Towards High Data Rate Hybrid RF/Optical Lunar Communication Architecture

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Background

Motivation

Lunar science and exploration is set to explode in the coming decade.

- NASA's Artemis Project will send first woman and next man to the moon by 2024 [1].
- Dozens of additional Lunar missions are planned by 2028 [2].
- Lunar missions will include human crews, rovers, smallSats, and more

These missions will require a reliable and high data rate network.

Existing Technology

RF (S, X, K band): Robust, but limited capability

- Mature and well-supported
- Low alignment requirements
- Operates under most weather conditions
- Difficult to achieve high data rates

Free Space Optical (FSO): High data rate, hard to use

- Gbps rates are common
- Stringent point/tracking requirements
- Easily disrupted by weather
- Sensitive to atmospheric turbulence [3]

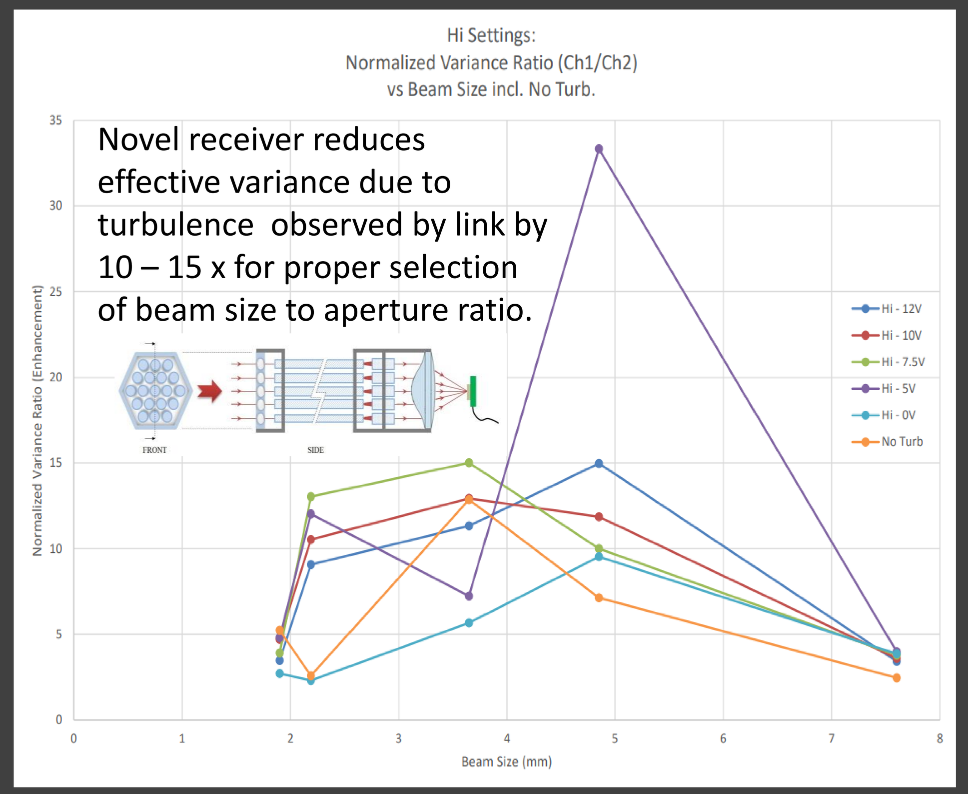
Neither can provide a network that is **both** reliable and fast.

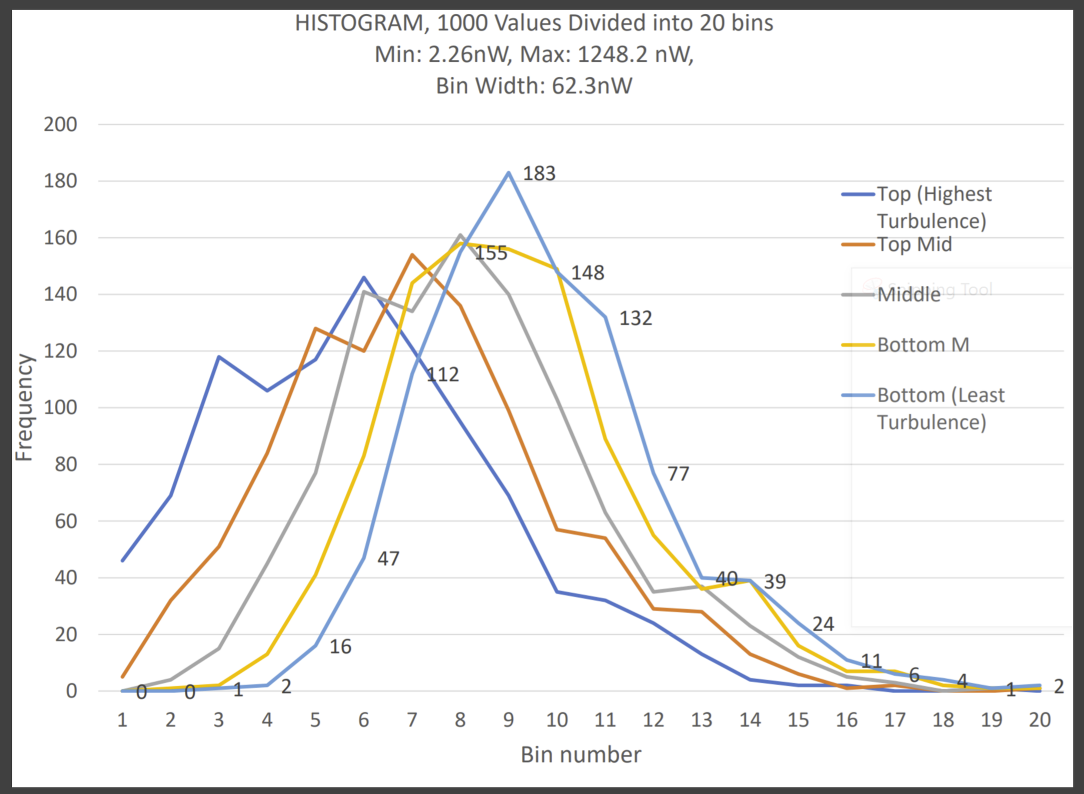
The Solution: Hybrid Network Design

Combine the high throughput of FSO with the reliability of RF. This is a difficult engineering challenge. There are many questions:

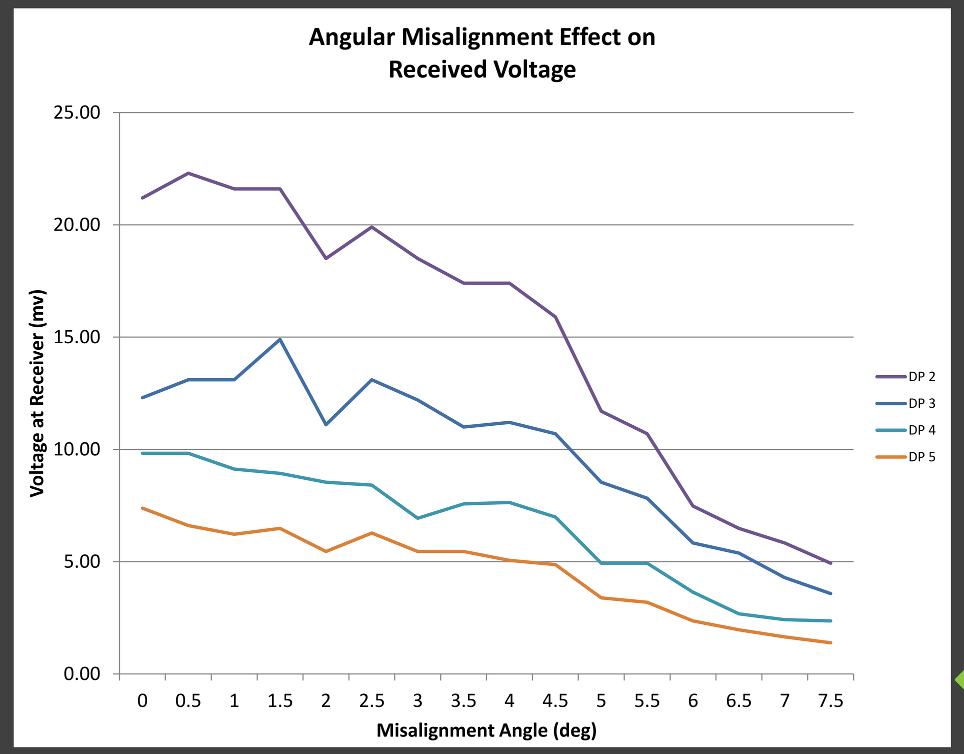
- Understanding the limits of FSO (atmosph., weather, etc.)
- Integration of RF/Optical Systems
- Network architecture and switching strategies

Active Projects: Atmospheric Effects

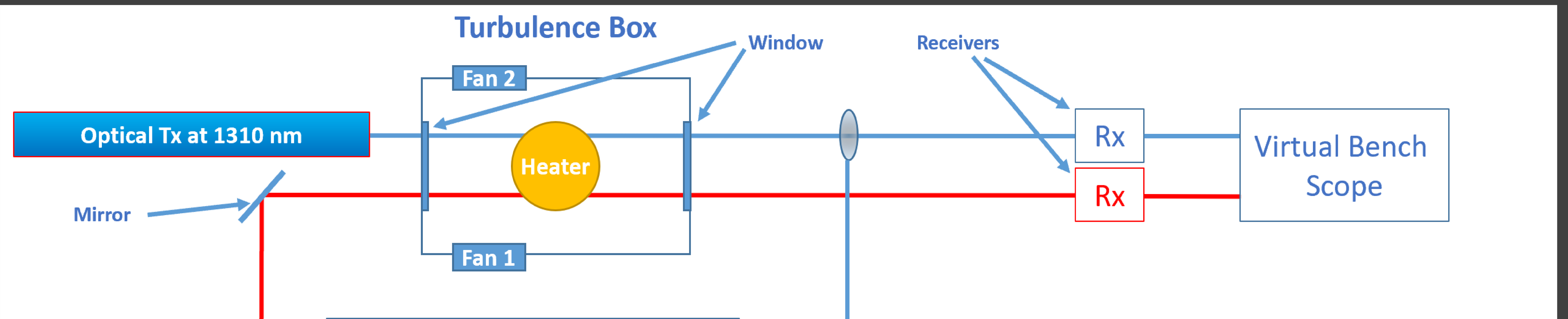




Simulated distributions of received power at satellite for 1000 km earth to LEO link, for different levels of turbulence. Six-layer atmosphere model used. Proper design of receiver – to achieve a specific minimum power and desired BER – can produce the needed link up-time to achieve a desired data throughput in a limited satellite window.



Novel Receiver has larger angular field of view – reduces aiming restrictions, could allow multiple access at same receiver.



Heater has four heat settings: No, Low, Med, High.

Two Fans blow into and out of the box to create a flow of air.

Fans have five settings: 0, 5, 7.5, 10 and 12 volts.

There is no humidity component in our experiment.

Six Beams were used: B1, B2, B3, B4, B6 & B7 With the following Beamwidths respectively:

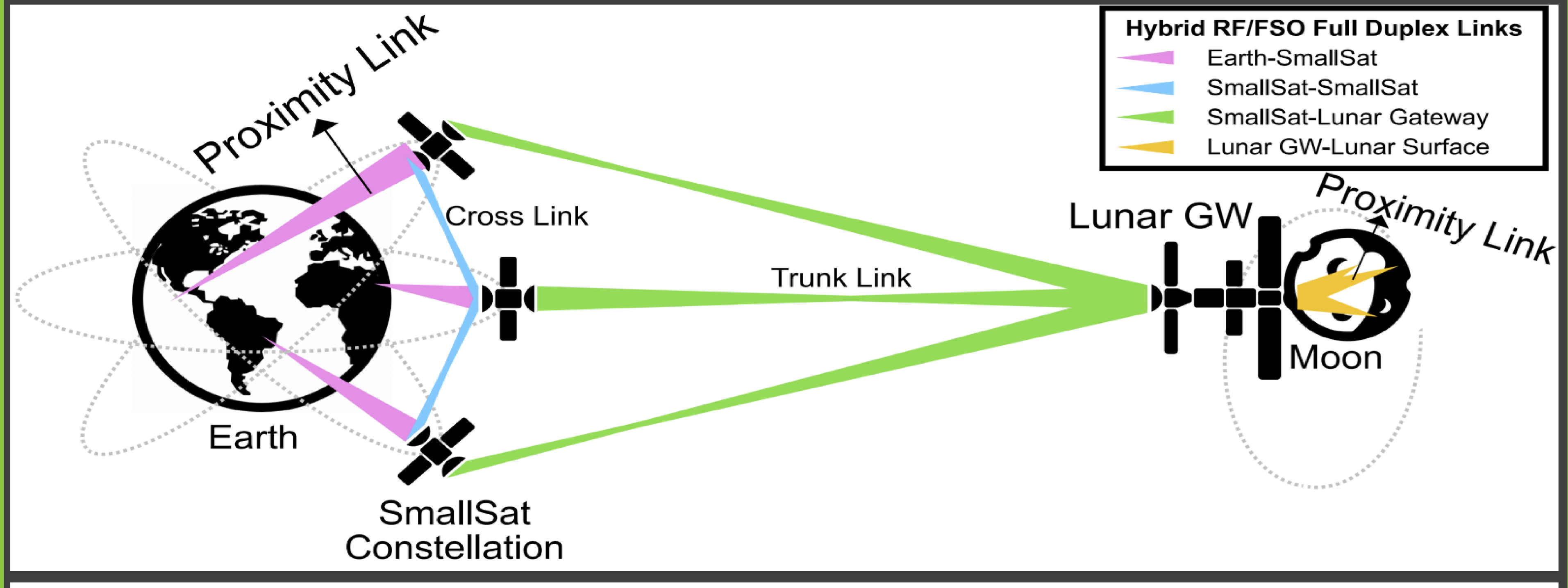
B1: 9.75 mm, B2: 7.60 mm, B3: 4.85 mm, B4: 3.65 mm, B6: 2.19 mm, B7: 2.00 mm

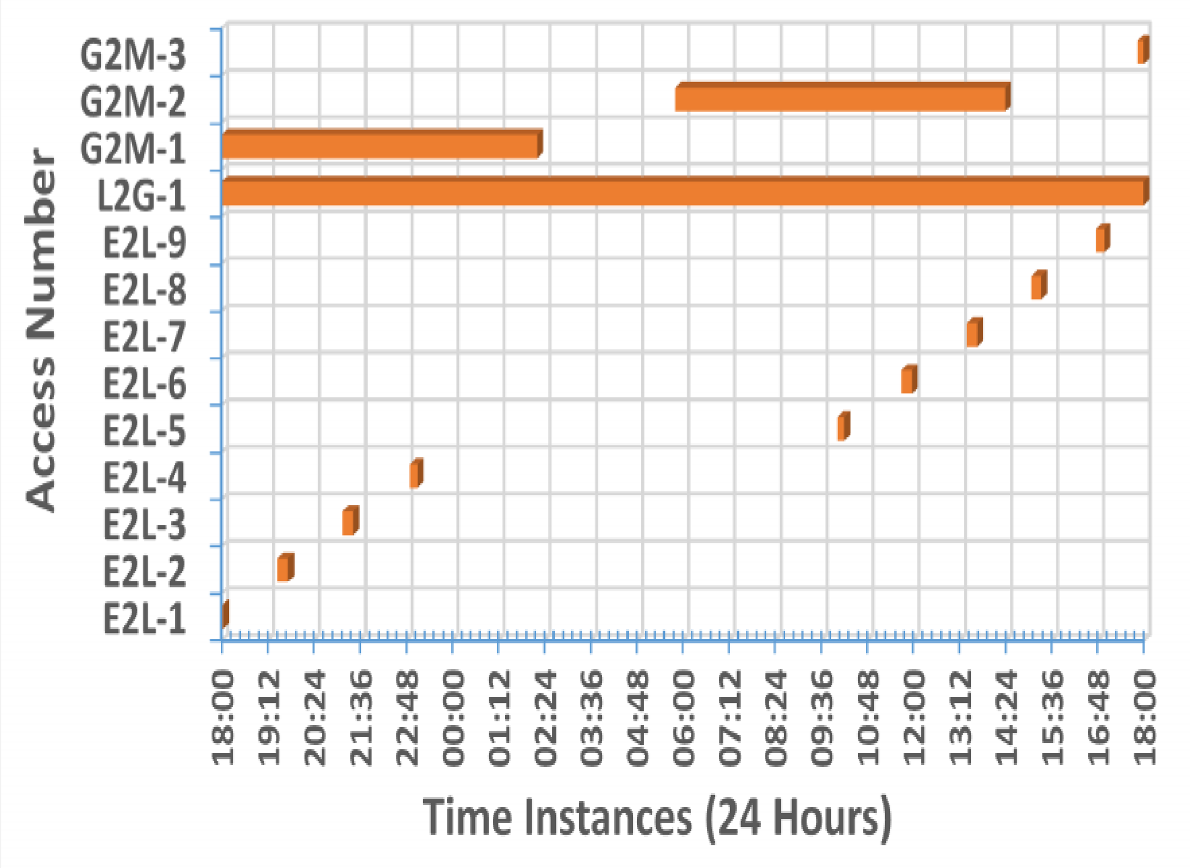
Channels 1, 2 & 4 of the Virtual Bench Scope were connected to:

Red Laser (Reference), Received bit sequence, & Transmitted bit sequence

For every heat and wind setting of each beam, there were ten takes. This means, (10x6x5x4) a total of 1200 takes. Each take has 935 lines of data.

Hybrid System Case Study





Statistical parameters of Earth to LEO access duration for different LEO constellations

LEO Const.	Access Count	Min (sec)	Mean (sec)	Max (sec)	Sum (sec)
1-by-1	09	150.628	0800.570	1026.864	07205.132
2-by-2	29	150.628	0940.415	1185.900	27272.037
3-by-3	43	499.098	1361.578	1763.173	58547.839
4-by-4	01	86400.00	86400.00	86400.00	86400.00

An experimental, indoor hybrid system is under construction (1 km path).

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