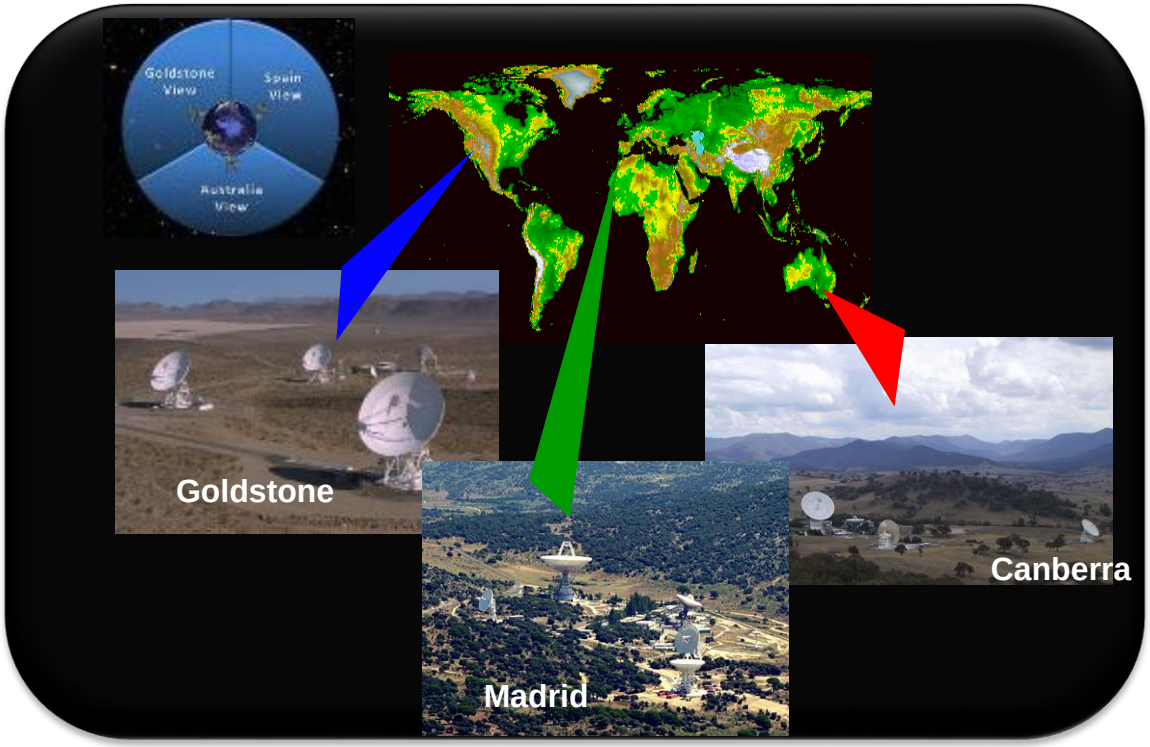
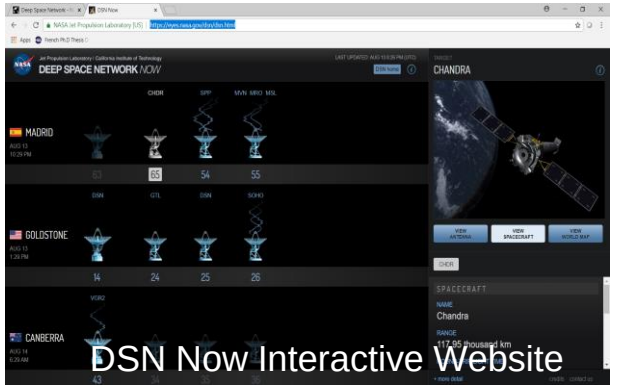
Report from JPL Frequency Standards Test Laboratory

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

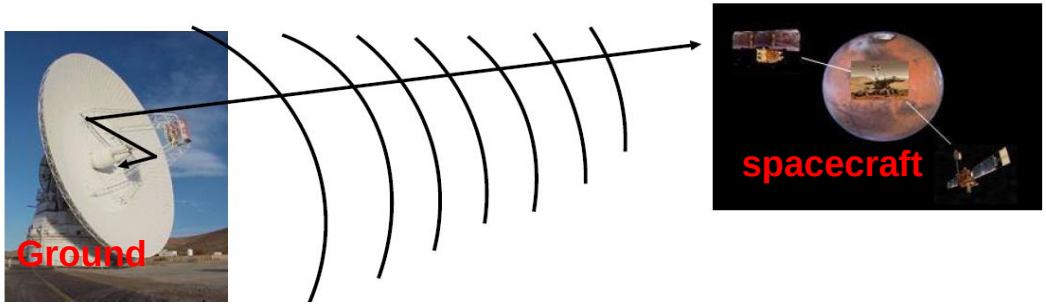
Jet Propulsion Laboratory
California Institute of Technology

NASA/JPL Deep Space Network and Exploration





DSN Now Interactive Website



https://www.nasa.gov/
https:/www.jpl.nasa.gov/
https://deepspace.jpl.nasa.gov/

DSN Frequency & Timing System (FTS)

Frequency Standards Test Lab @ JPL

State-of-Art Clock Technologies and Characterization

Stability Measurements

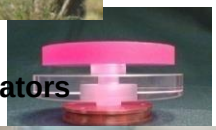
DSN Clocks

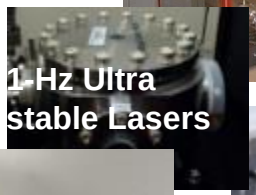
GPS Antennas

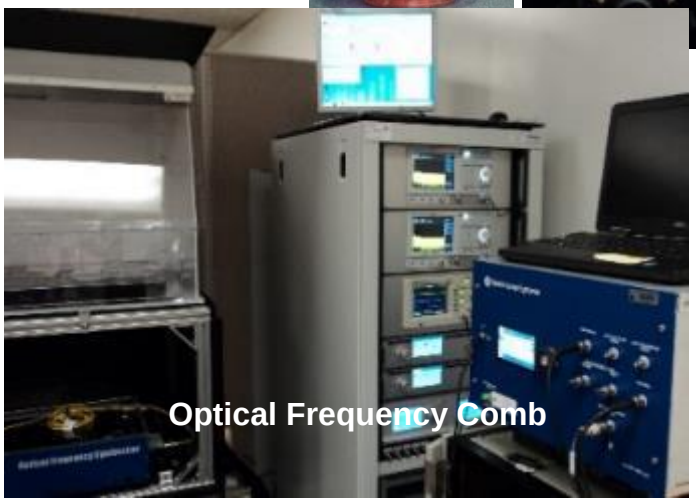
Environmental Tests

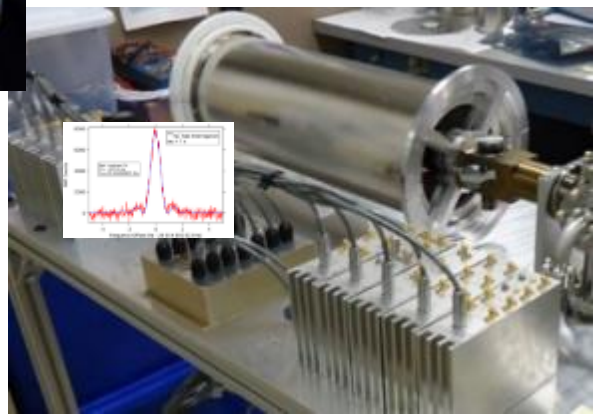
Atomic Standards

Low Noise Oscillators









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

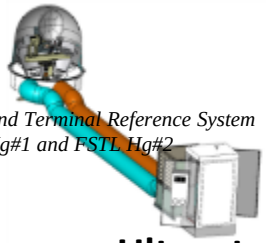
NASA-JPL Mercury Trapped Ion Clocks

- **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 ≤ 10^{-17}/day.
- 10^{-15} short term stability (~1 sec) via super LO's.

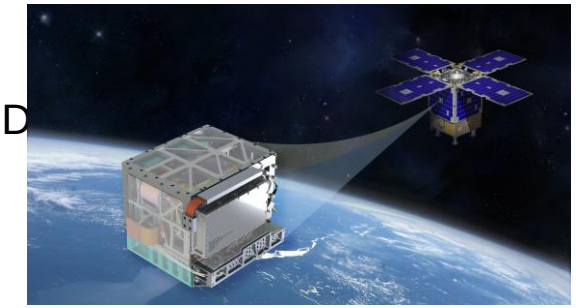


FSTL Ground Terminal Reference System
FSTL Hg#1 and FSTL Hg#2

Ultra stable ion clock

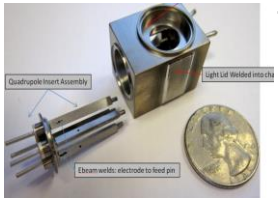
2. Space: DSAC Technology Demonstration Mission (TRL 5-7),

- Quartz USO based LO's.
- NASA Deep Space: ~ 20W and 5 kg goal
- GNSS (MAFS) : ~ 1x10^{-13} short term, 10^{-15} at 1 to 10 D
- Science and other apps….



3. Miniature, low power: DARPA ACES program

- 30 cm^3 scale ion trap
- Miniature UV light sources and LO's



<30 cm^3

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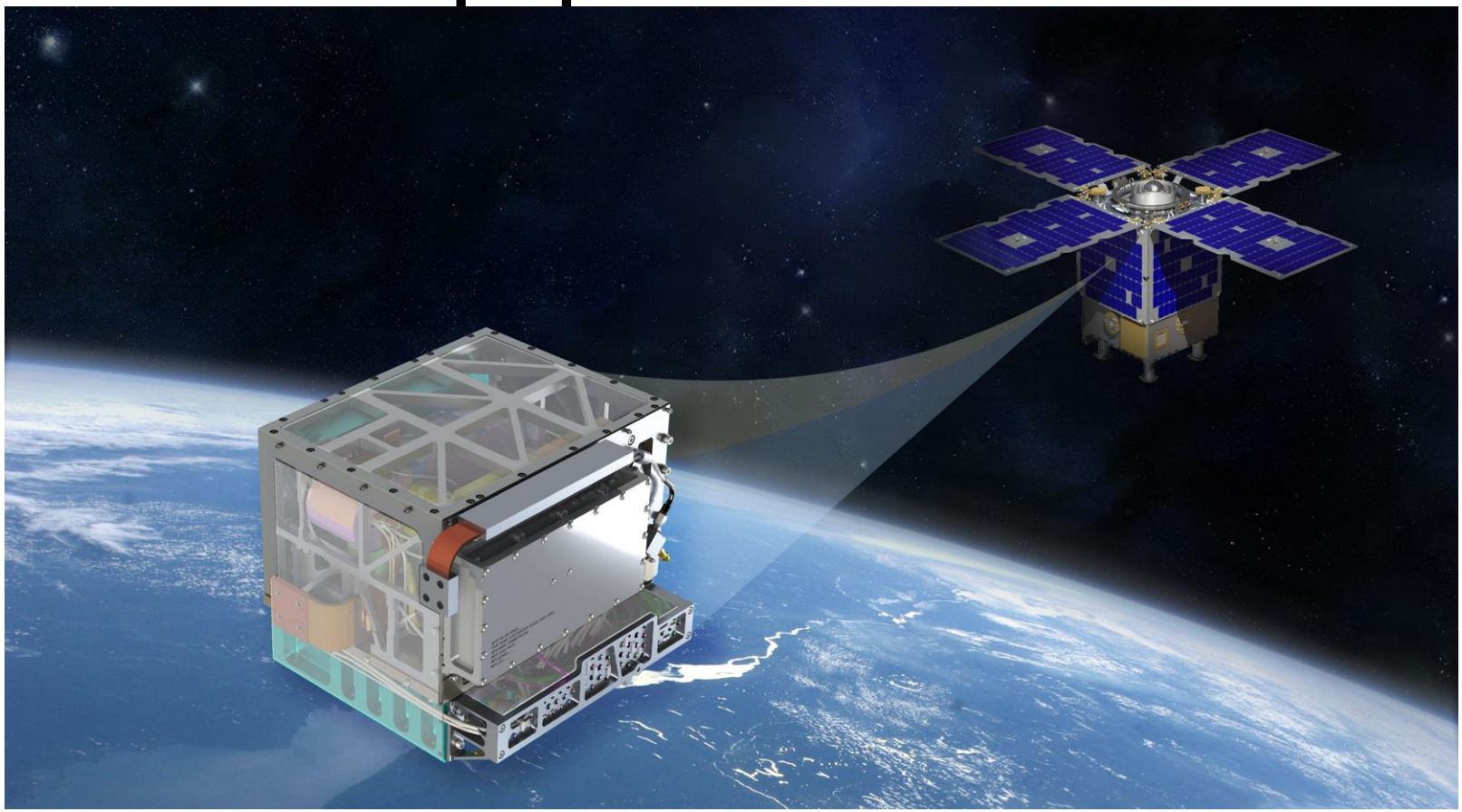
Deep Space Atomic Clock



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TDM

SCaN

GENERAL ATOMICS

STP2-DSAC Launched, June 24

https://www.youtube.com/watch?time_continue=139&v=qLEuCn8RT14

https://www.youtube.com/watch?v=ZbH8KoaqfDU

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/
  - Launched May 22, 2018.
  - On-board USO testing at JPL-FSTL.
  - GPS receiver for orbit determination
  - Laser Ranging Instrument*
  - Video: 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
  - Launched, June 24, 2019
  - JPL Tri-Global Navigation Satellite System Radio Occultation Receivers
  - Video: https://www.youtube.com/watch?v=qabMHoMyl1A 2:32 – 4:08

*https://doi.org/10.1103/PhysRevLett.123.031101

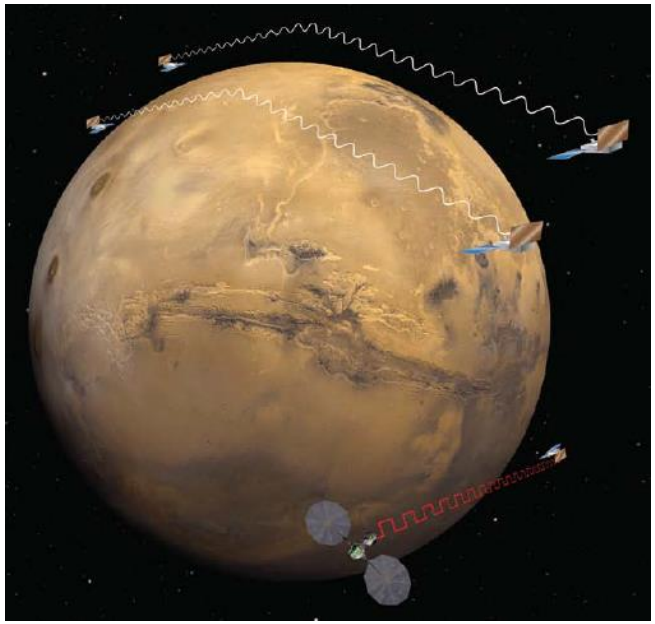
Application Clock Research and Development for NASA missions

- 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

*http://www.lcpm12.org/wp-content/uploads/2017/08/0910-0930-Williamson.pdf

- 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



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