**Technology Development Challenges to Meet TRL Goal**

**Making the technology rad hard**
- Existing technology developed for short (< 1 yr) CubeSat missions in LEO
- For HPD missions, a radiation tolerant version may be needed
- For most components, rad tolerant parts can be found
  - One exception: Time-to-Digital Converter (TDC) that performs the precision time-stamping
  - Solution: The PSSL, with STMD support, has been developing TDCs and related functionalities in software on rad tolerant FPGAs

**Precision beam pointing and acquisition still under development, currently TRL 4**

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**Technology Description, Current Performance Metrics, and Performance Goals**

- Compact, low power precision time transfer via exchange of nanosecond IR laser pulses
- 100 ps (3 cm) measured time-transfer accuracy
- Chip Scale Atomic Clock: 20 ns drift after $10^4$ s
- Ground-to-space or space-to-space links
- Rx: < 5 W peak  
  Tx: < 15 W peak
- Volume: < 2U  
  Mass: < 2 kg
- Ground-to-LEO demo of OPTI: July 2018
- LEO-to-LEO demo with related tech: 2020

**Current TRL**

- TRL 4
- TRL By May 2021
- TRL 6

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**Potential HPD Science Application (Optional)**

- Synchronization of measurements made by swarms or constellations of microsatellites or CubeSats
- Example:
  - Particle detectors on a number of small satellites orbiting the Sun
  - Synchronization of the constellation to ~1 ns → relative arrival times of particles at each S/C + relative range between S/C
  - Enables 4D mapping (X, Y, Z, t) of solar activity

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**Additional Comments**

- Additional information on two CubeSat tech demonstration missions (CHOMPTT and CLICK) provided in back-up charts

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Assumption: Technology required to be at TRL 5 by May 2021
CHOMPTT CubeSat Mission Concept

Clock discrepancy:

\[ \chi = t_{1}^{\text{space}} - \frac{t_{2}^{\text{ground}} + t_{0}^{\text{ground}}}{2} + \Delta t \]

Launch: July 2018
500 km circle, 85 deg
NASA ELaNa XIX - Rocketlab

[J. Anderson, et al. JASR 2017]
OPTI Flight Payload Assembly

Channel A (back)

Six, 1 cm retro array

Channel B (front)

808 nm laser beacons (4×0.5 W)

Supervisor (payload controller)
CHOMPTT 3U Spacecraft

- **PSSSL**
  - Nadir Sun Sensor
  - Pumpkin Large Aperture Plate

- **OPTI 1U Payload**

- **3U Solar Panel Mounting Plane**

- **GOMSpace P110**
  - 1U Solar Panels (x8)

- **1.5U NODes-derived BUS**
  - NODes-derived TASC
  - 1U Solar Panels (x5)

- **Pumpkin 3U Solid Chassis w/ Custom Cutouts**

- **Baby Burnwire PCBs**

- **Payload Data & Power cable**

- **NODes adapter Plate**
CubeSat Laser Infrared CrosslinK (CLICK)

Two 6U, 15 kg each, P/L < 2 kg
15 W Ave, 30 W peak
Launch in 2020

UF PSSL time-transfer hardware:
• FPGA modulator + CSAC
• TDC-based photoreciever
NASA ARC-led mission, S/C bus
MIT: Payload PI, Optical font-end,
pointing/tracking, laser comm mod/demod

>10 Mbps IR link,
~10 cm ranging, clock synch