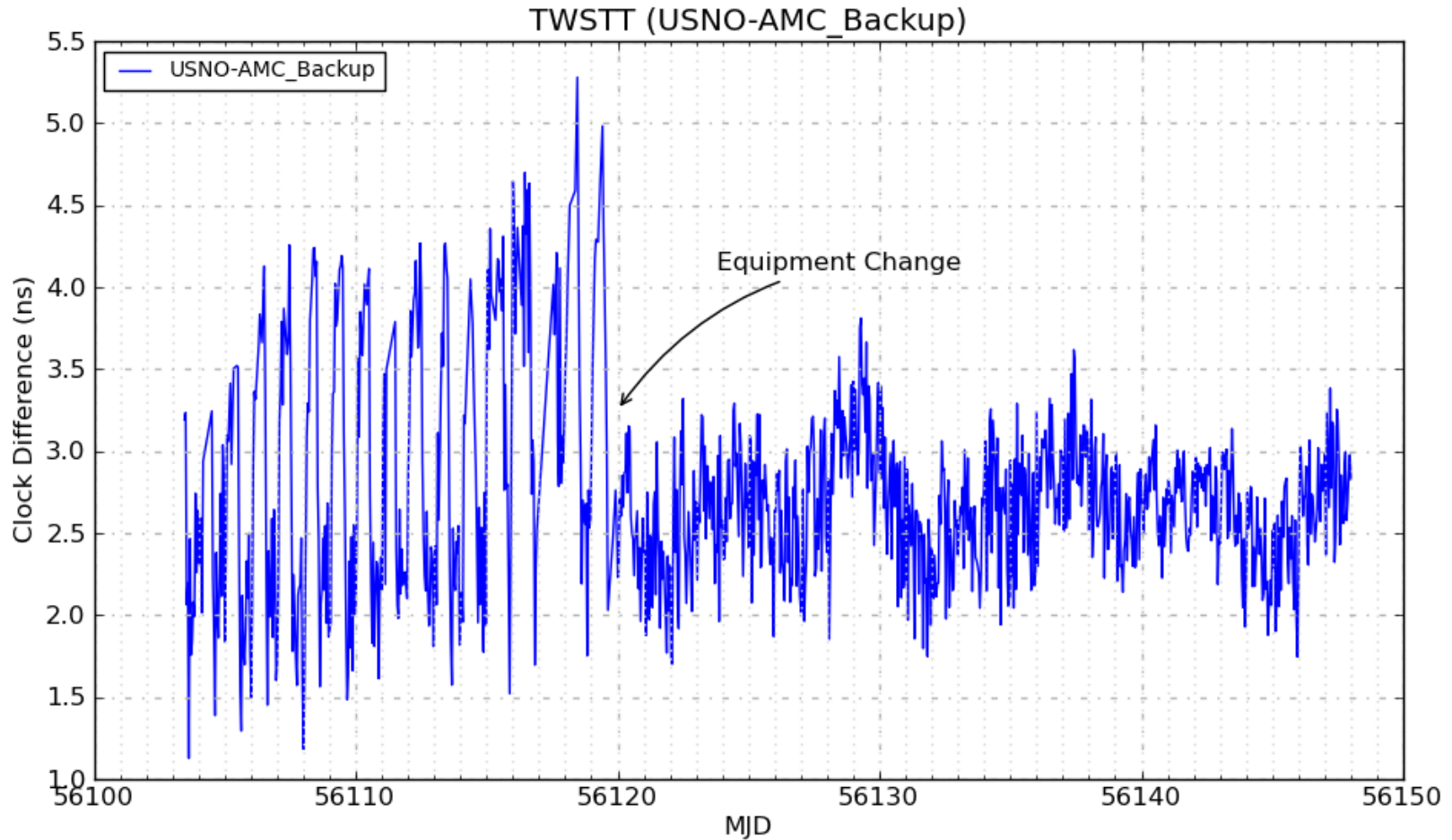


- Upgrading distribution amplifiers
- Interface panels w/ known delays
- Cable Trays
- Fans
- Battery backup





L-band exterior path antenna





Network Time Protocol



USNO Network Time Servers

Time Service Department



- **Internet** <http://tycho.usno.navy.mil/ntp.html>
 - 26 U.S. Stratum-1 Time Servers
 - USNO Master Clock & GPS SPS Time References
 - Millisecond Time Synchronization
 - >200 Billion Network Requests yearly
- **SIPRnet**
 - 2 U.S. Stratum-1 Time Servers operational
 - USNO Master Clock References
- **Authenticated NTP**
 - Limited to DoD and associates only
 - Civilians should contact NIST
- Number 1 authentication mode: **MULTIPLE SOURCES**



Internet and Other Time Products Time Service Department



- ftp server, <ftp://tycho.usno.navy.mil>
 - 9 million connections/month
- Time Service Web server, <http://tycho.usno.navy.mil>
 - 1.6 million connections/day
 - 2.9 Gigabytes transferred/day
 - Audio Service installed
- Telephone Voice Announcer
 - Traffic up to 4 million calls/year
 - USNO DC, 202-762-1401 (DSN 762)
 - USNO AMC, 719-567-6742 (DSN 560)
- Modem Time
 - Traffic falling, 10 calls/hour
 - USNO DC, 202-762-1594 (DSN 762); 1200 baud 8N1
 - USNO AMC, 719-567-6743 (DSN 560); 1200 baud 8N1



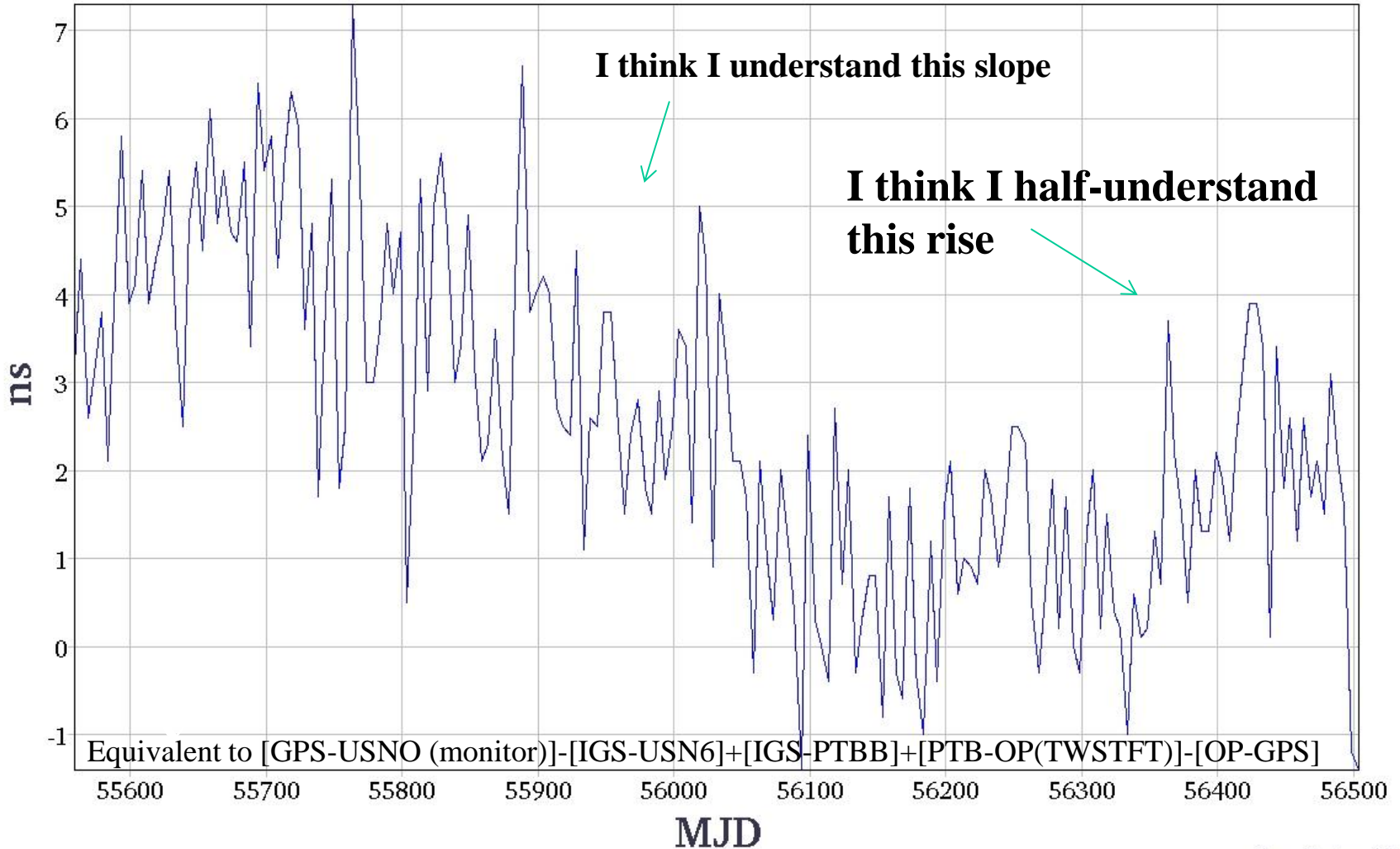
UTC Laboratory Issues



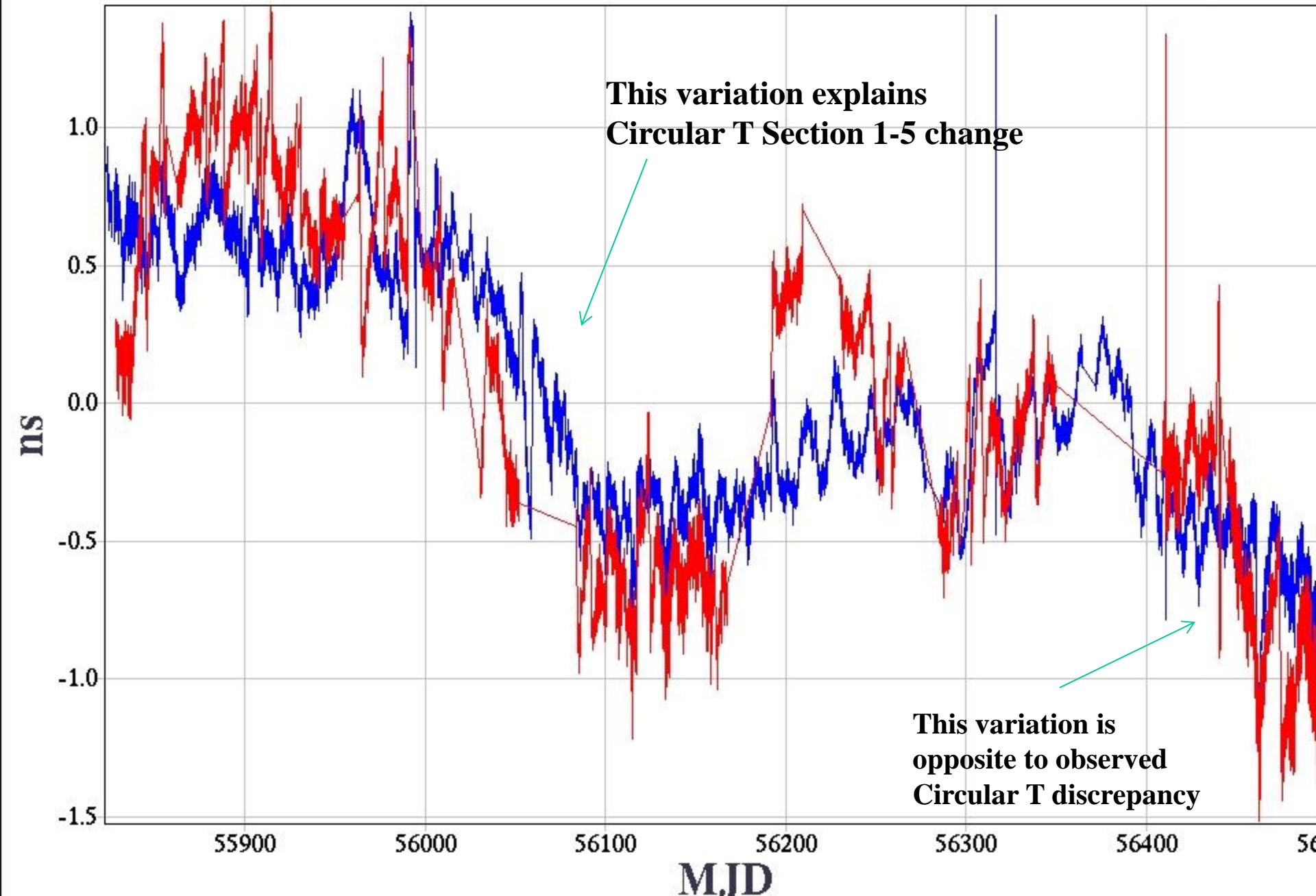
UTC- UTC(USNO) Is Reported Twice in Circular T ... but they don't agree



UTC-UTC(USNO) from Circular T Section 1 - Section 5



Operational-Redundant Antennas at the PTB

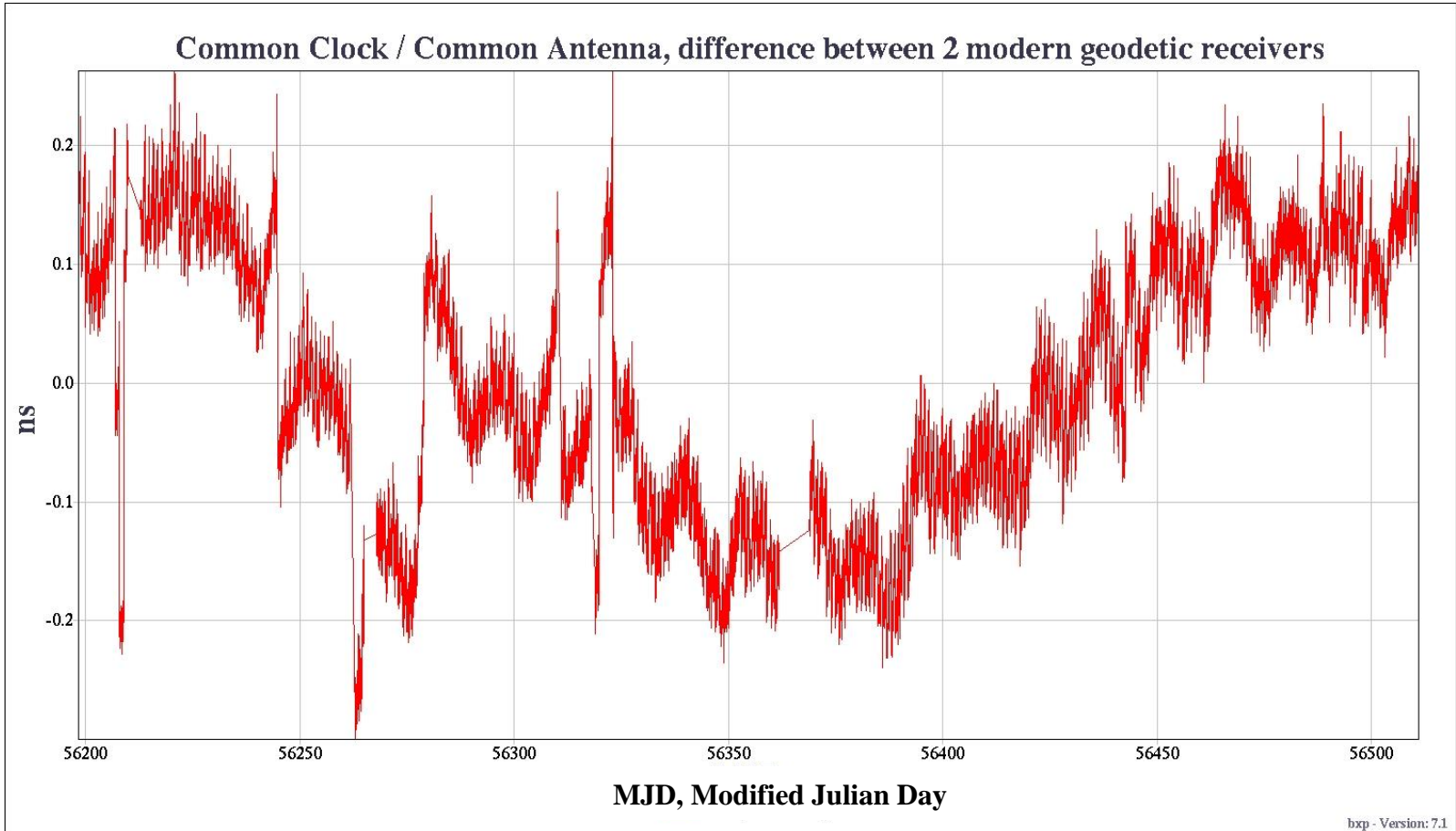


Double Difference OP-PTB via TWSTFT - via PPP (from BIPM)





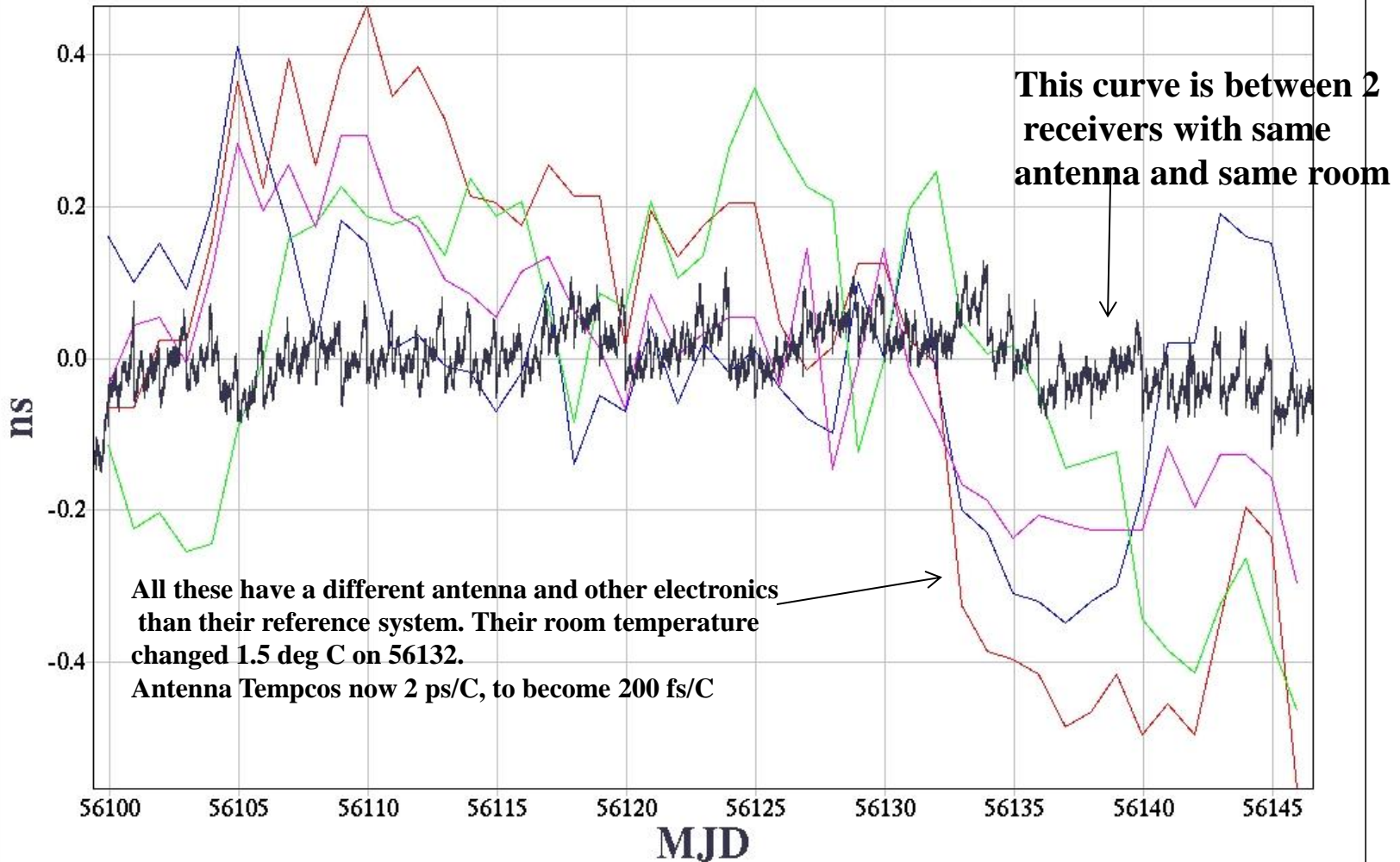
Yesterday's triumph is today's challenge





It's the electronics too

Common Antenna vs. Different "Low-Tempco" Antennas



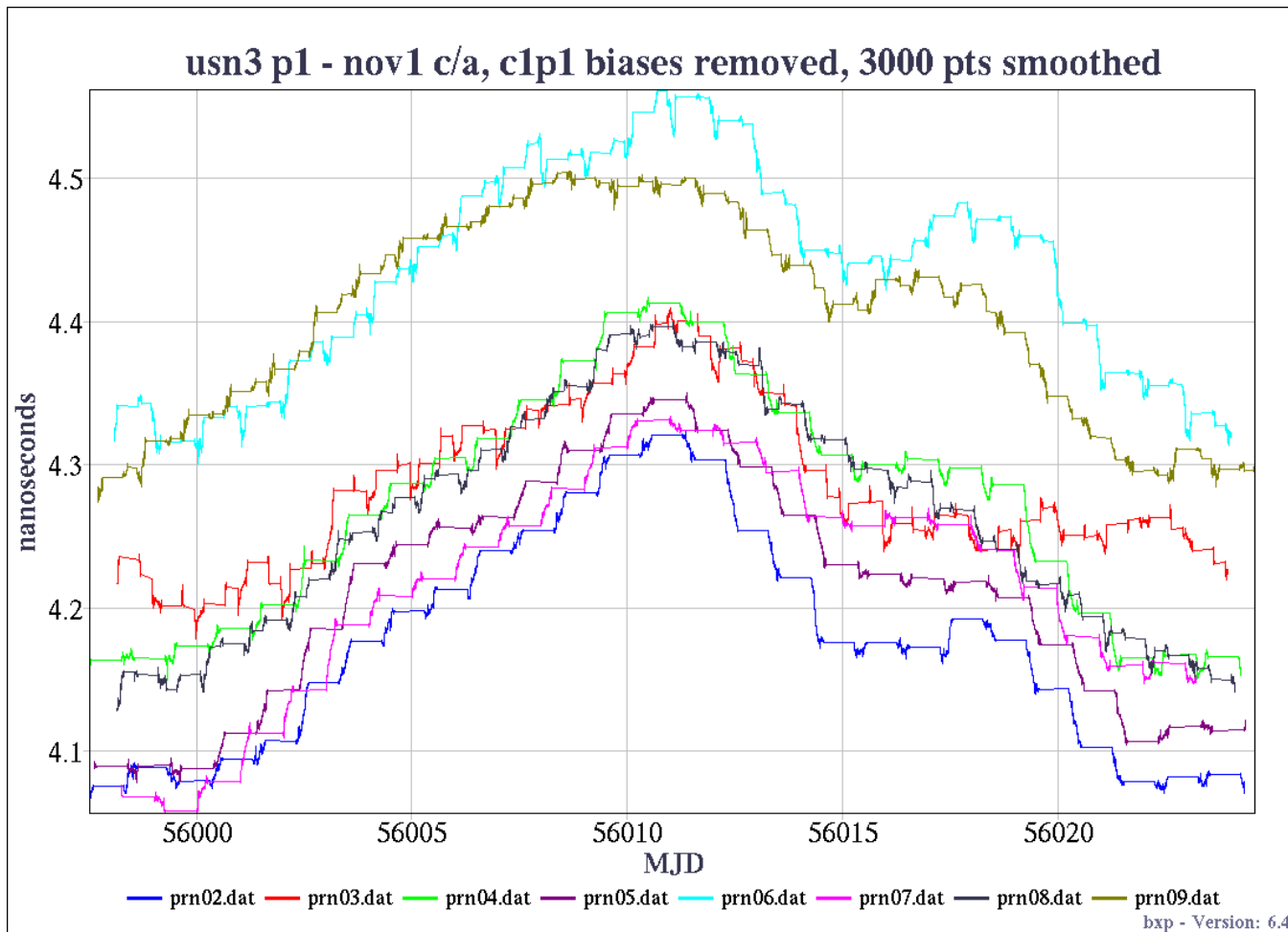
The reduced noise in common-room curve is due to use of carrier phase



C-P Bias Corrections Barely Enough

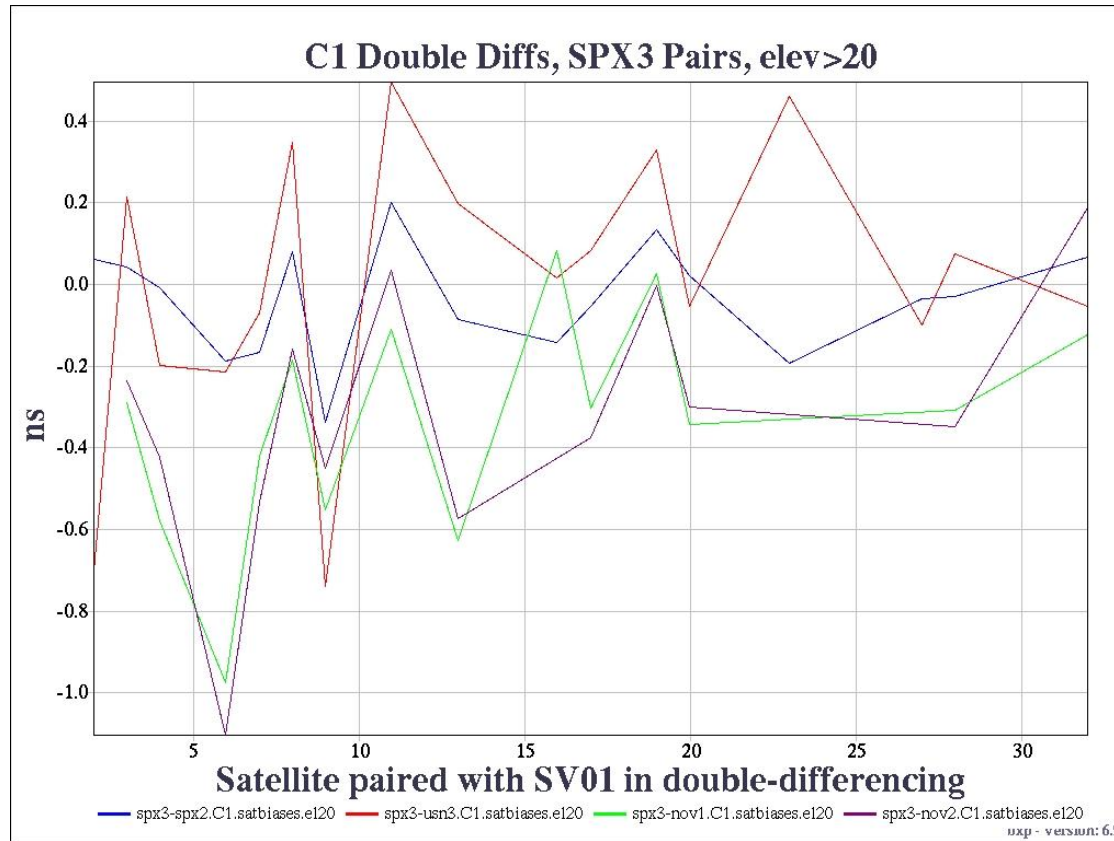


Raw Pseudorange Comparison, Ashtech vs. NovAtel, C-P biases applied
Each curve is a different satellite.





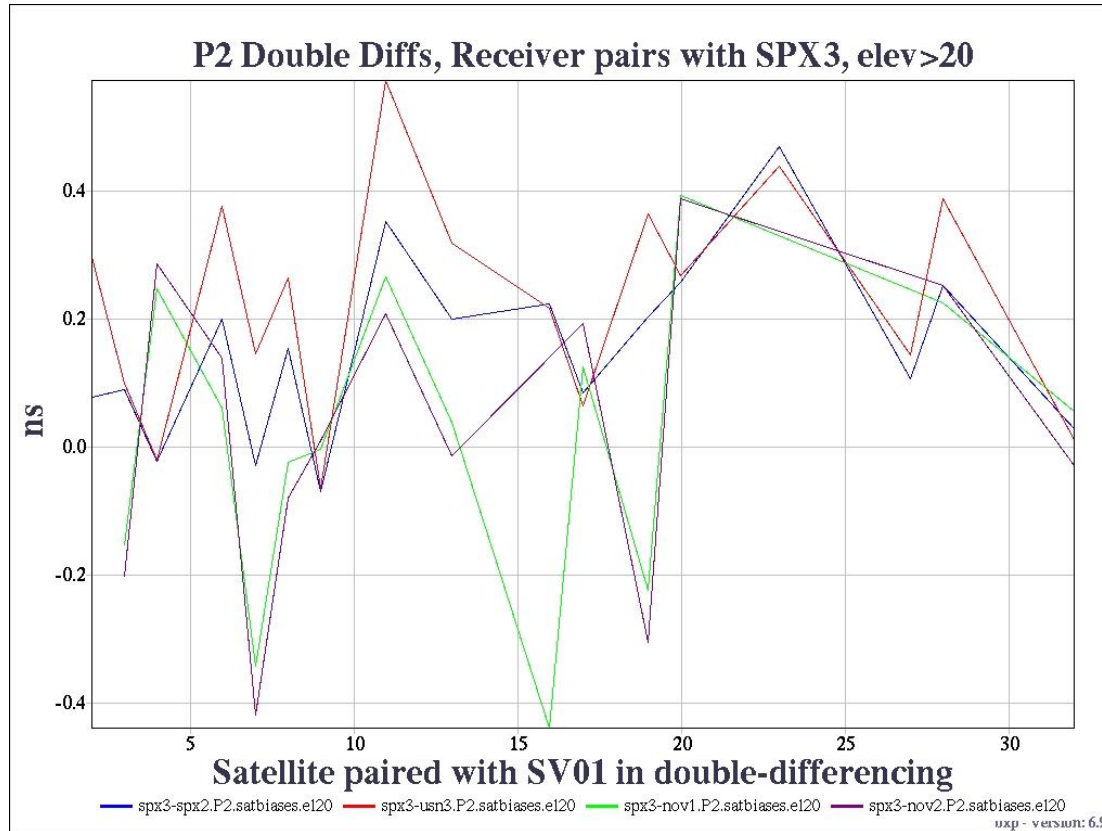
Each receiver-satellite pair has its own bias



Four Receiver Pairs Observing Satellite
Common Antenna/ Common Clock



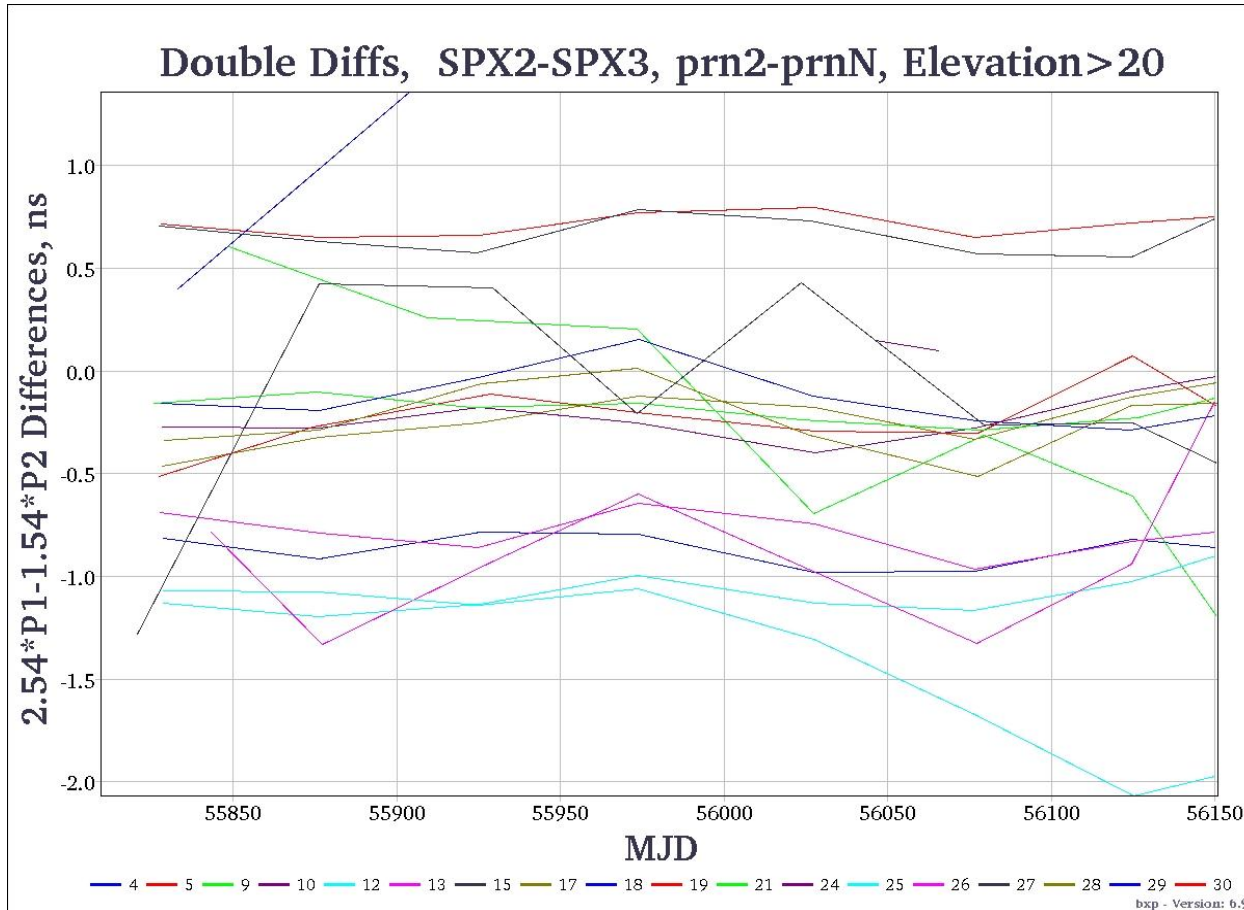
No Two Receivers Are Identical



Differencing C1, P1, P2 in two units of same make
Common Antenna / Common Clock



Receiver Biases Are Not Stable



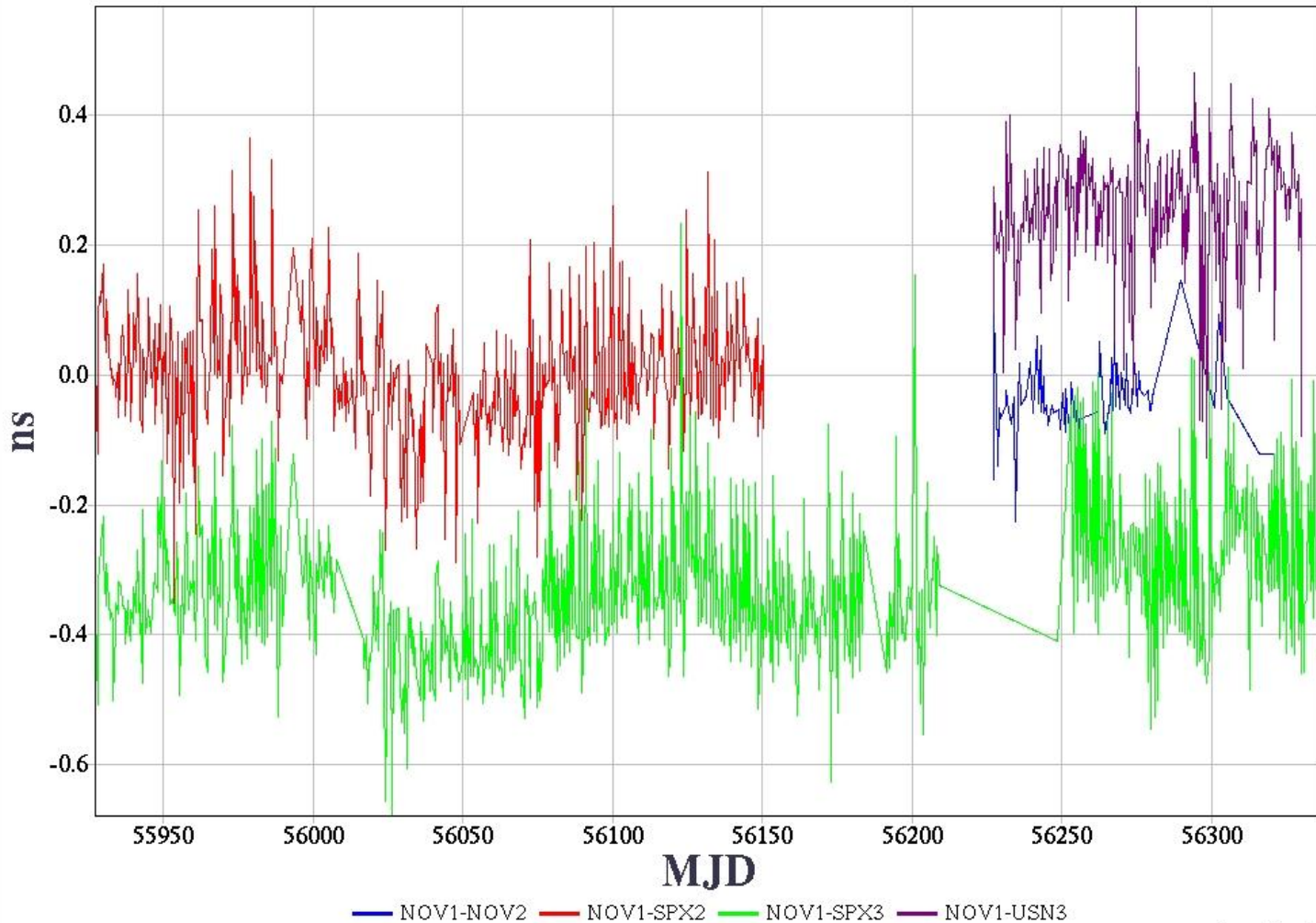
Differencing satellite and receiver pairs in P3
Satellites must be simultaneously observed



Persistence and 3 Kinds of Receivers

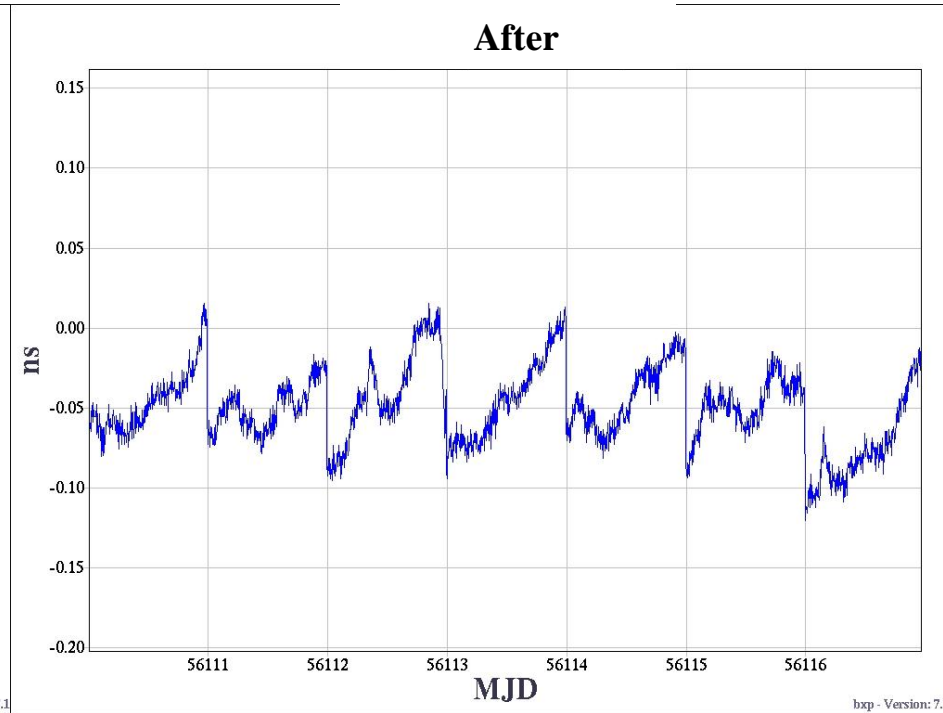
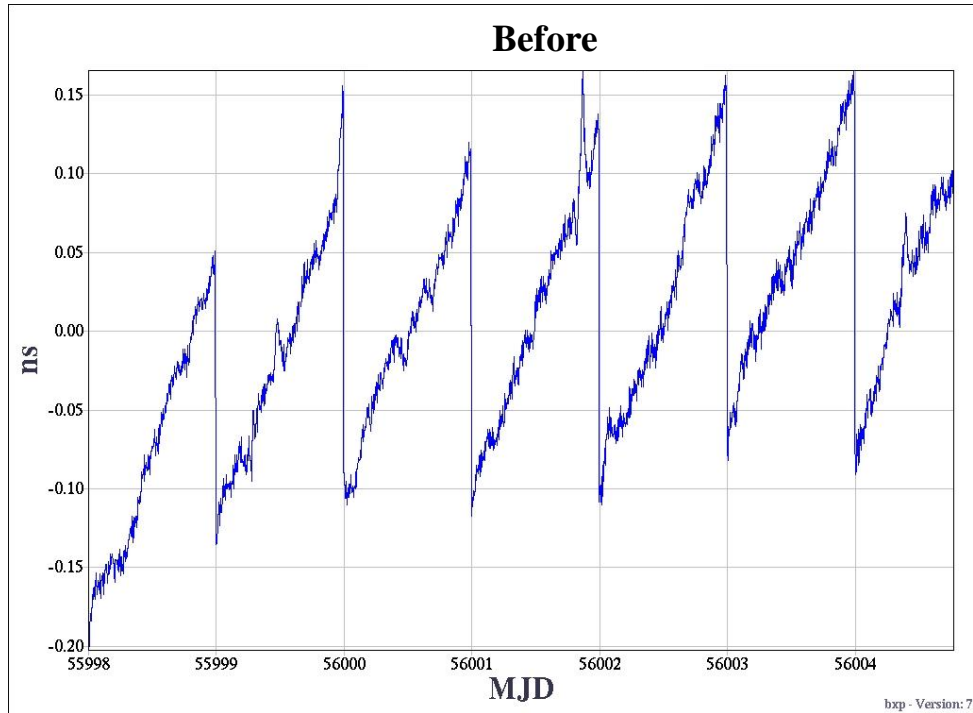


Four Receiver Pairs, P2, PRN01-PRN11, elev>20





Timing Receiver's Performance Before and After Firmware Change



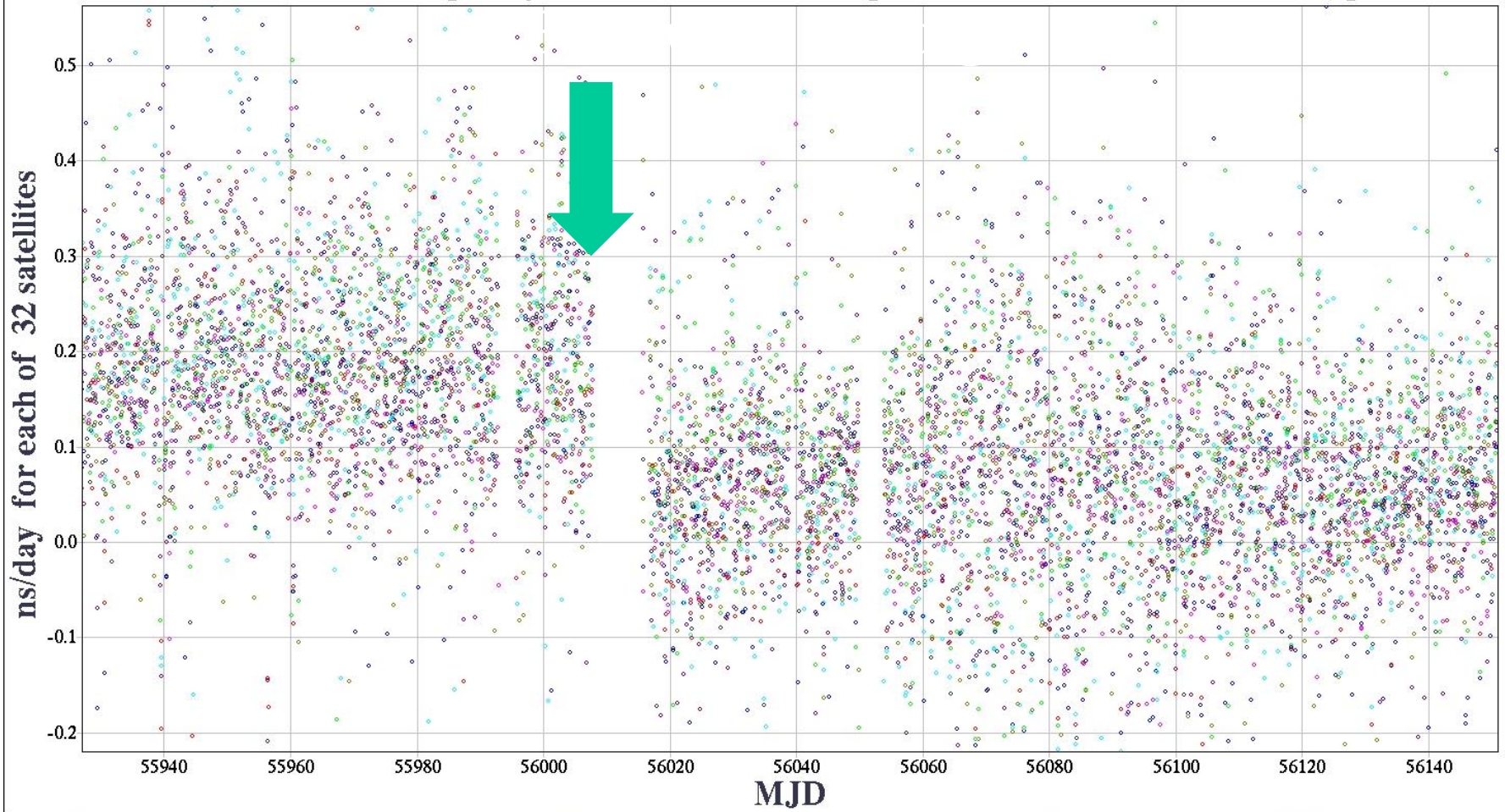
**Sawtooth daily pattern is occasionally reported in GPS carrier phase
This one may be due to problem in receiver's carrier phase loops**



Slopes Over Satellite Passes



frequency of "L3" over satellite pass, before/after firmware change



shwind spx2-spx3.L3.14.e120.phwind spx2-spx3.L3.15.e120.phwind spx2-spx3.L3.16.e120.phwind spx2-spx3.L3.17.e120.phwind spx2-spx3.L3.18.e120.phwind spx2-spx3.L3.19.e120.phwind



Roadmap to Upgraded GPS



- USNO provides GPS with one datum per day
 - The daily average of UTC(USNO)-GPS
 - Upload source could be USNO-DC or USNO-AMC
- USNO directly supports two GPS Monitor Stations
 - USNO-DC is a GPS monitor station through NGA
 - USNO-AMC provides frequency to Colorado Springs Monitor Station
- In the not-so-distant future (GPS III OCX)
 - M-Code and modernized civilian signal monitoring will be implemented.
 - USNO could upload satellite-specific dual-frequency data as often as every 15 minutes.
 - GPS to GNSS Time Offset
 - USNO and GPS to fully coordinate GPS bias signal pairs.
 - USNO-AMC will continue to be able to fully back up USNO-DC
 - Each will have three (3) rubidium fountains



Another time



USNO also measures the Earth Orientation Parameters, including the Earth's rotational angle, for GPS



ION-PTTI-13



- PTTI = Precise Time and Time Interval
- Under New Management
- USNO will post papers through PTTI-12
 - See <http://tycho.usno.navy.mil>
- Dec 2-5, 2013
 - Bellevue (Seattle), Washington



Disclaimer

- USNO does not endorse commercial products
 - Any identifications are provided for technical clarity only
- Past performance is not necessarily indicative of future results
- Information deemed reliable, but not guaranteed



Summary



- USNO specializes in real-time timekeeping
 - UTC realization
 - Dissemination
 - Monitoring
 - Device and analysis R&D
- Upgrades are continuously happening
- We work for you