CHOMPTT (CubeSat Handling of Multisystem Precision Timing Transfer): From Concept to Launch Pad

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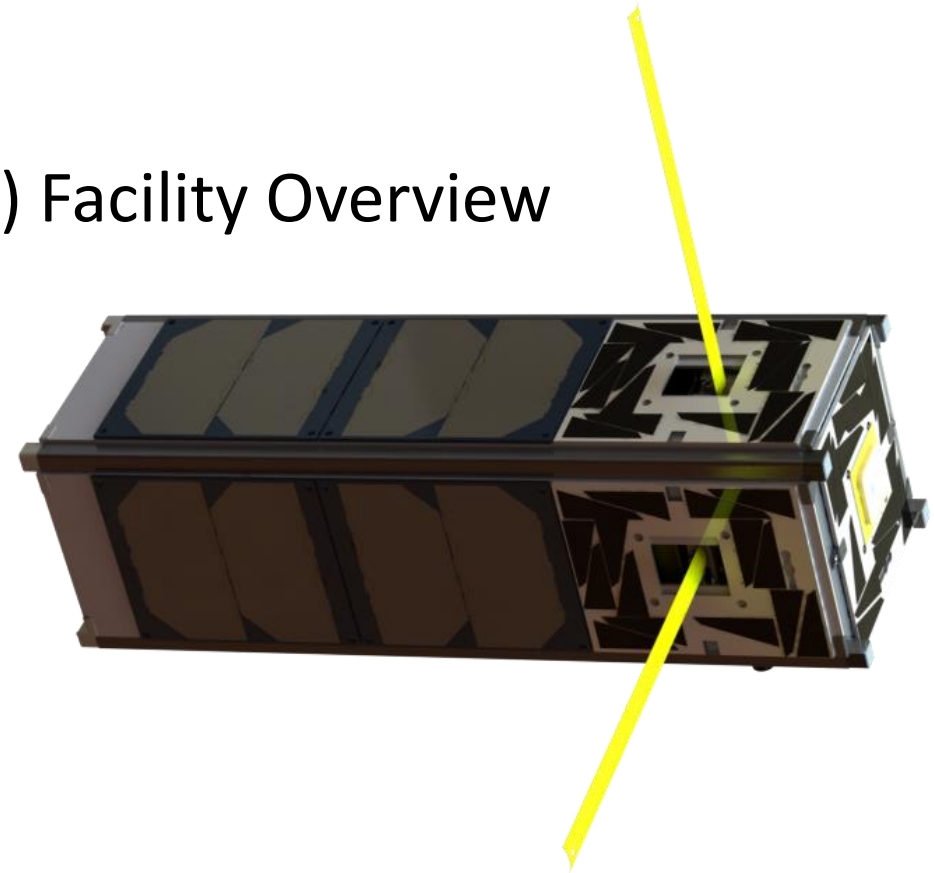
Agenda

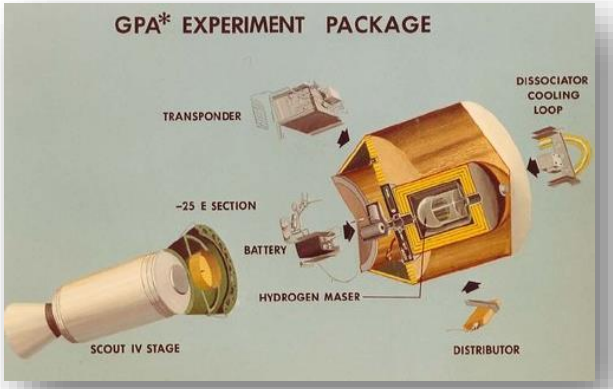
- Mission Overview
- Payload Design History
- Flight Payload Overview
- Spacecraft Overview
- SLR (Satellite Laser Ranging) Facility Overview
- Current Status



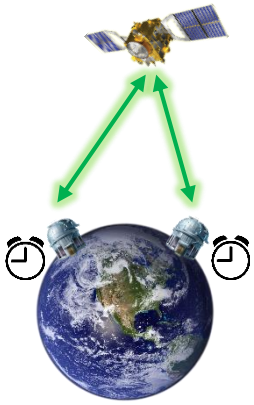
Background and Motivation

- Initial proposal for CHOMPTT in Fall 2012 for UNP8
- Application of precision time transfer to space:
  - Satellite navigation system
    - Beyond LEO
  - Global time standards
  - Test of general relativity
  - Satellite encryption/authentication
  - Communications and Networking
- Optical time transfer
  - More resilient to ionospheric effects than RF ($\propto 1/f^2$)
  - CNES T2L2 (2008), hosted payload on Jason-2

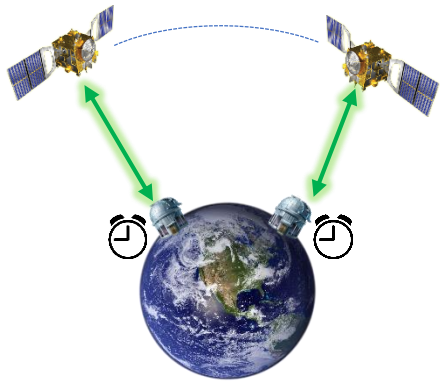
GPS Constellation



Gravity Probe A (1976)



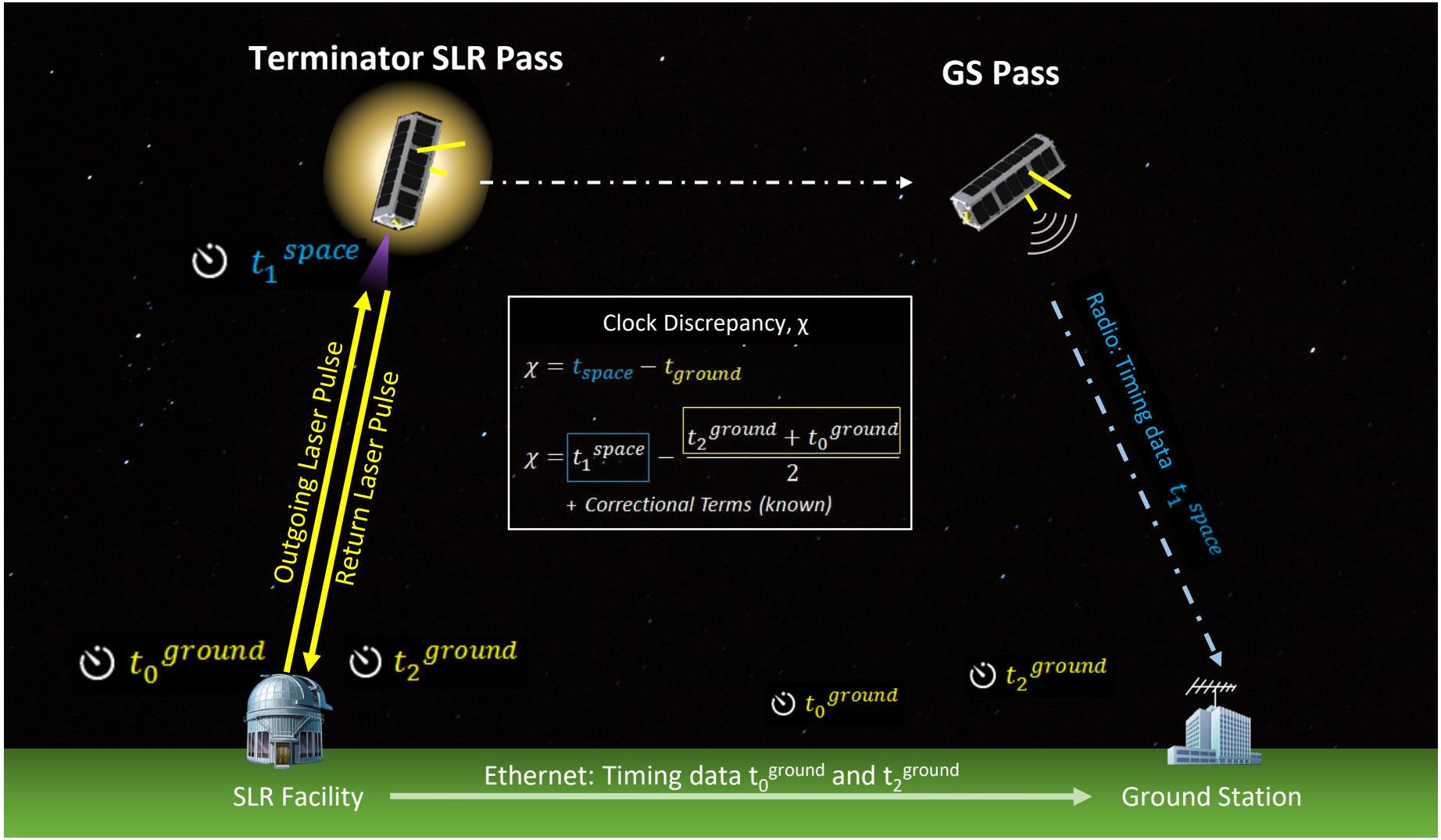
Common View



Non-common View

T2L2 mission [P. Guillemot et al 2006]

Mission Overview

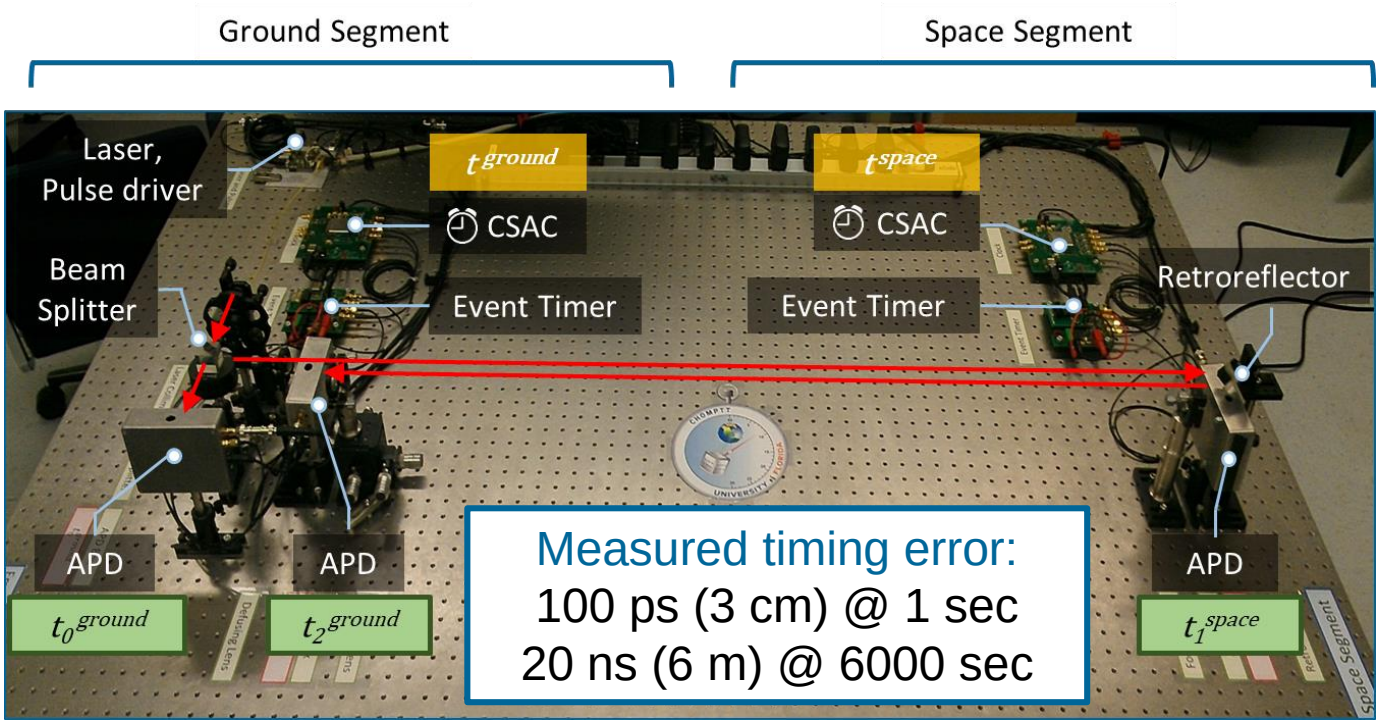


Single Time-Transfer <200 ps time transfer error, < 20 ns clock drift after 1 orbit

OPTI 1.0

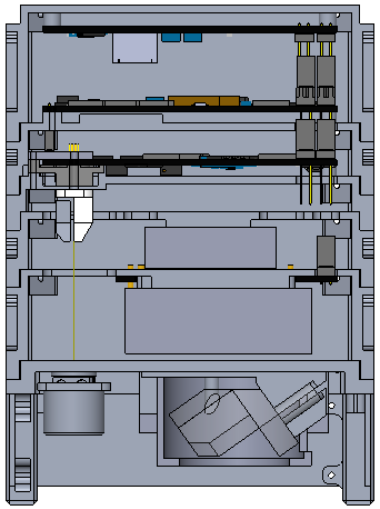
(Optical Precision Timing Instrument)

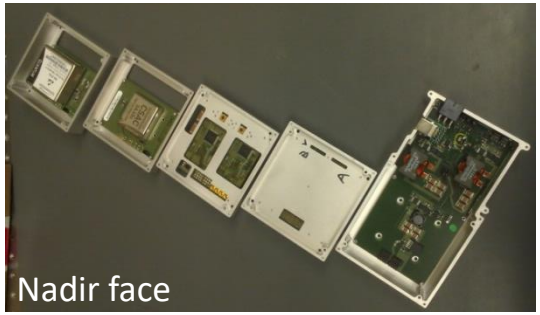
- Design based on AFRL UNP Mission Requirements
- Key Technologies: Precision timing electronics, a Chip Scale Atomic Clock (CSAC), Avalanche Photodetector
- Successful laboratory testing of breadboard

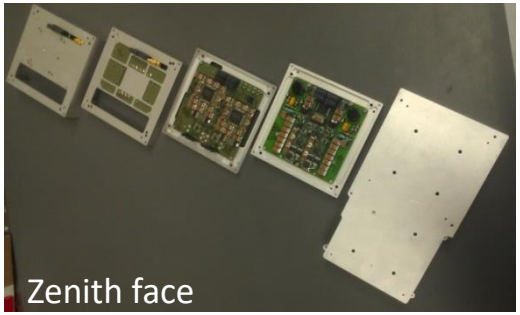


OPTI 2.0

- EDU unit for the UNP8 unit configuration
- Much higher power ~8W average because of Miniature atomic clock
- 1.5 U form factor with reconfigurable clocks
- Power regulation and distribution
- High Altitude Balloon Test
  - ~100,000 ft. for 6+ hours
  - Obtained system health data
  - Successful power cycle test
- UF planned to design entire CubeSat



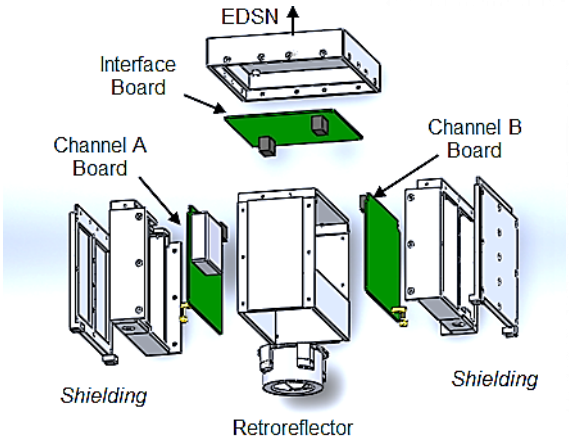

Nadir face

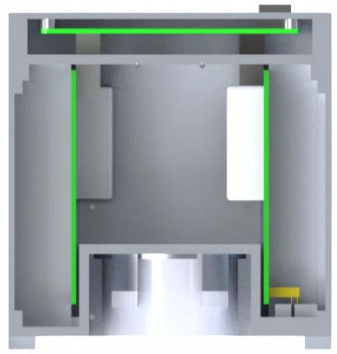

Zenith face

OPTI 3.0

NASA Ames/Advanced Exploration Systems began CHOMPTT support

- NASA Ames bus: EDSN Derived Bus (Summer 2015)
- New low-power mission requirements from bus (<2 W average)
- Decrease size to 1U
- Key technologies: precision timing electronics, two CSACs, APD, single 1 in. retroreflector design

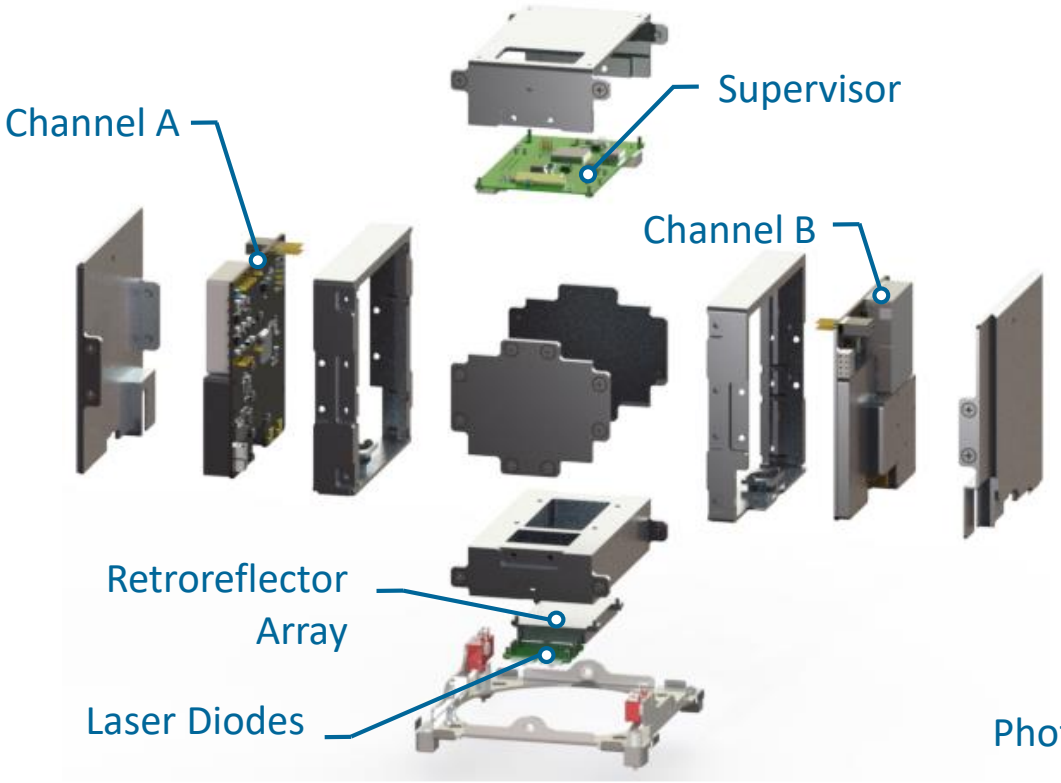


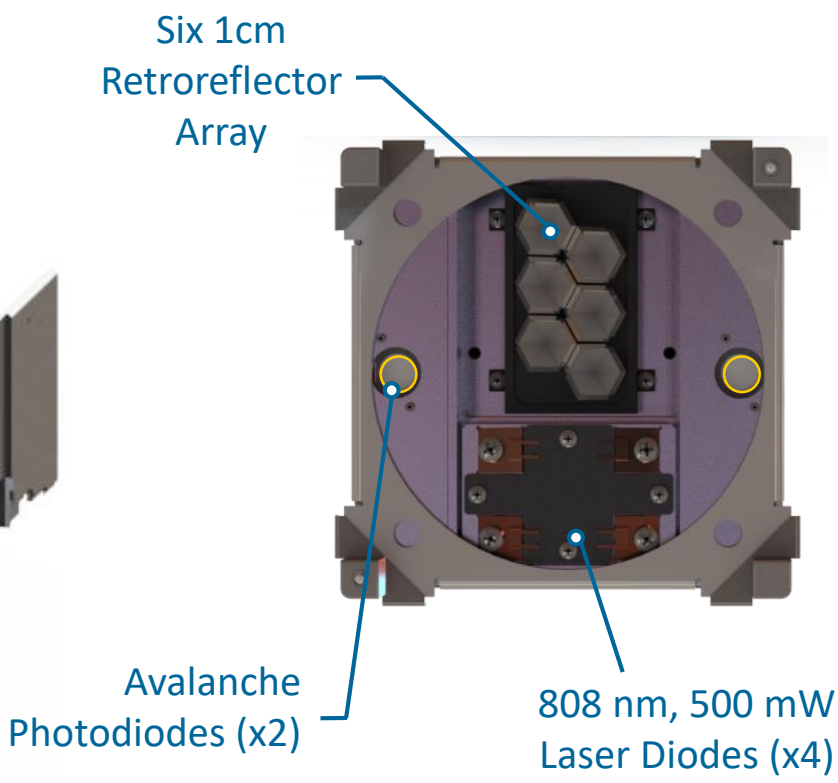


EDU Unit for current flight version

OPTI 3.1 (FlightPayload)

- New/defined SLR requirements
- Include beacon laser diodes
- Include additional debug ports and test points

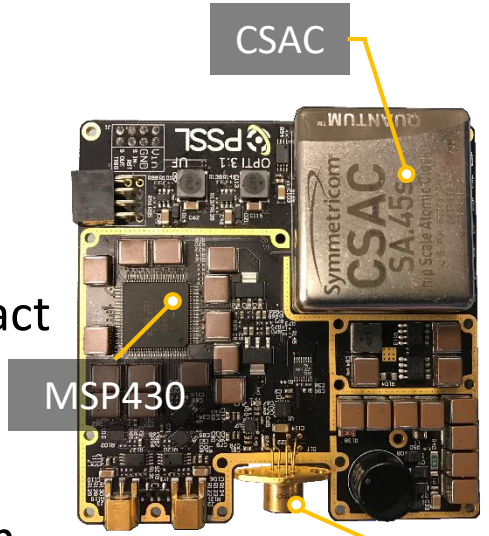




Flight Channel Board

- Responsible for Precision Timing
- Key Components:
  - TDC-GPX
    - Integrated solution
    - Measurement based on propagation delay
    - Autonomous temperature compensation using DLL
    - 10 ps single shot accuracy
  - MSP430
    - Microcontroller, Provides course clock counts
  - CSAC (Chip Scale Atomic Clock)
    - Low size, power, and weight so minimal budget impact
    - Allan Deviation: 3.26 x 10^{-12} after one orbit
  - Avalanche Photodetector
    - InGaAs APD with wavelength detection 900-1630 nm
    - High gain, small package with TEC included

Bottom View

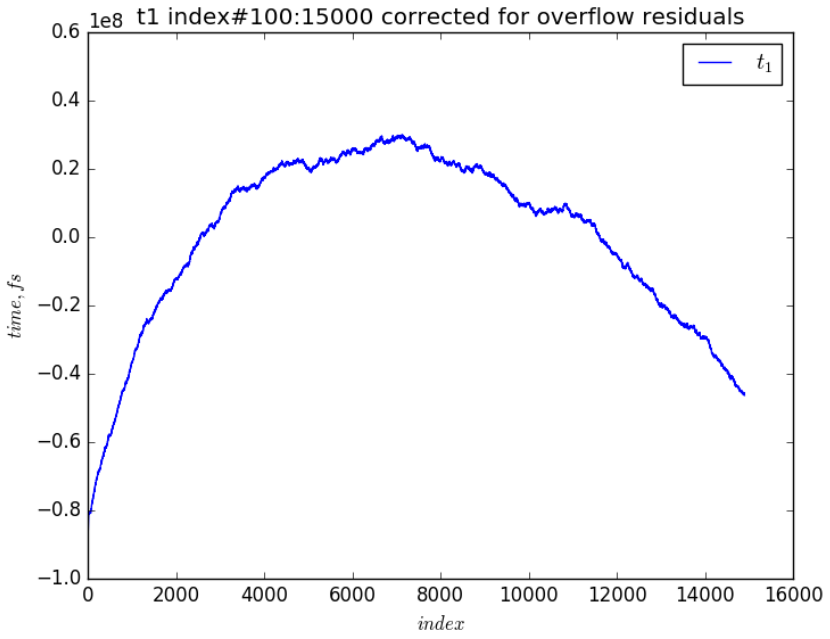


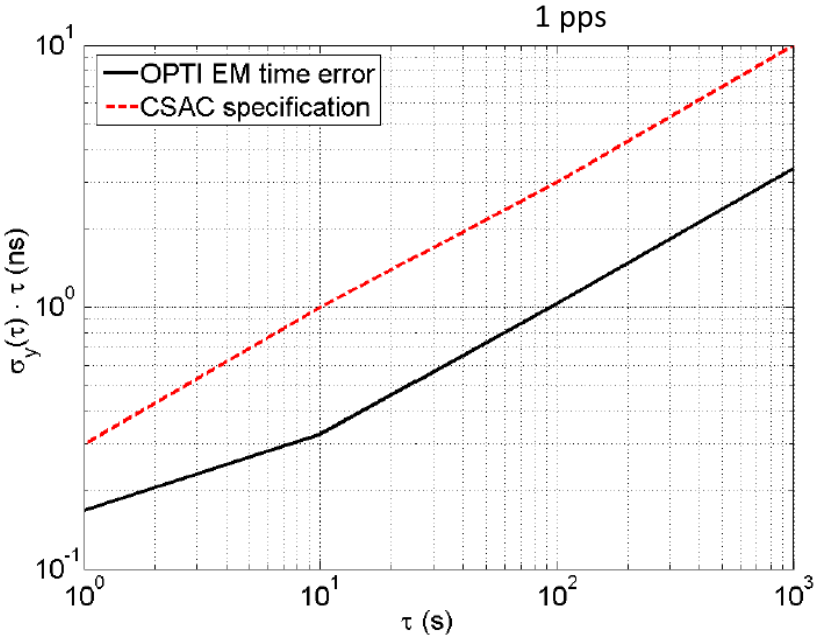
Top View

Channel Board Results

Measured timing error:
150 ps (4.5 cm) @ 1 sec
3.5 ns (1 m) @ 1000 sec

- Less optical received than on orbit
- Timestamped all ~15000 pulses with no artifacts





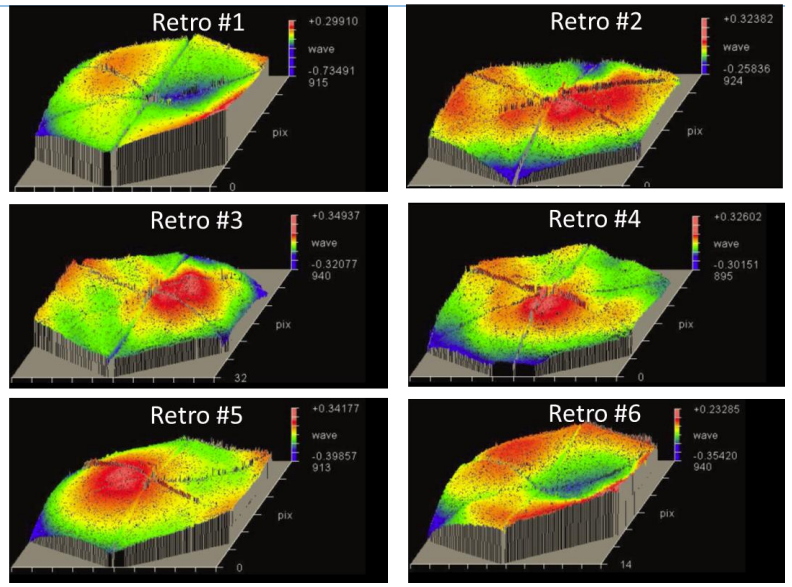
Flight Supervisor Board

- Data management and storage between the two channel boards
- Current driver for laser diodes
- Key Components
  - Custom current driver on board (4X)
  - N25Q00AA 1 Gb NOR Flash Memory
  - MSP430

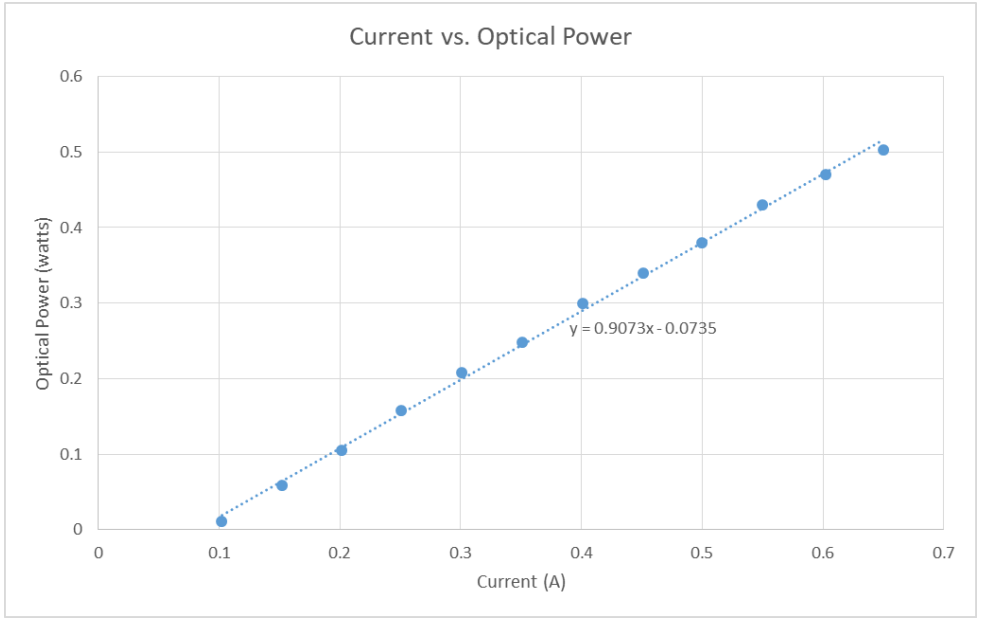
Flight Optical Assembly

- Hollow Retroreflector Array (HRA): Six (6) Ø 0.40 [10mm] Clear Aperture
  - Individual Retroreflector Accuracy: 15 arc seconds.

Testing at: SPAWAR

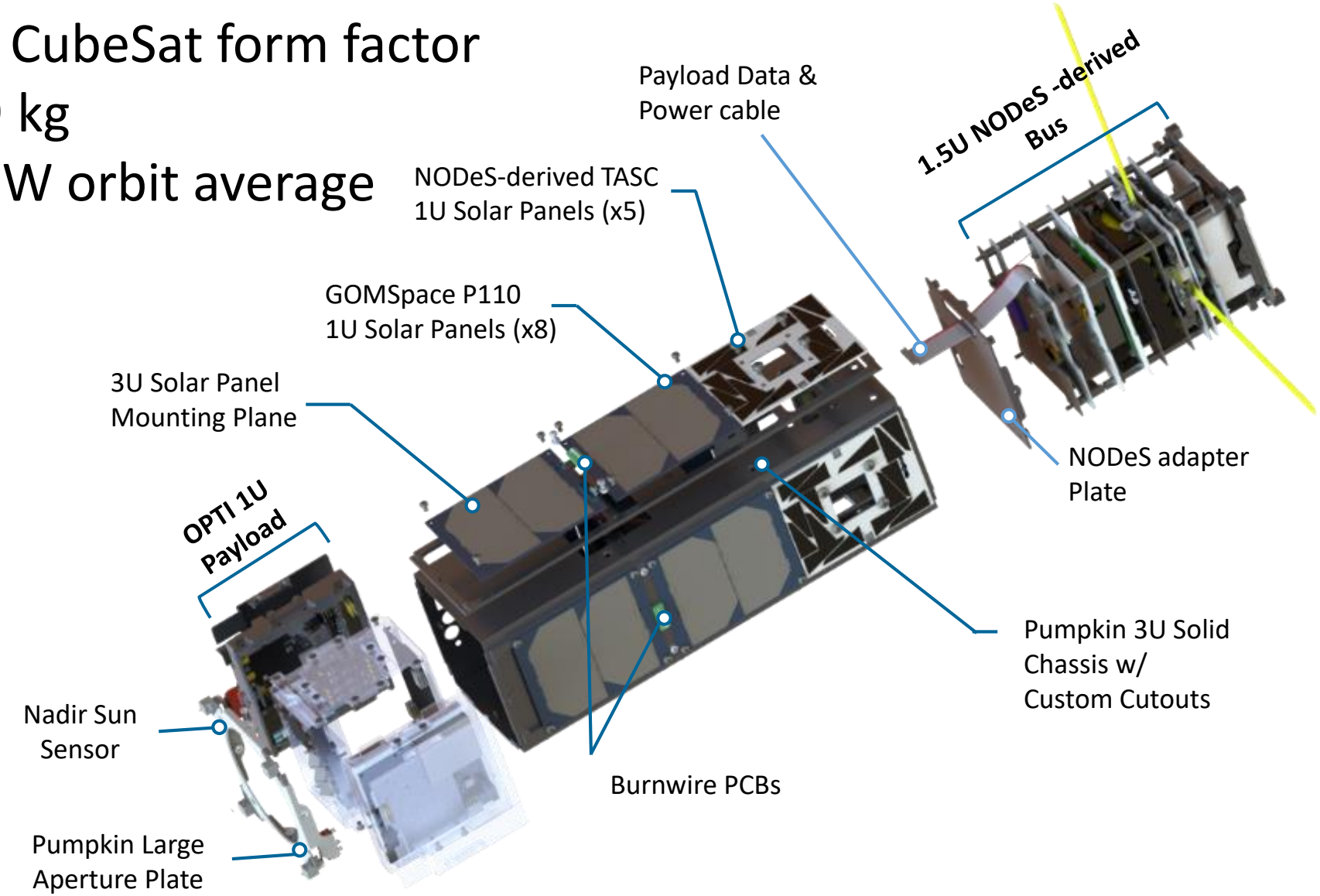


- Laser Diodes
  - 4X 808 nm
  - 4X 500 mW optical power

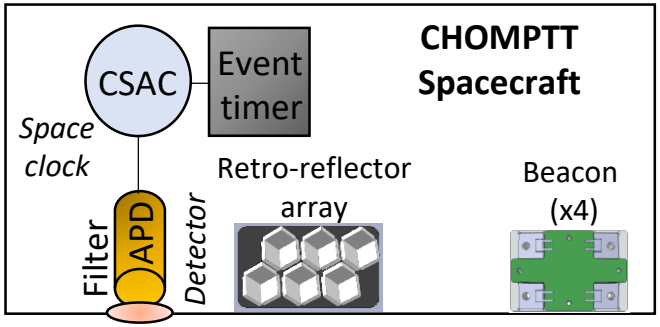


Spacecraft

- 3U CubeSat form factor
- 3.9 kg
- <2 W orbit average



SLR Facility (TISTEF/UCF)



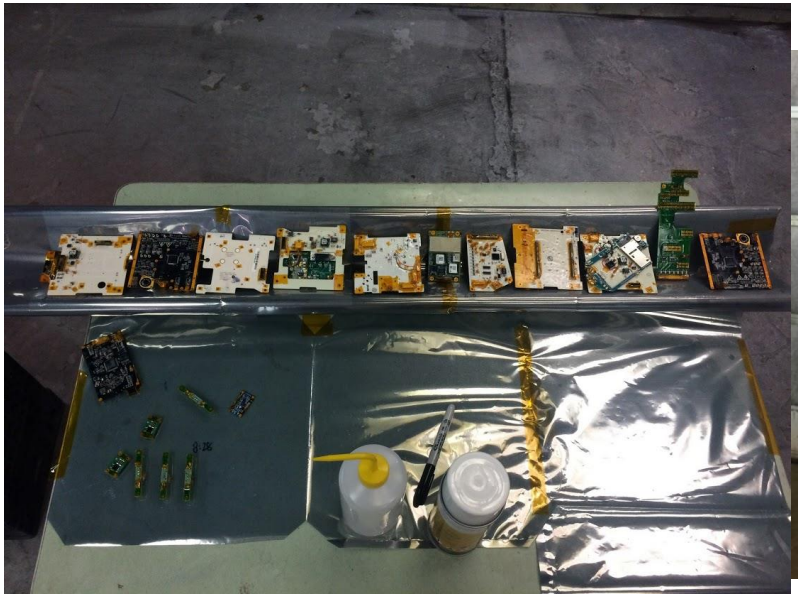
Coherent Flare 50/50

- 1064 nm
- 1 mJ
- Linear Polarized

Satellite Laser Ranging Facility

Status

- ElaNa XIX Launch
  - Rocket Labs LV
  - Electron, Mahia NZ
  - Low Earth Orbit:
    - 500 km x 85 deg
  - Delivery: Q4 2017
  - Launch: Q1 2018

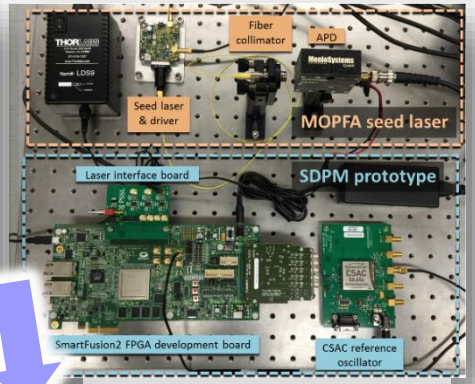


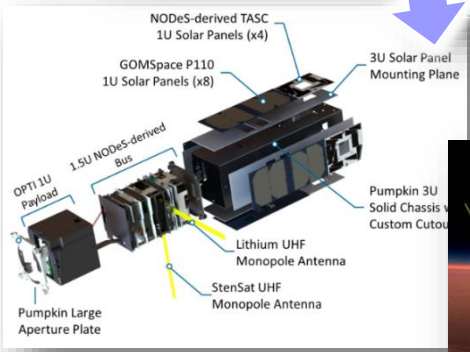
- Finished conformal coating and functional testing of flight boards
- Working towards final integration and verification tests
- Shake and Bake this month
- Final testing in FL with SLR and ground station in Sept.

PSSL Postdoc, Scientist positions

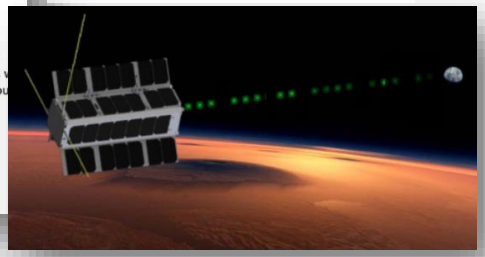
- Positions available in the following areas:
  - Digital & analog electronics/avionics for space
  - Optics, photonics, lasers and detectors
  - Control & estimation techniques applied to complex systems
- Contact: jwconklin@ufl.edu

Precision timing, Opto-electronics



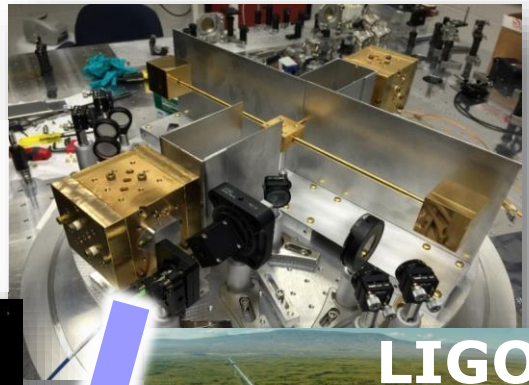


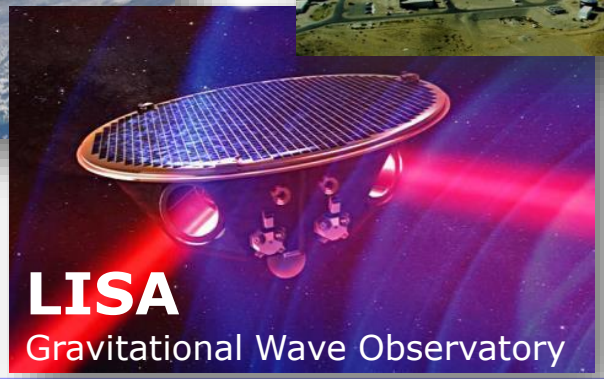
Navigation & Optical Comms



Inertial sensors, drag-free systems

Geodesy & Gravitational waves





Vibrational Testing

- Vibration testing to GEVS specs on all three axis
- All four beacons were functional to spec after the vibrational test