



Report from NRL

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CGSIC, Timing Subcommittee

12 September 2016

Navigation Technology Satellite (NTS)

- NRL has contributed to GPS technology and system development since the beginning of the program
- Contributions began with System Concept Studies, and the Development, Orbit and Operation of the NTS
- NTS flew the first GPS pseudo-random ranging code transmitters, and demonstrated the first GPS on-board atomic clock operation

NRL conducted the Joint GPS Clock Technology Program

- Developed production sources of space and ground hydrogen masers, and space cesium atomic clocks for the GPS satellites
- Clock Electronics Design
- Transition to Industry Partners for production

GPS Space and Ground Clock Analysis

- NRL provides Space and Ground atomic clock performance analysis to the GPS program

Precision Clock Measurement and Evaluation Capabilities in Support of Multiple NRL Programs

- Provides Capability for Measuring and Characterizing Clocks
- Maintains Realization of Coordinated Universal Time, UTC(NRL)
 - 6 Masers; 12 Cesiums
- Multiple Multi-Channel Precision Dual Mixer Measurement Systems
- Precise Time and Frequency Distribution Systems
- Automated Data Collection and Archival Systems
- Supports the GPS Space Clock Extended Life Tests



In process of upgrading:

- Environmental chambers
- Masers
- Measurement Systems



Provides Long-Term Testing of Production Space Clocks for the GPS Program

- **Conducted Series of GPS Clock Life Tests at the NRL PCEF**
 - Two Block IIR Rubidium Atomic Frequency Standards (RAFS)
 - 1997 to 2004
 - Two Block IIF Digital Cesium Beam Frequency Standards (DCBFS)
 - Intermittently 2004 to 2006
 - Resumed November 2010 to present
 - Two Block IIF RAFS
 - August 2008 to present
 - Two GPS III RAFS
 - Expected arrival December 2016
- **Production Units**
- **Validate prior to launch**

GPS Space Clocks Extended Life Test Objectives

- **NRL Life Tests serve as a baseline for on-orbit clock performance**
 - Provide long term observation that cannot be conducted in the clock manufacturer's production environment
 - Simulate space-like environment for vacuum and temperature
 - Evaluate performance parameters
 - Clock and telemetry
 - Identify premature failure modes
 - Characterize clock over long term

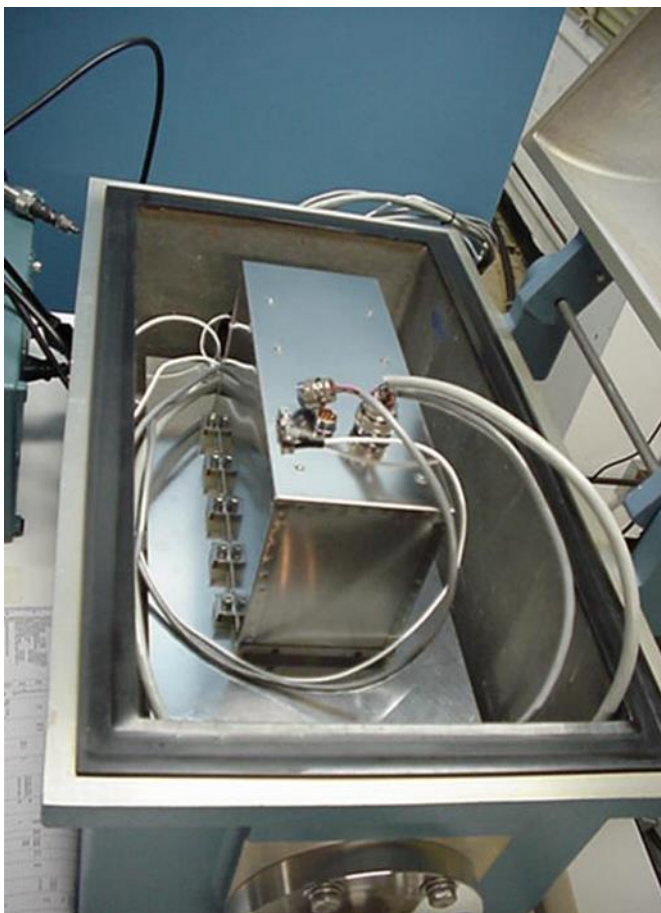
- **GPS Life Testing Joint Collaboration**
 - NRL
 - GPS Directorate
 - Satellite Manufacturers
 - Clock Manufacturers

GPS Block IIF Life Test Chambers



GPS Block IIF Life Test Units

RAFS



DCBFS



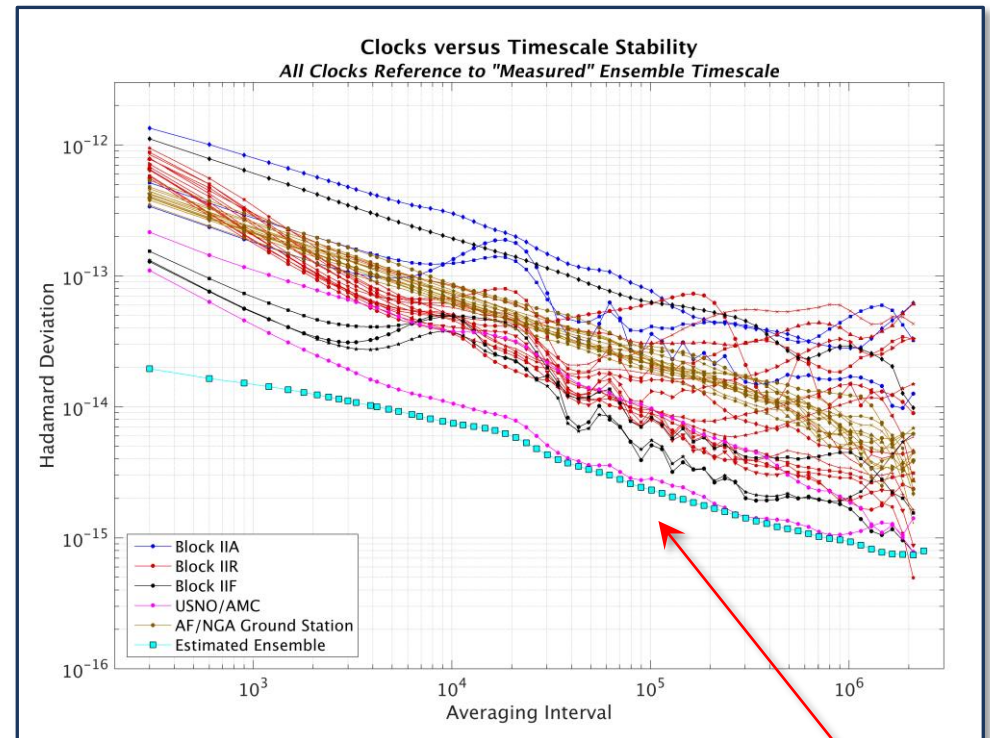
Provide Long-Term Performance Analysis of all Operational GPS Satellite and Monitor Station Clocks for the 2nd Space Operations Squadron (2 SOPS) at the GPS Master Control Station (MCS)

- NRL has provided the on-orbit performance of GPS satellite clocks since the beginning of the GPS program
- Measurements are collected from a network of 16 ground monitor stations operated by the USAF and NGA
- NRL Analysis used by 2SOPS to Tune the OCS Kalman Filter
 - Reports provided on a quarterly basis
 - Referenced to UTC(USNO)
- Metrics used in the analyses include:
 - Clock Frequency and Drift
 - Frequency stability based on the Allan (ADEV) and Hadamard (HDEV) Deviations
- Maintain comprehensive on-line database for all satellite and monitor station tracking data

Next Generation GPS Time Timescale

Provide Algorithms and Software for Next Generation GPS System Time as part of the GPS OCX Ground Segment Upgrade

- NRL developing the Algorithms and Software for Generating Next-Generation GPS Time Timescale within the OCX Operational Kalman Filter
- Improvements to the GPS Time Timescale
 - Clock weighting for better handling of mixed clock types
 - Automated clock break detection
 - Robust outlier and anomalous clock behavior mitigation
- Jet Propulsion Lab (JPL) providing Orbit Determination Software
- NRL Supports JPL with Timescale Software
- NRL → JPL → Harris → Raytheon



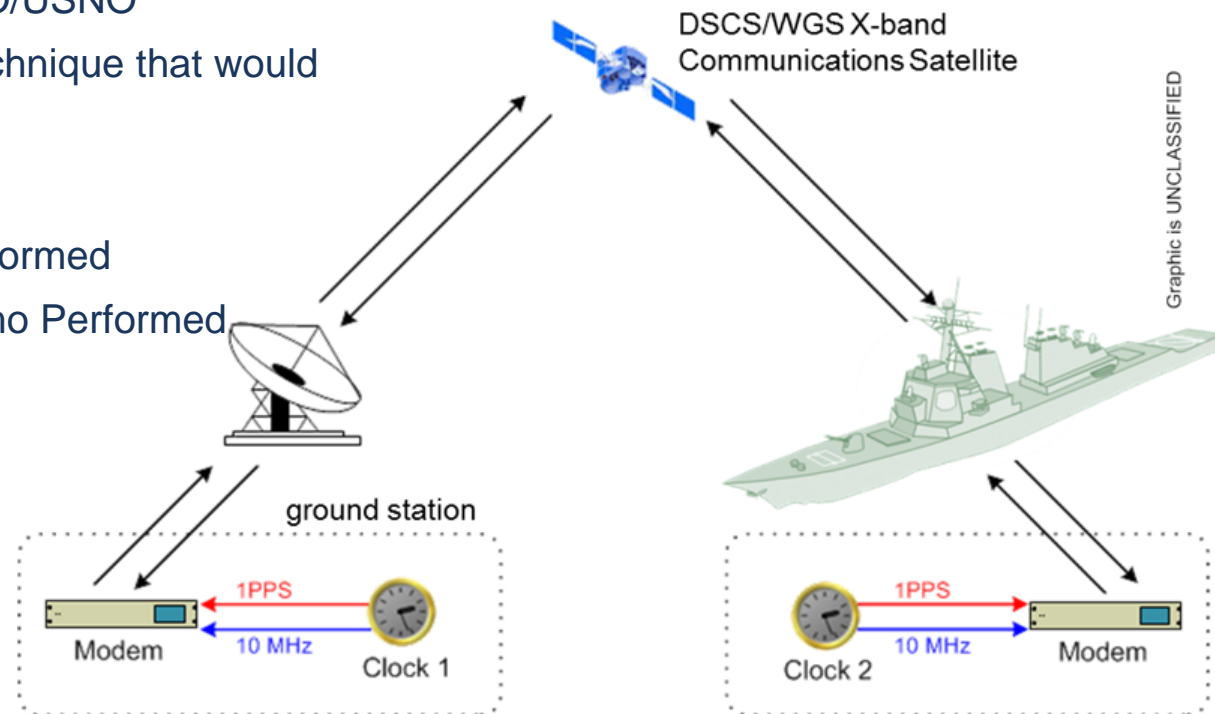
Generating a new robust timekeeping capability for the Next Generation GPS

Support DARPA Demonstration of Alternative Time Transfer Capability At Sea by Two Way Satellite Time Transfer

- Goal to Improve Global Availability of Time Transfer Exceeding GPS Capability
- Utilize Existing Shipboard Comms Systems
- Utilize DoD Timing Network for Demonstration
- GPS-Independent Time & Synchronization Capability
- Cooperative Effort with SPAWAR/PEO/USNO
- NRL to Develop and Demonstrate Technique that would Transition to USNO for Operations

Status

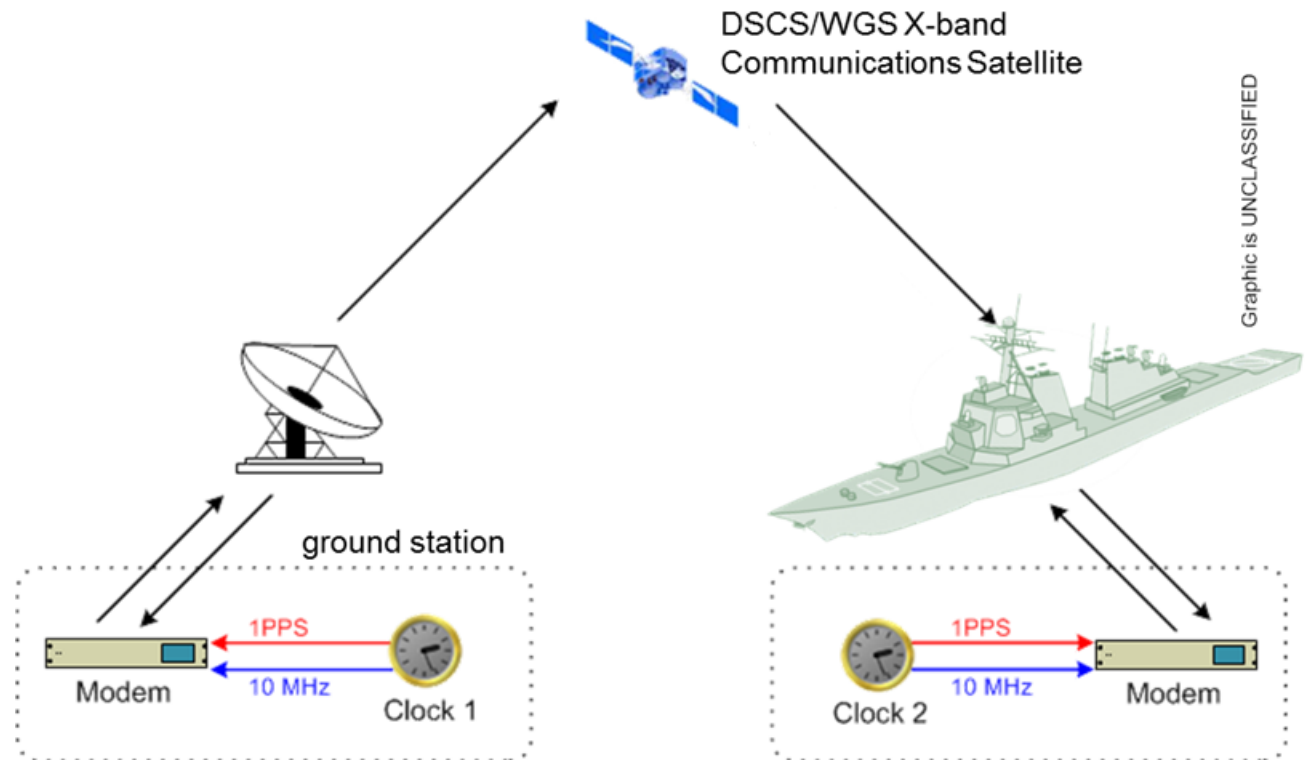
- March 2016 - Land-Based Demo Performed
- August 2016 - Trident Warrior 16 Demo Performed



One-Way Satellite Time Transfer

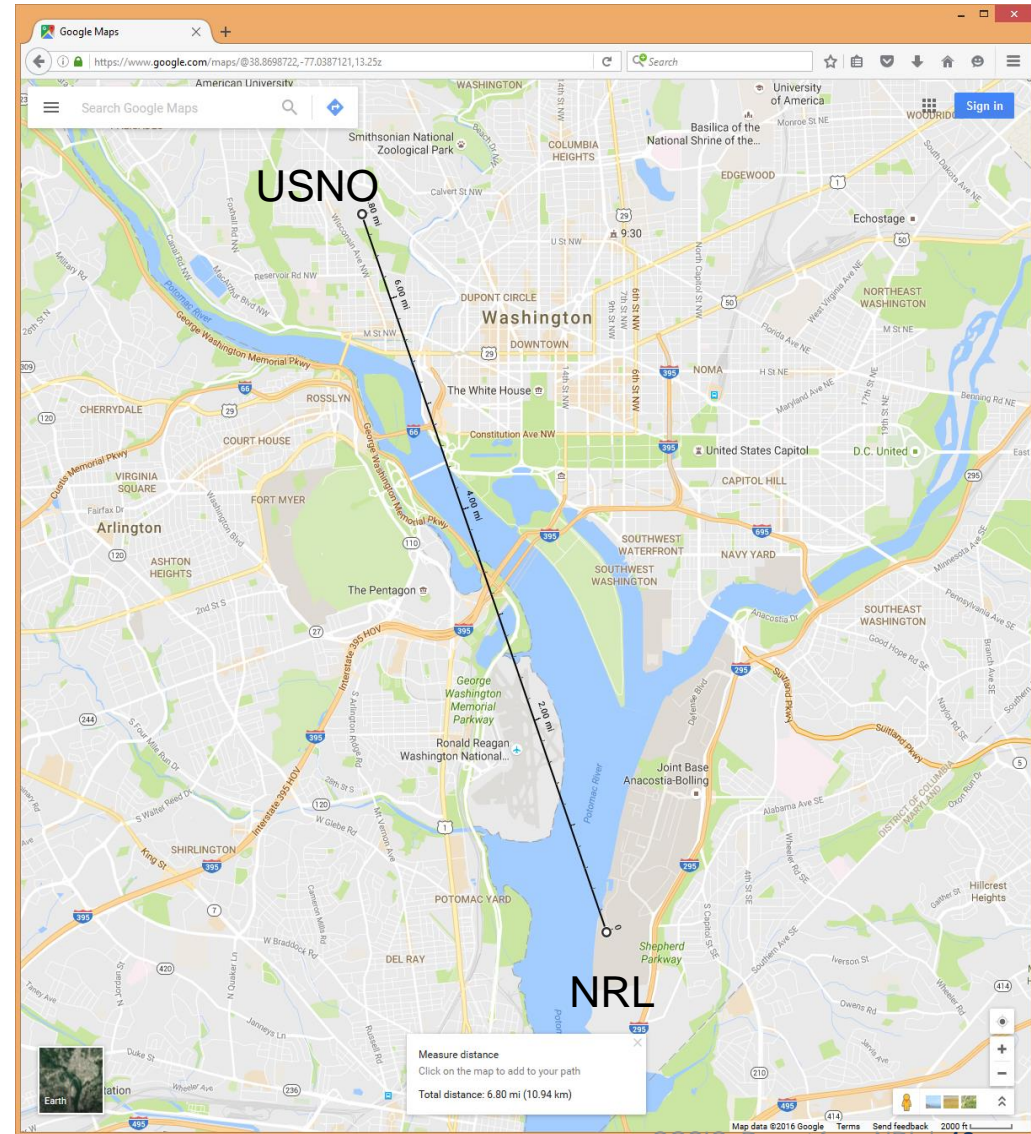
Develop Technique and Data to support One-Way Satellite Time Transfer

- Goal to Improve Global Availability of Passive Time Transfer
- Would dovetail nicely with NEXTANT for Navy application
- Utilize DoD Timing Network for Demonstration



Laboratory Time Transfer Links

- Geodetic GPS
- Television (WTTG DTV) Common-View
- Dedicated Fiber link (USNO-NRL)
- Link-16 (Summer 2016)
- Ku-Band TWSTT (Fall 2016)
- X-Band TWSTT (Fall 2016)



48th Annual Precise Time and Time Interval (PTTI) Systems and Applications Meeting

PTTI 2017

(Co-located with ION International Technical Meeting)

January 30 – February 2, 2017

Hyatt Regency
Monterey, California

General Chair

Mr. Ryan Dupuis
Excelitas Technologies

Program Chair

Mr. Michael Lombardi
National Institute of Standards and Technology

Abstract Deadline: October 3, 2016

PTTI Tutorials January 30

Tutorials Chair

Dr. Jay Hanssen
U.S. Naval Observatory

- **Reference Time Scales and Traceability Concepts**
Dr. Felicitas Arias, BIPM
- **Precision Measurements and Calibration**
Mr. David Howe, NIST
- **Introduction to Atomic Frequency Standards**
Dr. Robert Tjoelker, NASA JPL
- **Global Navigation Satellite Systems**
Dr. Pascale Defraigne, Royal Observatory Belgium
- **Fiber Based Time and Frequency Transfer**
Dr. Sven-Christian Ebnehag, SPTR Institute of Sweden
- **Earth's Time Varying Rotation**
Dr. Richard Gross, JHU APL

- Clock Technology for PTTI Applications
- Computer Time Transfer: NTP, PTP, and Related Systems
- GNSS Time Transfer
- PTTI Measurement Techniques
- Time Transfer via Ground Based Radio Signals
- Time Transfer via Optical Fibers
- Geostationary Satellite Time and Frequency Transfer
- Optical Clocks and the Eventual Redefinition of the SI Second
- PTTI Services in Emerging Nations
- The Role of PTTI in:
 - Improving GNSS Invulnerability, Reliability, and Performance
 - Consumer Market Applications
 - Electric Power Distribution
 - Telecommunications
- Time is Money: The Role of PTTI in the Financial Sector
- Time Scales and Algorithms
- Timing Laboratory Activities and Updates
- Timing Activities at International Agencies/Organizations