Report From the

U.S. Naval Observatory

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Timing Session of the
Civil GPS Service Interface Committee (CGSIC)
September 20, 2010
Portland, Oregon

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

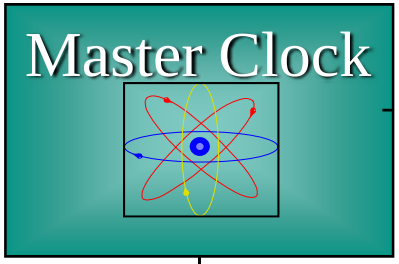
Master Clock Washington, DC

- 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



Alternate Master Clock

Voice

Computer Modem

Internet

GPS

Two-way Satellite Time Transfer

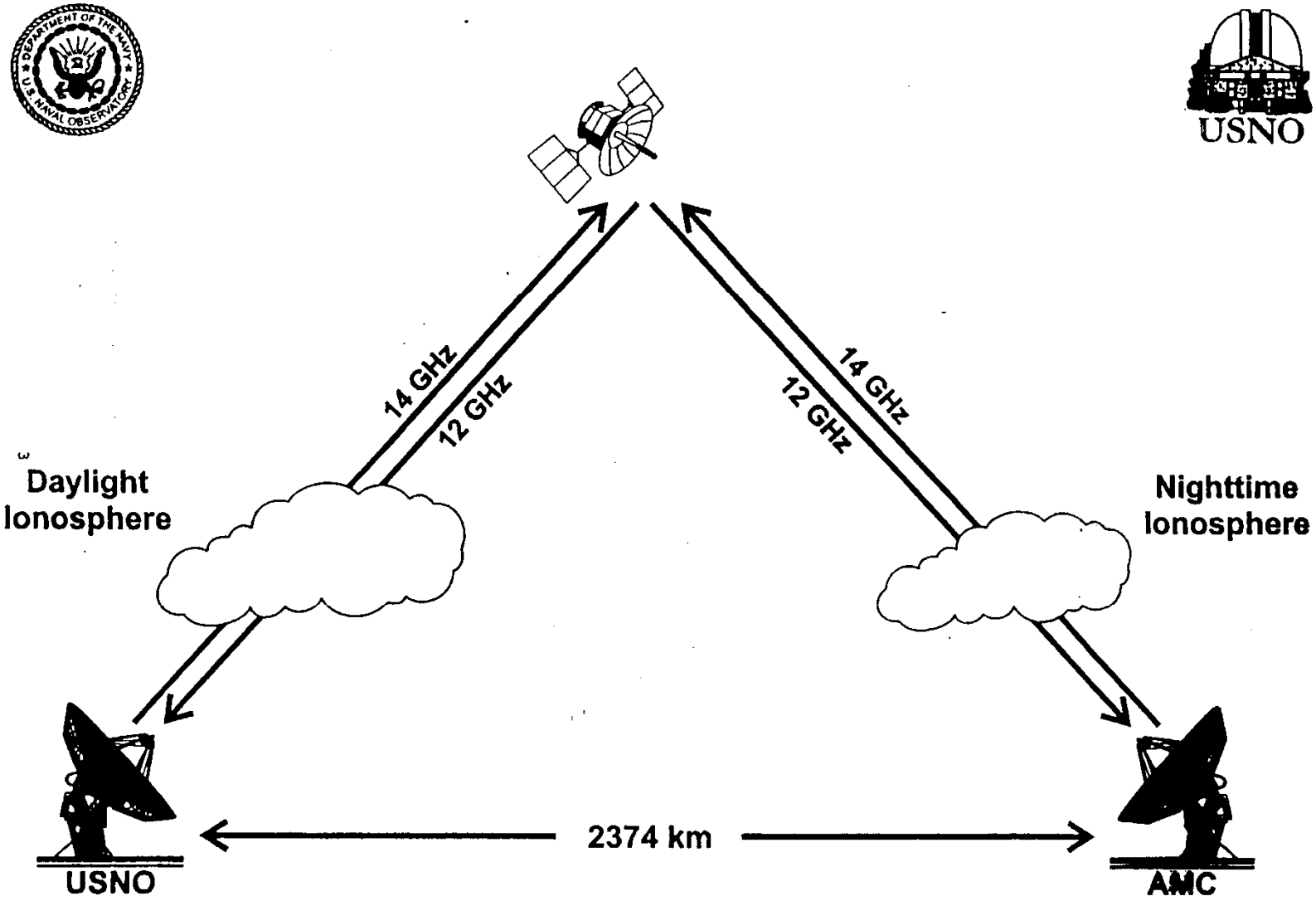
- Ships, Submarines, Aircraft
- Ground Forces
- Shore Activities
- Space Commands
- NIMA
- GPS

- Communications Centers
- Operation Centers

- GPS
- DSCS
- Classified Programs

- GPS
- DSCS
- Satellite Tracking Ranges
- Satellite Ground Control Stations

Two-Way Satellite Time Transfer



TWSTT at a Glance

- Time at 1.0 nanosecond to specific users
  - Now operational with Hawaii (Kokee Park)
    - Linking with NICT (Japan)
    - Supporting QZSS
  - 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

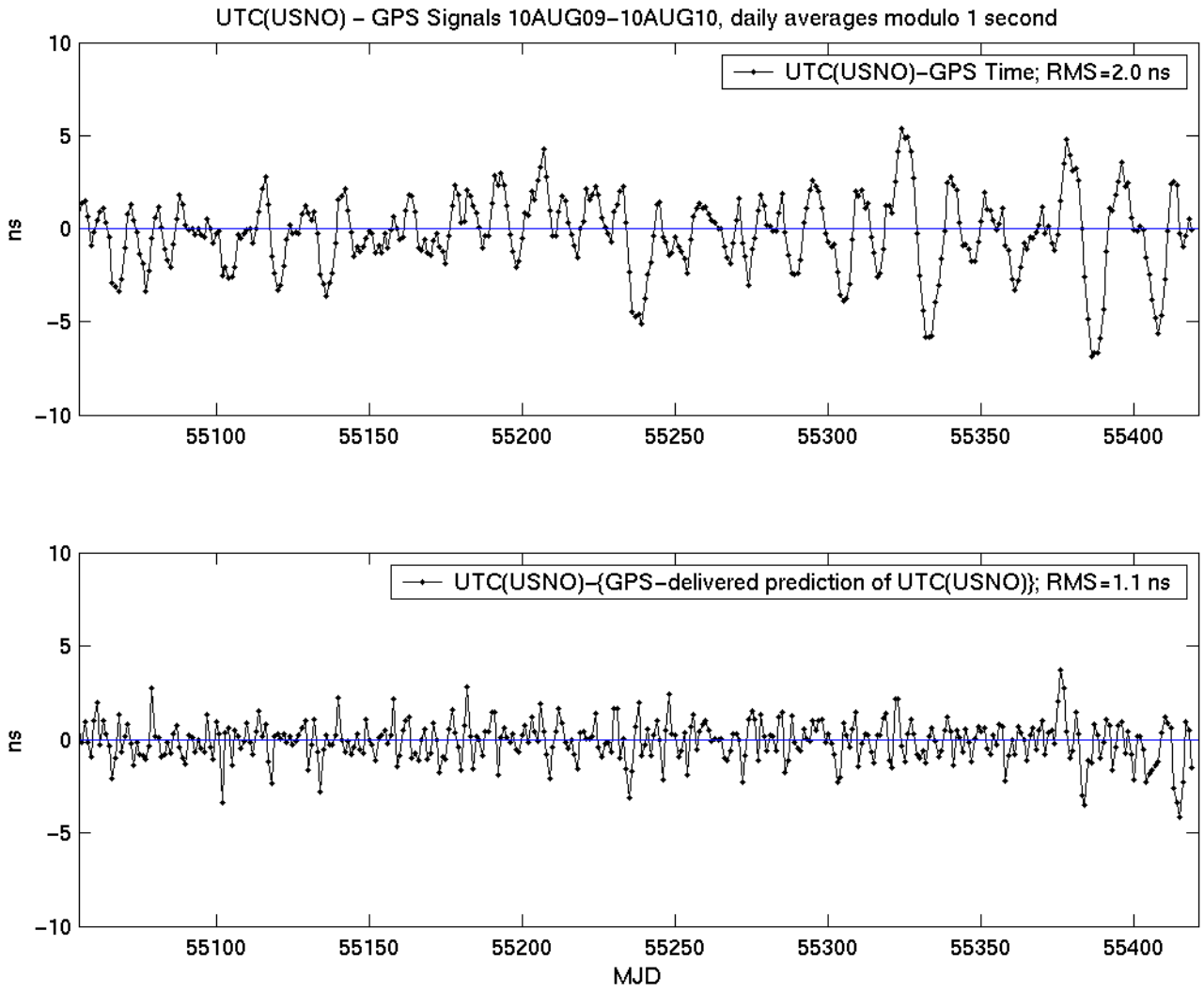
USNO Network Time Servers
Time Service Department

- **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**

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**
  - **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

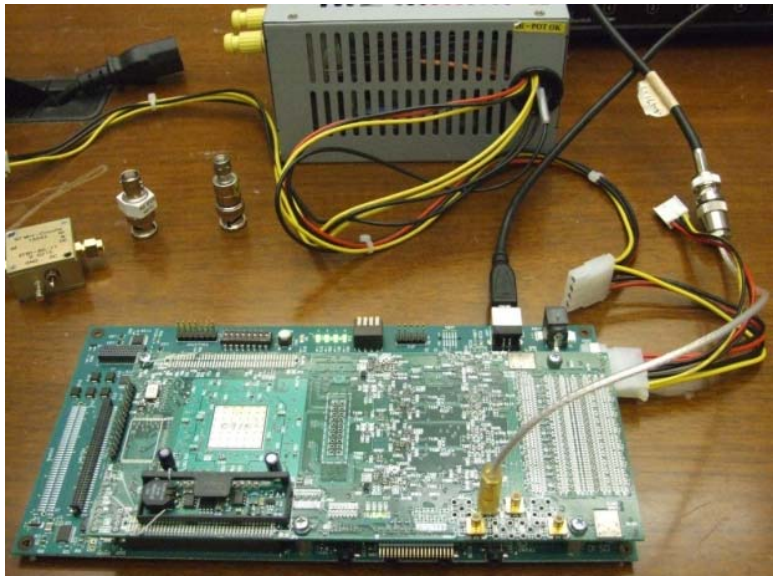


International Cooperation

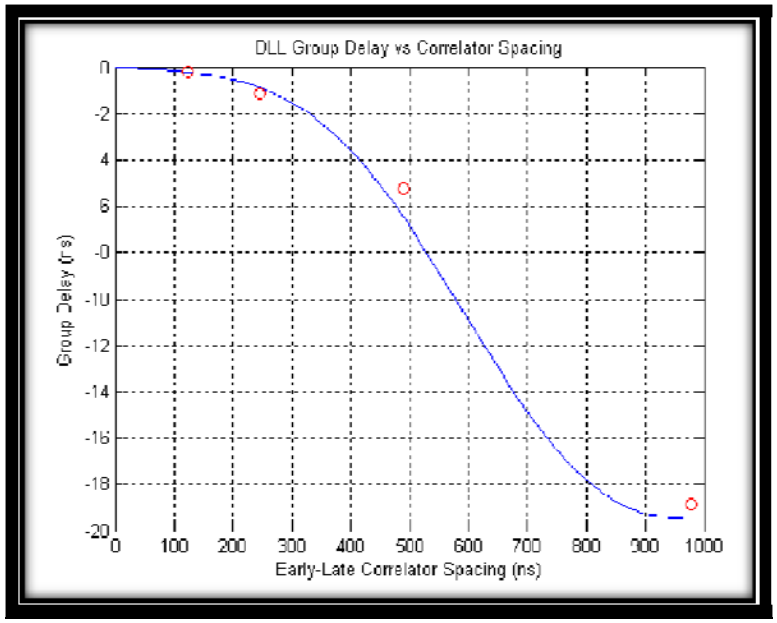
New Galileo uplink site, and masts for GNSS antennas

ONR Project: GPS Biases

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



Hardware Receiver



Circles are observed timing bias
Curve is MATLAB simulation

USNO Portion of the GPS III Error Budget

All values 1 σ	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
TOTAL	1.0 ns (1σ)	.375 ns (1σ)

Master Clock Improving

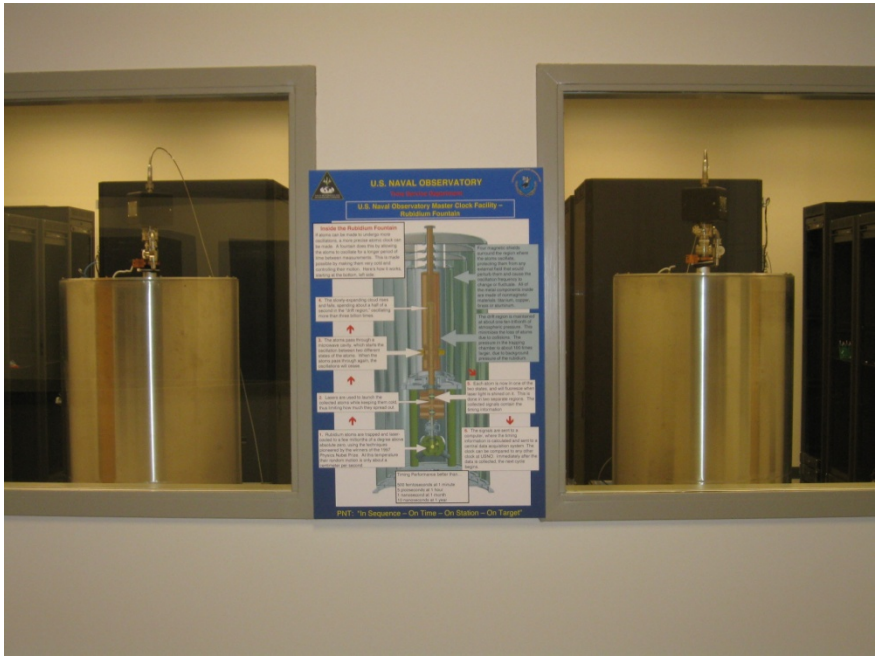
- For Future Requirements
  - GPS III
  - Space
- Order of Magnitude Needed
  - More robust (reliable)
  - More precise (more self-consistent)
  - More accurate (closer to target)
- We know how to do it
  - Better clocks, better care, better time transfer

New Clock Building: under test

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

Fail-safe HVAC: some flaws corrected

Fountains Under Shakedown



NRF2 and NRF3 under test in new clock building

NRF4, NRF5, NRF6, and NRF7 are under construction

USNO Operational Clock Ensemble

- Maser ensemble
  - 8 masers refurbished
  - 2 more masers on order
- Cesium Ensemble
  - Replacement beam tubes fully funded

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

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-10

- PTTI = Precise Time and Time Interval
- PTTI Systems and Applications Meeting
  - Nov 15-18, 2010
  - Reston, Va
    - (near Dulles Airport, Washington DC)
  - USNO Tour
- 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