Report from JPL Frequency Standards Test Laboratory

Dr. Lin Yi, Technologist, Sept. 16, 2019
Frequency And Timing Advanced Instrument Development Group

9/16/2019, CGSIC Timing Subcommittee, ION-GNSS+ 2019
DSN Frequency & Timing System (FTS)
Frequency Standards Test Lab @ JPL
State-of-Art Clock Technologies and Characterization

Stability Measurements

GPS Antennas

Environmental Tests

Atomic Standards

Ultra-Stable Hg+ Clocks (LITS-10-12)
(NASA, DOD, ESA, Commercial)

DSN Clocks

Ultra-Stable Lasers

Low Noise Oscillators

Optical Frequency Comb
NASA-JPL Mercury Trapped Ion Clocks

- **Long life, continuous, high stability operation**
- **Mercury Linear Ion Clock Paths and Applications:**
  1. **Ultra-Stable Performance:** UTC timescales, ESA ACES mission
     “Compensated” Multi-pole ion clock technologies:
     - $10^{-16}$ at 1 to 10 days, drift $\leq 10^{-17}$/day.
     - $10^{-15}$ short term stability ($\sim$1 sec) via super LO’s.
  2. **Space:** DSAC Technology Demonstration Mission (TRL 5-7),
     - Quartz USO based LO’s.
     - NASA Deep Space: $\sim 20$W and 5 kg goal
     - GNSS (MAFS): $\sim 1 \times 10^{-13}$ short term, $10^{-15}$ at 1 to 10 days
     - Science and other apps….
  3. **Miniature, low power:** DARPA ACES program
     - 30 cm$^3$ scale ion trap
     - Miniature UV light sources and LO’s

9/16/2019, CGSIC Timing Subcommittee, ION-GNSS+ 2019
Deep Space Atomic Clock

STP2-DSAC Launched, June 24
https://www.youtube.com/watch?time_continue=139&v=qLEuCn8RT14
https://www.youtube.com/watch?v=ZbH8KoaqfDU

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement by the United States Government or the Jet Propulsion Laboratory, California Institute of Technology.
Precision Frequency and Timing Related Missions in other groups at JPL

- **GRACE-FO (Gravity Recovery and Climate Experiment Follow-On):**
  - https://gracefo.jpl.nasa.gov/
  - **On-board USO testing at JPL-FSTL.**
  - GPS receiver for orbit determination
  - Laser Ranging Instrument*
  - Video: [https://www.youtube.com/watch?v=s93i7m82h54](https://www.youtube.com/watch?v=s93i7m82h54)

- **COSMIC-2 (Constellation Observing System for Meteorology, Ionosphere, and Climate-2)**
  - [https://www.nesdis.noaa.gov/COSMIC-2](https://www.nesdis.noaa.gov/COSMIC-2)
  - Launched, June 24, 2019
  - JPL Tri-Global Navigation Satellite System Radio Occultation Receivers
  - Video: [https://www.youtube.com/watch?v=qabMHoMyl1A](https://www.youtube.com/watch?v=qabMHoMyl1A) 2:32 – 4:08

Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement by the United States Government or the Jet Propulsion Laboratory, California Institute of Technology.

*https://doi.org/10.1103/PhysRevLett.123.031101
Application Clock Research and Development for NASA missions

- Further maturation of Hg+ space clock technology and navigation application infusion
- Continuous awareness of performance, operability, reliability and sustainability for precision frequency and timing instruments at NASA-DSN/FSTL

- Oscillators/clocks for deep space CubeSat constellation for planetary radio occultation
  - To study atmosphere in order to
    - Understand Mars history
    - Provide near surface weather report for human exploration
    - Understand Venus, Titan
  - Global/fast coverage, low cost, ride-share with flagship missions

- Integrated photonics to make optical frequency comb for Radio Science in Astrophysics (such as VLBI)/Exoplanet Hunt
  - Comb generation with highly non-linear mono-lithic integrated photonics
  - Stable laser reference
  - Low size, weight and power