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

- 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

Daylight Ionosphere

Nighttime Ionosphere

USNO

AMC

2374 km

14 GHz

12 GHz
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

  – 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

UTC(USNO) – GPS Signals 6SEP08–6SEP09, daily averages modulo 1 second

UTC(USNO)–GPS Time; RMS=1.9 ns

UTC(USNO)–(GPS–delivered prediction of UTC(USNO)); RMS=1.1 ns
GPS and USNO Timing

UTC(USNO) Monthly Standard Deviations

Month-yr

Nanoseconds, Log scale

UTC(USNO)-GPS
UTC(USNO)-UTC(via GPS)
# USNO Portion of the GPS III Error Budget

<table>
<thead>
<tr>
<th>All values $1 \sigma$</th>
<th>Threshold</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal in Space</td>
<td>0.75 ns</td>
<td>0.25 ns</td>
</tr>
<tr>
<td>M-Code Rcvrs</td>
<td>0.625 ns</td>
<td>0.275 ns</td>
</tr>
<tr>
<td>UTC(USNO)</td>
<td>0.25 ns/day</td>
<td>.05 ns/day</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1.0 ns ($1 \sigma$)</td>
<td>.375 ns ($1 \sigma$)</td>
</tr>
</tbody>
</table>
ONR Project: GPS Biases

- 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 3.7x10^{-18}/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