Overview and Status of the Lunar Laser Communications Demonstration

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To be world’s first lunar lasercom

Space terminal to fly on Lunar Atmosphere and Dust Environment Explorer (LADEE)

LADEE main mission:

- Measure fragile lunar atmosphere before it is perturbed by further human activity
- Measure electrostatically transported dust grains and assess their likely effects on future human activities

LADEE Launch July 2013

- 1 month transfer orbits
- 1 month lasercom
- 3 months science
Outline

• Overview of LLCD
• LLCD Space Terminal
• LLCD Ground Terminals
• Pointing, acquisition, and tracking
LLCD Objectives

• Primary objective
  – Demonstrate duplex lasercom from the Earth to lunar orbit

• Demonstration goals
  – 600 Mbps downlink from LADEE to an Earth receiver
  – 20 Mbps uplink from an Earth transmitter to LADEE
  – 2-way time-of-flight with errors less than 200 psec
  – Operate in as many orbital and atmospheric conditions as possible in short mission

• LLCD is a technology demonstration on the LADEE mission
  – Operates on non-interference basis with science payloads during one-month “commissioning” phase
Lunar Laser Communication Demo System

Lunar Lasercom Ground Terminal (LLGT)

Lunar Lasercom Space Terminal (LLST)

Lunar Lasercom "OCTL" Terminal (LLOT)

OGS Terminal

Teide Observatory

Deep Space NW

LADEE Mission Ops Center

LADEE Science Ops Center

LLOC Echo

MITLL

Table Mtn

Location TBD

NISN

ARC

GSFC
Spacecraft Configuration

LADEE Science Payloads

Space Terminal Optical Module

Space Terminal Controller Electronics

Space Terminal Modem Module

Space terminal mass ~ 30 kg
Space terminal power ~ 130 W
Beam stabilization:
- Inertial sensors > 4Hz
- Nutating fiber sensor < 4 Hz
- Voice coil actuators of entire optical subsystem
Status of Optical Module
Qualification Unit / Flight Unit

Qual: MIRU*, COTS Gimbal

Qual: Beryllium telescope integrated with small optics

*MIRU – Magnetohydrodynamic Inertial Reference Unit
• **Uplink functions**
  – Pre-amplified 4PPM receiver
  – Decoder/de-interleaver
  – Command and data demux
  – 10,20 Mbps

• **Downlink functions**
  – 0.5-W MOPA transmitter
  – Encode/interleave
  – 16PPM modulator
  – Mux terminal telemetry, looped-back uplink, spacecraft data
  – 40-620 Mbps
Flight Controller Electronics

Flight Modem receiver electronics board

Flight Modem digital board

Flight Modem laser board

Flight fiber components

Example comm measurements

Modem in final phases of slice integration
LLST Testing

Jitter Test Set (in clean room)

Optical Test Set for OM (in clean room)

Communications Test Bed (here, with Modem EDU) – fiber-coupled to Ground Terminal Modem via inter-lab fiber
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LLGT Telescope System

- 2-axis gimbal

- 4@15 cm uplink telescopes
  - Fiber-coupled to 4 10-W EDFAs

- 4@40 cm downlink telescopes
  - Each fiber-coupled (MM) to four-array of SNDAs
  - Four SNDA arrays all in one cryo

- Telescopes housed in temperature-controlled mini-dome
Transportable LLGT

Control Room in 40-ft converted shipping container houses system electronics and operator console.

Enclosure maintains controlled environment for telescopes.

Chiller provides cooling for telescopes, He compressor, and Control Room.

Rolling fabric/steel cover protects telescopes from weather when LLGT not in use.

System to be installed and operated at White Sands Complex in New Mexico.

12’x12’ concrete pad

Single gimbal points all telescopes.
LLGT Optics and Structure

Uplink telescope (built in-house)

Downlink telescope (COTS)

Gimbal with Enclosure frame

Control electronics (1 of 4 complete)

Enclosure

Back-end optics

Telescopes and optics complete. Being integrated.
Superconducting Nanowire Photon Counting

Incident photon
80 nm

Superconducting NbN nanowire
Photon absorption
Resistive state formation
Joule heating
Current shunted into transmission line
Self-resetting

4-element SNDA (14 um)

Cryogenic operation required (< 3K)
Array allows high-flux detection despite individual wire reset times
LLGT Nanowire Arrays

Actual detector: NbN nanowire on SiO$_2$ patterned in “meander” shape

Interleaving multiple detectors results in shorter equivalent reset time

High detection efficiency >70%
Fast reset time < 15 ns
Low timing jitter < 40 ps

Designed and built at MIT and Lincoln Lab
Nanowire systems complete. In comprehensive tests with Space Modem.
Multiple copies being used for:
- LLST Optical Module in test
- LLST Modem in test
- Coordinated LLGT/LLST tests
- Flight PAT software development
- LLST in-flight command sequence development
Site Location Weather Considerations

- Original plan – White Sands, NM – known to have daily rainstorms in mid-late summer
- Present launch plans could force operations during this time – allowed LLST time very limited – could be greatly shortened by cloud outages
- Two-pronged approach to address this
  - Added second terminal at JPL’s OCTL
  - Looking for better site for LLGT
- LLGT site – complex decision
  - Seasonal weather statistics
  - Independence of weather from OCTL
  - Difficulty of locating at certain sites – environmental, etc
  - Aircraft avoidance complexity
  - Cost of transport, local ops, mission ops
- Transportable LLGT allows near-arbitrary selection
Lunar Lasercom OCTL Terminal

- Cloud statistics at JPL’s Optical Communications Telescope Laboratory on Table Mountain in Wrightwood, CA are particularly good
- 1-meter telescope being outfitted with
  - Wide-angle photon-counting PMT receiver
  - Multi-beamlet uplink
- Will provide uplink for Space Terminal tracking
- Receiver capable of receiving up to 311 Mbps
- Will allow use of very limited Space Terminal resources even when LLGT is clouded over
  - Depending on LLGT location, when both clear, could demonstrate handover (break-before-make)
Lunar Lasercom OCTL Terminal

OCTL building with dome

OCTL telescope (1-meter)
What Will be Accomplished?

- Validation of link design for high-rate duplex lasercom at lunar ranges
- Demonstration of ranging capability based on wide bandwidth duplex communications system
- Operation of beyond-GEO lasercom system
  - Details of spacecraft coordination
  - Link availability
  - Performance in wide range of conditions
  - Planning
  - Etc.
Summary

• Optical communications offers the potential for substantial improvements in deep space communications capabilities while reducing burden on spacecraft

• LLCD will be NASA’s first step in making lasercom a reality for future NASA missions

• JPL OCTL added this year as second ground terminal

• Development on track for launch in May 2013