Jet Propulsion Laboratory
California Institute of Technology

OPTICAL COMMUNICATION NODE IN SPACE

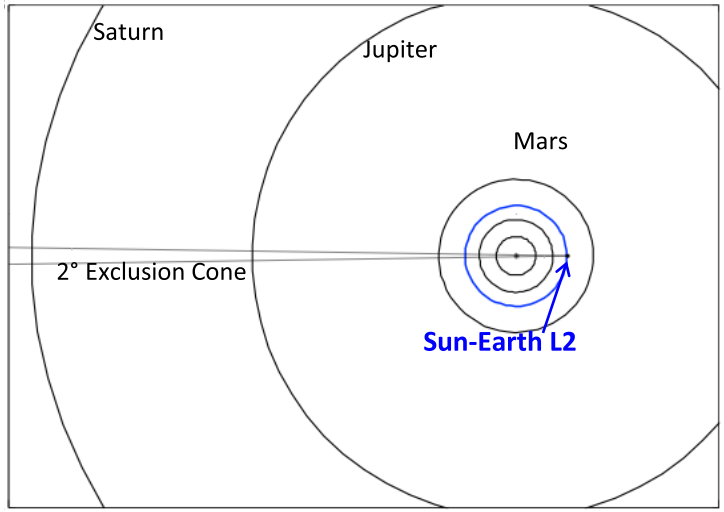
Abhijit Biswas, John O. Elliott, Nathan Strange, Hamid Hemmati
Jet Propulsion Laboratory , California Institute of Technology

Robert Marshalek
Ball Aerospace Technology Corporation

Jet Propulsion Laboratory
California Institute of Technology

HIGH LEVEL CONCEPT DESCRIPTION

- **Utilize large optics for deploying Optical Communication Node (OCN) in space**
  - Earth-Sun Lagrange (L2) for reliable service to deep-space assets throughout solar system
  - Overcome
    - Outages and performance penalty due to atmosphere/weather
  - Better mission coverage for Mars and Outer Planets than DSN or future Optical Ground Network
  - Compatible with multiple users
- **Concept based on "as is" large optics**
  - Development cost will be relatively low
  - Need near-Sun pointing capability realizing the benefits
- **Key data-products enabled by (OCN)**
  - Stream video from deep-space
  - Hyper-spectral imagery and higher resolution science
  - Transmit lasers across solar system
  - Dual mode-receiver direct and coherent

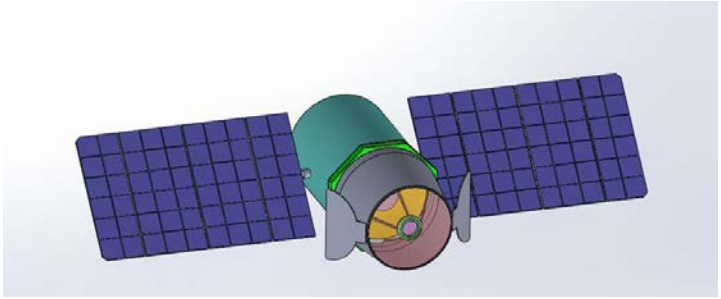


Sun-Earth L2 allows communications with the whole Solar System except for a 2° cone in the direction of the Sun… exceeding the capability of 3 DSN sites with a singe telescope.

HIGH LEVEL CONCEPT DESCRIPTION (cont.)

Jet Propulsion Laboratory
California Institute of Technology

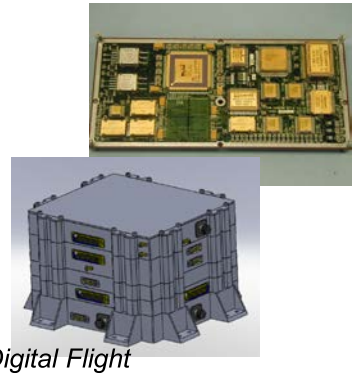
- **Spacecraft for large optics ~ 3180 kg wet mass**
  - Minimum 10 year life at L2
  - 30 arcsec pointing control, 0.25 arcsec stability (10sec)
  - 2500 W electrical power (expandable)
  - 128 Gb storage (expandable)
  - 100 Mb/s relay back to 34m DSN antenna
  - Falcon-9 or Atlas V 511 Class Launch Vehicle



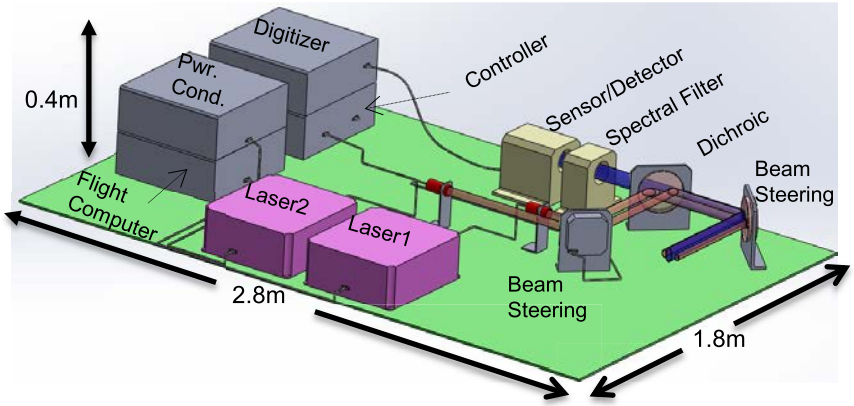
- **Couple optical transceiver to large optics**
  - TRL 5 or higher for most components and assemblies
  - Studies to support near Sun pointing
    - Solar protection and stray light management
  - Photon-counting detectors developed under OCT funding

100 W pulsed Fiber laser

Prototype Solar Filter

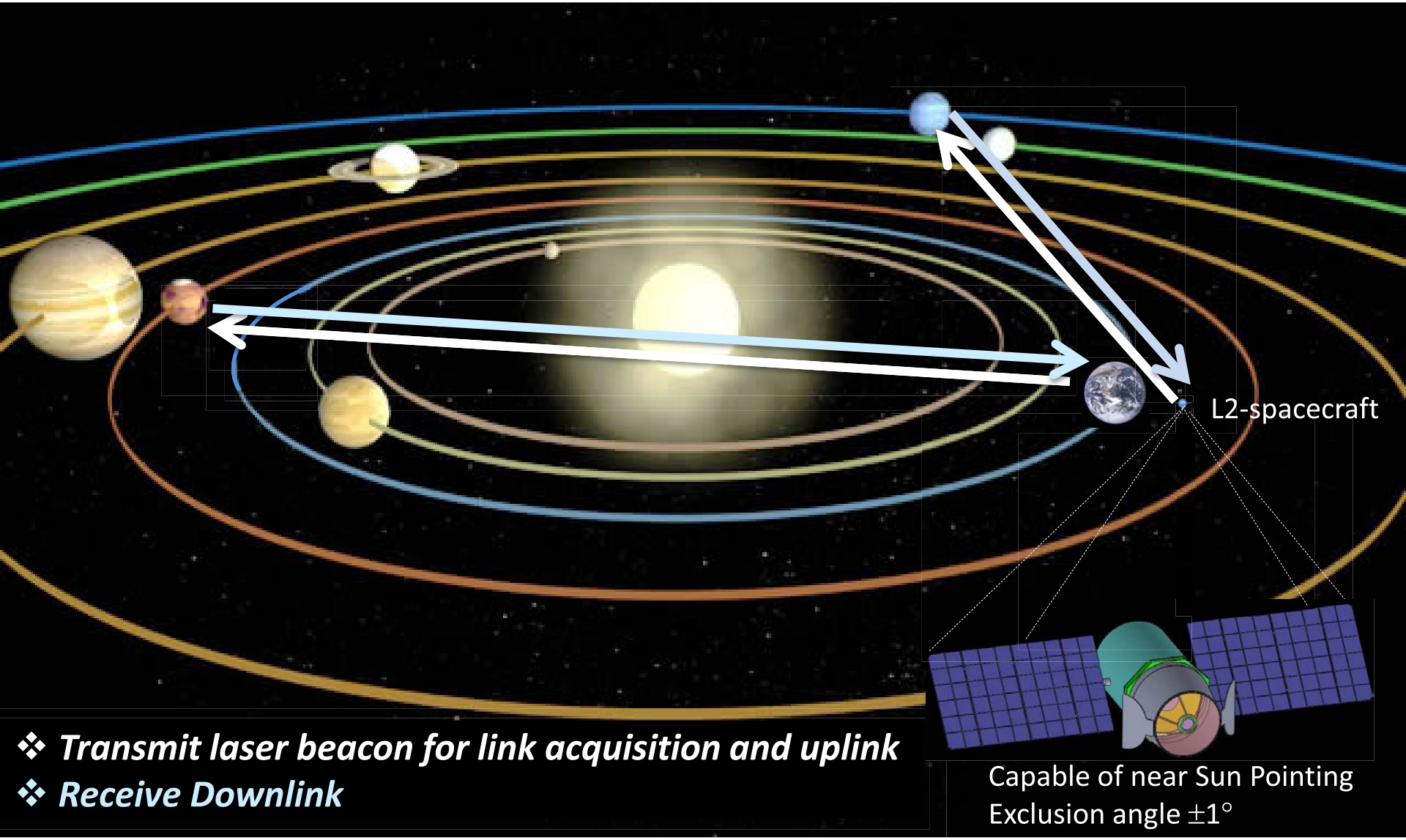


Digital Flight Processor



CONCEPT OF OPERATIONS (cont.)

Jet Propulsion Laboratory
California Institute of Technology

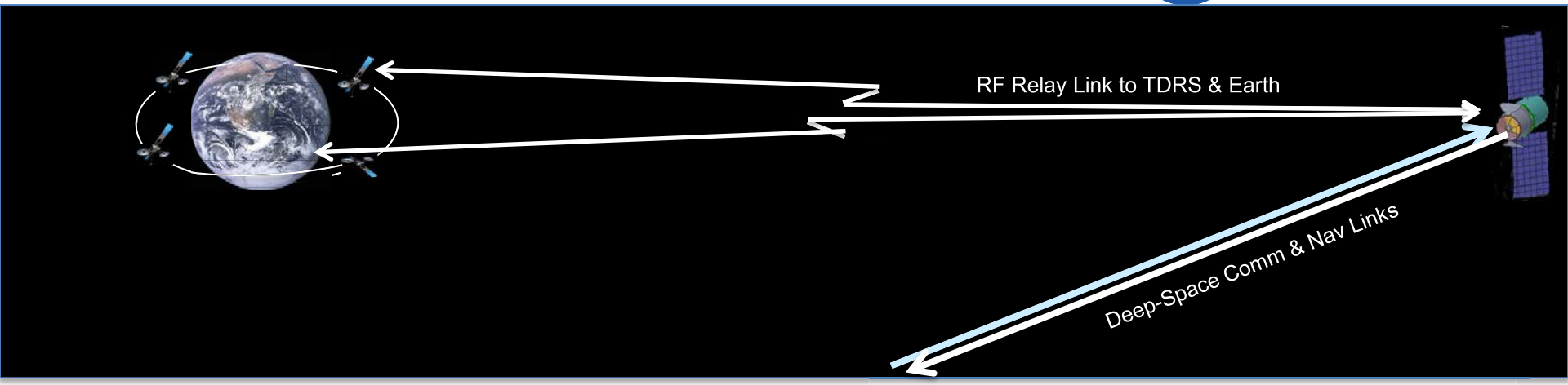


- ***Transmit laser beacon for link acquisition and uplink***
- ***Receive Downlink***

Capable of near Sun Pointing
Exclusion angle ±1°

CONCEPT OF OPERATIONS (cont.)

Jet Propulsion Laboratory
California Institute of Technology

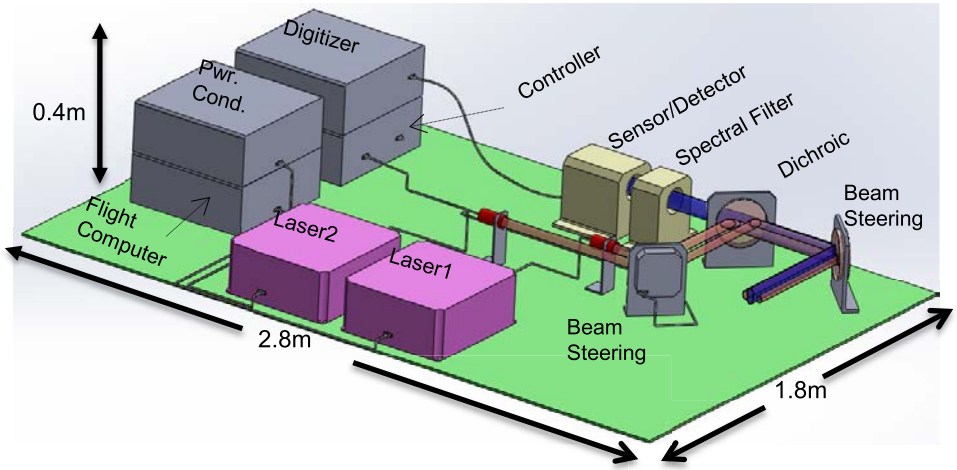


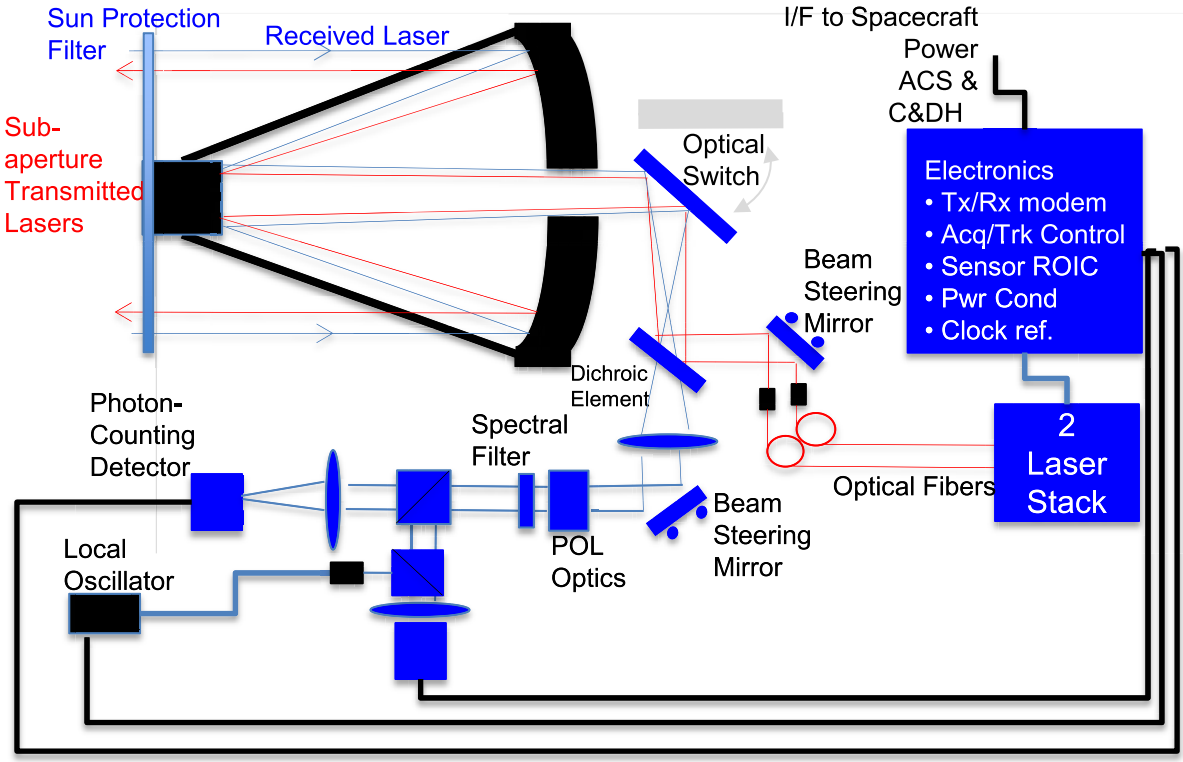
- **Enhanced Deep-space optical communication capabilities**
  - Uninterrupted optical service for deep-space assets (**Mars and Outer Planets**)
  - Strong beacon advantageous for modest aperture deep-space terminals
    - Rovers, lander and probes
  - Millimeter precision range accuracy, currently limited to Jupiter distances with ground lasers
  - Locked carrier with coherent mode can provide novel data products
  - Light science with transmitted and received laser signals
    - Planetary atmosphere occultation measurements
    - Farraday rotation from magnetic fields
- **Networked to DSN**
  - Received data digitized and compressed on-board
  - Relayed back to Earth DSN stations for decoding and information extraction
  - Explore networking with TDRS satellites for higher contact time

OPTICAL TERMINAL ARCHITECTURE

Jet Propulsion Laboratory
California Institute of Technology

- **Optical transceiver architecture**
  - **Sub-aperture transmit**
  - **Full aperture receive**
    - Large FOV and wider transmitter beams ease pointing
  - **Point 1° from Sun**
    - Extends contact time
    - Ground optical telescopes have 3-5° sun exclusion
  - **With wide-field acquisition sensor**
    - Celestial object assisted acquisition
  - **500 W laser optical power**
  - **2.5 cubic meters**
  - **246 kg**
  - **1100 W Power**

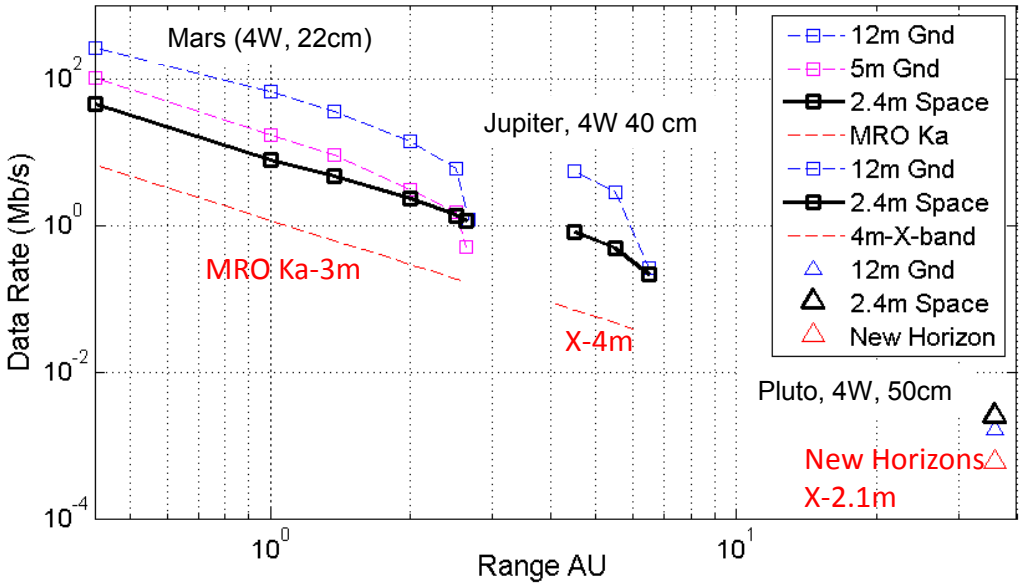




SCIENTIFIC TECHNICAL OPERATIONAL BENEFITS of SN

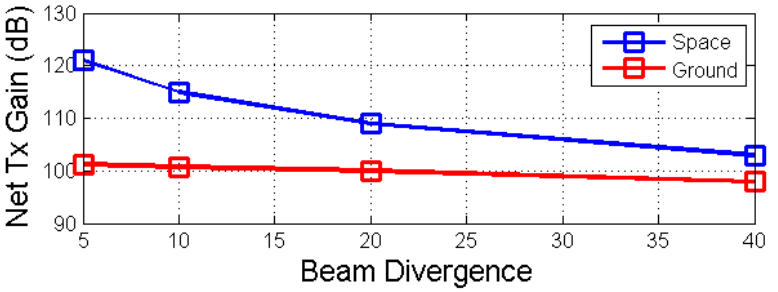
Jet Propulsion Laboratory
California Institute of Technology

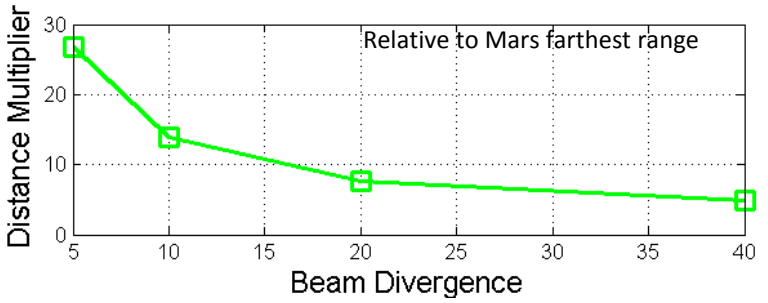
- **Downlink comparison space vs ground**
  - Additive noise degrades ground performance
  - Single ground telescope data-volume can be offset by space node
    - Time spent at particular range
    - Increased contact time
    - Lack of outages
  - Architecture with space and ground node may be optimal



- **Laser transmission to deep-space is advantageous from space-node**

- Transmitting space-based beacon is limited by pointing control
  - *Near-Earth optical terminals have demonstrated sub-micro-radian pointing capability*
- Ground-based beacon is limited by atmospheric turbulence
  - *Adaptive correction extremely challenging*
  - *Constrained by regulatory restrictions*
- Distance multiplier from gain in transmitting beacons allows extending reach to edge of solar system





SUMMARY

Jet Propulsion Laboratory
California Institute of Technology

- **Study will accelerate access to Optical Communication service throughout solar system**
  - Aligned to Communication and Navigation System Roadmap (April 2012) by SCaN Program Office
- **Low cost utilization of large optics in space**
  - Minimal modification of large optics may be required
  - Commercial solar system exploration missions can be serviced with this node
  - Provides needed reliability & bandwidth for future human missions
- **Accomplishes Multiple Objectives**
  - Reliable high-bandwidth communication service
  - Unique opportunities for precision laser ranging and light science
- **Concept is "doable" leveraging past missions**
  - Deployment and operations of large mirrors in space
  - Recent successful demonstrations of lasercom
  - Elements needing further study
    - Design considerations for near-sun pointing
    - Space optical receiver
- **Seek partnerships across agency and industry**
  - Ball Aerospace Technology Corporation on-board
    - Long history of successfully deploying space optics
    - Developed TRL 6 laser comm terminal from TSAT