Science Mission Directorate

2018 Technology Demonstration Industry Day

Technology Demonstration MO

Technology Title: CubeSat Laser Infrared CrosslinK (CLICK) Mission

Affiliation: MIT STAR Lab and University of Florida PSSL

Assumptions: Technology required to be at TRL 5 by 2021

Technology Description, Current Performance Metrics, and Performance Goals

The mission goal is to advance state of the art in free space optical communications by demonstrating the feasibility of nanosatellite lasercom crosslinks using low cost, low complexity compact optical transceivers.

Performance metrics (baseline & extended goals):

- Demonstrate an optical communications crosslink at a data rate of at least 20 Mbps at a range of 580 km with BER better than 1E-4
  (extended goal: 20 Mbps at 855 km)
- Ability to maintain crosslink for at least 5 min duration
  (extended goal: crosslink for 10 min)
- Ability to operate a full-duplex crosslink
- Demonstrate precision ranging of at least 0.5 m without using GPS at a range of 580 km (extended goal: 5 cm at range of 855 km)

Current TRL

3

TRL By May 2021

9

Industry State of the Art Technology Performance

- Aerospace's Optical Communications and Sensor Demonstration (OCSD) CubeSats plan to demonstrate >5 Mbps downlink to 20 and 80 cm ground stations, but they do not include fine pointing.
- The Ranging and Nanosatellite Guidance Experiment (RANGE) will demonstrate inter-satellite ranging, but not fine pointing or high rate communications.
- Planned commercial demonstrations currently at higher size, weight, power, and cost.
- CLICK has full duplex, power efficiency, precision ranging, precision pointing, low cost COTS, at **20 Mbps and 580 km range.**

Technology Development Challenges to Meet TRL Goal

Component level breadboard validation testing is underway after successfully completing PDR. The CLICK transceiver module is currently TRL 3-4, with next challenges to complete flight-like boards, optomechanics, packaging, and software.

- FPGA development for ranging and full-duplex lasercom signal modulation and demodulation concurrent with signal processing for range measurement.
- Embedded software development for real-time, coarse-to-fine spacecraft pointing from beacon measurements.
- Flight-like software port of control algorithms for MEMS mirror beam steering.
- Validation of alignment and calibration of optomechanical assembly

Potential HPD Science Application (Optional)

- Lasercom crosslinks provide **intersatellite communication** opportunities for swarms and distributed aperture formation flying constellations..
- **Ranging** without using GPS can be used to determine relative position between multiple spacecraft in a swarm on heliocentric or planetary missions and support **time synchronized distributed measurements**.
- Lasercom crosslinks can also be used to **sound planetary atmospheres** in order to retrieve atmospheric properties such as temperature profiles and concentration of different species.

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Contact Information

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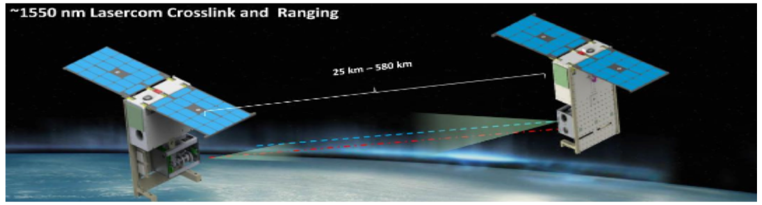
Project Manager: David Mayer (david.j.mayer@nasa.gov)

Additional Comments

CLICK successfully completed its Payload Preliminary Design Review on April 24th 2018, for flight on two 6U CubeSats. Proposed launch date is 2020.



CLICK Overview

Leveraging previous investments by NASA STMD, STTR, AFRL UNP, and both universities, CLICK will demonstrate free space optical crosslinks with with picosecond timing accuracy (University of Florida), and precision pointing, acquisition, and tracking controls (MIT AeroAstro) in Low Earth Orbit.

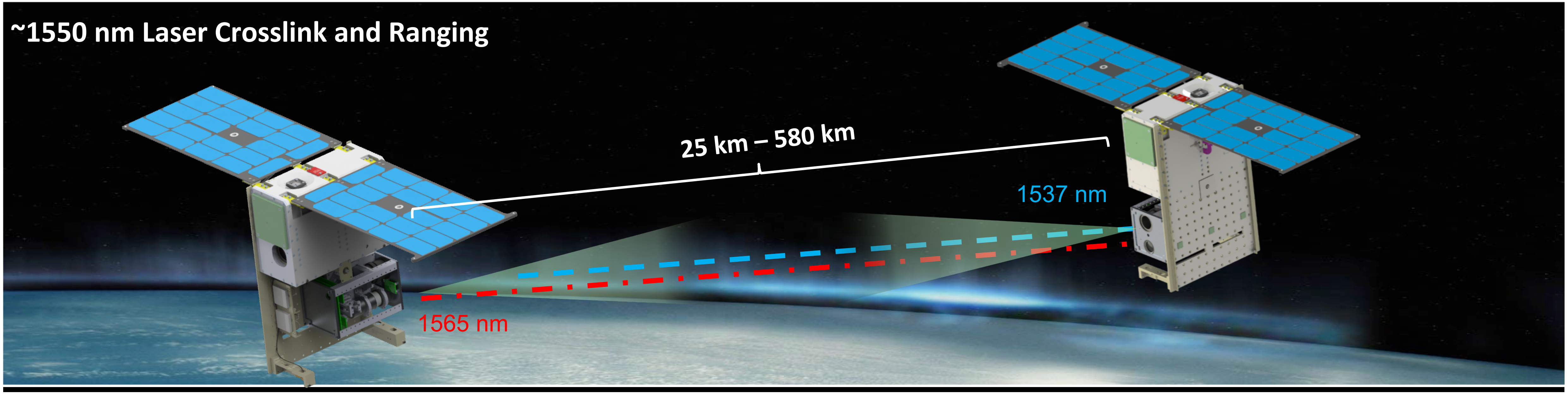
Size: Two 6U Spacecraft (CLICK terminal <2U)

Weight: CLICK terminal < 2 kg

CLICK Power: 15 W avg, 35 W peak

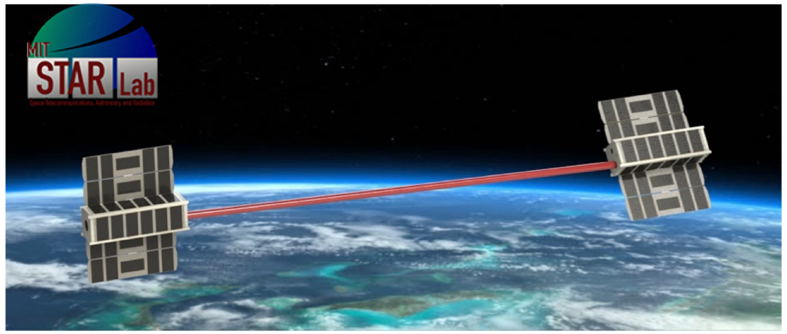
Future Applications:

- Enables nanosatellite missions that involve distributed apertures, constellations, or swarms to transfer high data rates (such as images or a video stream) from node-to-node or from daughter-to-mother spacecraft.
- Enables navigation (precision range and range rate) in GPS-denied environments or environments such as deep space



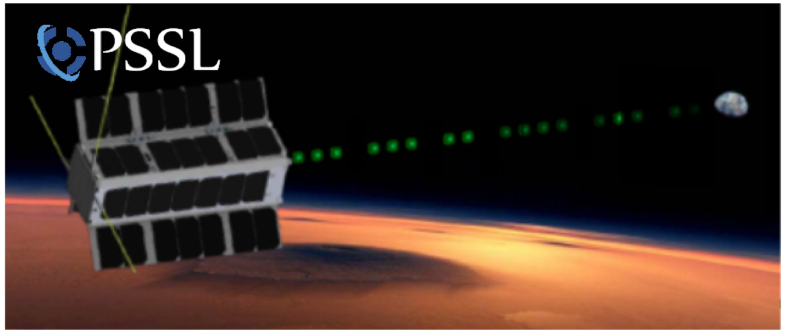
Contact: Kerri Cahoy kcahoy@mit.edu and Peter Grenfell pgrenfel@mit.edu

CLICK Background



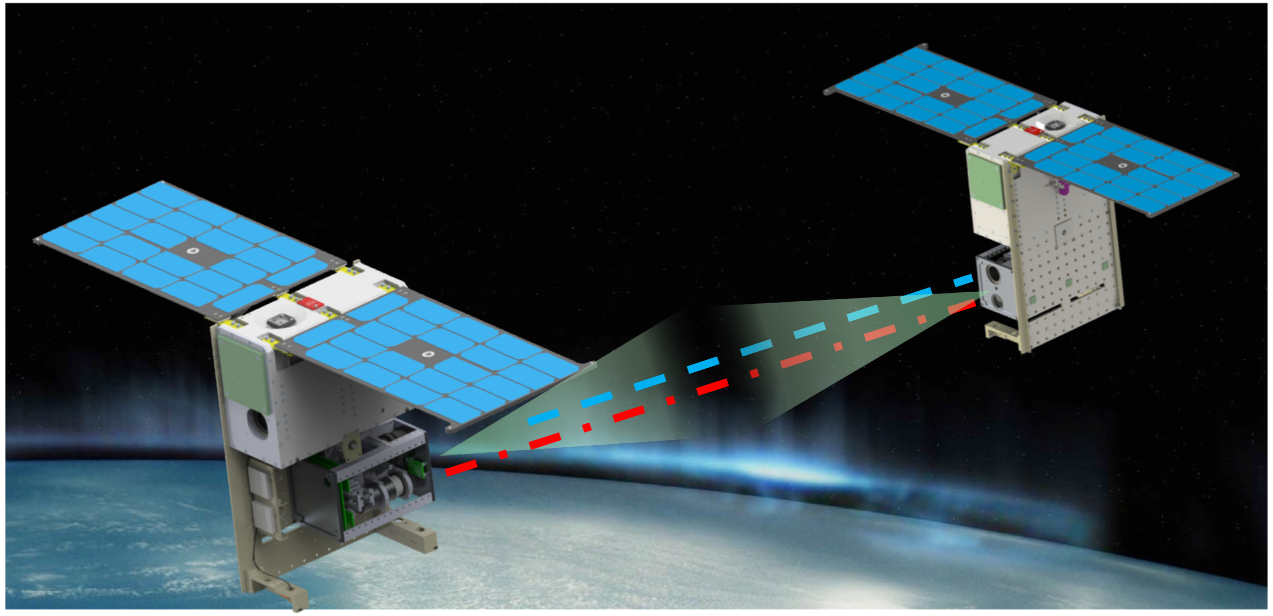
Free-space Lasercom and Radiation Experiment (FLARE)

- MIT entry to UNP NS-9
- Two 3U CubeSats with a 1550 nm crosslink lasercom payload and a custom MIT designed bus



Miniature Optical Communications Transceiver (MOCT)

- University of Florida awarded NASA SSTP-STP 2017
- Software defined pulse modulator with precision ranging accurate to 6 cm

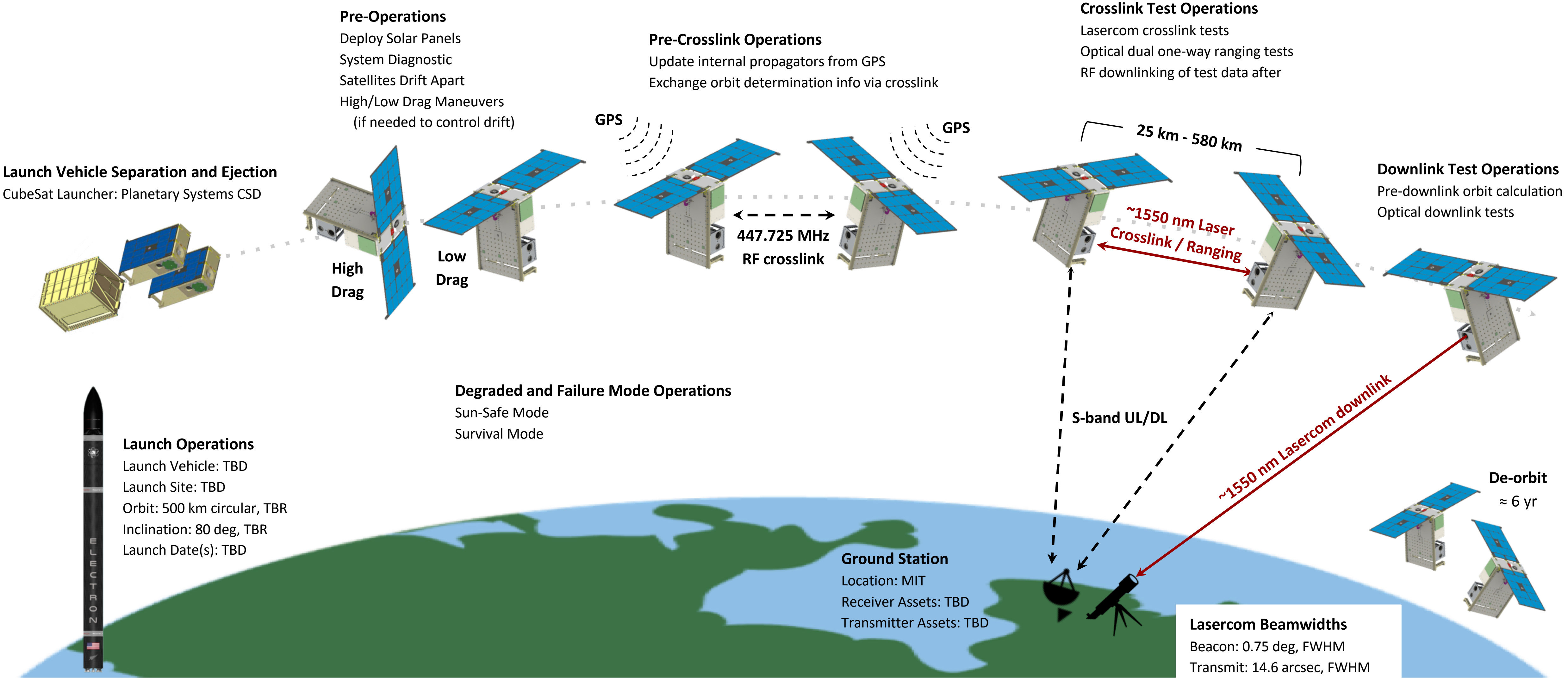


CubeSat Laser Infrared CrosslinK (CLICK)

- Joint mission that incorporates attributes of both FLARE and MOCT
- Funded by NASA STMD-SSTP
- CLICK will prove next generation, low cost, low complexity lasercom technology that is scalable to Gbps data rates
- Includes delivery of two lasercom terminals fully tested and ready to integrate into a proposed smallsat demonstration mission utilizing two 6U ORS buses

Contact: Kerri Cahoy kcahoy@mit.edu and Peter Grenfell pgrenfel@mit.edu

CLICK Concept of Operations



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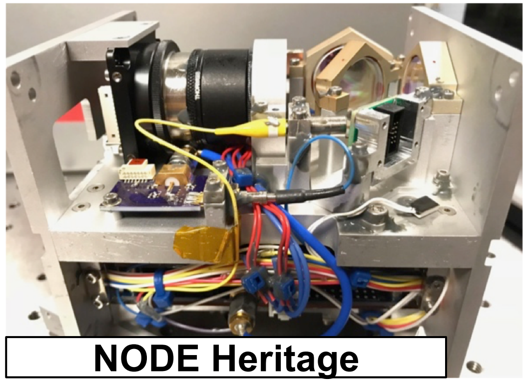
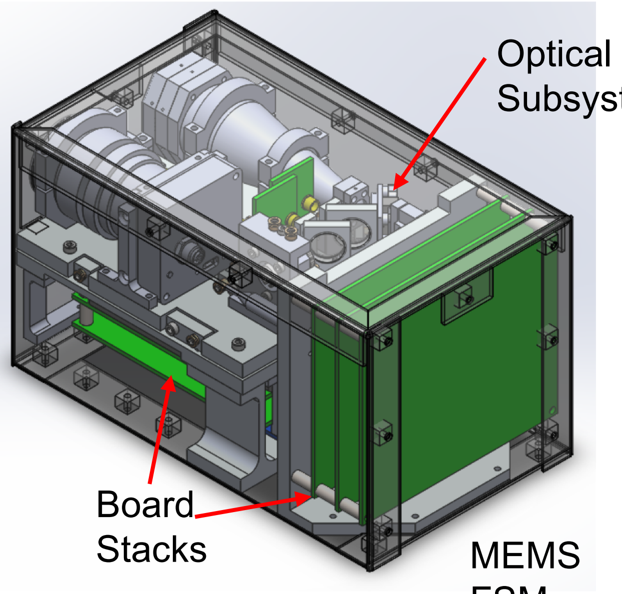
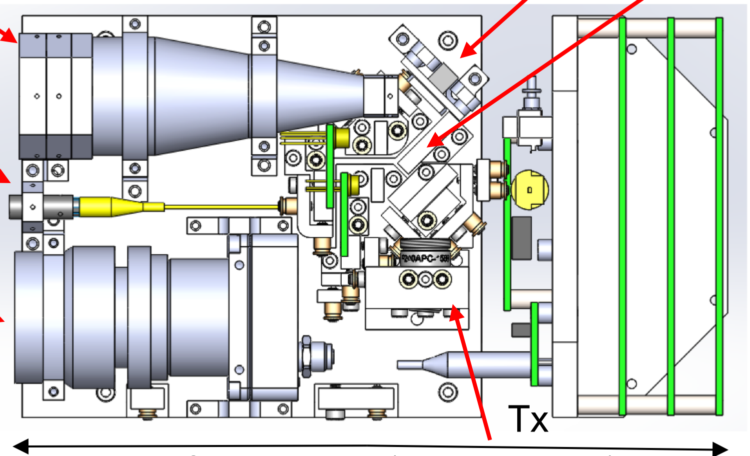
CLICK Terminal Overview

Technical Summary	
Application	Compact lasercom transceiver suitable for small-satellite constellations and swarms
Communications	20 Mbps, Full-Duplex, PPM, 1537 / 1565 nm, 14.6” divergence, 200 mW
Crosslink Ranges	25 km to 580 km (855 km extended)
Downlink	LEO to 30 cm Ground Station
Size, Weight, and Power	Volume < 2U, Mass < 2 kg, Peak power <35W
Beacon	976 nm, 0.75° divergence, 500 mW 10° FOV 5 Mpx CMOS Camera







Images courtesy D. Barnes, M. LaRocca, L. Yenchesky (MIT)

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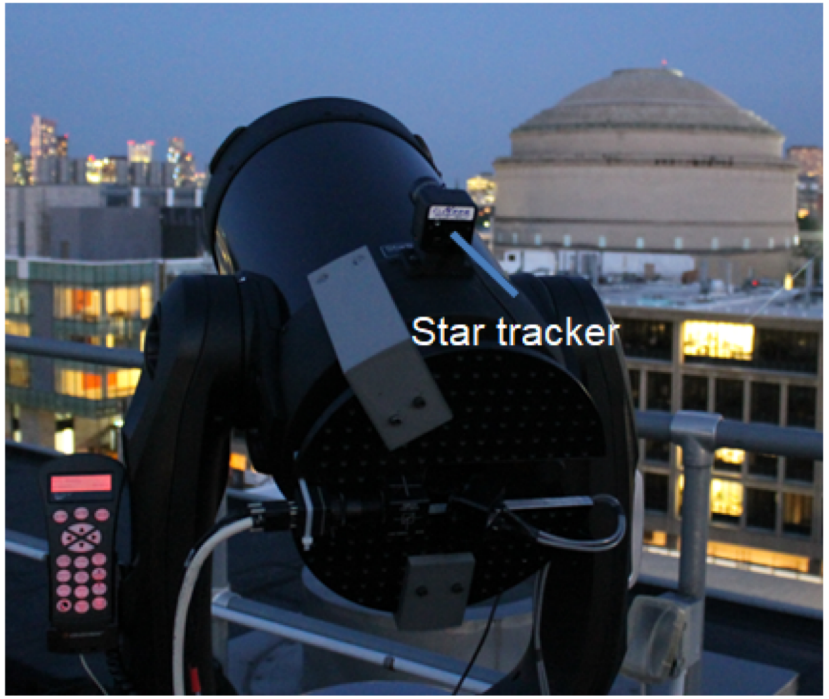
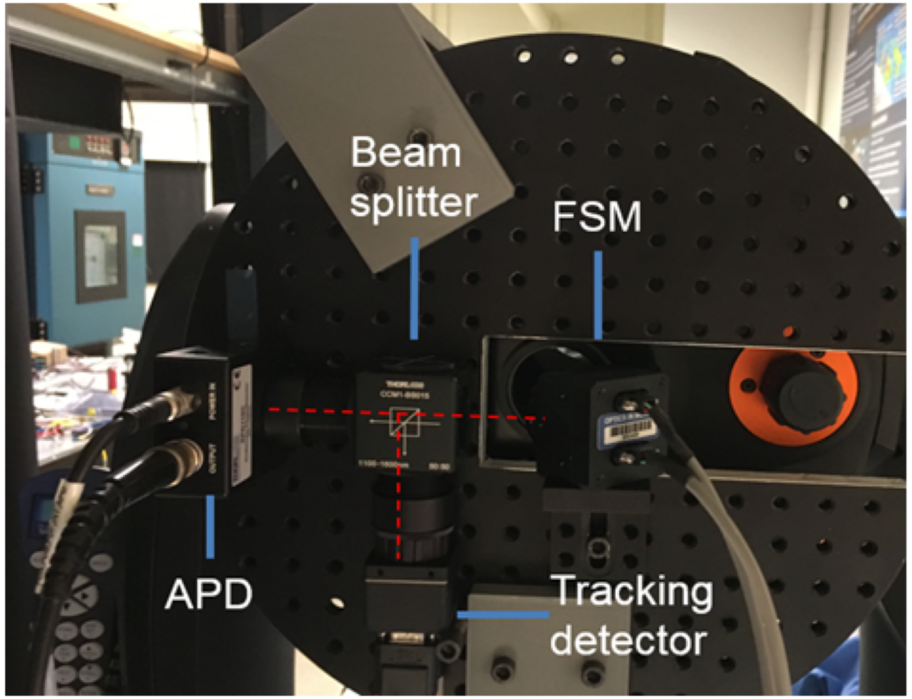
MIT Optical Ground Station: PorTeL

Tracking Assembly (Coarse Stage)



Receiver Assembly (Fine Stage)



Telescope
Celestron CPC1100
- Ø11" (28 cm)
- f/10
- 0.6 deg FOV

Star tracker
iNova PLB-Mx2
- f = 35 mm lens
- 7.8×5.9 deg FOV

Fast steering mirror
Optics in Motion 1"
- Voice-coil actuated
- >850 Hz bandwidth

Tracking detector
Sensors Unlimited SWIR 320CSX
- 320×256 pixels
- 12.5 micron pitch
- 60 Hz full-frame rate

Receiver
Voxtel RDC1-NJAF APD
- 300 MHz
- 200 microns

Demonstrated reliable < 5 arcsec RMS tracking of LEO targets

K. Reising

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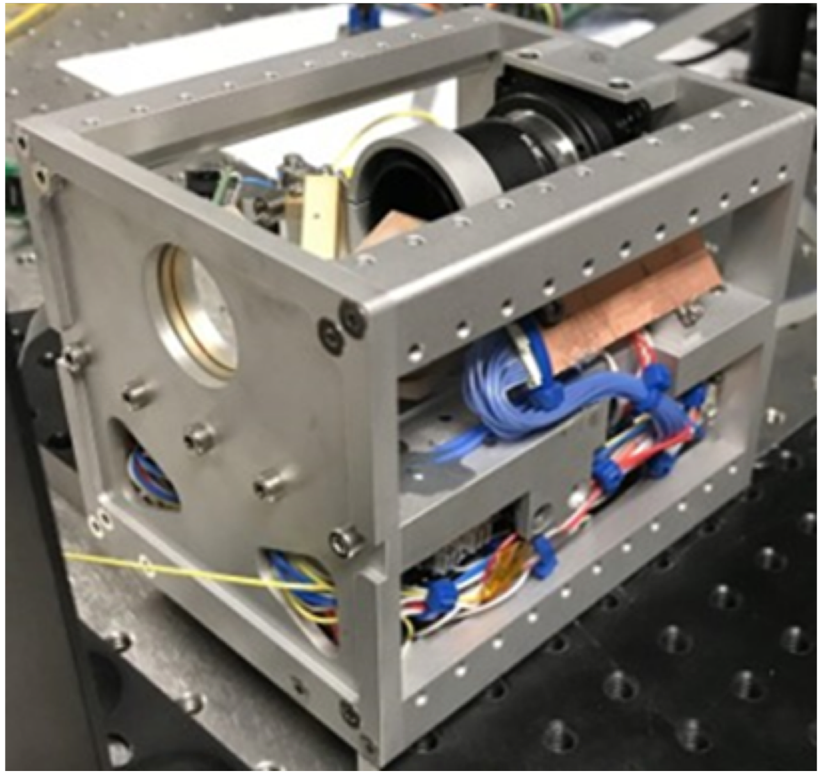
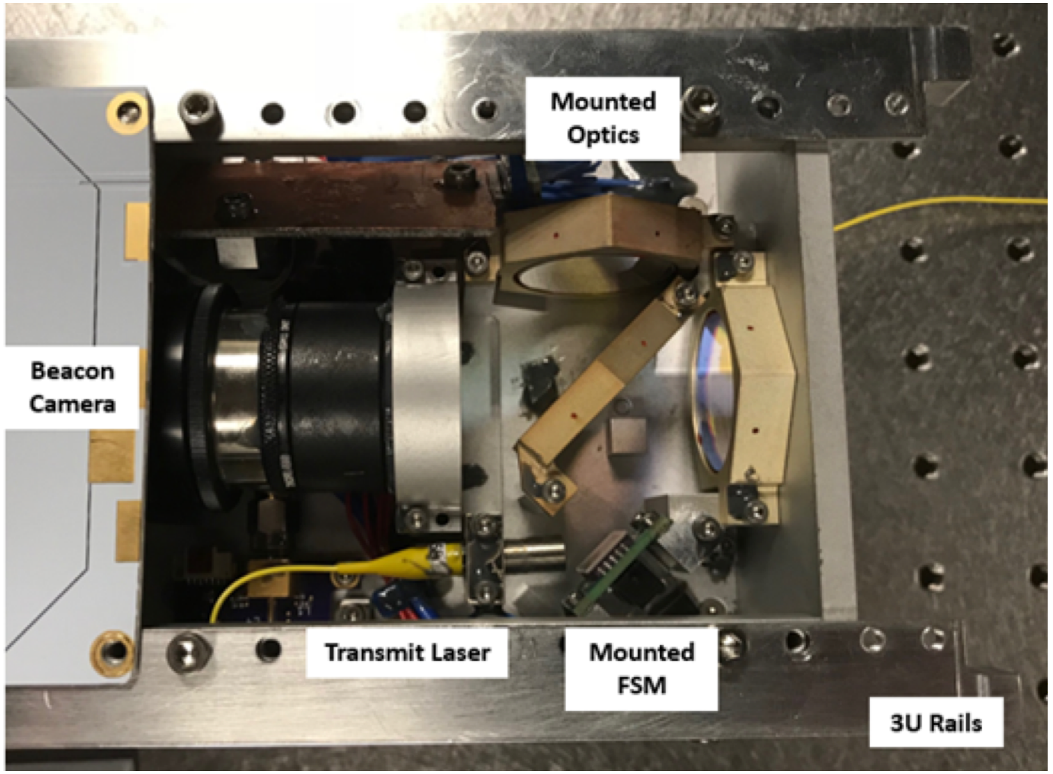
NODE Downlink Terminal

CLICK builds on fine pointing lasercom downlink capability from MIT Nanosatellite Optical Downlink Experiment (NODE) project.





NODE EM, *Courtesy D. Barnes (MIT)*

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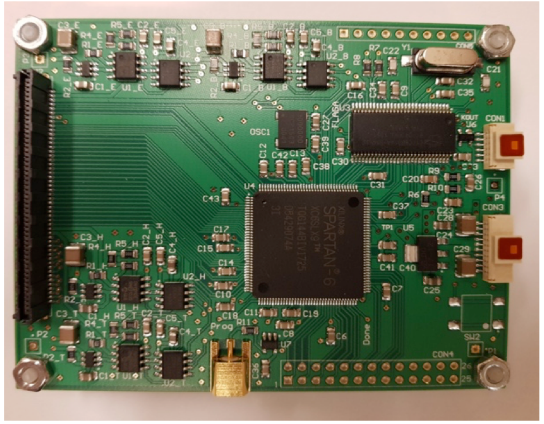
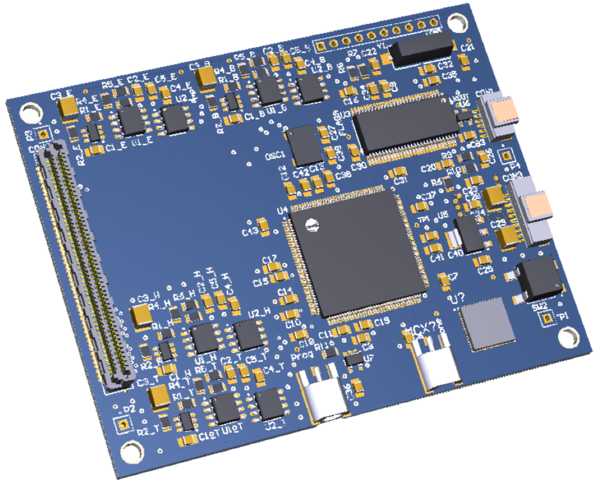
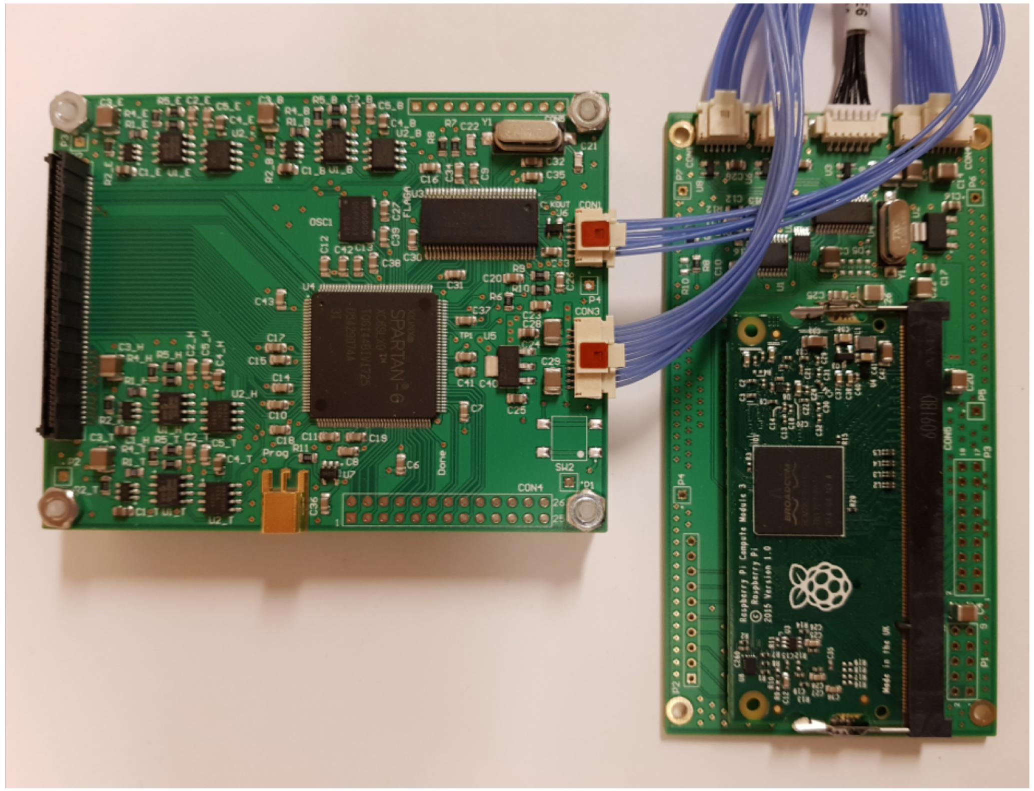
NODE Electronics Boards

NODE FPGA board





CLICK FPGA board



NODE FPGA board and CPU

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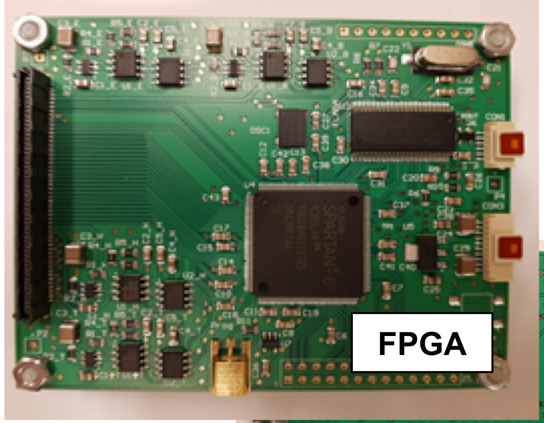
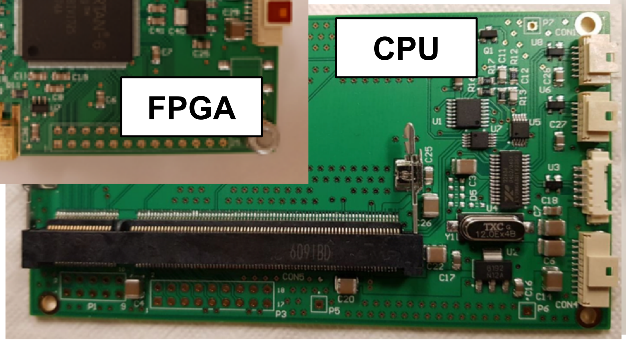
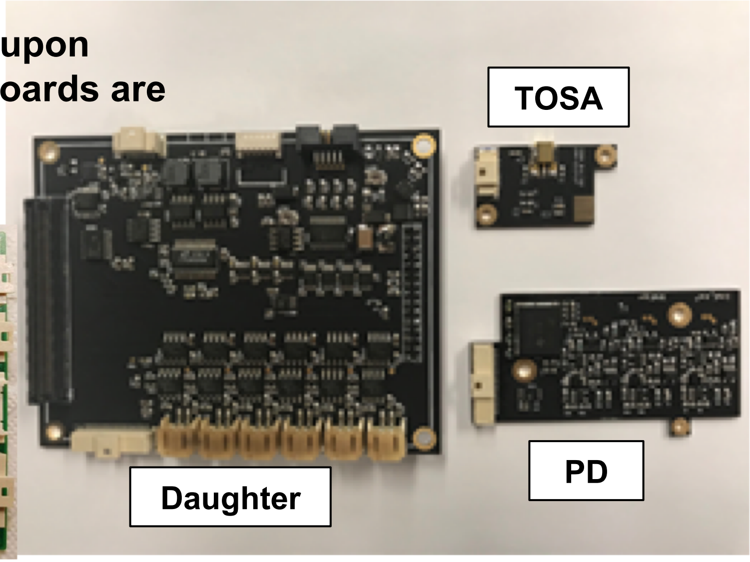
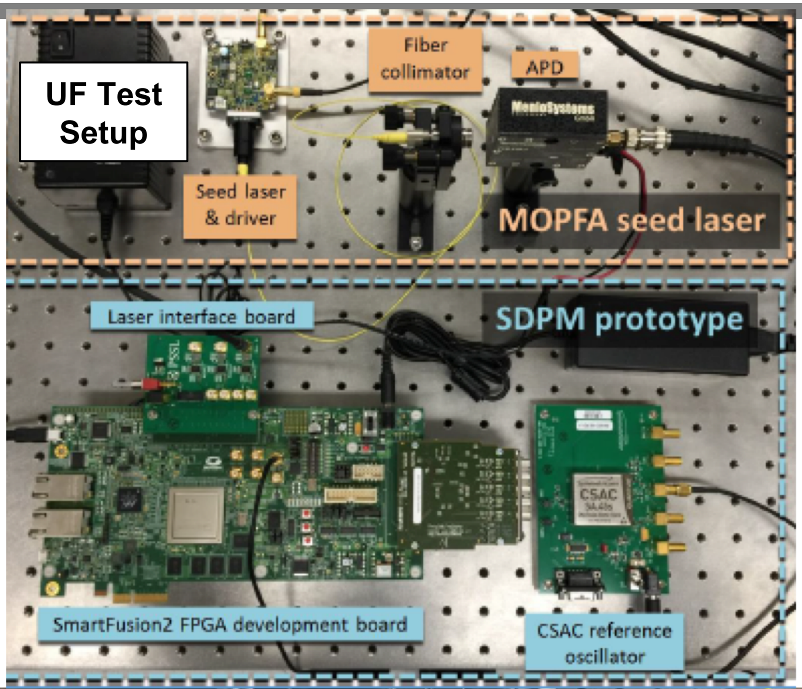
CLICK Prototype Testing



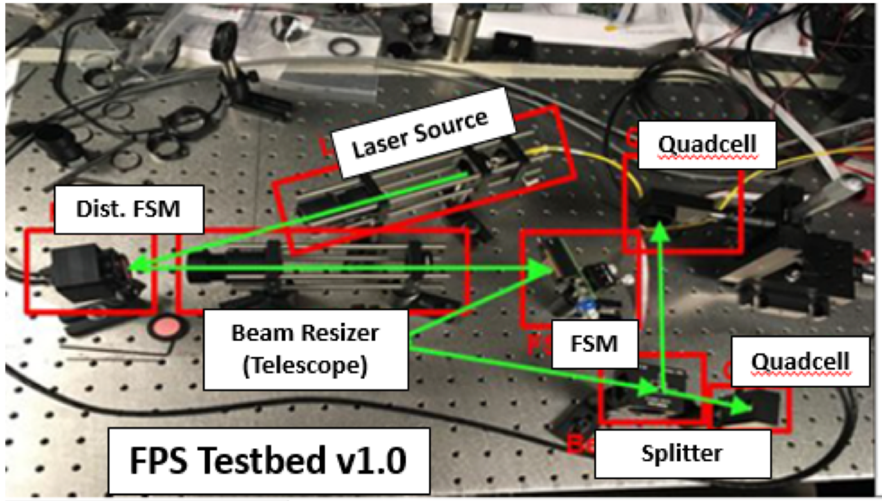


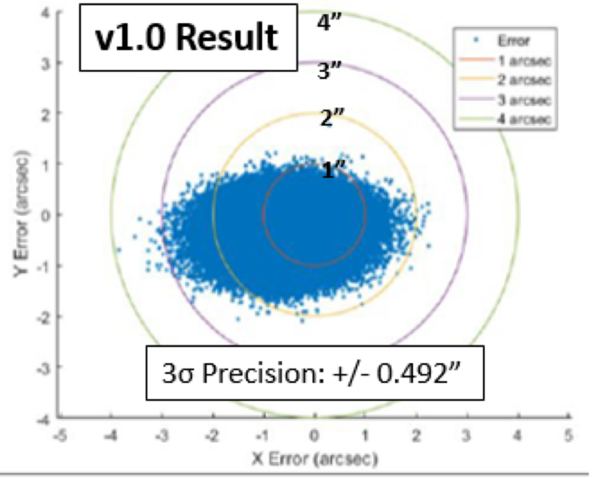
NODE boards, upon which CLICK boards are based

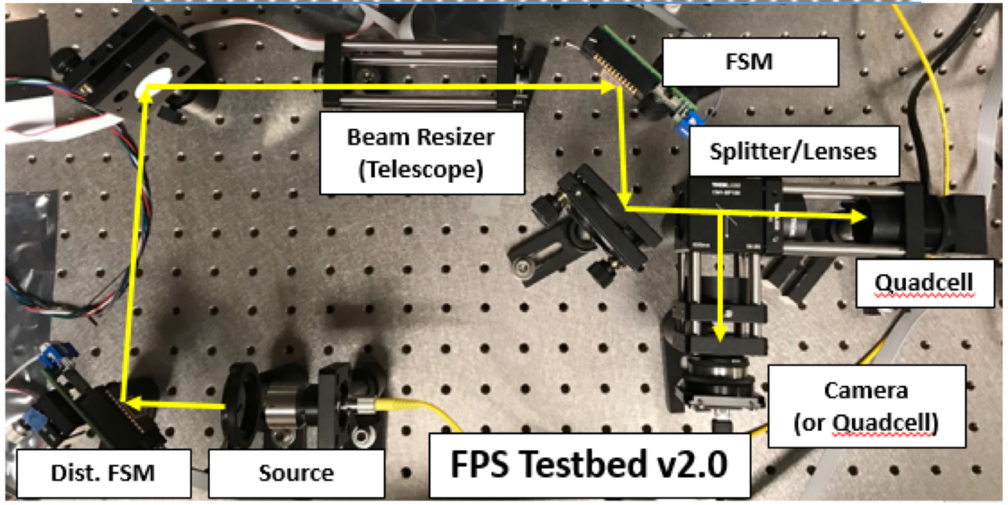




Images Courtesy H. Yoon , P. Grenfell, R. Diez, C. Haughwout (MIT), P. Serra, N. Barnwell (UF)







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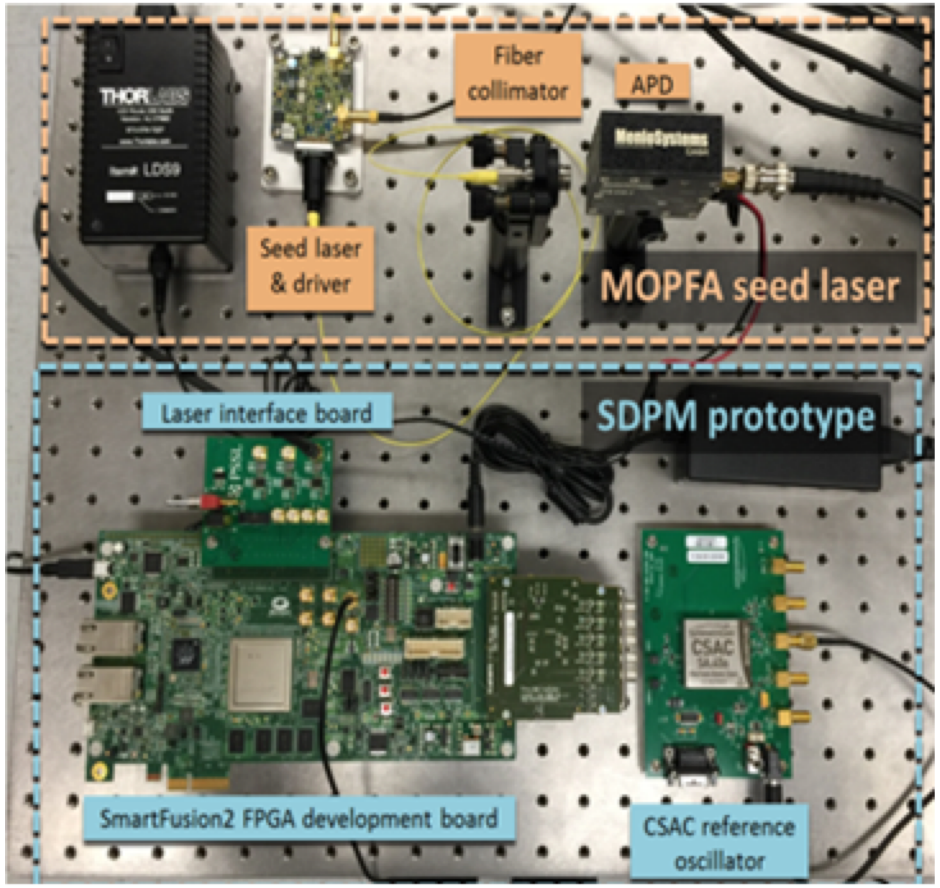
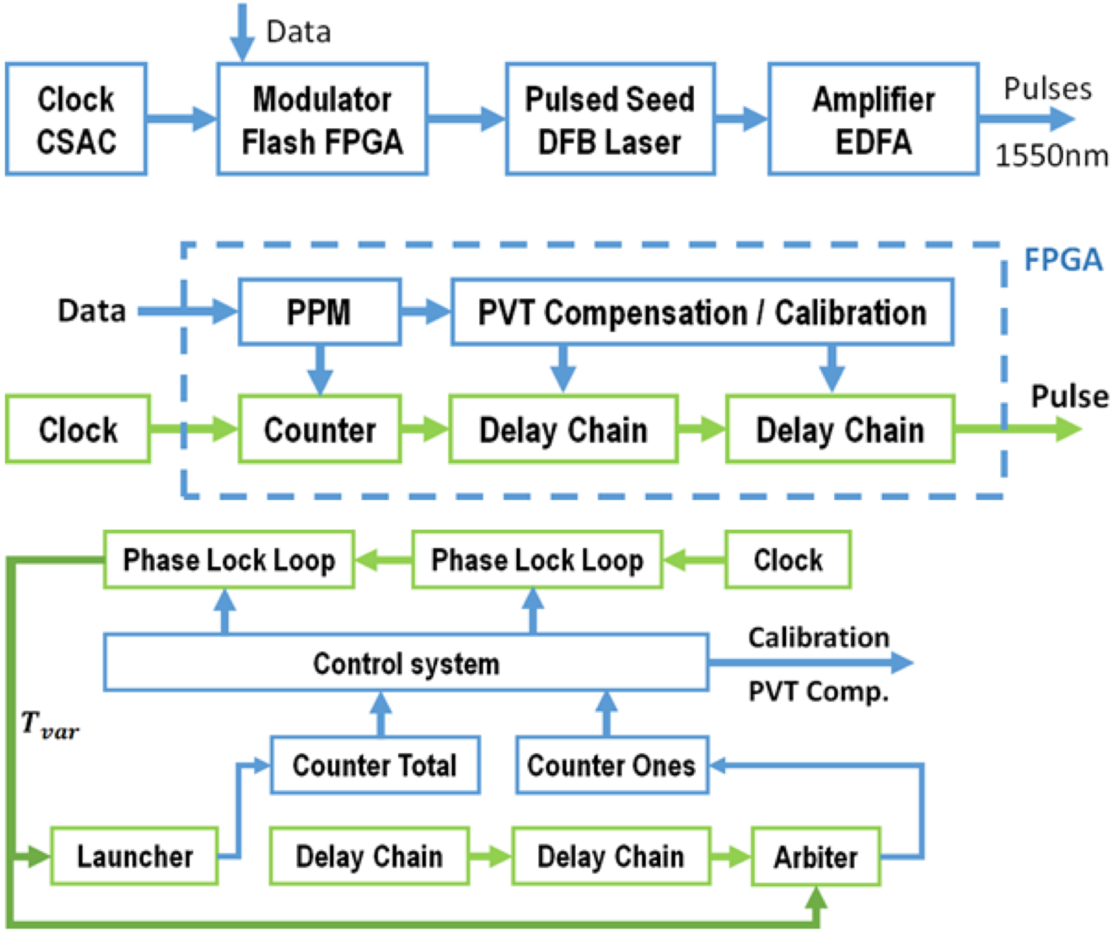
Univ. Florida MOCT Prototyping



Courtesy P. Serra



Courtesy P. Serra

MOCT System

Software-Defined Pulse Modulator

Calibration Circuit
(also in FPGA)

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