Comm for Small Sats: The LADEE Communications Subsystem

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Agenda

• Overview
• Design
  – S-Band Transponder
  – Antennas
• Integration & Test (I&T)
• Mission Operations
• Lessons Learned
• Summary/Conclusion
Lunar Atmosphere and Dust Environment Explorer

Objective
- Measure Lunar Dust
- Examine the lunar atmosphere

Key parameters
- Launch Vehicle: Minotaur V
- Launch Site: Wallops Flight Facility
- Launched Sept 6, 2013, Impacted April 17, 2014
- Total Mission Length: 8 months

Spacecraft
- Type: Small Orbiter - Category II, Enhanced Class D
- Providers: NASA ARC and NASA GSFC

Instruments
- Science Instruments:
  - LDEX: Lunar Dust EXperiment
  - NMS: Neutral Mass Spectrometer
  - UVS: Ultra Violet Spectrometer
- Technology Payload: Lunar Laser Communications Demo

Not covered in this talk, covered in-depth in SPIE Photonics West 2014.
LADEE Communications Overview

- S-Band Transponder
- Three evolved antennas
  - Two omnidirectional low gain
  - One directional medium gain
Integrated S-Band Transponder Unit
Space Micro μSTDN -100

- Integrated with diplexer/splitter/coupler
- Compatible with multiple ground stations
  - DSN (Deep Space Network)
  - NEN (Near Earth Network)
  - SN (Space Network, TDRSS)
- RS-422 interface instead of relay closures
  - Allowed for flexible number of commands
- Test ports for both transmit and receive
  - Greatly aided during I&T
- Precision coherent ranging
- Multiple Data Rates: 1 kbps-128 kbps, suppressed and residual carrier capability
- RF Out: 8W total, 4W/Omni; Power draw: up to 45 W
Genetically Evolved Antennas
By Antenna Development Corporation (AntDevCo), Carnegie Mellon University, NASA Ames Intelligent Systems Division

- Two omnidirectional low gain antennas
- One medium gain (transmit only)
- Utilized new, rapid, antenna design process based on Darwinian evolutionary algorithms originally developed at Ames
- Flight proven on ST-5 Mission, Interface Region Imaging Spectrograph (IRIS), and now LADEE
Integration and Test (I&T)

Test equipment rack built at Ames
- RF Level Matching Interface
- Full suite of test instruments configured together to allow for automation

Hardware Acceptance Configuration

Test equipment rack integrated with RT Logic T70/70XL and Hardware-in-the-Loop (HIL) to perform full end to end command and telemetry testing
LADEE Encapsulation
LADEE Launch: September 6, 2013!
• Clean acquisition through TDRSS
• Clean handover to DSN
LADEE Launch!

- Clean acquisition through TDRSS
- Clean handover to DSN
On Orbit Checkout

LADEE Omni Antennas Combined Pattern, 2249 Mhz

- Boresight predictions consistent with reality
- No reliable way of predicting performance within interference regions
- Cold area
- Sweet Spot

(Observed) – (Model): +5 dB, +2 dB, 0 dB, -2 dB, -5 dB
Mission Operations

• Regular operation at max of 128 kbps w/large link margin

• Dynamic Link Analysis Tool (DLAT) developed for LADEE but can be generalized to any spacecraft

• Experienced multipath
Dynamic Link Analysis Tool (DLAT)

- Developed for LADEE but can be generalized to any spacecraft
  - Excel = Ground station parameters
  - STK = Spacecraft and Groundstation Models
  - MATLAB = GUI, Ops Parameters, Final Output
Multipath

Symbol Signal to Noise Ratio at Ground Station (dB)

Received Power (dBm) at Ground Station
Lessons Learned

• There is still no space qualified “COTS” comm subsystem
  • Long lead, so start early!!

• Risk Mitigation with small/new vendors
  • Logic Simulators and Vendor-Built EGSE
  • Clear specifications and measurement methods
  • Pre-Release/Acceptance Compatibility Testing
    • Ground Networks
    • Portable Hardware-In-the-Loop (HIL) (“Traveling Road Show”)

• Multipath will occur when close to the surface of an orbiting body, and must be anticipated during Mission Ops
Summary/Conclusion

Utilizing state of the art technologies for low-cost small satellite communications, the LADEE Communications Subsystem performed beyond expectations on-orbit and now has the flight heritage for future small spacecraft communications systems.

- Flight qualified small sat -
  - S-band transponder
  - Evolved S-Band antennas
  - Dynamic Link Analysis Tool
  - Test Equipment Suite

![Engineering Unit in Thermal Chamber](image-url)
Thanks: Mark Allard (LADEE Communications Subsystem Lead), Michael Lindsay (DLAT), Brian Lewis (LADEE S/C Sys Engr), Victor Sank (GSFC), Howard Garon (GSFC), DSN, NEN/SN, Space Micro, AntDevCo, the rest of the LADEE team!
Questions?
Backup Slides
Mission Critical Events:

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<th>Type</th>
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<td>Initial Safe-Mode Acquisition</td>
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<td>Lunar Orbit Insertion 1 (LOI-1)</td>
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<td>Contingency OMM Burns</td>
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Mission Phase:

1. Launch: Minotaur V Launch Vehicle
2. TLI: STAR 37 FM Upper Stage
3. TCM(s): Perigee/Apogee Bipropellant
4. LOI: Bipropellant

Phasing Loops: ~23 days

Time in Phasing Loops: ~23 days

Decay