# Capturing History versus Developing a Standard for the Future

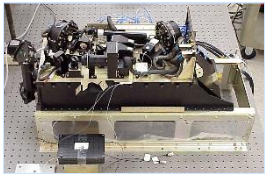
# 26 March 2015

**Optical Communications Working Group**

**Pasadena, California**

# 2001 GeoLITE demonstrated High Rate, Space-Based Lasercom for LEO / GEO Applications

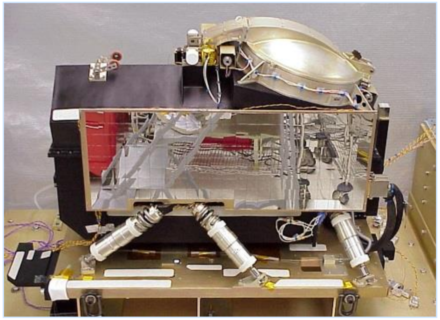
**Lincoln Laboratory**
**Provided an Optical Communications Package for the Department of Defense which Successfully Demonstrated:**



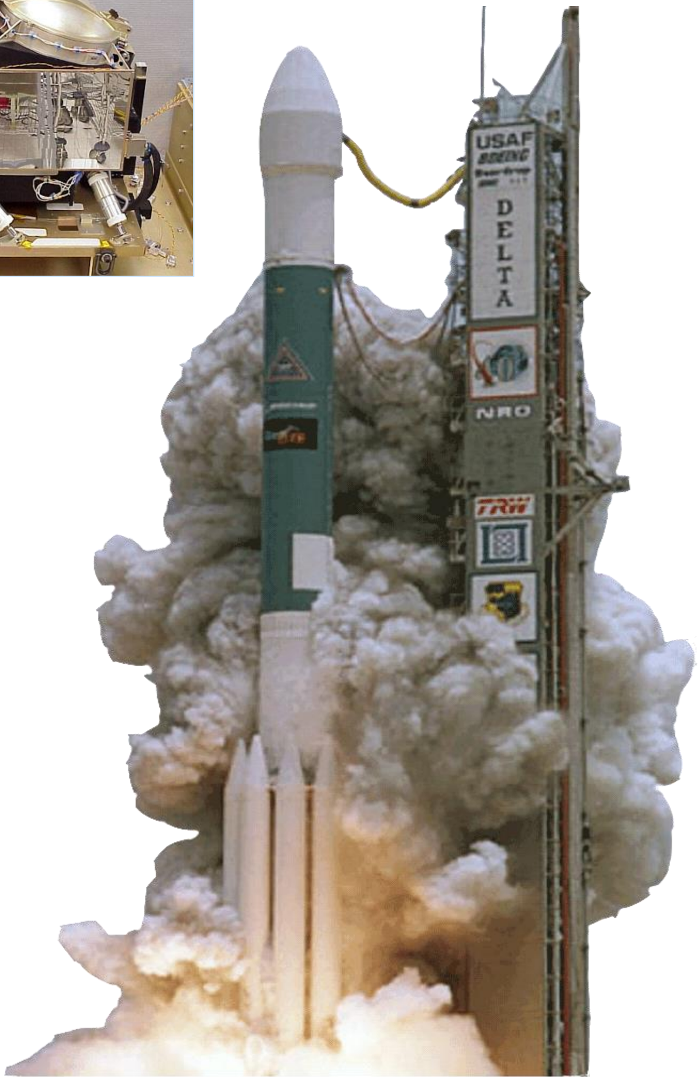
**Small Free-Space Optics**

**Pump and Beacon Laser Module**

- Up and down lasercom, including space-to-ground and space-to-aircraft
- Robust solution to the challenging problem of stabilizing very narrow beams
- Suitability of many commercial telecommunication components for space



**Optical Module**

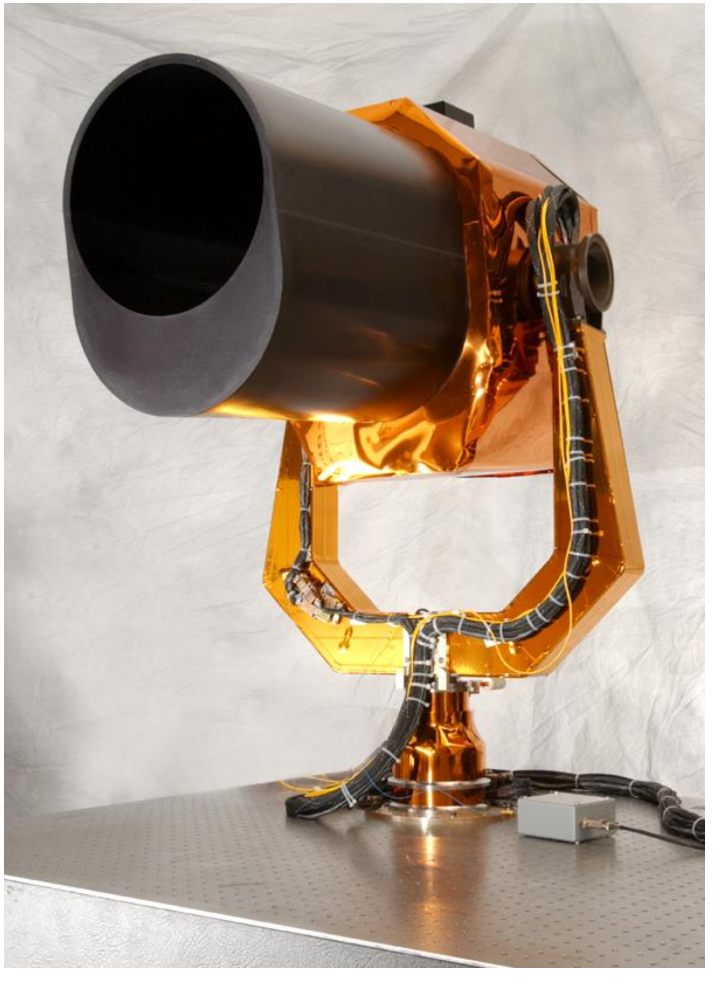


# Official GeoLITE Press Releases

- The GeoLITE program investigated the use of laser communications technologies to eliminate communications as a constraint to the collection, analysis, processing and dissemination of information critical to national security.
  - http://www.nro.gov/news/press/2002/2002-02.pdf
  - http://www.nro.gov/news/press/2001/2001-02.pdf
  - https://www.ll.mit.edu/mission/communications/communicationsbondurant.html

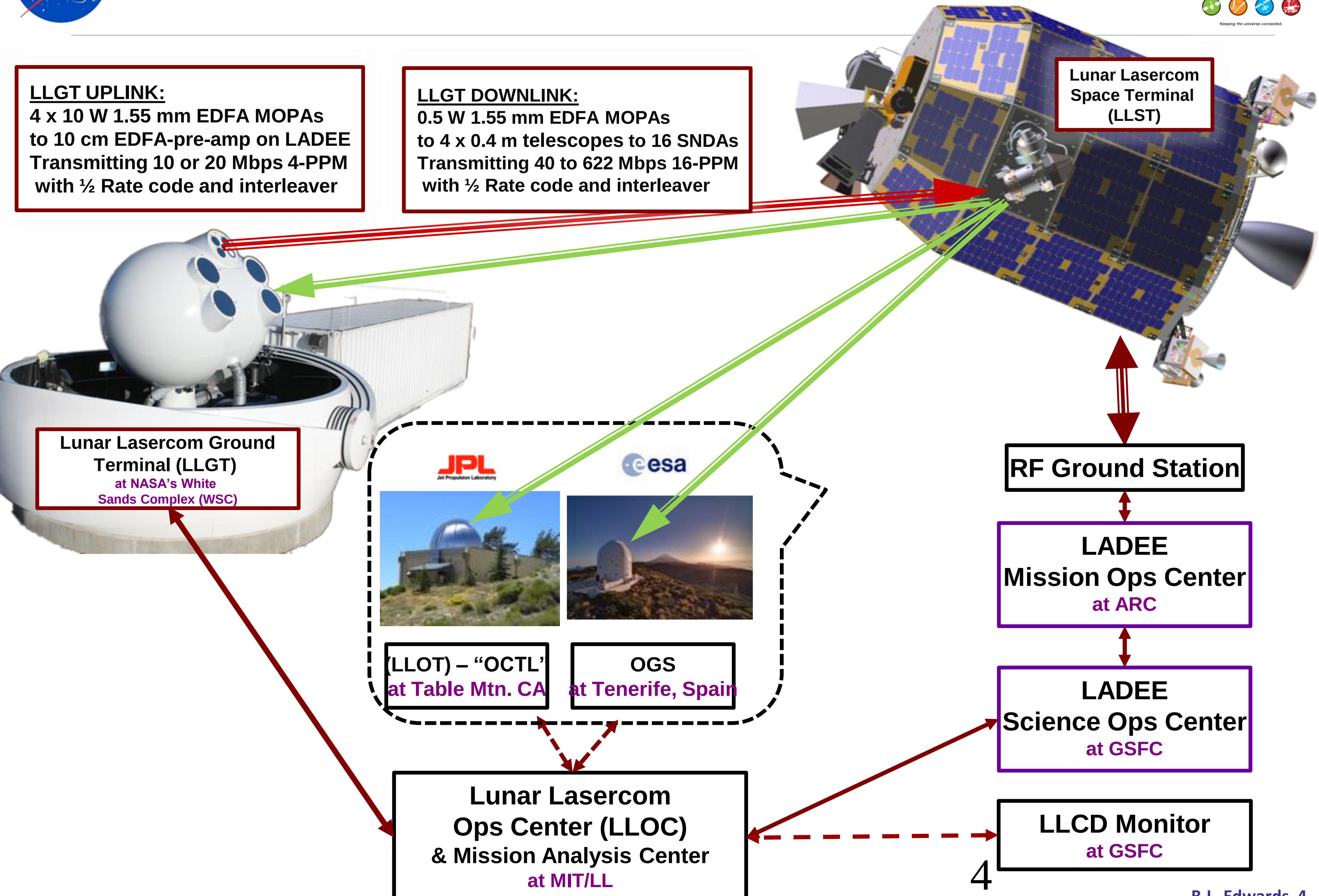
# 2003-2008 High Rate Commercial Lasercom Work by United States Industry

- Up to 40 Gbps at up to 85,000 km range
- Up to 12 inch transmit/receive gimbaled telescope/payload with large elevation (+/- 65 deg) and azimuth (+/- 130 deg) field of regard
- Multi-W, single-channel InGaAsP/EDFA transmitter
- Compliant modulation and error control
- EDFA LNA/InGaAs PIN photodiode receiver
- WFOV acquisition receiver
- NFOV track sensor
- ~ 300 lbs, 350 W projected for flight (10 Gbps bidirectional operation)



Long-Range Optical Head Assembly

# 2013 Lunar Laser Communication Demonstration



# LLCD Accomplishments via the Lunar Lasercom Ground Terminal

**Performance to Date:**

- ✓ Regular, instantaneous (seconds!) all-optical acquisition and tracking between LLST and LLGT
- ✓ Error-free D/L to LLGT at 40, 80, 155, 311 Mbps
- ✓ 622 Mbps D/L regularly achieved with a code word error rate (CER) < $1 \times 10^{-5}$ (Req. < $1 \times 10^{-4}$)
- ✓ Error-free U/L from LLGT at 10, 20 Mbps
- ✓ Initial TOF measurements collected and being processed to allow centimeter-class ranging
- ✓ Error-free operation at low Moon elevation angles (< 4 degrees at White Sands/LLGT!)
- ✓ Operation to within 3 degrees of the Sun at up to 622 Mbps with no degradation in performance!


- ✓ LLST U/L commanding sent and LLST telemetry received over optical link
- ✓ LADEE spacecraft data downlinked through high-speed data interface to LLST Modem; entire 1 GB LADEE buffer downlinked in < 5 min @ 40 Mbps (LADEE C&DH limit)
- ✓ Multiple streaming HD videos transmitted to the Moon and looped back to LLGT at 20 Mbps (limited by U/L rate)
- ✓ All-optical (no RF!) Comm passes using automated scripts to awaken and point LLST on schedule

# LLCD Accomplishments via JPL's OCTL Facility and ESA's Optical Ground Stations

**JPL's LLOT Ground Terminal (OCTL)**

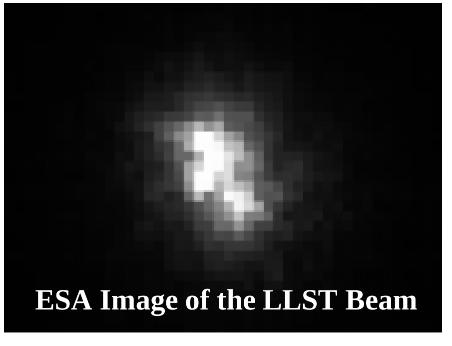
- ✓ Regular, instantaneous (seconds!) all-optical acquisition and tracking between LLST and OCTL
- ✓ Properly-framed, error-free D/L to JPL's OCTL at 40, 80 Mbps
- ✓ Operation at low elevation angles of the Moon ( 8 degrees at JPL's Table Mountain/LLOT)
- ✓ "Hand-off" from WSC to JPL during pass in < 2 min!

**ESA's LL-OGS Ground Terminal**

- ✓ Received communication D/L to ESA's OGS at 40 Mbps (new station)
- ○ Fine-tracking on U/L sometimes achieved at LLST, but signal level is 5 dB too low to permit U/L comm
- ○ Final week of passes will try to exercise improved OGS U/L beam pointing

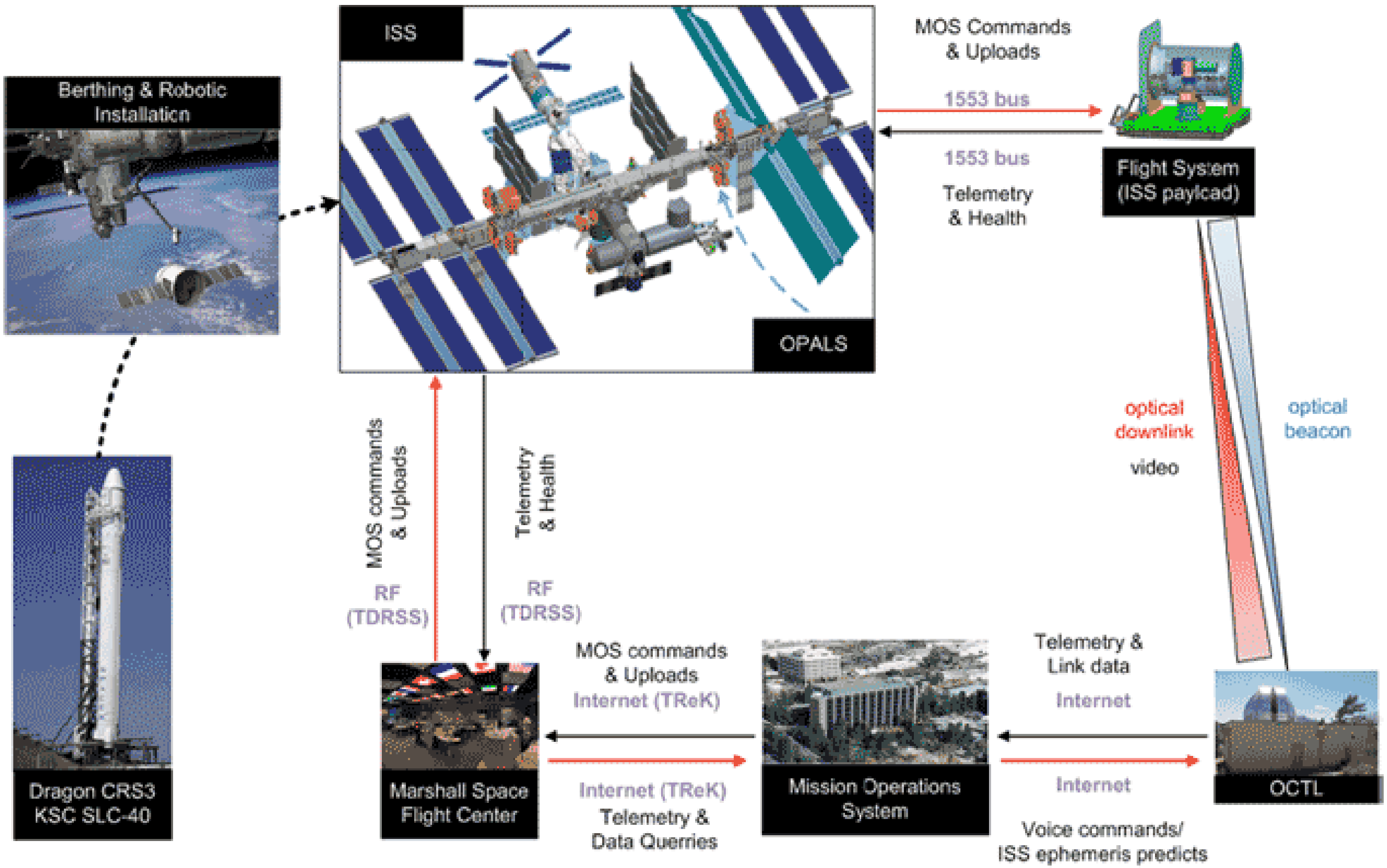
JPL's OCTL Facility in Southern CA

ESA's LL-OGS on Tenerife, Spain



ESA Image of the LLST Beam

# 2014 Optical Payload for Lasercomm Science (OPALS)



# Optical Communications Facets of OPALS

- Optical link performance characterization & validation
- Atmospheric turbulence characterization
  - Obtain downlink aperture-averaged fading statistics by recording received power
  - Obtain uplink scintillation statistics by recording beacon power on flight system
- Link availability studies
  - Geometry, atmospheric & environmental, day vs. night
- Pointing performance
  - OCTL Open loop tracking
  - Flight System acquisition, tracking, stability

| DOWNLINK CHARACTERISTICS | | |
|---|---|---|
| **SIGNALING** | | |
| Modulation | OOK | - |
| Uncoded BER | 1.00E-04 | - |
| ECC | Reed-Solomon | - |
| Modulation Rate | 30-50 | Mb/s |
| **TRANSMITTER** | | |
| Downlink wavelength | 1550 | nm |
| Beam Divergence (1/e^2) | 1.65 | mrad |
| Average laser power | 2.5 | W |
| Power transmitted from FS | >0.833 | W |
| **POINTING** | | |
| Pointing Bias | 150.0 | mrad |
| Pointing Jitter (RMS) | 125.0 | mrad |
| **LINK GEOMETRY** | | |
| Max Zenith Angle | 65 | deg |
| Max Range | 700 | km |

| BEACON CHARACTERISTICS | | |
|---|---|---|
| Uplink wavelength | 976 | nm |
| Average Laser power | 5 | W |
| Beam divergence | 1.7 | mrad |
| Power transmitted from OCTL | 1.26 | W |

# Key Objectives for This Working Group

- **As a reminder, NASA is looking for the following from the CCSDS Optical Communications Working Group**
  - Develop optical communications standards to allow inter-operability and cross support
  - Develop standards to support the exchange of real-time weather and atmospheric data
  - NASA would like to have a High Data Rate standard in place to influence our decisions regarding optical communications and the next generation of space based relay satellites
  - NASA needs a Low Complexity standard for inexpensive University-class and Cube-sat class spacecraft
  - NASA would like to have a High Photon Efficiency standard as we start to build very large optical ground stations

# Our Focus Should Be On The Future

- This Working Group should focus on the future.  What kind of standard should be developed to support interoperability?

- NASA is not looking for a text book or a history book on past accomplishments

  - NASA does not believe that "backwards compatibility" is something that needs to be captured in a CCSDS document unless there is a **compelling need for future systems**

  - NASA is not proposing anything that is tied to previous United States experience.
    - Our High Data Rate recommendation starts from our efforts on the Laser Communications Relay Demonstration, but we are already making changes to our proposal to address international comments on our recommendation.  NASA is happy to negotiate more changes, including using a coding and synchronization method developed in coordination with the CCSDS Coding and Synchronization Working Group.
    - Our High Photon Efficiency recommendation is not backwards compatible with the highly successful Lunar Laser Communication Demonstration.
    - Instead NASA is using the knowledge and experience from previous work to help us develop a recommendation for the future

# Summary

- NASA understands the importance of international cross support for today's Radio Frequency systems and would like to see the same for future optical communication systems

- NASA is looking for the following Blue Book recommendations from the CCSDS Optical Communications Working Group:

  - High Data Rate recommendation
  - High Photon Efficiency recommendation
  - Low Complexity recommendation

- However, NASA does not want CCSDS to publish a recommendation that can not be implemented due to technical reasons or costs

  - A standard is of limited value if space agencies do not actually implement the standard

- NASA feels strongly that the recommendations should focus on the future of this new and evolving communications technology and not what has been accomplished in the past