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# *A Study Of An Optical Lunar Surface Communications Network With High Bandwidth Direct To Earth Link*

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Communications Architectures & Research Section

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# *Outline*

- Objective of study
- Lunar surface network
- Ground station network coverage
- Top five channels to lunar surface optical communications
  - Lunar dust removal experiment
  - Disruption Tolerant Network over optical carrier experiment
- Summary

# *Objective of Study*

- Advance architectures for lunar surface communication by application of optical communications
- Concept of operations and concept of use
- Reliability and risks associated with Lunar Surface Optical Communications
- Technology needs and high-level development plan for updating the ETDP Optical Communications input.

# Lunar Surface Comm Architecture

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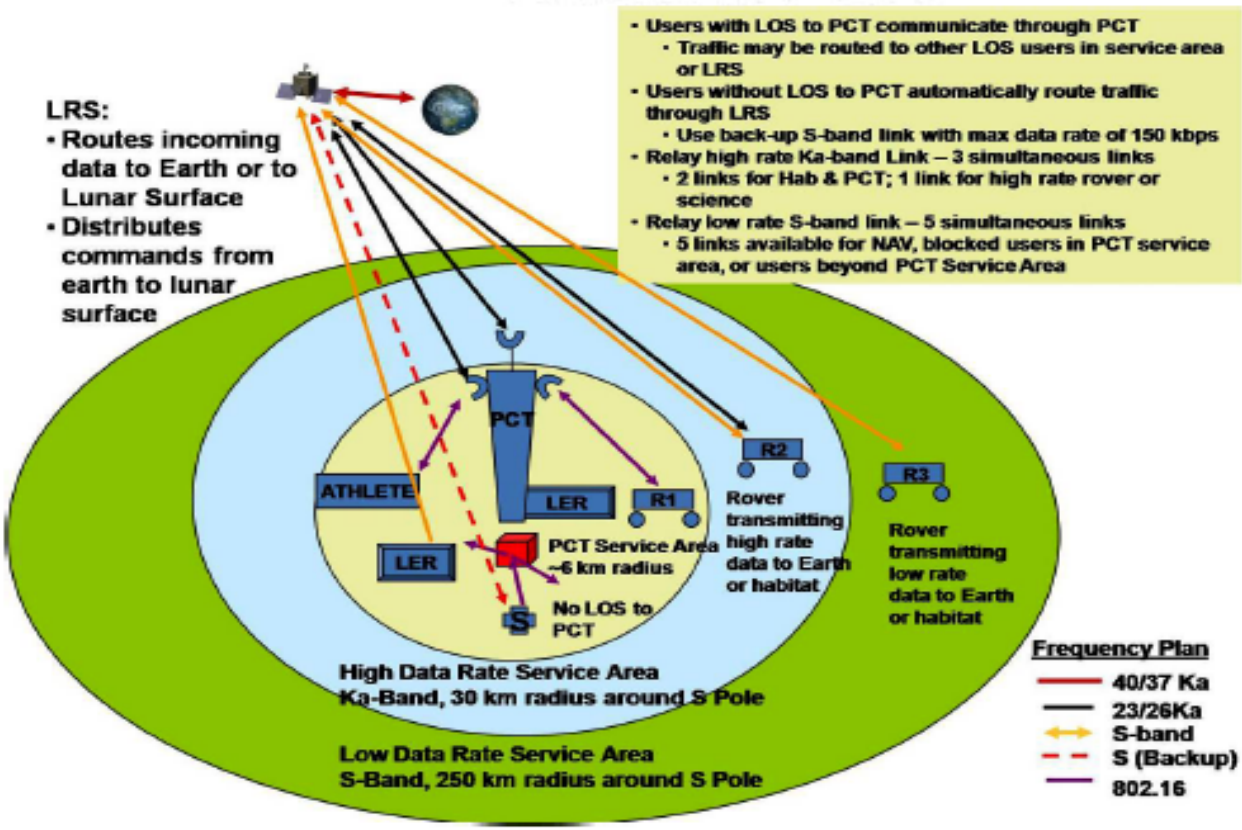


| Element Name | Communicating To | Return (Mb/s) | Forward (Mb/s) |
|---|---|---|---|
| Earth Based Ground Station | LRS or Lunar Surface | 100 | 25 |
| Lunar Relay Satellite | Earth Based Ground Stations | 100 | 25 |
| | Lunar Surface | 100 | 25 |
| Portable Communications Tower (PCT) | LRS | 25 | 100 |
| | Earth based Ground Stations | 25 | 100 |
| | Intra-surface Elements | 43 | 43 |
| ECS - 1 | To Earth or LRS | 25 | 6 |

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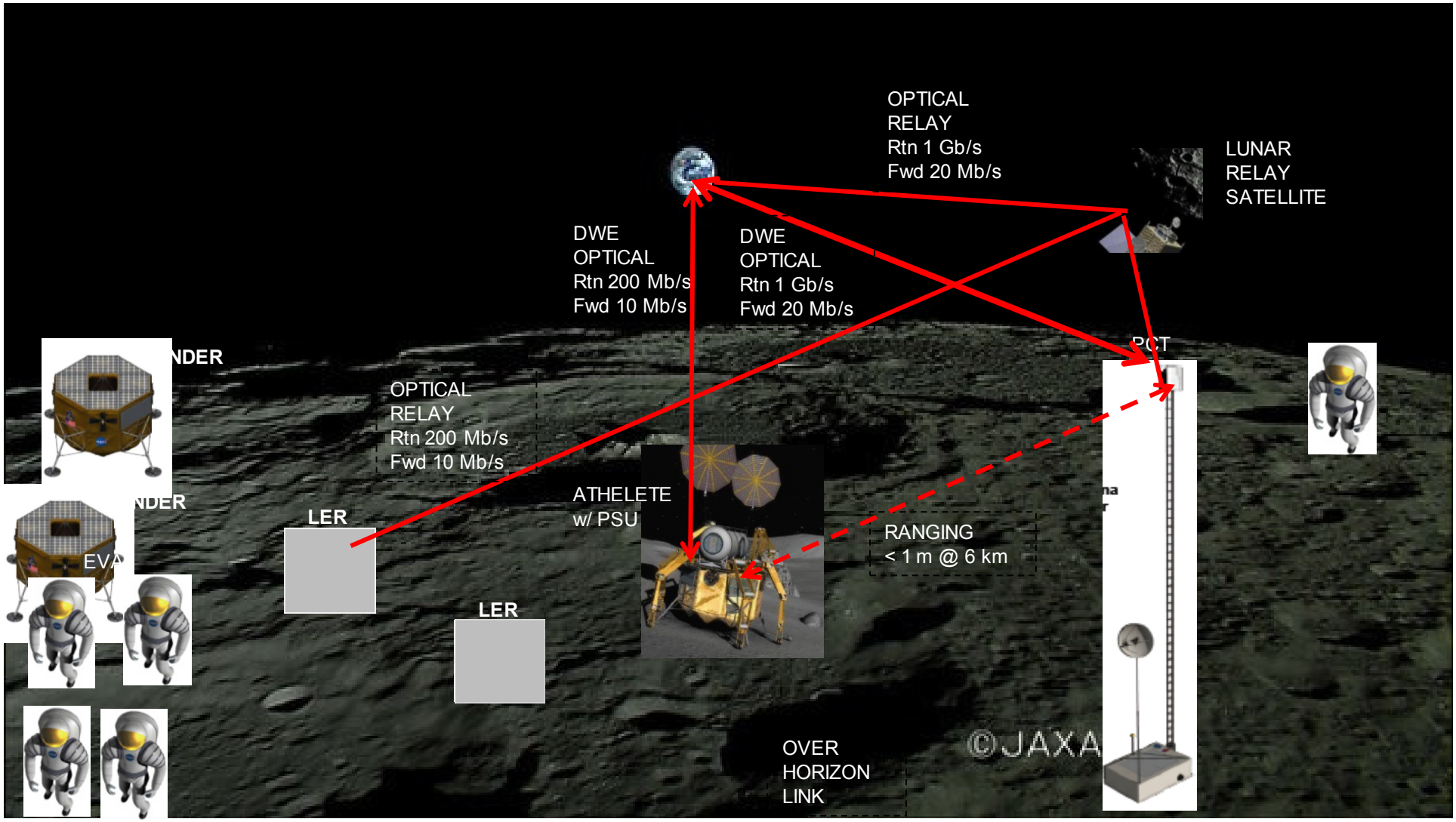
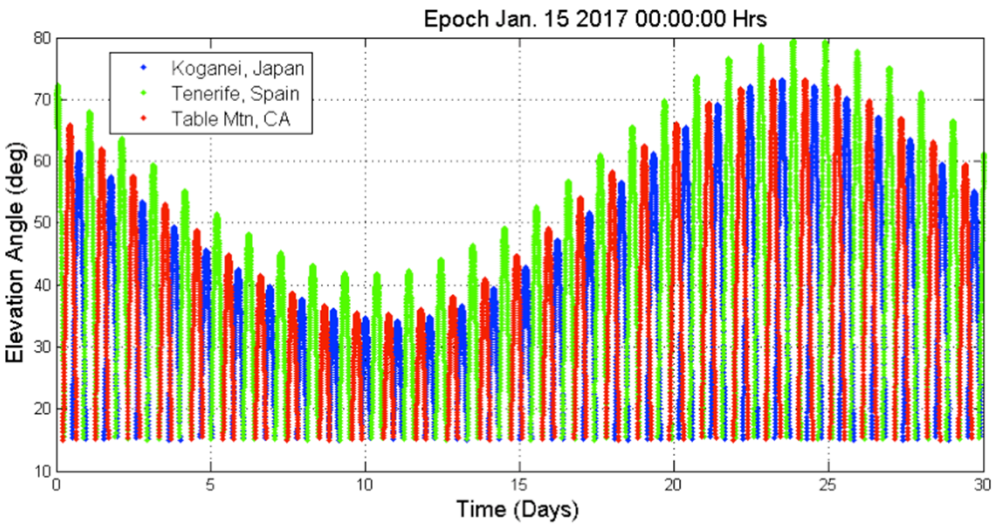
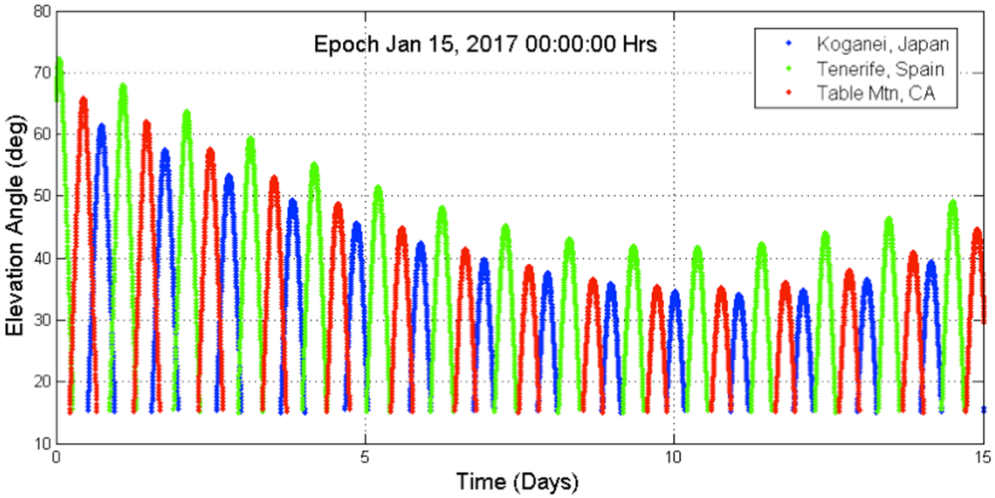
# High bandwidth lunar network & DTE optical links



# *Coverage From Dispersed Ground Stations*

- Table Mountain CA, Koganei, Japan, and Tenerife, Canary Islands can provide greater than 99% coverage from a South Polar lunar location



# Moon-Earth Link Analysis

| Description | Lunar Tx, W | Lunar Tx/Rx dia, cm | Data rate Mb/s | Wavelength, nm | Comments |
|---|---|---|---|---|---|
| Return Lunar mobile to Earth | 1 | 5 | >200 | 1550 | |
| Return Lunar stationary to Earth | 1 | 10 | >1000 | 1550 | |
| Forward Earth to Lunar mobile | | 5 | >1 | 1550 (1030) | 40-W total power in 8 beams in 80urad ($1/e^2$) beam. |
| Forward Earth to Lunar stationary | | 10 | >10 | 1550 (1030) | |

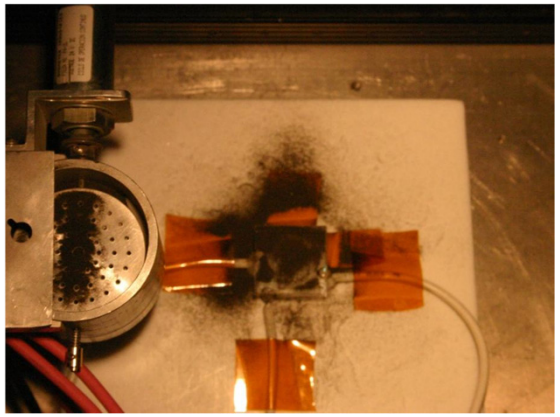
- 5-cm mobile terminal with 1W transmitted optical power supports
  - >20 0Mb/s return link to lunar relay satellite or to 1-m class ground telescope
  - >1 Mbps forward link from Earth station transmitting 40 W optical power
  - Estimated mass & dc power: 14.4 kg & 22-W

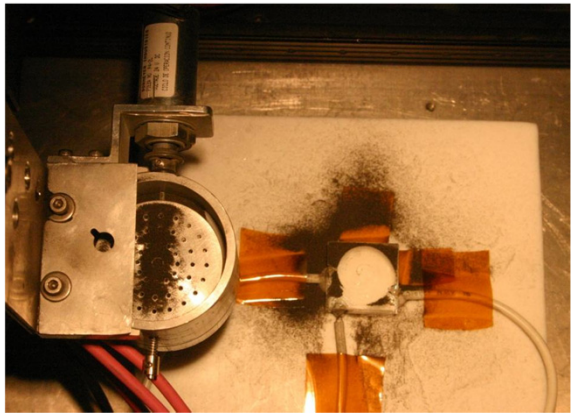
# *Top Five Challenges*

1. Effects of blast ejecta (lunar dust) on optical surfaces
2. Transparent interface of optical physical layer to network and higher Lunar comm/nav layers
3. Acquisition and tracking without impeding mobility of mobile assets
4. Thermal cycling through lunar diurnal cycle and survivability of optical components and lasers
5. Long-term life cycle effects such as laser/detector lifetimes in lunar environment

# Lunar Dust Deposition & Removal

| Compound | Formula | Moh's Hardness | Composition (WT%) | |
|---|---|---|---|---|
| | | | Maria | Highlands |
| Silica | $SiO_2$ | 7 | 45.4 | 45.5 |
| Alumina | $Al_2O_3$ | 9 | 14.9 | 24 |
| Lime | CaO | 4.5 | 11.8 | 15.9 |
| Iron Oxide | FeO | 6.5 | 14.1 | 5.9 |
| Magnesia | MgO | 5.8 | 9.2 | 7.5 |
| Titanium Dioxide | $TiO_2$ | 5.5- 6.5 | 3.9 | 0.6 |
| Sodium Oxide | $Na_2O$ | - | 0.6 | 0.6 |

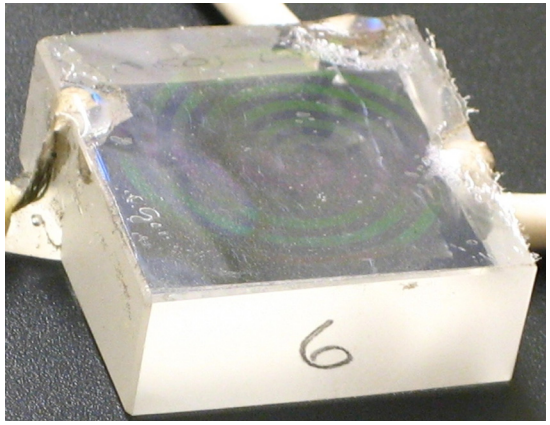




- Lunar composition simulated by 50 – 75 µm JSC-1A lunar dust simulant
  - Deposited and tested under in vacuum conditions

# Results

- The pattern introduces a phase change in the light across beam
  - Will alter the propagated beam pattern.
- The pattern is distinctly visible when viewed from an angle
  - Pattern will result in reduction in transmitted radiation
  - High-energy beams can result in local heating of the pattern that could damage or degrade electrode or window.
- Surface of the sample exhibited scratch marks after dust removal
  - Sapphire is more appropriate window material Moh's hardness comparable to constituents of lunar dust



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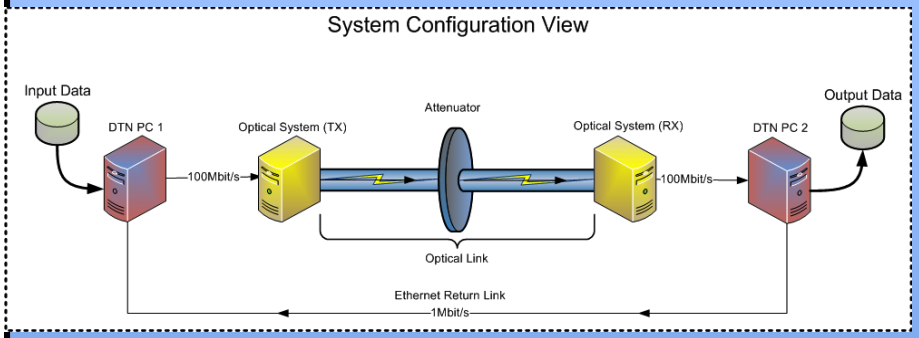
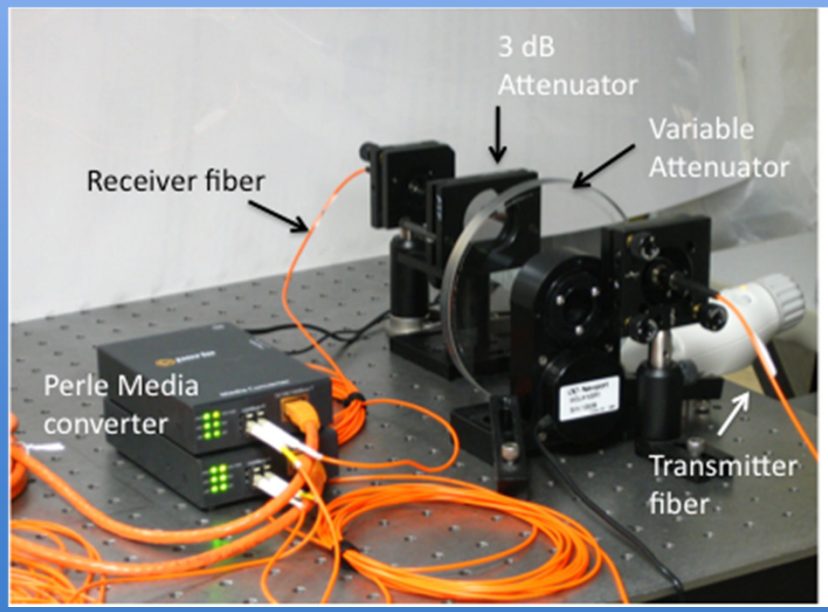
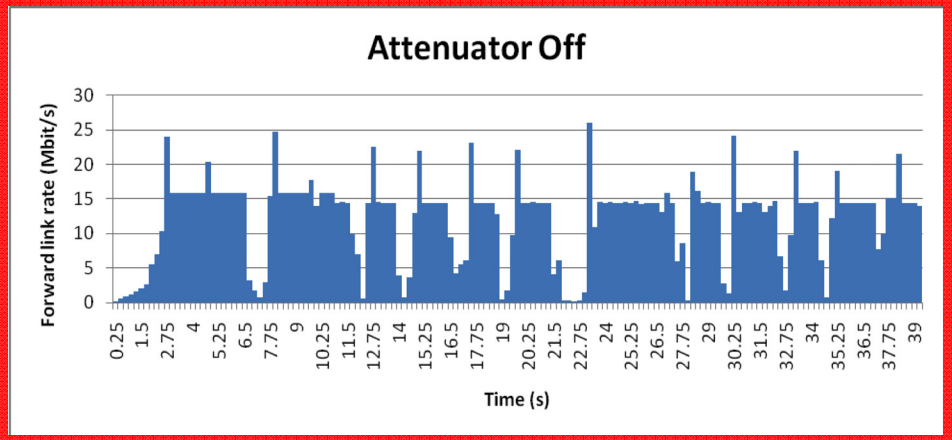
# DTN over optical link

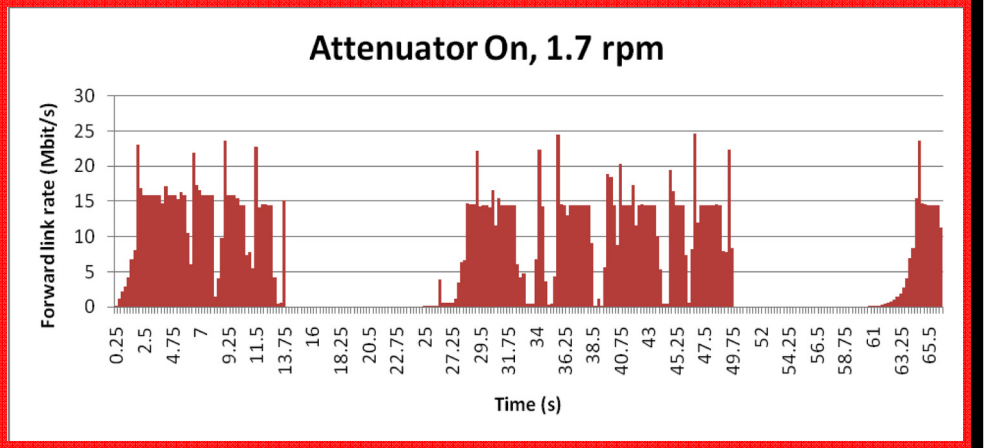
## Architecture




## Results



# *Summary*

- Analyzed optical DTE and lunar relay satellite link analyses
  - >200 Mbps downlink to 1-m Earth receiver and >1 Mbps uplink achieved with mobile 5-cm lunar transceiver
  - >1Gbps downlink and >10 Mpbs uplink achieved with 10-cm stationary lunar transceiver
  - MITLL 2013 LLCD plans to demonstrate 622 Mbps downlink with 20 Mbps uplink between lunar orbiter and ground station
- Identified top five technology challenges to deploying lunar optical network
  - Performed preliminary experiments on two of challenges:
  - (i) lunar dust removal and (ii)DTN over optical carrier
- Exploring opportunities to evaluate DTN over optical link in a multi-node network e.g. Desert RATS.