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)

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

Technology Development Challenges to Meet TRL Goal

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 intersatellite 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.

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.

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.

Contact Information

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Project Manager: David Mayer (david.j.mayer@nasa.gov)
Leveraging previous investments by NASA STMD, STTR, AFRL UNP, and both universities, CLICK will demonstrate free space optical crosslinks 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
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
**CLICK Concept of Operations**

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### Launch Operations
- **Launch Vehicle:** TBD
- **Launch Site:** TBD
- **Orbit:** 500 km circular, TBR
- **Inclination:** 80 deg, TBR
- **Launch Date(s):** TBD

### Pre-Operations
- Deploy Solar Panels
- System Diagnostic
- Satellites Drift Apart
- High/Low Drag Maneuvers
  (if needed to control drift)

### Pre-Crosslink Operations
- Update internal propagators from GPS
- Exchange orbit determination info via crosslink

### Crosslink Test Operations
- Lasercom crosslink tests
- Optical dual one-way ranging tests
- RF downlinking of test data after

### Degraded and Failure Mode Operations
- Sun-Safe Mode
- Survival Mode

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### Ground Station
- **Location:** MIT
- **Receiver Assets:** TBD
- **Transmitter Assets:** TBD

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### Lasercom Beamwidths
- **Beacon:** 0.75 deg, FWHM
- **Transmit:** 14.6 arcsec, FWHM

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### Downlink Test Operations
- Pre-downlink orbit calculation
- Optical downlink tests

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**4/24/2018**

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## Technical Summary

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

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**NODE Heritage**

Images courtesy D. Barnes, M. LaRocca, L. Yenchesky (MIT)
MIT Optical Ground Station: PorTeL

Tracking Assembly (Coarse Stage)

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

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

Demonstrated reliable < 5 arcsec RMS tracking of LEO targets

Receiver Assembly (Fine Stage)

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

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

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

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

NODE EM, Courtesy D. Barnes (MIT)
NODE Electronics Boards

NODE FPGA board

CLICK FPGA board

NODE FPGA board and CPU
Click Prototype Testing

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

Click Prototype Testing

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