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**Report From the  
U.S. Naval Observatory**

**Dr. Demetrios Matsakis  
CGSIC Timing Session  
September 22, 2009**



# DoD Directive 4650.05

- Signed by Deputy SecDef 19 Feb 2008
- 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 Position, Navigation, and Timing (PNT) committees and working groups, as necessary
  - Serve as the DoD PTTI Manager



# USNO Master Clocks

## Master Clock Washington, DC

- 57 High Performance Cesiums
- 24 Cavity-Tuned Masers

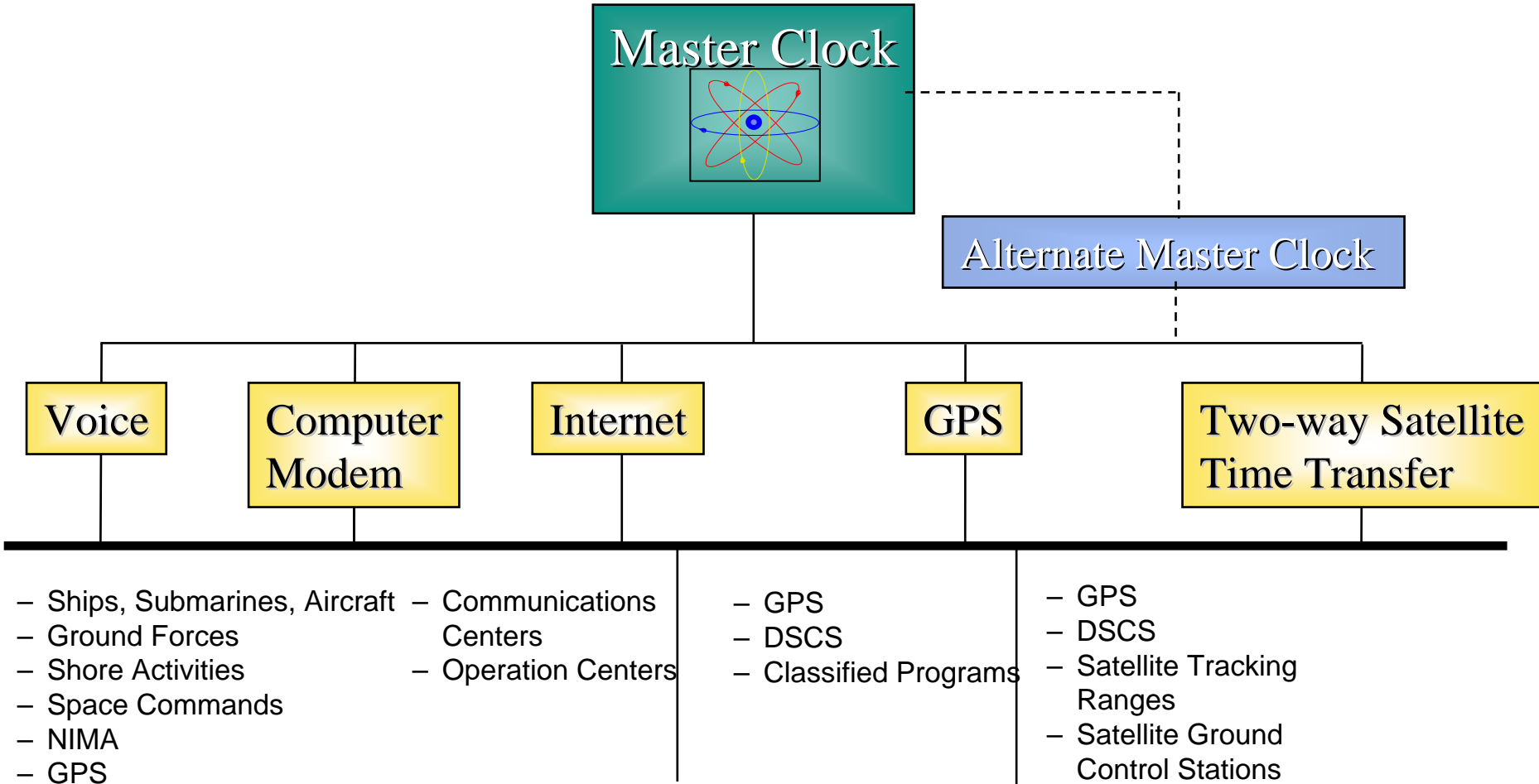


## Alternate Master Clock Schriever AFB

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

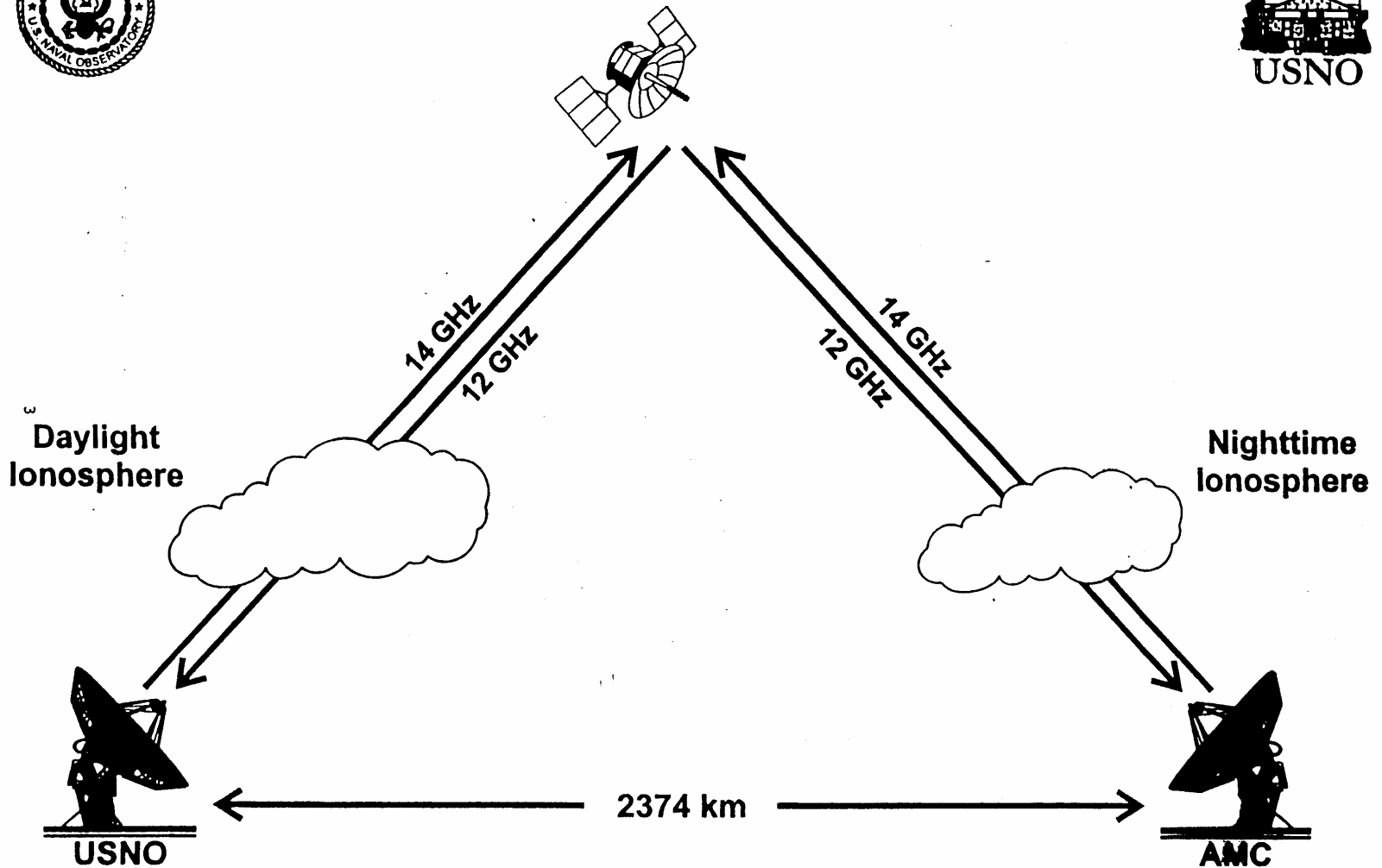


# DoD Time Dissemination





# Two-Way Satellite Time Transfer





# TWSTT at a Glance

- Time at 1.0 nanosecond to specific users
  - Expanding to Hawaii (Kokee Park)
    - Link with NICT (Japan)
  - Cape Canaveral operations expanded
    - Added 3 Caribbean and Atlantic sites
- International Timekeeping (BIPM)
- AMC time link
- Improvements Required for Operations
  - Engineering for better and cheaper
    - Satellite Simulators
    - Thermal Control
  - Calibration requires frequent and expensive travel



# 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
  - 2 OCONUS awaiting deployment
  - USNO Master Clock References
- This year we may experiment with authentication for DoD
- **Contact: Richard E. Schmidt, 202-762-1578 DSN 762-1578, [res@usno.navy.mil](mailto:res@usno.navy.mil)**



# Internet and Other Time Products

## Time Service Department

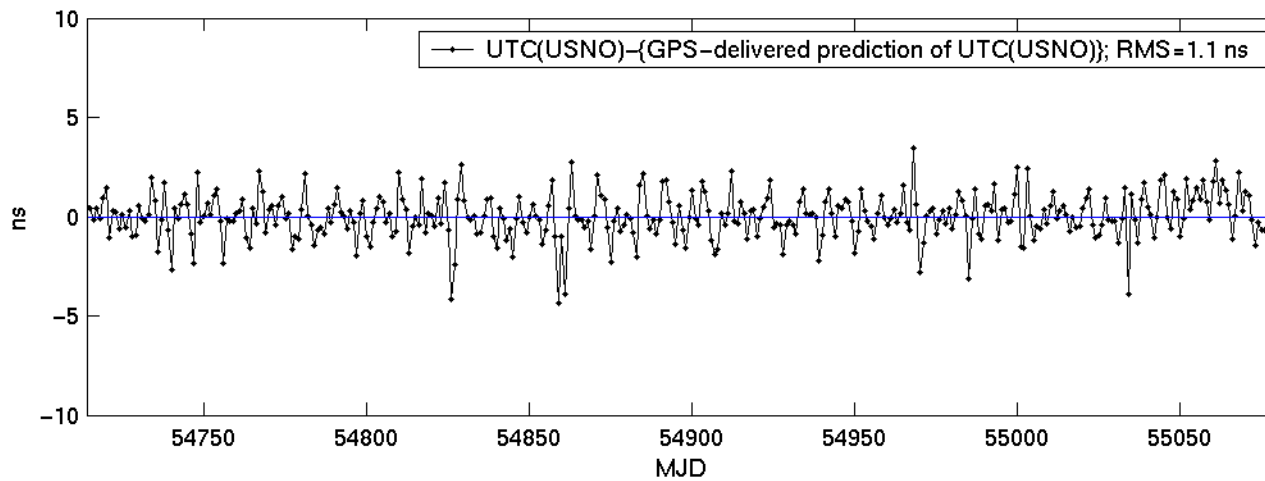
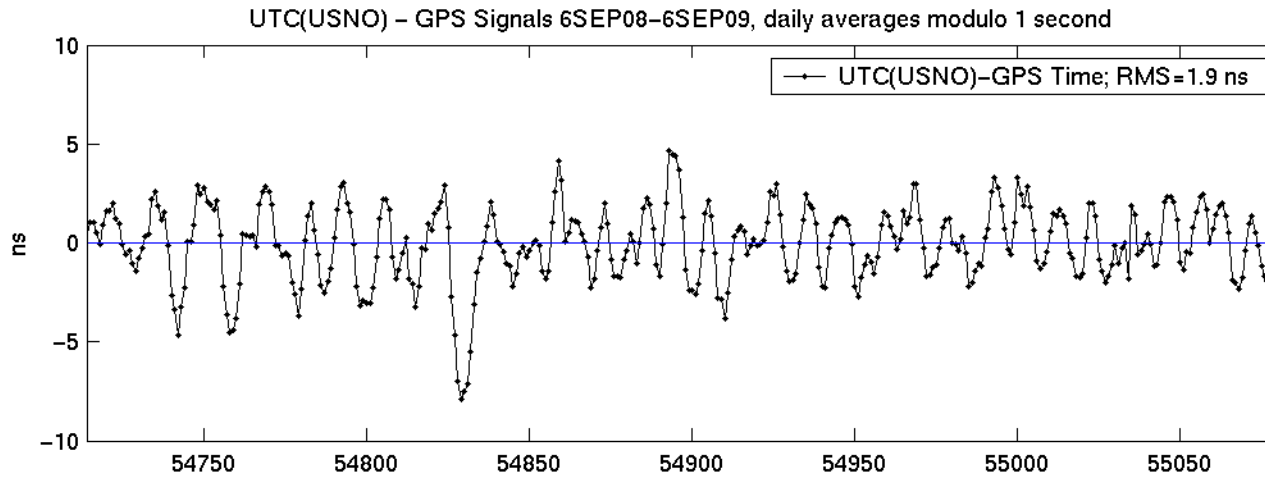
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- **ftp server, <ftp://tycho.usno.navy.mil>**
  - 9 million connections/month
- **Time Service Web server, <http://tycho.usno.navy.mil>**
  - 1.6 million connections/day
  - 2.9 Gigabytes transferred/day
  - Audio Service installed
- **Telephone Voice Announcer**
  - **Upgraded: 3 million calls/year**
  - USNO DC, **202-762-1401 (DSN 762)**
  - USNO AMC, **719-567-6742 (DSN 560)**
- **Modem Time**
  - USNO DC, **202-762-1594 (DSN 762); 1200 baud 8N1**
  - USNO AMC, **719-567-6743 (DSN 560); 1200 baud 8N1**



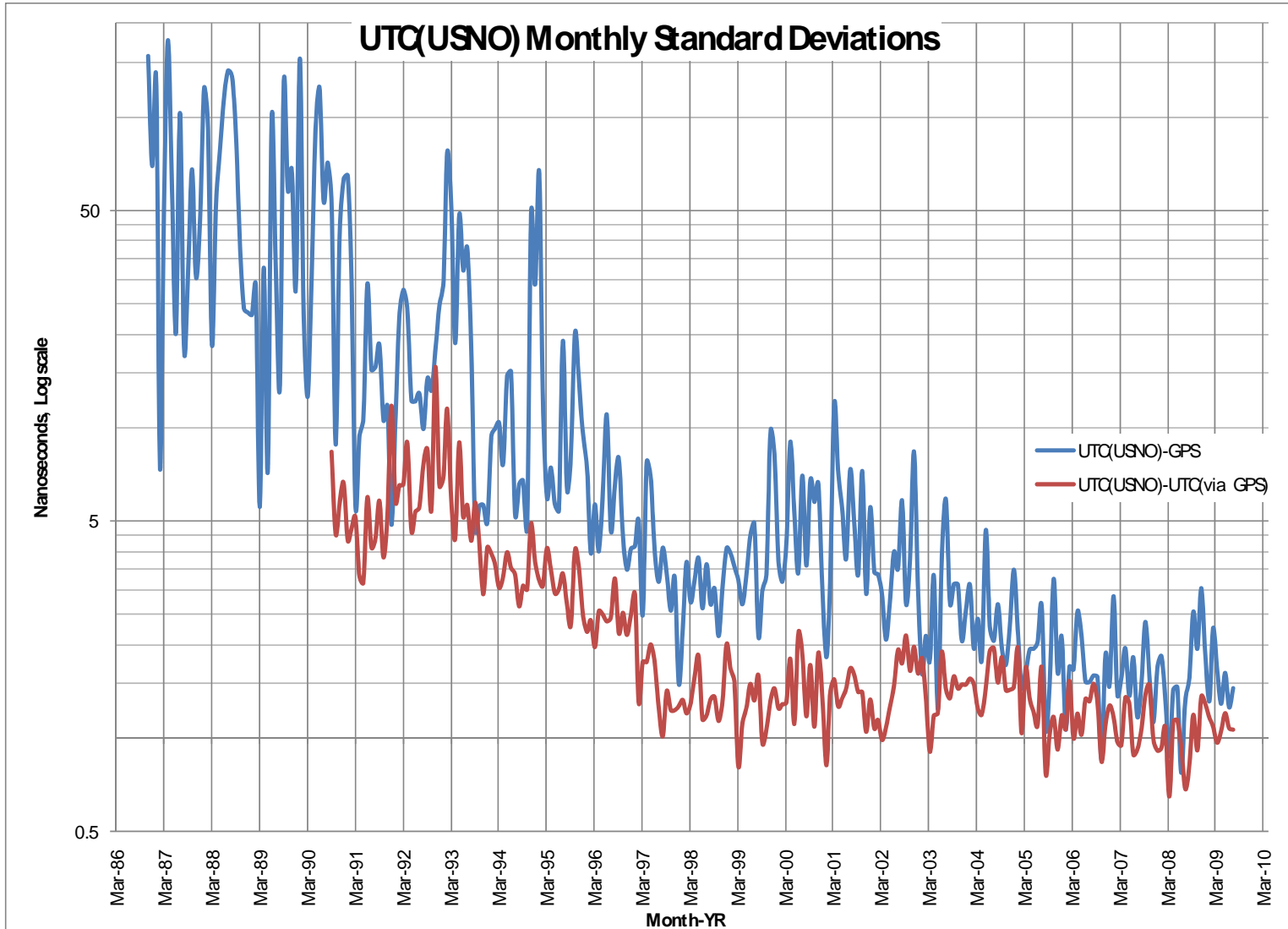


# GPS Time Transfer Performance





# GPS and USNO Timing





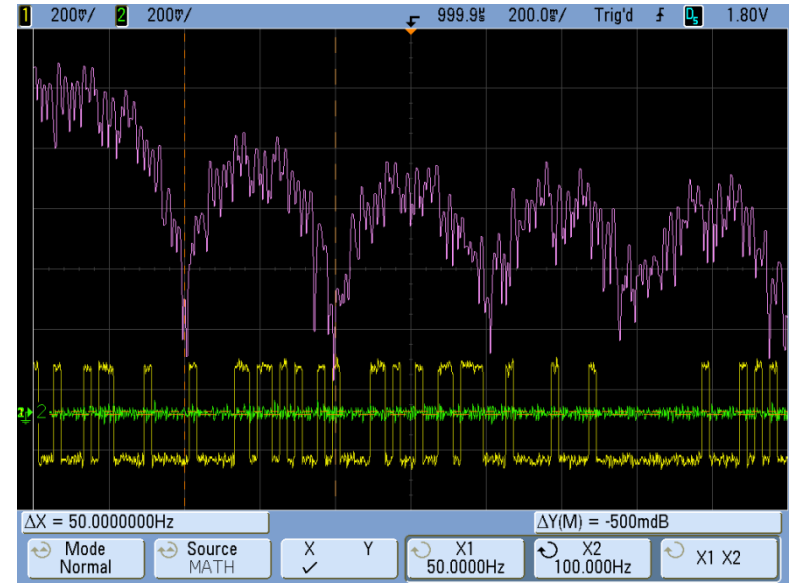
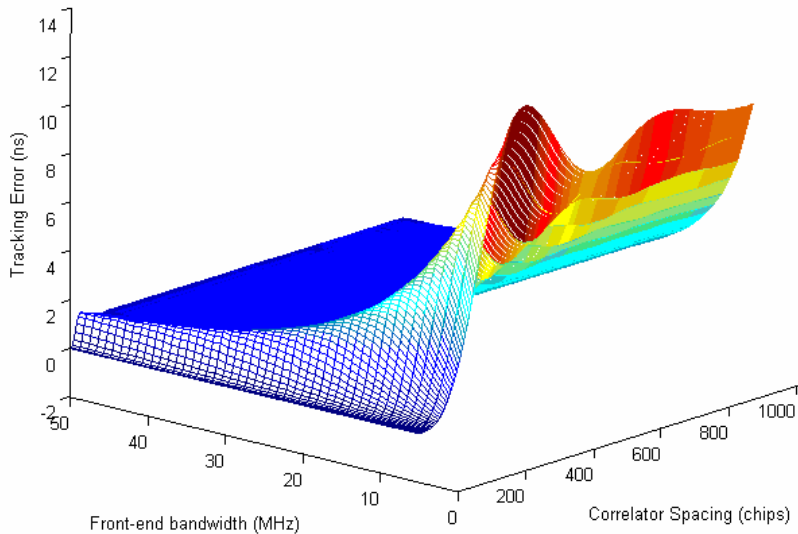
# USNO Portion of the GPS III Error Budget

All values $1\sigma$	Threshold	Objective
Signal in Space	0.75 ns	0.25 ns
M-Code Rcvrs	0.625 ns	0.275 ns
UTC(USNO)	0.25 ns/day	.05 ns/day
<b>TOTAL</b>	<b>1.0 ns (<math>1\sigma</math>)</b>	<b>.375 ns (<math>1\sigma</math>)</b>



# ONR Project: GPS Biases

Noncoherent DLL (E-L) vs Spacing and Front-end BW



- Time measured by GPS receiver depends upon receiver settings convoluted with each satellite's peculiarities
- Hegarty et. al, PTTI-04; Matsakis, ION-AM-07



# Master Clock Improving

- For Future Requirements
  - GPS III
  - Space
- Order of Magnitude Needed
  - More robust (reliable)
  - More precise (more self-consistent)
  - More accurate (closer to target)
- We know how to do it
  - Better clocks, better care, better time transfer



# New Clock Building: Dedicated



Specifications: Temperature +/- 0.1 C Humidity +/- 3% RH \*ALWAYS\*





# Fail-safe HVAC: Passing Tests





# Our 99 Clocks ...

- Major maser maintenance: on order
  - 8 masers to be refurbished
- Cesium clock maintenance: on order
  - 12 cesiums to get new tubes
  - 12 more tubes funded for FY10





# Clock Rooms in New Building



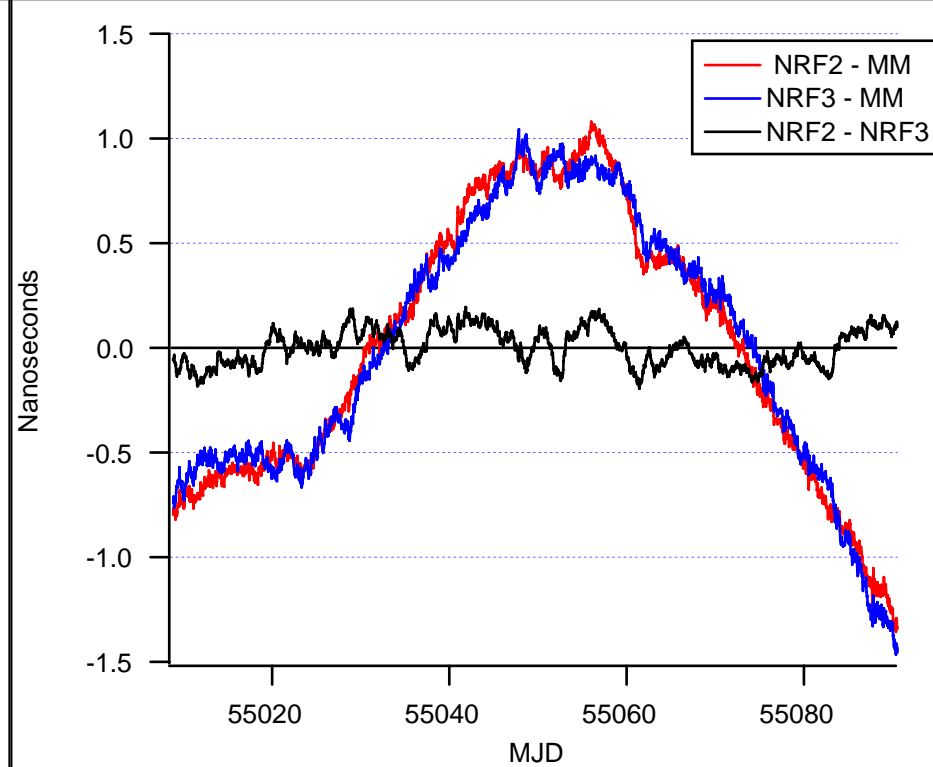
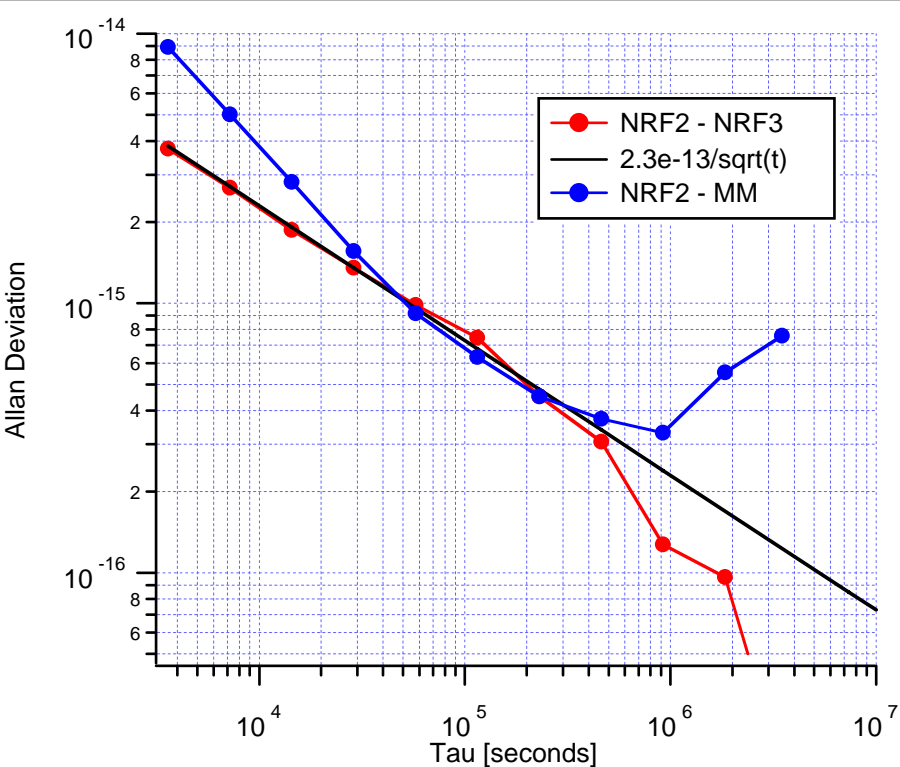


# Computing: Upgraded





# Fountains: Lookin' Good



- 82 days of continuous operation
- No relative drift between fountains with uncertainty of  $3.7 \times 10^{-18}/\text{day}$
- USNO Maser Mean is “odd-man” out
  - “Juggling” tests show even greater stability



# 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
  - SAASM-enabled receivers, now in use, will fully handle operations
  - M-Code receivers, now under development, will be made operational
  - USNO could upload satellite-specific dual-frequency data every 15 minutes
  - USNO-AMC will continue to be able to fully back up USNO-DC
    - Each will have three (3) rubidium fountains



# PTTI-09

- PTTI = Precise Time and Time Interval
- PTTI Systems and Applications Meeting
  - Nov 16-19, 2009
  - Albuquerque, NM
- For meeting: <http://www.pttimeeting.org>
  - For past papers too



# Summary

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