Small Sat Lasercom

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Deep-Space Optical Communications (DSOC)
Overview, Capabilities and Footprint

Performance using 4W average laser power w/22 cm flight transceiver to 5m ground telescope

Beacon & Uplink
1030 nm
292 kb/s
@ 0.4 AU

CBE MASS (kg) 28
Mass margin (%) 30
CBE POWER (W) 76
Power Margin (%) 31
Optical Head: 45 x 45 x 49 cm (95E3 cc)
Elect. Box: 29 x 23 x 23 cm (15E3 cc)

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DSOC Key Characteristics

- Deep-space optical communications characteristics
  - Photon-efficient communications
  - Pulse-position modulation with Near capacity achieving codes
  - Laser beacon + Earth image assisted pointing from space
  - Integrates new technologies

Ground Segment

- Hale Telescope
- Ground Laser Receiver (GLR)
  - Photon-counting ground detectors
  - 50% Eff. WSi nanowire arrays
- Ground Laser Transmitter (GLT)
  - 1030 nm Ground Lasers
- OCTL Telescope
- Silicon Carbide Telescope & Optics

Flight Laser Transceiver (FLT) Assembly
- Uplink receiver
- Downlink transmitter

- Electronics Box
  - 1550 nm Space Laser Transmitter
  - Electronics processing & control cards, firmware, software, clock

- Point-Ahead Mirror
- Spacecraft Disturbance Isolation Assembly
  - 50 dB rejection

(c) 2014 California Institute of Technology. Government sponsorship acknowledged
AC7 10 W Downlink Laser

- Gain-switched diode + 2-stage fiber amp
- Operation at 1.06 μm
- All-fiber design, 25% wallplug efficiency
- Passively cooled; ΔT capability ~25°

2.5 x 10 x 10 cm
Two Flight Units and Spare Builds
0.5 mJ fully spliced fiber MOPA system

- Fully spliced MOPA system
- Tapered fiber final amplification stage for LMA and high beam quality
- Directly modulated MO signal
LMPC CubeSat – Aerospace AeroCube-9 (AC-9)

- HgCdTe responds from 0.4 to 4 microns to single photons (1000 electrons per photon)
- AC9 will use narrowband filters to pass 1.06, 1.55 and 2.06 microns for daylight operation
- Launch Nov 2016 (delivery Aug 2016)

**HgCdTe electron initiated avalanche photodiode (e-APD) array**

- Developed by DRS Technologies in Dallas TX
- 2x8 pixels with built in read-out integrated circuit (ROIC), 20 μm diameter active area, 64 μm pitch, with μ-lens array F/7 optical path, 7 mm diameter entrance aperture
- 90% quantum efficiency
- >1000 APD gain, more than sufficient to override ROIC noise
- Linear mode photon counting (LMPC) detectors from visible to mid-wave infrared (VIS/MWIR) wavelength range.
Upgraded Mt. Wilson Facility

**MAFIOT** - Mt. Wilson Aerospace Facility for Integrated Optical Tests

**MOCAM** - Mt. Wilson Optical Communication and Atmospheric Measurements

80 cm Rx telescope
Co-boresighted hp laser

30 cm Rx telescope
Lasercom & atmos. meas.
Pre AC7: AC4 Ground Target Laser Diode Illumination

- AeroCube
- WFOV Acq. Scope
- Mt. Wilson
- Receive Telescope 30 cm

Range 650 - 775 km

MOCAM

Santa Monica Bay
Pasadena
Mt Wilson Observatory
Beaconless Attitude Determination and Control System

- The Attitude Control System is designed to point the downlink laser to within 0.04 Degrees (3σ) of the optical ground station.

- A combination of custom designed attitude sensors (sun and earth) and star trackers are used to meet stringent power, size and performance requirements.

- Miniature Reaction Wheels and Torque Rods are used for actuation and momentum control.

<table>
<thead>
<tr>
<th>Error Sources</th>
<th>Pointing Error 3σ (Deg)</th>
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<tbody>
<tr>
<td>Payload to AD Frame Alignment (post-cal)</td>
<td>0.010</td>
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<td>Real-time Clock Drift</td>
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<td>Orbit Determination / Ephemeris Error</td>
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<tr>
<td><strong>Spec</strong></td>
<td><strong>0.200</strong></td>
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</table>

Sun Sensor Quad Cell

Miniature Reaction Wheels

Miniature Star Tracker (photo with baffle deployed)

~ 3 cm

~ 4 cm
Potential Communication Demo between AC7 and AC9

• Input Assumptions:
  – 10 Watts in a 0.1 degree beam full width
  – 2000 km range
  – 2.5 cm receive aperture

• Anticipate near Gbit rate