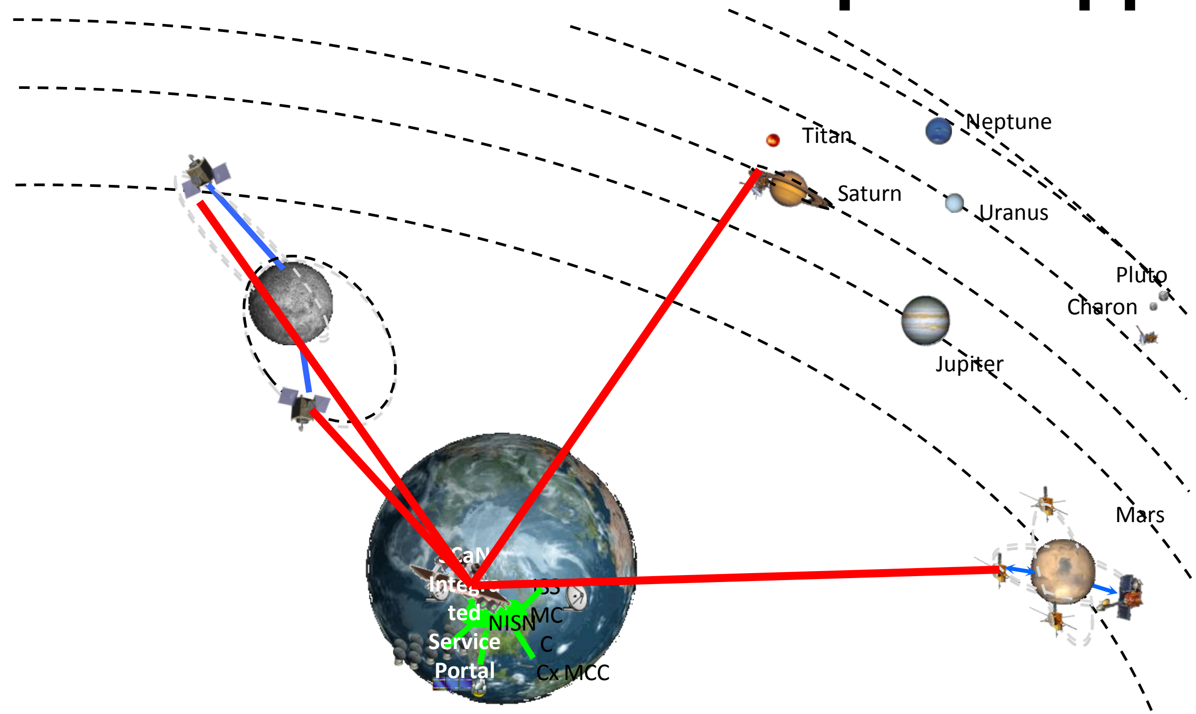
NASA Plan for Development of Optical Communication for Space Applications



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NASA, Space Communications and Navigation Office

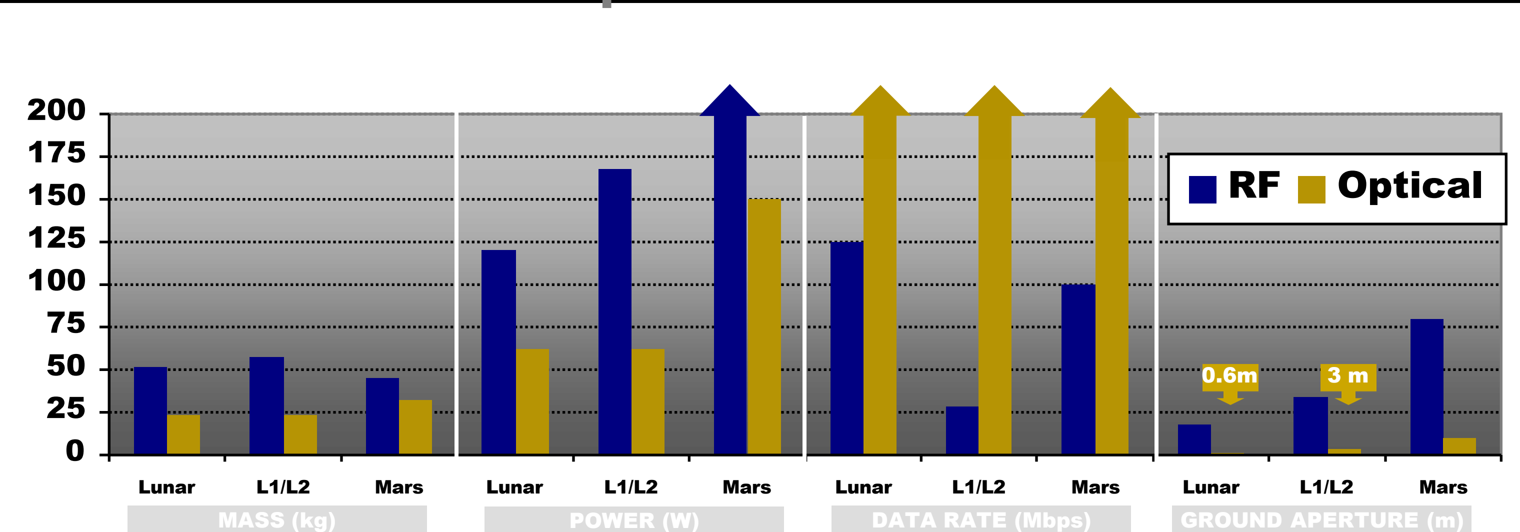
Agenda

- NASA Optical Communications Overview
  - Why Optical?
  - Why Now
  - Where are we today - LADEE
- Plan for Future Demonstrations
  - Near Earth
  - Deep Space
- Operational Infrastructure Concepts
  - Ground-based
  - Space-based

Why Optical Communications?

- **Higher Data Rates**
  - Order of magnitude higher than RF
  - Enables use of Earth Sensing instruments at the Moon and Mars and beyond
  - More productivity from science spacecraft
- **Lower Size, Weight, and Power Burden on Spacecraft Compared to RF Systems**
  - Spacecraft resources available for science instruments / extended missions

Benefits of Optical Communications



A comparison of Lunar (LRO), L1/L2 (JWST), and Mars RF solutions against optical comm. solutions shows vast improvements in mass, power, data rate, and ground complexity*

Depending on the mission application, an optical communications solution could achieve…

- ~50% savings in mass
  - Reduced mass enables decreased spacecraft cost and/or increased science through more mass for the instruments
- ~65% savings in power
  - Reduced power enables increased mission life and/or increased science measurements
- Up to 20-fold increase in data rate
  - Increased data rates enable increased data collection and reduced mission operations complexity

…over existing RF solutions

* Assumes photon-counting technology

Mars Reconnaissance Orbiter (MRO) Example

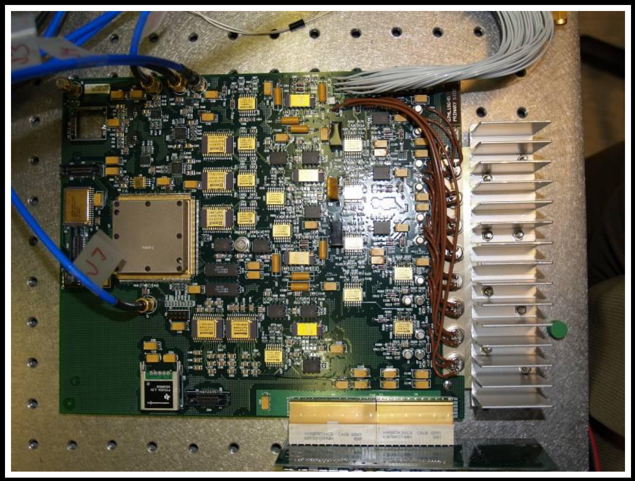
This recent image taken by the Mars Reconnaissance Orbiter represents what one could see from a helicopter ride at 1000 feet above the planet. While this mission is collecting some of the highest resolution images of Mars to date and it will collect 10 to 20 times more data than previous Mars missions, bandwidth is still a bottleneck.

Data collection for climate observations must be turned off while not over the poles because we cannot get the data back.

At MRO's maximum data rate of 6 Mbps (the highest of any Mars mission), it takes nearly 7.5 hours to empty its on-board recorder and 1.5 hours to transfer a single HiRISE image to earth.

In contrast, with an optical communications solution at 100 Mbps, the recorder could be emptied in 26 minutes, and an image could be transferred to earth in less than 5 minutes.

Why Now?

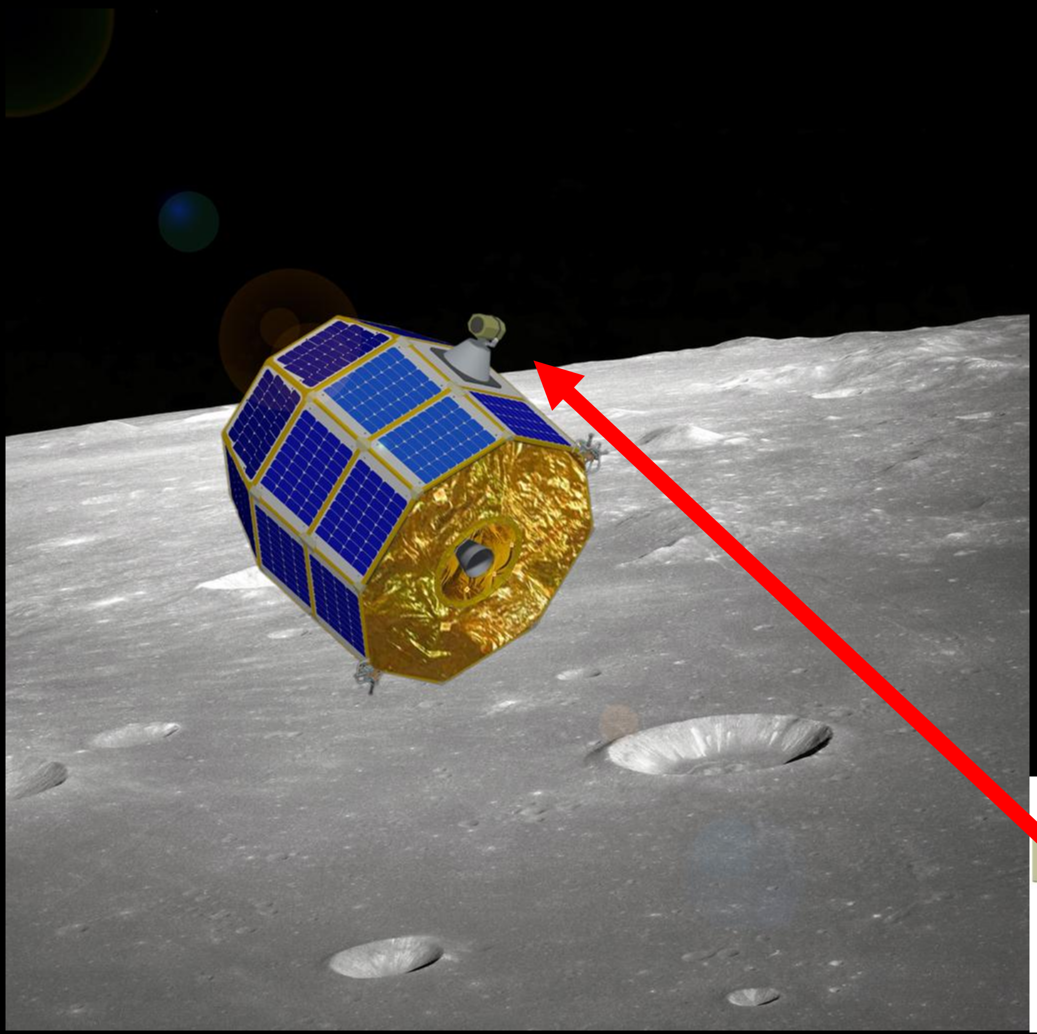


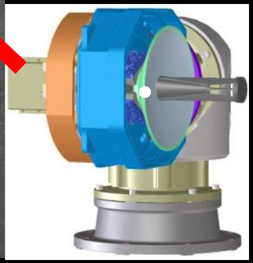
- Optical Communications technology is ready in the lab today
- Space qualification process requires demonstration flights to prove capability in the space environment
  - conducting first flight with the LADEE demonstration

- Revolutionary comms technology enables greater mission flexibility to meet needs of the emerging lunar and Mars exploration era
- Retain US leadership in space communications technology

Taking the 1st Step Now

In Partnership with SMD on LADEE Spacecraft

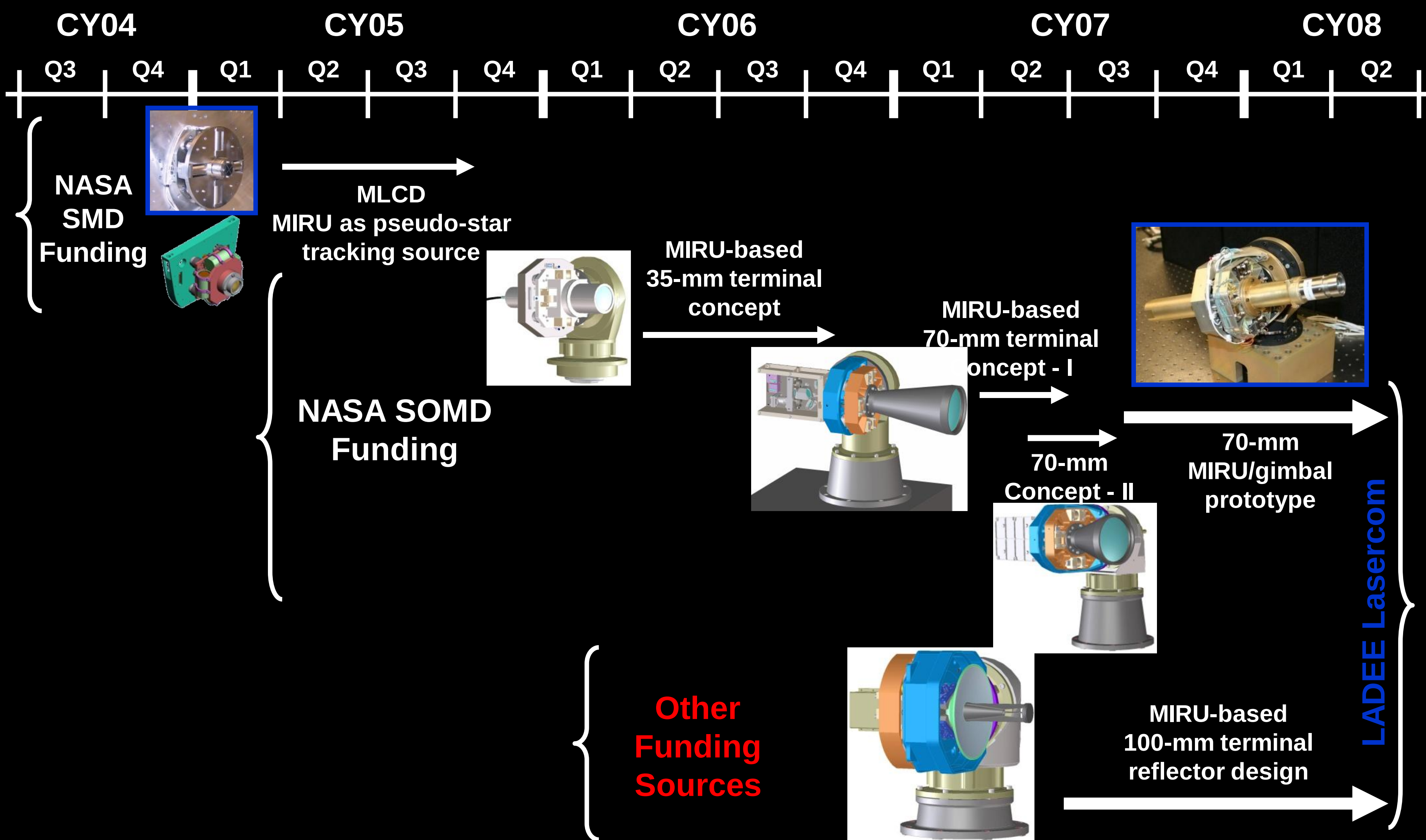




- **Will provide 600 Mbps from moon**
  - **10 cm terminal**
  - **Earth-based Beacon-aided acquisition & tracking**

- **Optical Terminal for LADEE on track**
  - **PDR Scheduled for 2 – 4 June**
  - **Fits within LADEE resource margins**
  - **Earth-based photon-counting technology**

LADEE Optical Comm Terminal Genesis



LADEE Ground Terminal

Photon-Counting Downlink Receiver

•Highly efficient, readily expandable architecture

•Photon-counting detectors

•16-ary Pulse Position Modulation

• Downlink rate up to 622 Mbit/s

•Two-way time-of-flight measurement

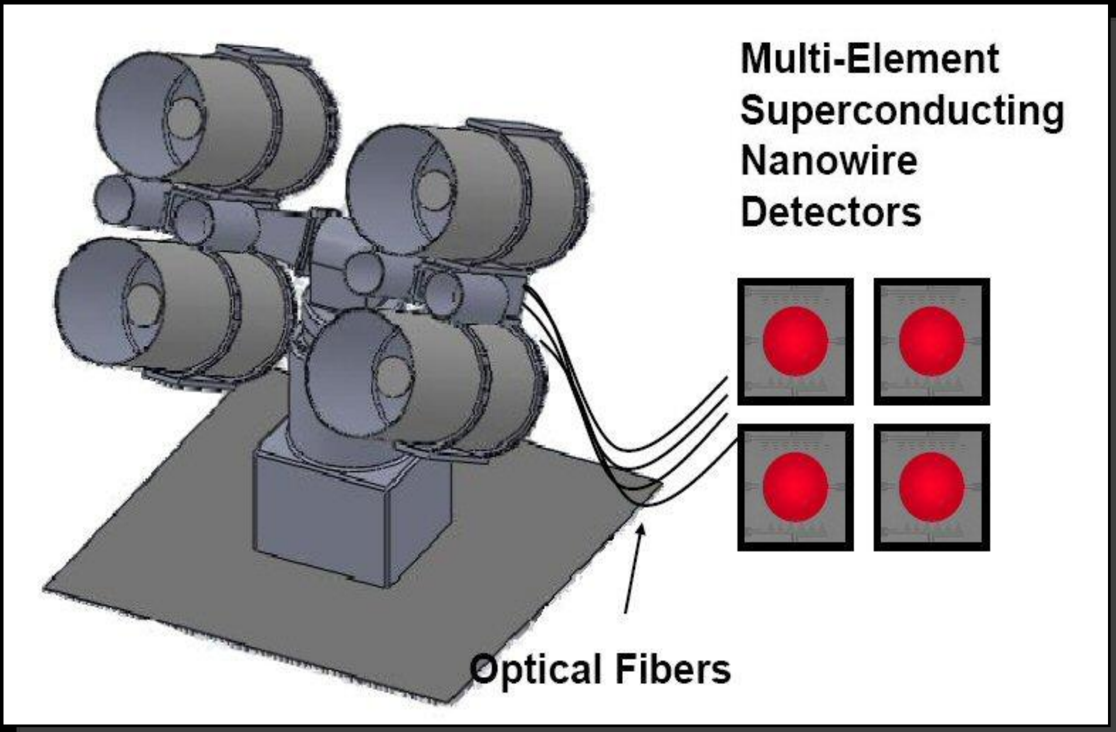
•Single gimbal approach:

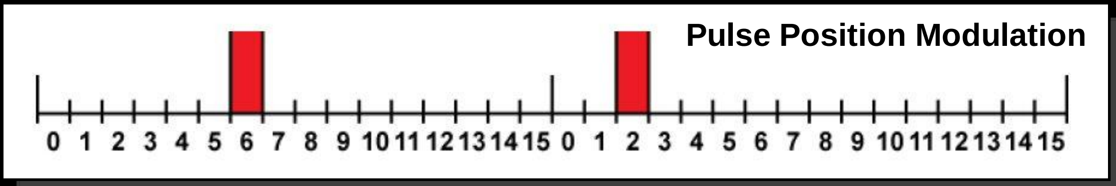
•Downlink receiver

- –4x40-cm telescopes
- –fiber coupled
- – cryogenic detectors
- –30 ps timing resolution

•Uplink transmitter

- –4x15-cm telescopes
- –10w per telescope
- –Eye safe





Enabling NASA’s Optical Communications Capability

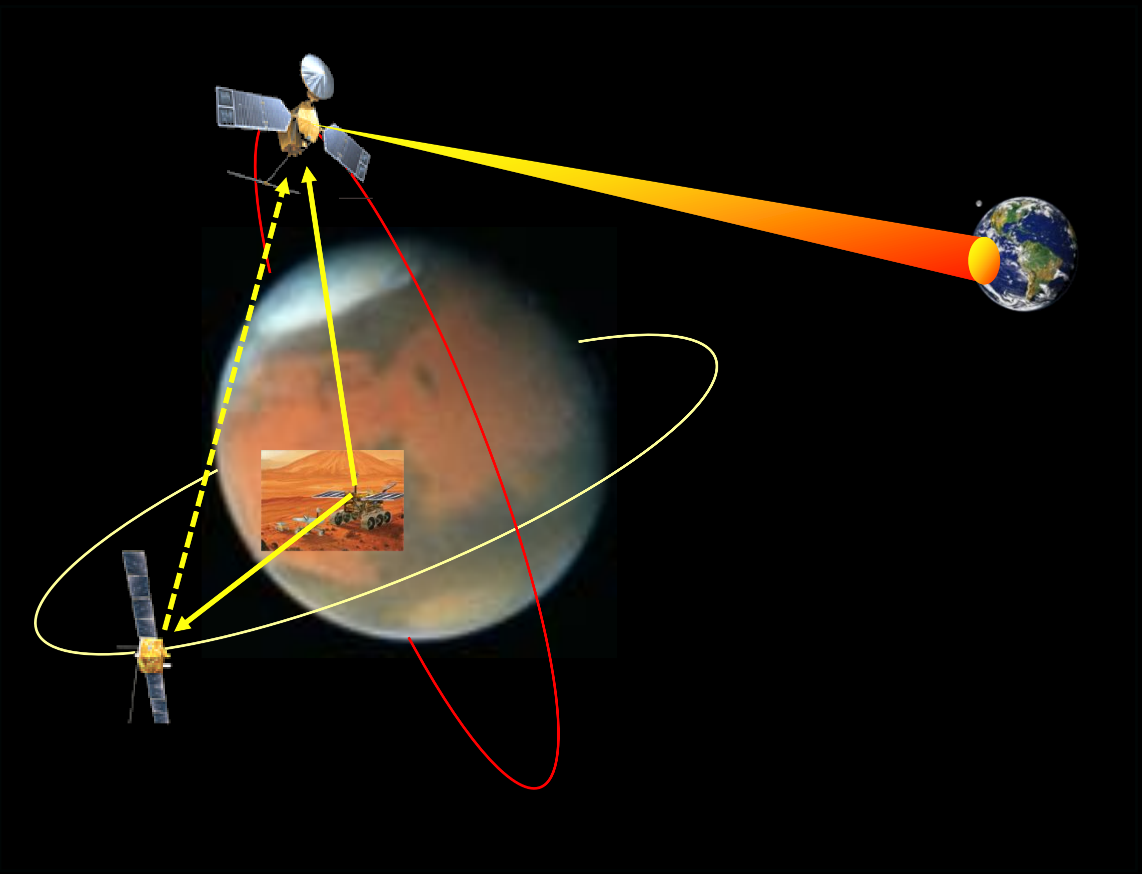
Near Term Efforts

- **Flight Demos**:
  - Near Earth: LADEE, 2nd terminal, JDEM
  - Deep Space: 30 cm ~2018; 100 cm ~2020 (under study)
  - Associated “test” ground terminals
- **Technology Development**
  - 3 main initiatives
    - Improve photon-counting detector efficiency
    - Space qualified photon-counting detectors
    - Pointing and stability
  - Parallels flight Demo Program

Long Range Operational Infrastructure

- **Ground Infrastructure**
  - Built on 2.2 m apertures: single for Near Earth; arrayed for Deep Space
  - Locate initially at 3 global sites with available infrastructure (fibre, etc)
  - Later add 2 Alternate sites for robustness
- **Space-based Option**
  - 2 GEOs
  - RF to Ground (WSC)
  - 10 Arrayed 2.2 m apertures with space qualified photon-counting detectors
  - Enables beacon-aided tracking farther from Earth; high rate uplink

Beginning the Next Step



- 30 cm / 10 W Deep Space Terminal
- KDP-A in 2010
    - Conceptual Design
    - High Fidelity Cost estimate
    - 2nd Source Cost estimate
    - Include ground terminal with photon-counting technology
    - 30 Mb/s from 2.2 AU
    - Mass/power estimate: 60 Kg, 160 W
    - ~2018 launch

Operational Infrastructure Concept Ground-based Option

- Decision to go operational will be based on the results of the demonstration flights and the then current cost estimates
  - First step would be for near Earth capability
  - Ground-based receiver installations with beacon uplinks
- Near Earth Ground-based Terminal System Concepts
  - Use ~2.2 m telescopes that can provide Near Earth optical communication but can later become basic building block of Deep Space capability by combining telescopes in an array
  - Initially start with three global installations in locations where weather is favorable and facilities such as fiber are available
  - Add two alternate sites for weather back up
- Deep Space Ground-based Terminal System Concepts
  - Add telescopes to Near Earth sites
  - Provide arrays of ~2.2 m telescopes to build to sufficient aperture size
  - Ground-based beacon however, power level must be studied

Operational Infrastructure Concept Space-based Option

- Performance of space-based “Earth end of the link” terminals would appear to be best option
  - Above the weather
  - Lower power beacon
  - Two satellites could provide same level of coverage of nine ground-based installations
- Space-based concepts
  - GEO satellites
  - High efficiency detectors for receivers
  - RF link to Earth
  - Arrays of ~2.2 m telescopes
- Some current technical challenges
  - Today’s most efficient detectors (nano-wires) require super cooling adding to satellite complexity
  - Space-based pointing accuracy is challenge
  - Spacecraft size significant due to large number of arrayed telescopes required

Summary

- NASA considers optical communication a potential “game changer” for space communications
- There are still technical challenges but we have developed enough in the lab to warrant the beginning of an aggressive demonstration campaign
- If results of the demonstrations prove the expected performance can be achieved, either a ground-based, or possibly a space-based infrastructure would need to be built