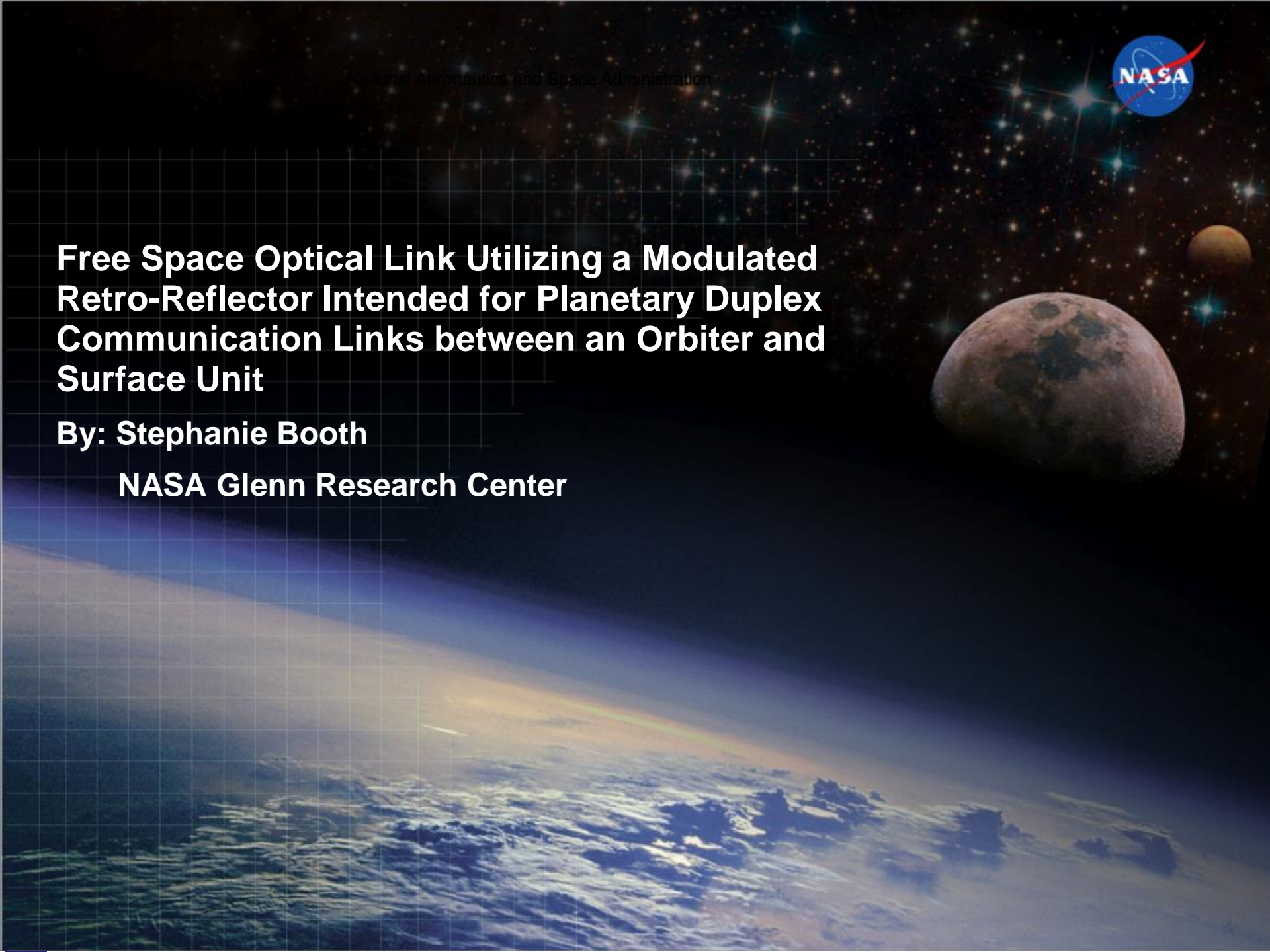




# **Free Space Optical Link Utilizing a Modulated Retro-Reflector Intended for Planetary Duplex Communication Links between an Orbiter and Surface Unit**

**By: Stephanie Booth**

**NASA Glenn Research Center**





# Agenda

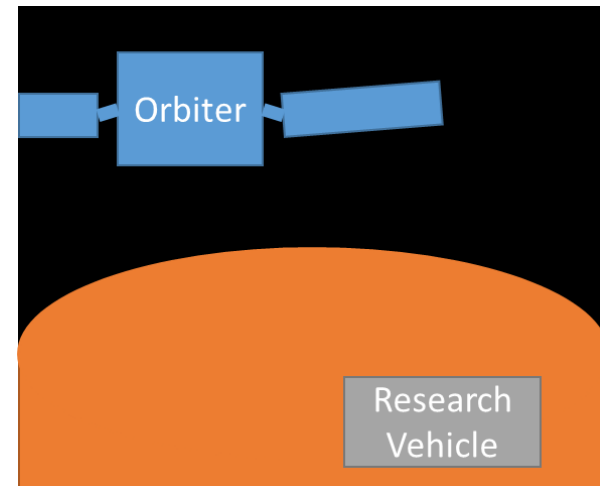
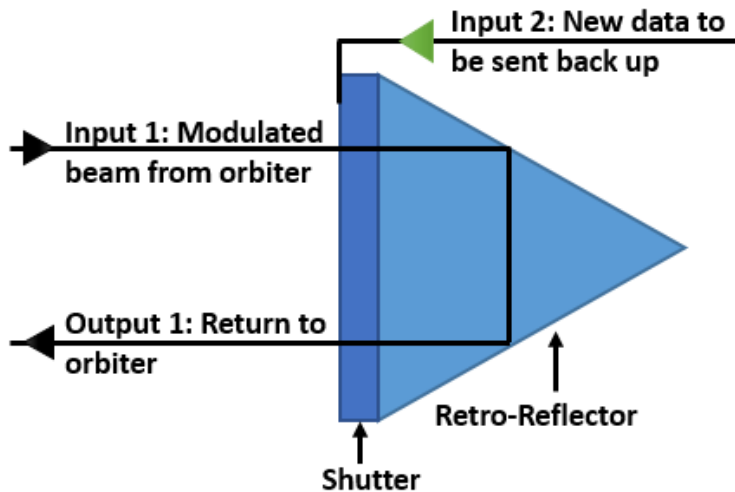
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- 1. Introduction**
- 2. Proposed scenario**
- 3. Modulation overview**
- 4. Simulation - to test the proposed scenario**
- 5. Experimentation - to test the modulation**
- 6. Conclusions**



# The Beginning

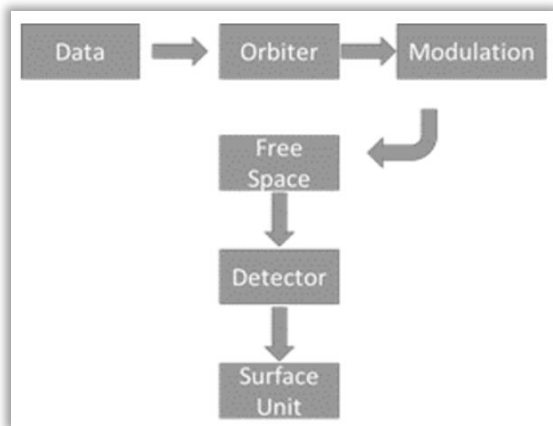
- Why optical communications instead of radio frequency (RF)?
- How did we optically communicate before?
- Why use a modulated retro-reflector (MRR)?
- Why do we care?



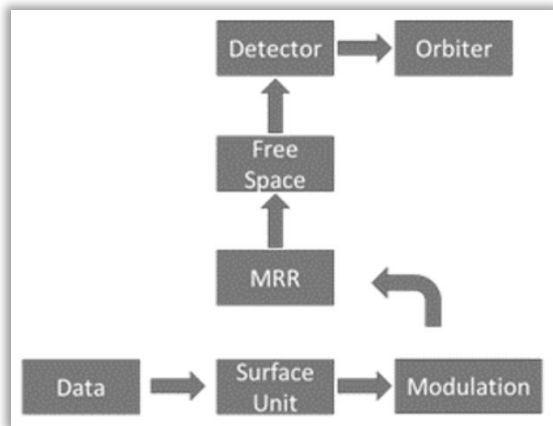


# My Proposal

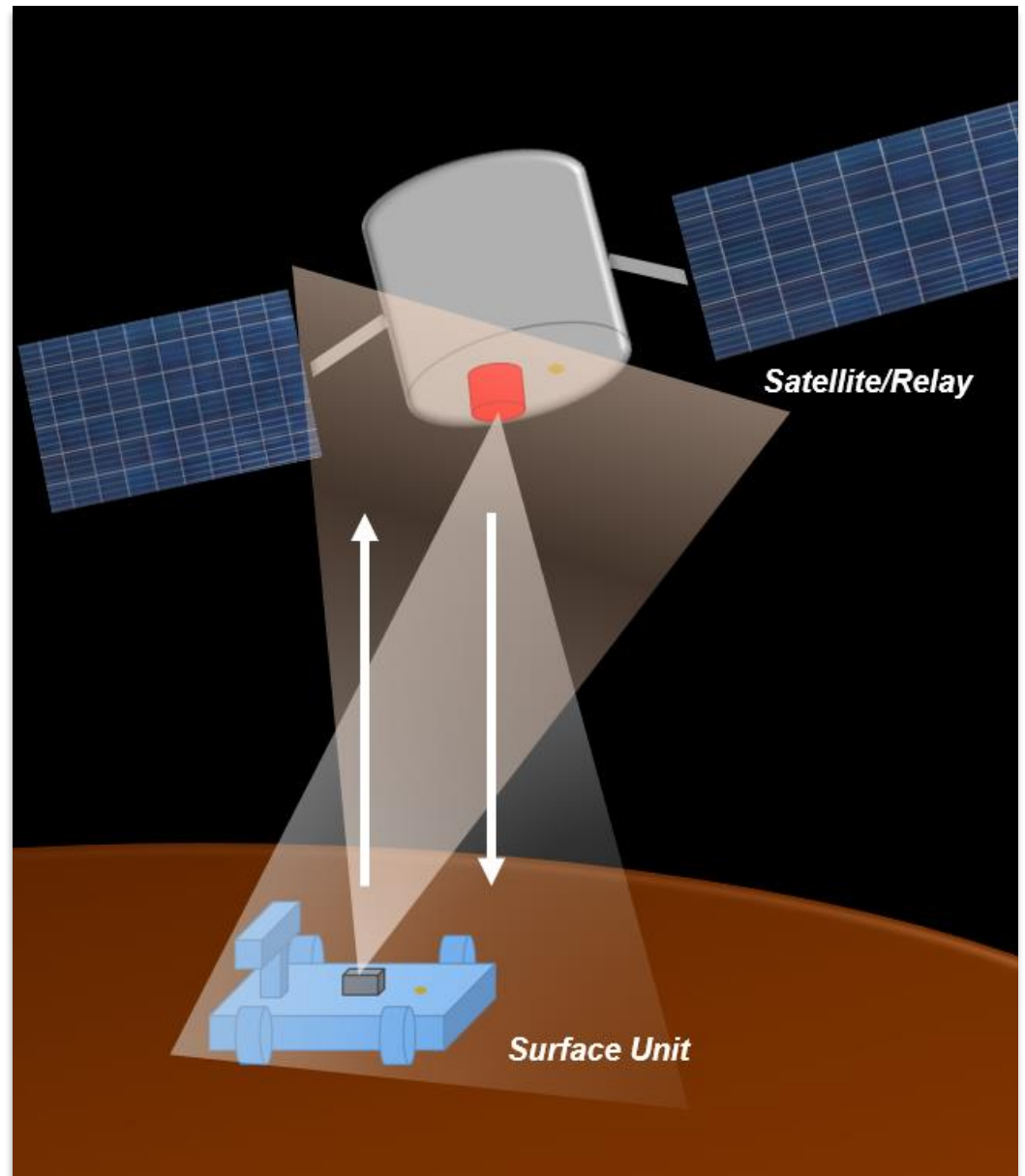
- Let's say....Mars
- Orbiter contains the laser, rover contains the MRR



**Orbiter System**



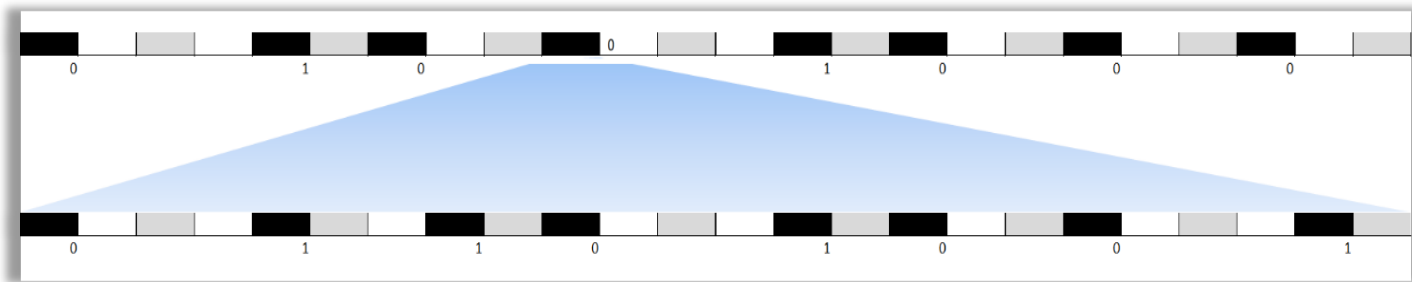
**Surface Unit System**





# How to Modulate Our Beam

- **Keep it simple:**
  - Pulse Position Modulation (PPM)
- **But nested PPM...with a guard time slot**





# Let Us Simulate

- **Components**

- 1550 nm laser
- Avalanche photodiode detectors (gain of 100)

- **Link Budget Values**

- Target Error Rate  $10^{-6}$  BER
- Planetary irradiance:  $0.00874 \text{ W/cm}^2/\text{sr}/\mu\text{m}$

- **Use Mars Reconnaissance Orbiter (MRO)**

- BSP files of MRO's aerobreaking

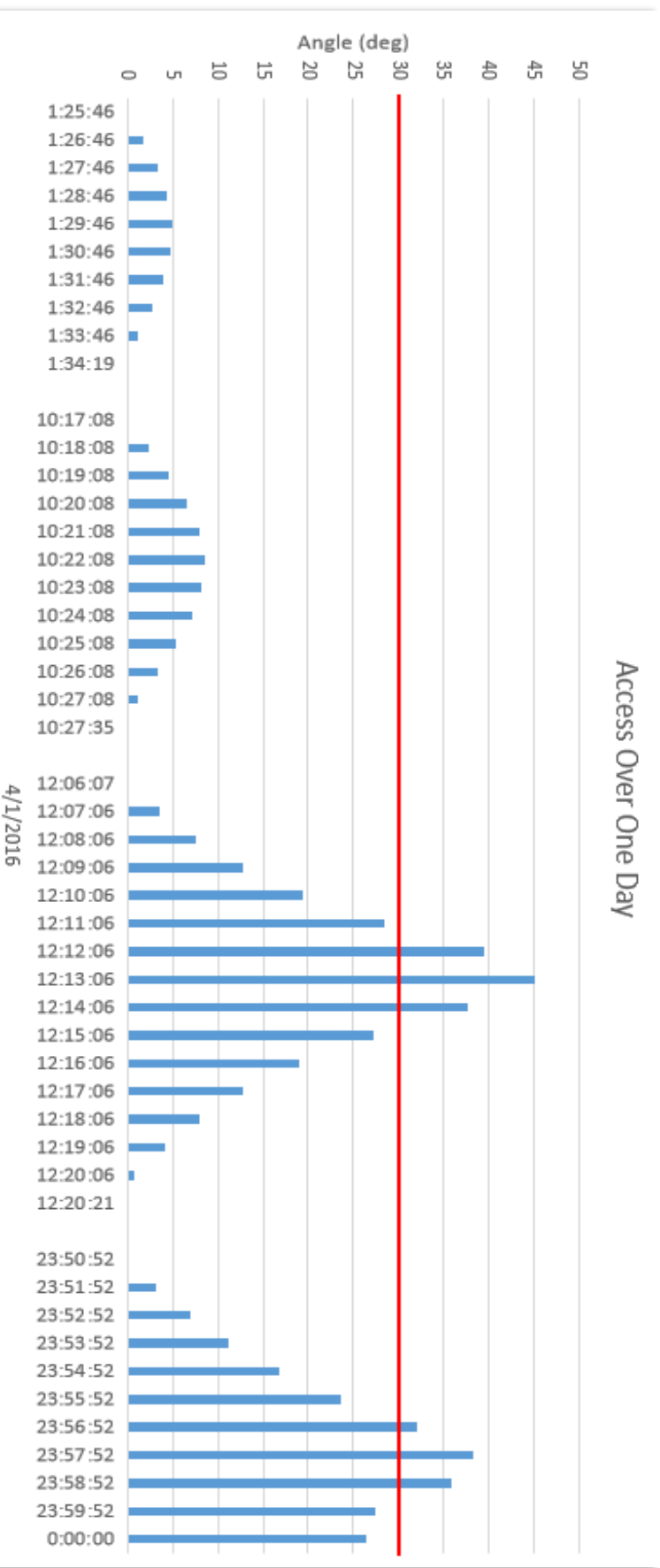
- Aperture detector diameters: 10 cm and 2 cm
- MRR aperture diameter: 2 cm
- MRR surface roughness: 2 cm
- Sky irradiance:  $0.0035 \text{ W/cm}^2/\text{sr}/\mu\text{m}$
- Downlink data rate: 150 kbps
- Uplink data rate: 300 kbps





## Some Results

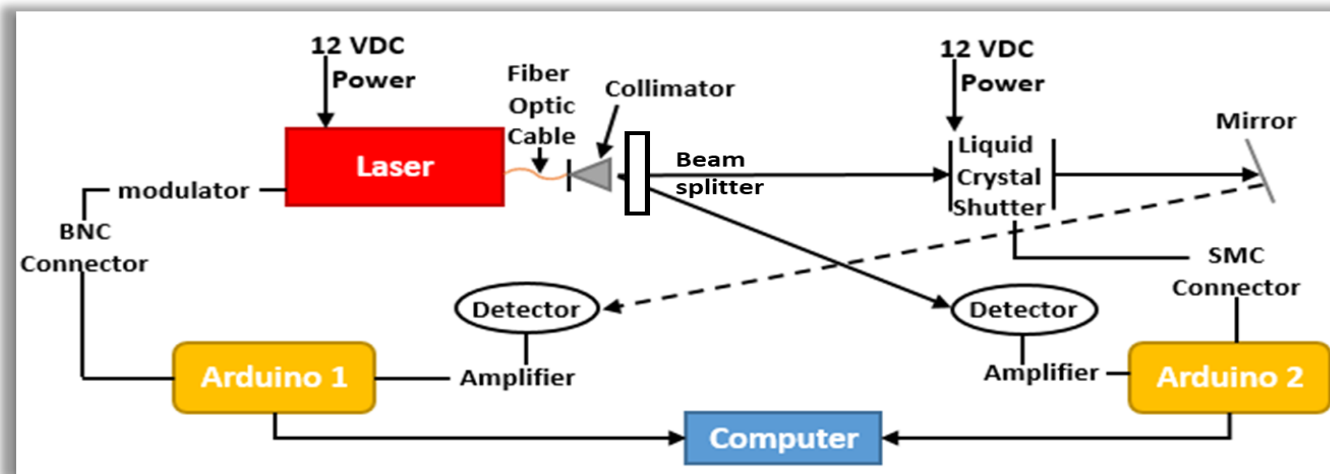
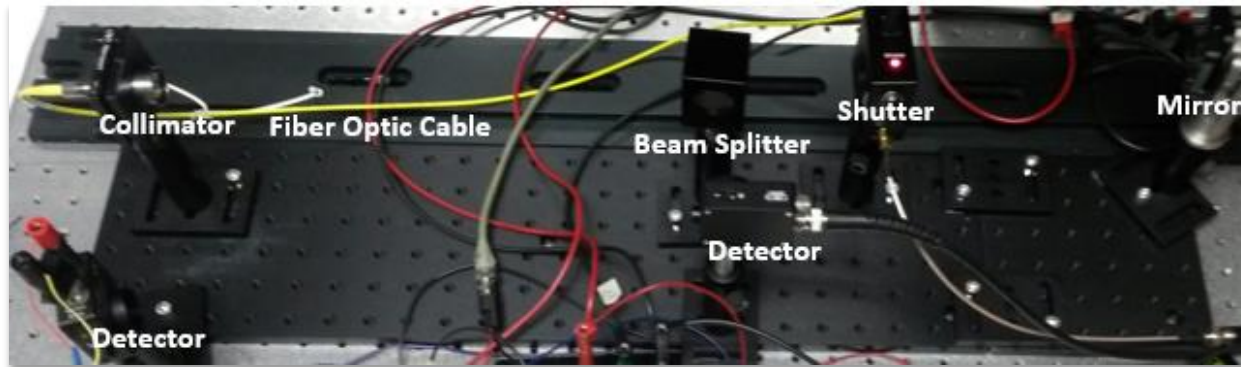
- 45.85 total line-of-sight minutes
- Calculations require 30-degree limit
  - ~6.55 minutes
- Some points in the data had enough margin to increase the data rate





# Testing Our Modulation

- **Component changes from the simulation**
  - 635 nm (red) laser
  - MRR is mirror and liquid crystal shutter
  - Beam splitter
  - Arduino Uno and Mega 2560

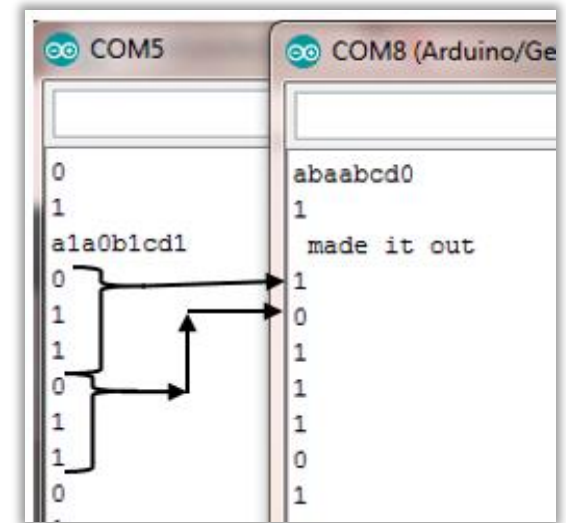
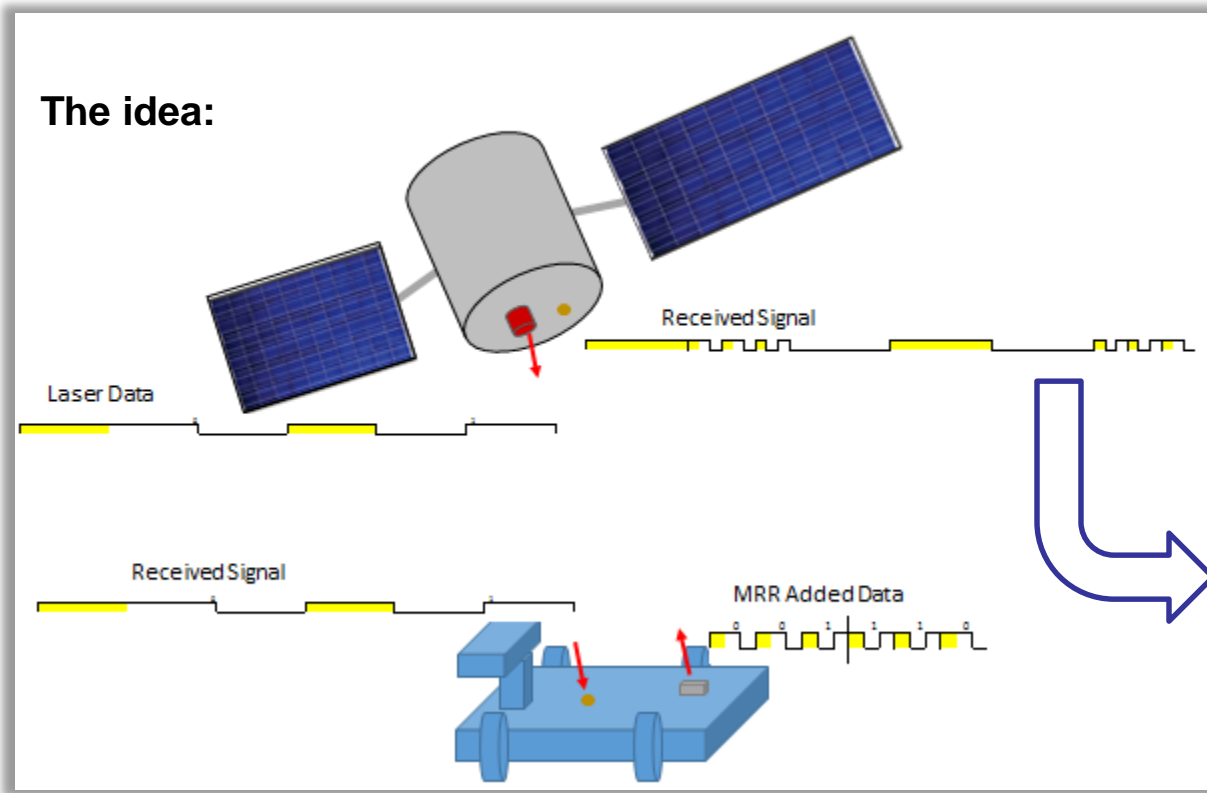






# Proof

- Laser sends 1011
- Surface Unit adds within each bit three bits: 011



Rover

Orbiter



# Conclusions and Future Work

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- **Two parts of the system were successful in their test**
  - Proposed scenario is possible, i.e. proved by simulation
  - Modulation scheme is feasible, i.e. proved by experimentation
- **Proposed scenario was calculated at less than optimal conditions**
  - Still performed better than Electra on Curiosity in most cases
  - Higher data rates are possible!
- **Ideal for small mobile low power situations**

## Future Work:

- **See how our contact times for communication improve lowering down to Electra**
- **Check out other modulation schemes that might be better optimized for this communication**



# Any Questions?

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