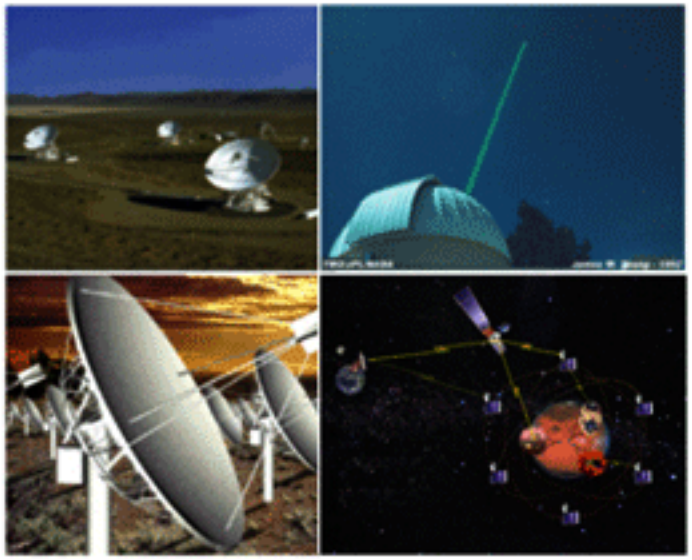
Next Generation Deep Space Network:

Finding Common Solutions for an Uncommon Challenge

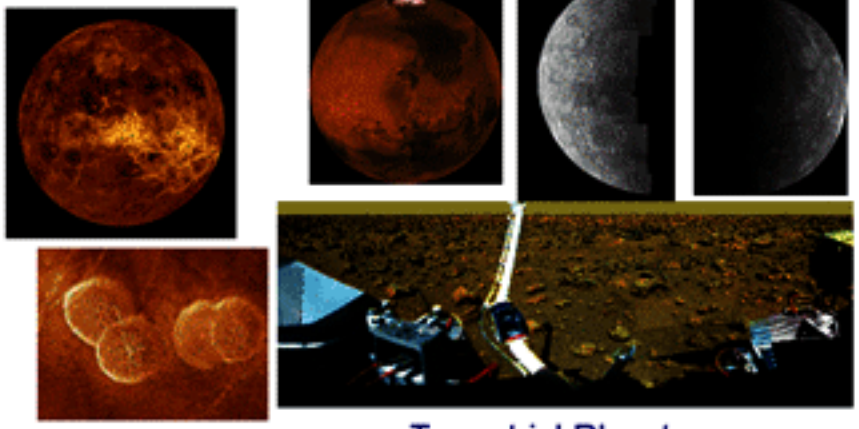


Bill Weber
Director, Interplanetary Network Directorate
Jet Propulsion Laboratory
California Institute of Technology

GSAW 2005
March 1, 2005

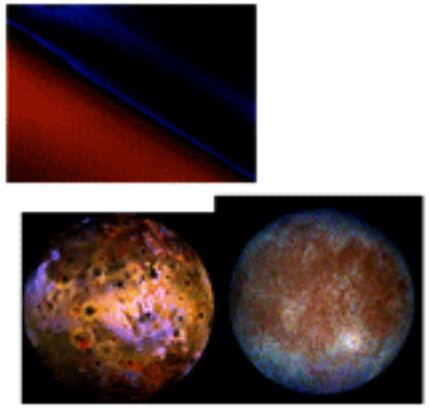
Forty Years of Exploration

Asteroids

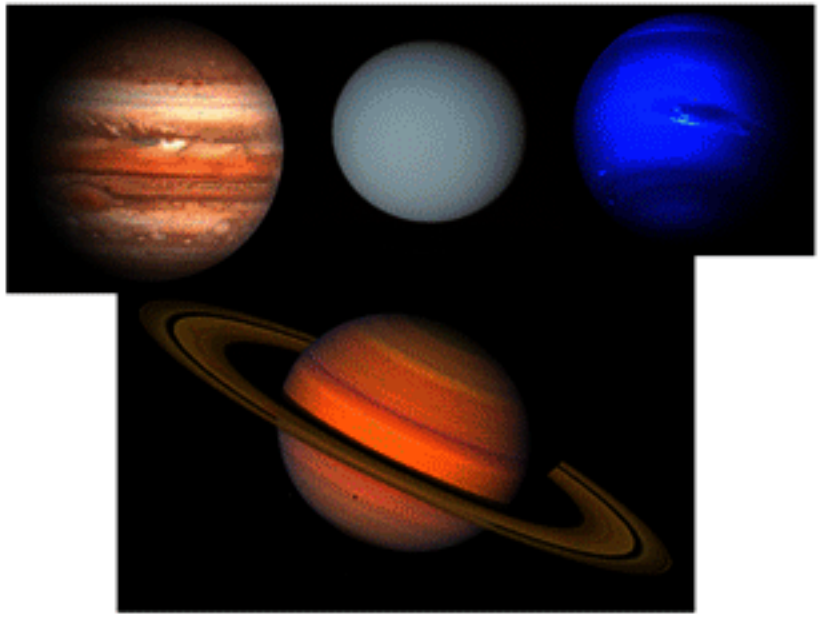


Terrestrial Planets

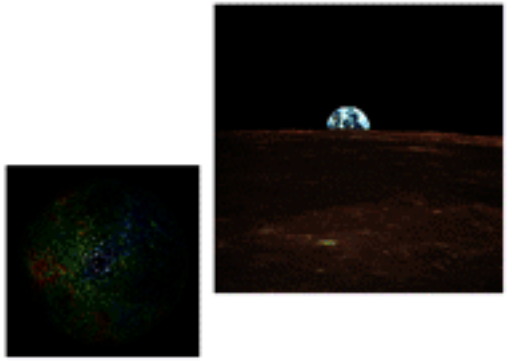
Comets



Planetary Satellites

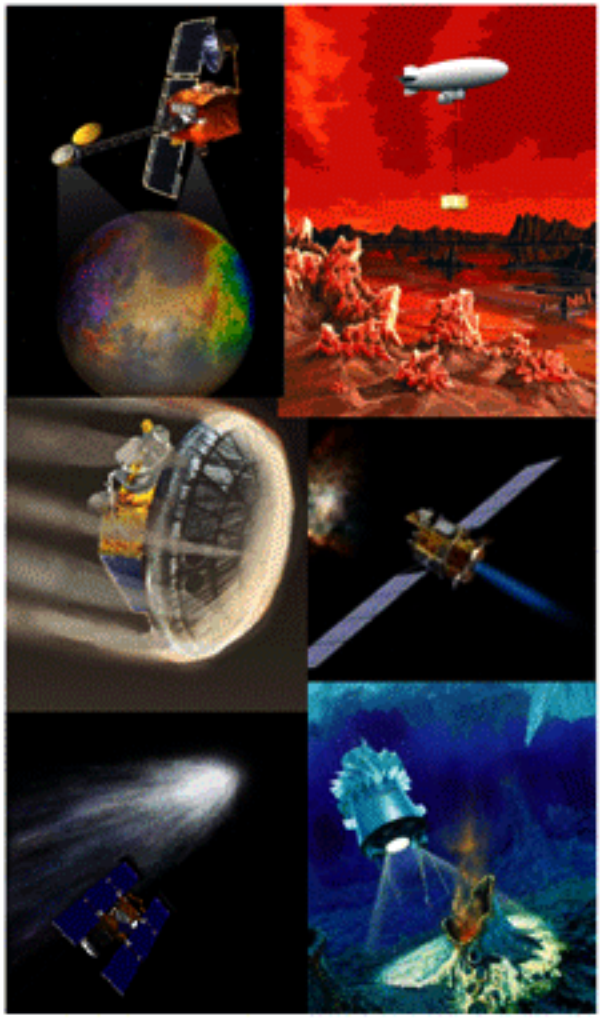


Giant Planets



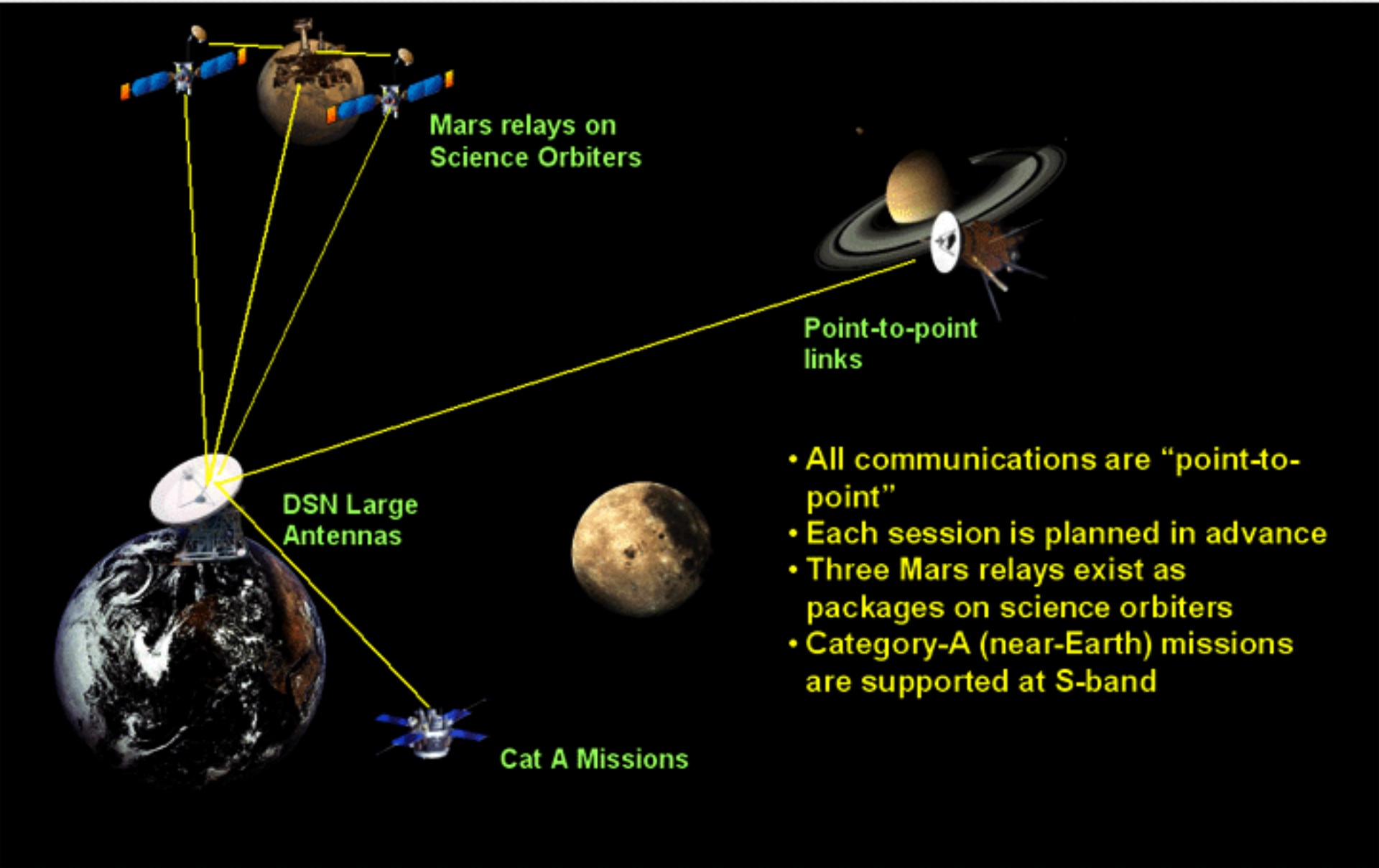
The Moon

Challenges for Deep Space Missions



- **Extreme Distance**
  - Comm performance scales as 1/Distance^2
  - Signals from Neptune are *~10 billion* times weaker than from Geostationary Earth Orbit
  - GEO to the Moon only *~100* times
- **Long Round Trip Light Times**
  - Critical events require autonomy
  - Rapid response to environments
- **Wide Range of Environments**
  - Challenging thermal, radiation, shock requirements
  - Fault-tolerant hardware and software
- **Unique Navigation Scenarios**
  - Small body ops, gravity assist trajectories, aerocapture/aerobraking, SEP, libration point missions, etc.
- **High Launch/Delivery Cost per Unit Payload Mass**
  - Drives need for low mass, low power flight systems

Today's Comm & Nav Architecture



- All communications are "point-to-point"
- Each session is planned in advance
- Three Mars relays exist as packages on science orbiters
- Category-A (near-Earth) missions are supported at S-band

The NASA Mission

To understand and protect our home planet

To explore the Universe and search for life

To inspire the next generation of explorers

.... as only NASA can

JPL's Mission Flows from the NASA Mission

We enable the nation to explore space for the benefit of humanity.

Our Mission is :

1. *To explore our own and neighboring planetary systems*
2. *To search for life outside the Earth's confine*
3. *To further our understanding of the origins and evolution of the Universe and the laws that govern it*
4. *To make critical measurements to understand our home planet and help protect its environment*
5. ***To enable a virtual presence throughout the solar system by creating the Interplanetary Network***
6. *To apply JPL's unique skills to address problems of national significance and security*
7. *To inspire the next generation of explorers*

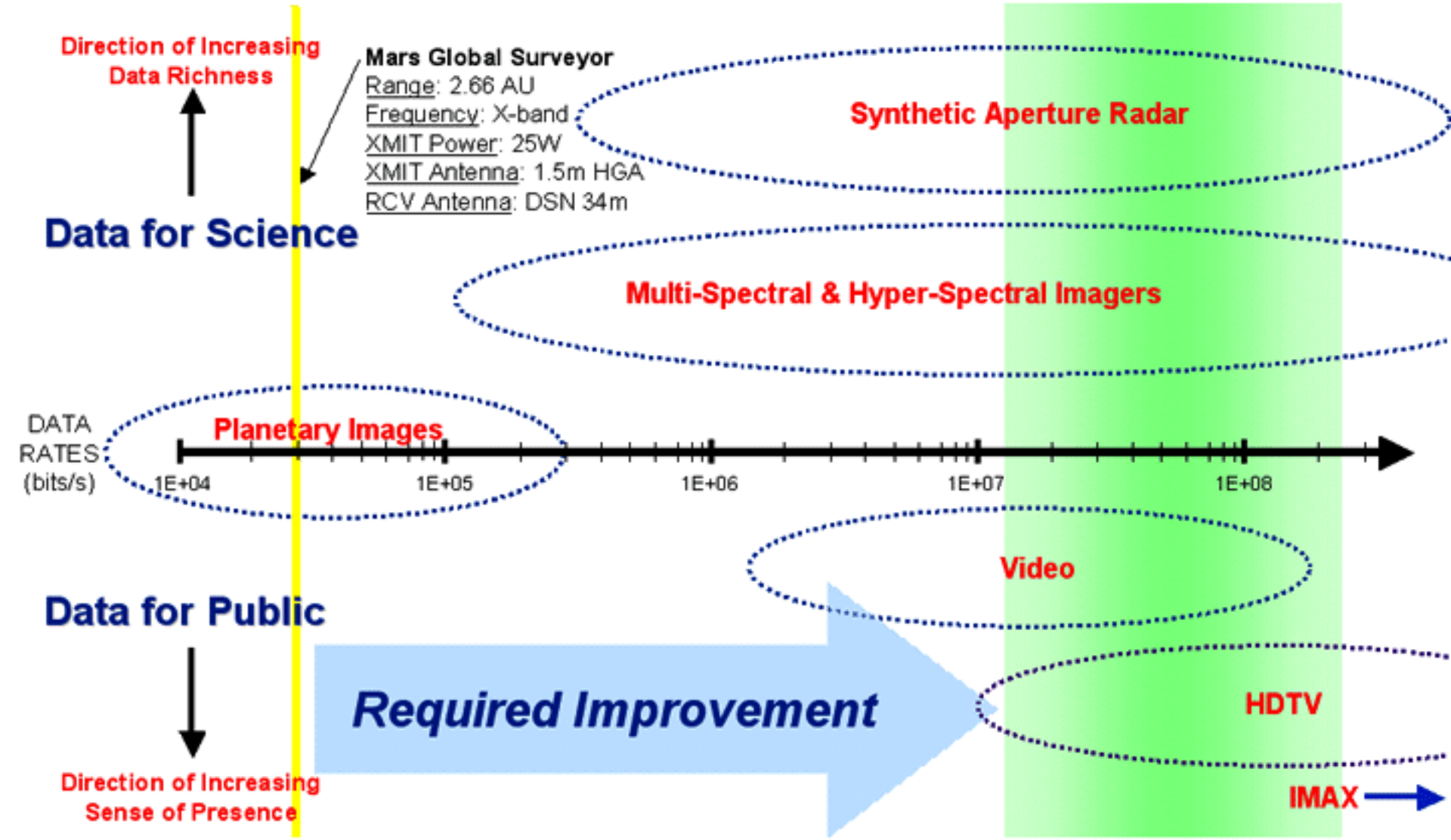
The Interplanetary Network

Mission Statement

Enable telescience and telepresence throughout the Solar System and beyond….

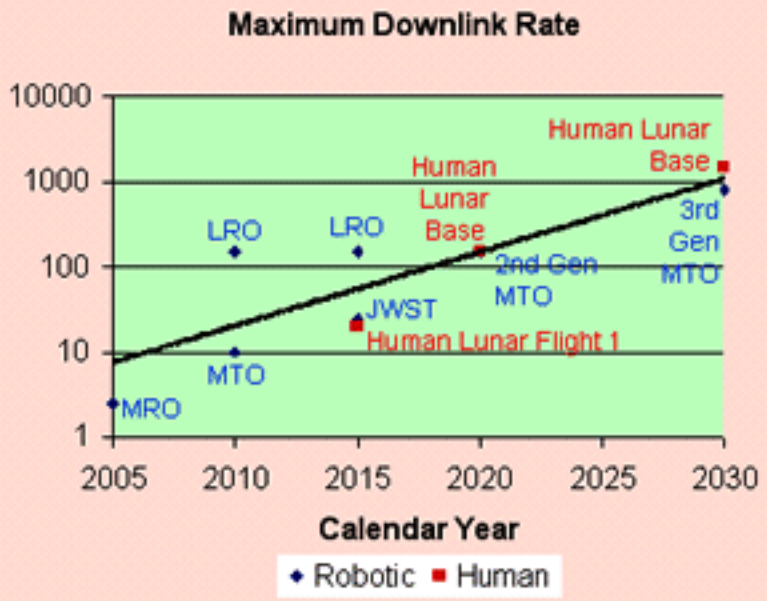
"Bringing the sensors to the scientists, and the planets to the public."

Remote Sensing at Planets as We do at Earth



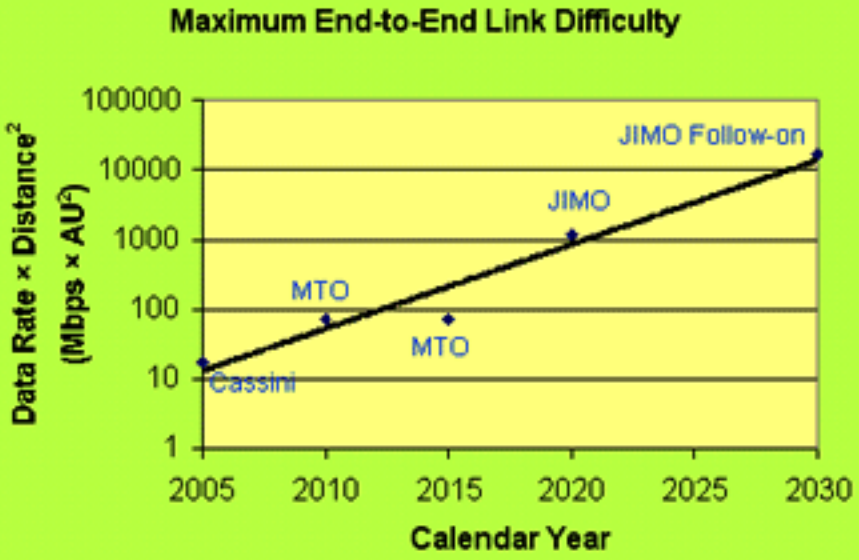
Deep Space Downlink Requirements

Data Throughput



- Mars robotic and lunar human missions drive maximum data rates up by almost 3 orders of magnitude over next 25 years – probably an underestimate.

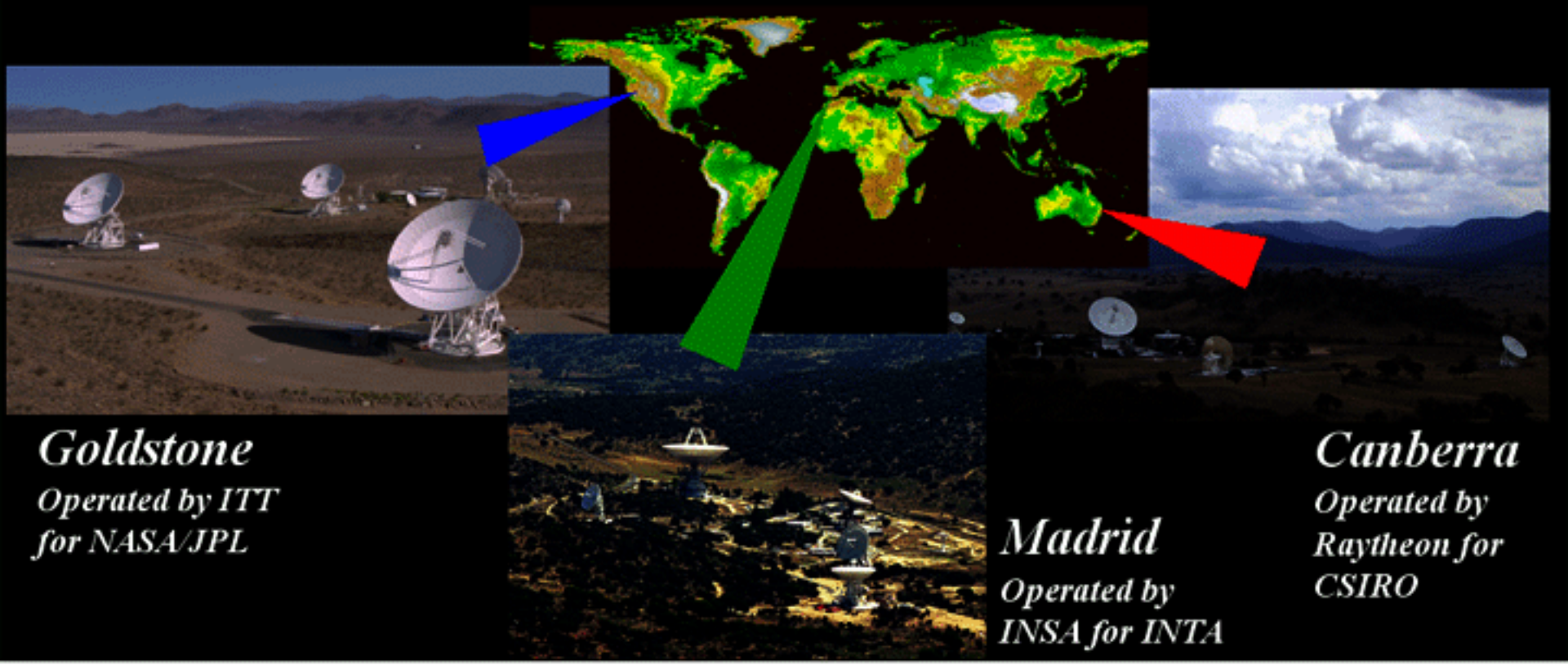
Link Difficulty



- Robotic missions to Jupiter and Saturn drive up difficulty of attempted link by a over 3 orders of magnitude over next 25 years – probably an underestimate.

The Deep Space Network

- Three major tracking sites around the globe provide continuous communications and navigation support for the world's deep space missions

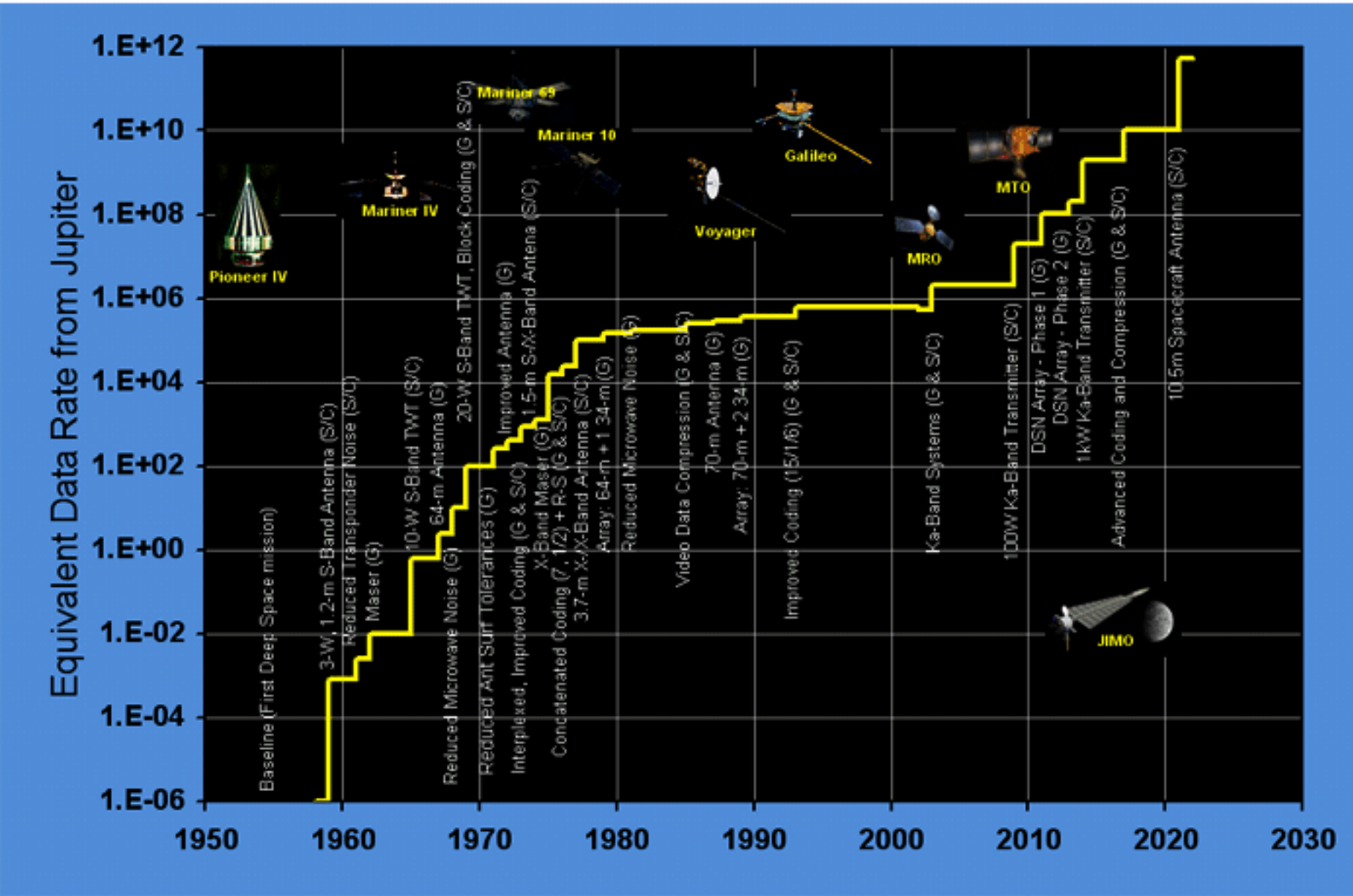


Goldstone
Operated by ITT for NASA/JPL

Madrid
Operated by INSA for INTA

Canberra
Operated by Raytheon for CSIRO

Projection of Telemetry Performance



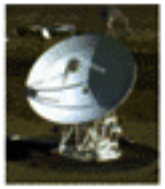
Results of Old Age!

NRAO's 30-year old 90m Antenna in its Ultimately Relaxed State

DSN Dilemma

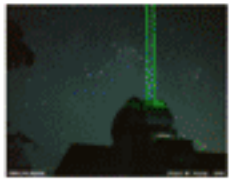
- **Challenges**
  - **Aging infrastructure currently supporting 3 dozen missions**
  - **Need for 3 orders of magnitude increase in capabilities**
  - **Current infrastructure is not extensible**
  - **Need to start new paradigm, while supporting the old!**

Solutions Exist….

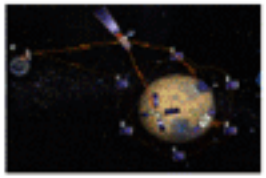




Upgrade the current DSN to Ka-band; advance RF flight components

Prototype large arrays of small antennas

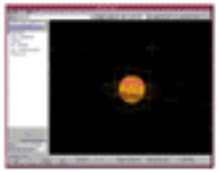
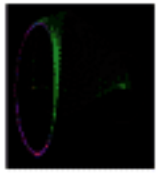
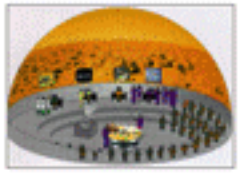



Demonstrate deep space optical communications

Expand Mars network; evolve IPN


Develop network and multi-mission operations systems, tools, and standards

Advance mission design, navigation, and science/public user tools

The DSN Array

Data Return: Meets data rate requirements of most future missions and is easily scalable

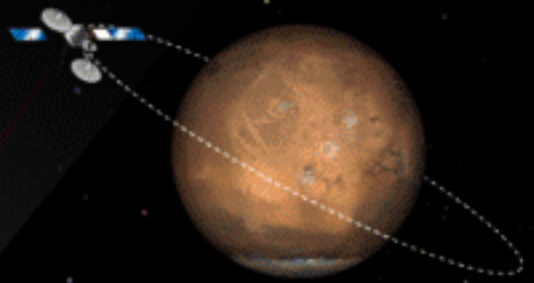
Reliable: Provides graceful degradation in performance in case of antenna or receiver failures

Cost Effective: Best path to needed future capability

6-meter Test Antenna

Optical Communications

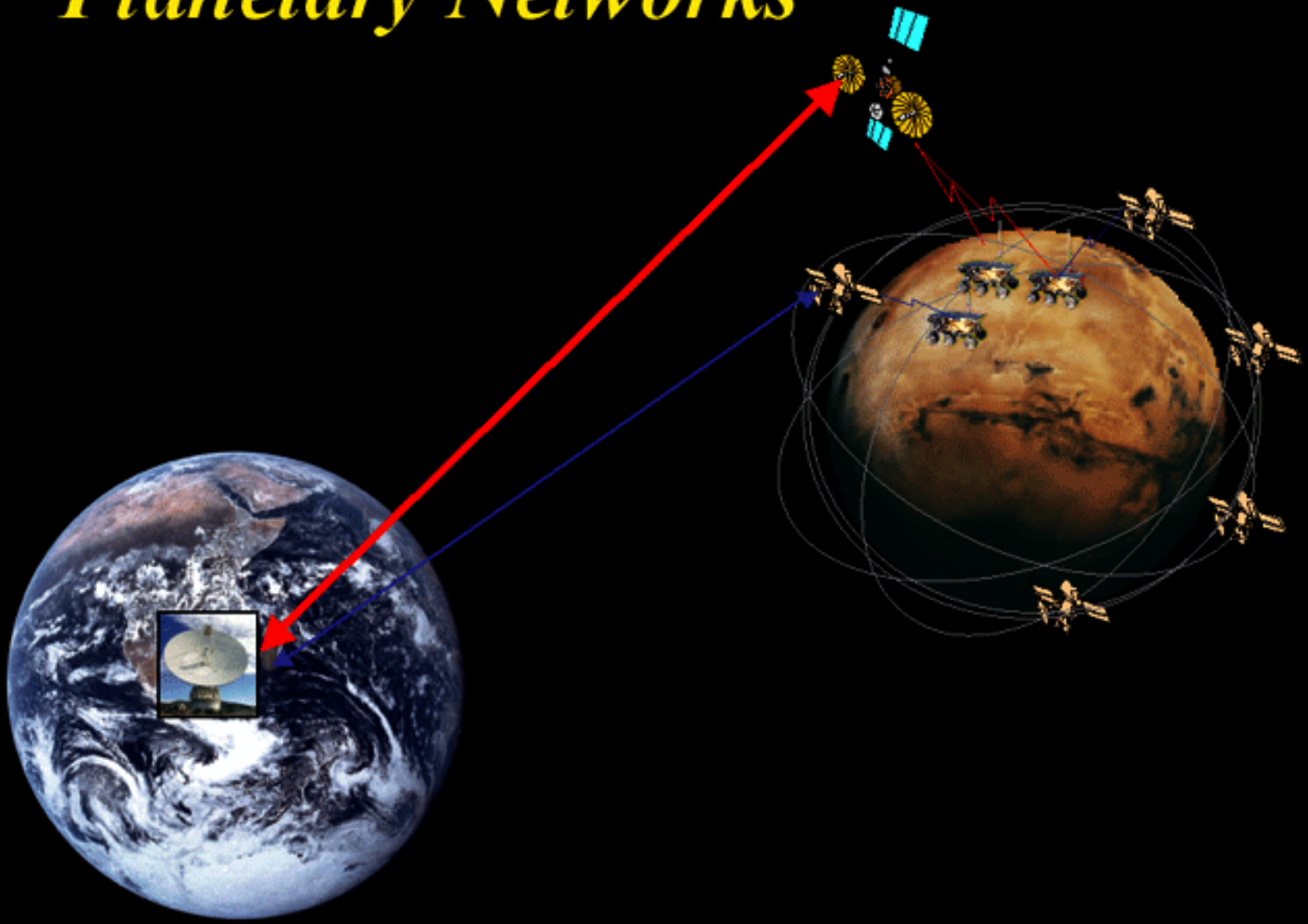
- Optical communications promises further performance improvements over RF
- It is at the beginning of its technology growth curve
- We can leverage the substantial DoD investment

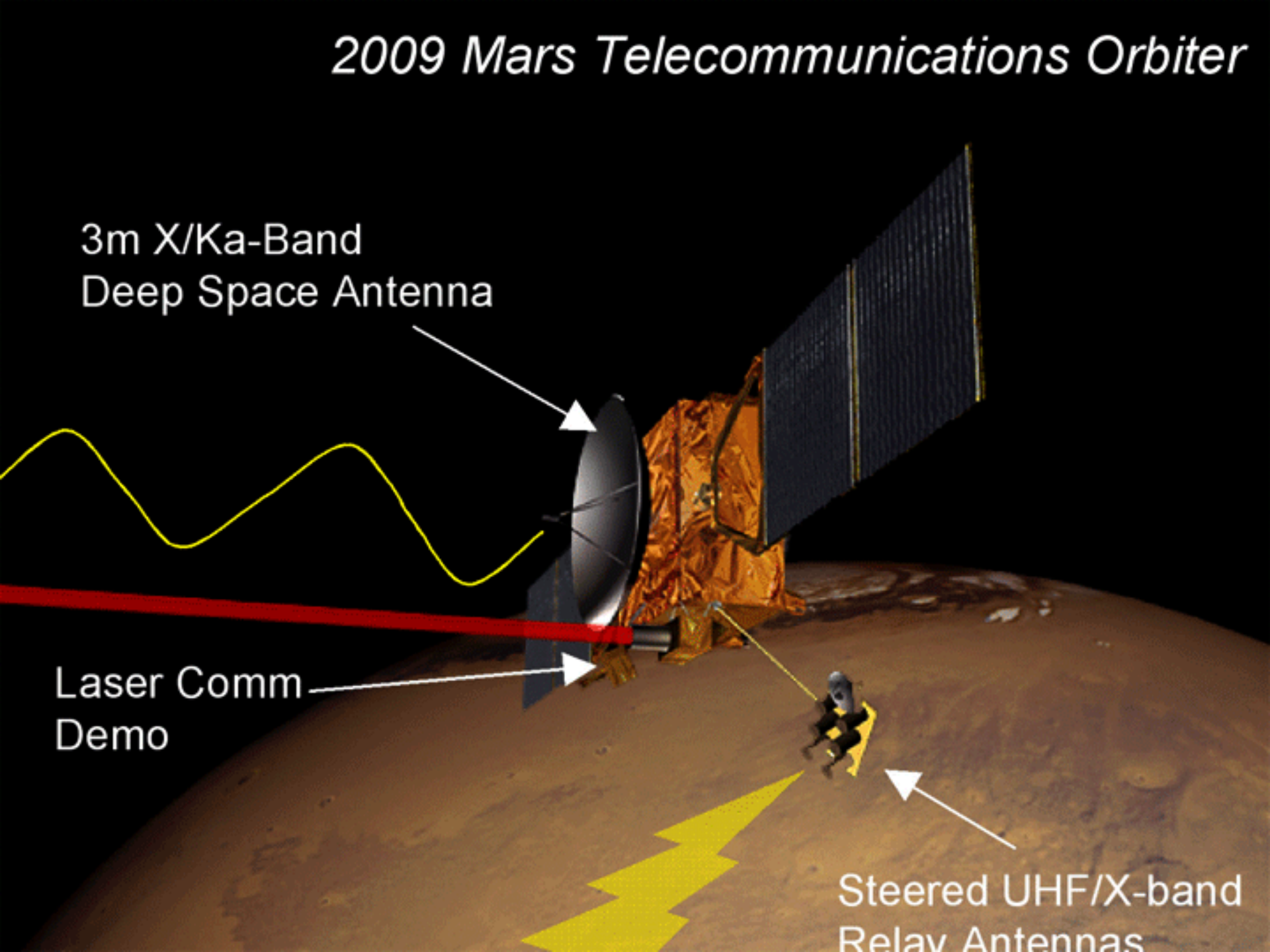


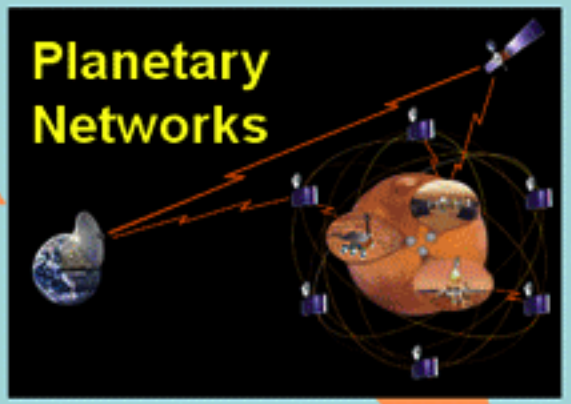
Mars Laser Comm Demo (MLCD)

- Flight demonstration terminal on Mars Telecom Orbiter (MTO)
- Launch 2009
- 5-m ground receiver (Palomar Telescope)
- OCTL 1-m Telescope for uplink
- 1-10 Mbps from Mars

Planetary Networks



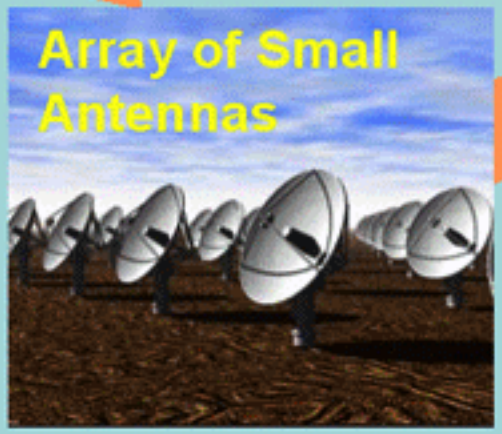

2009 Mars Telecommunications Orbiter
3m X/Ka-Band
Deep Space Antenna
Laser Comm
Demo
Steered UHF/X-band
Relay Antennas



High performance exploration

Increased accessibility

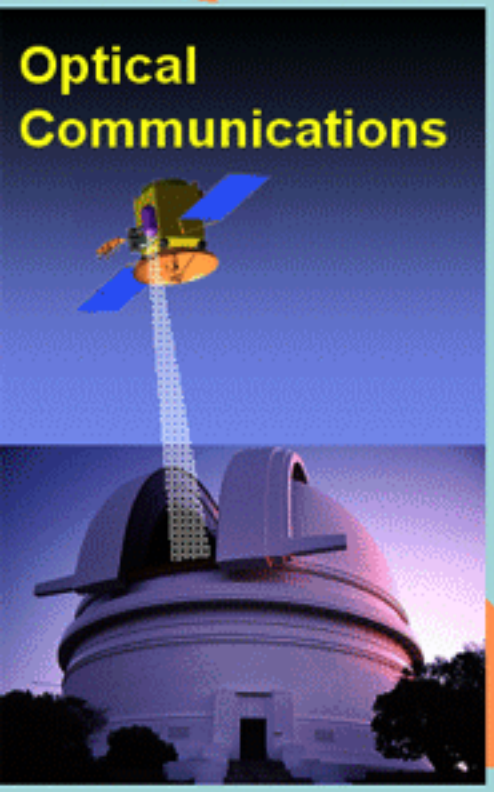
Improved nav and position locations



Modular and expandable

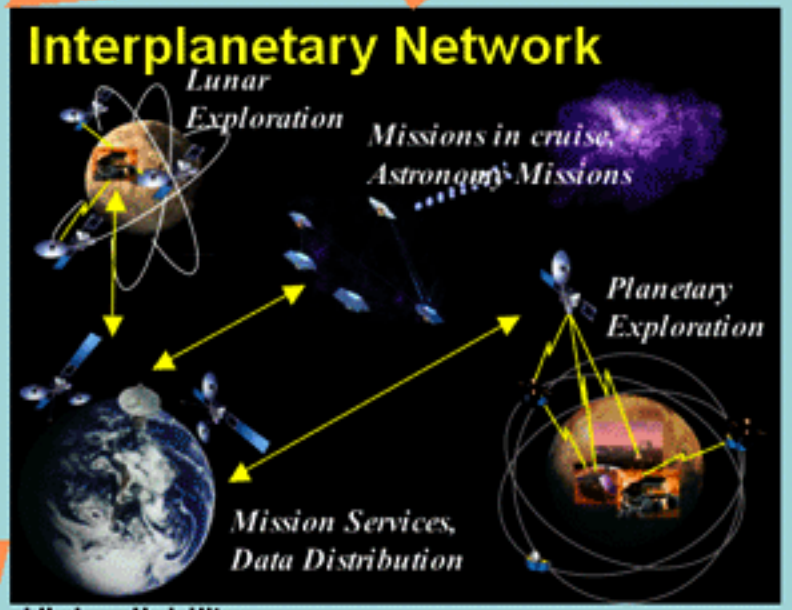
Low cost manufacturing and operations

x100 performance



High bandwidth communications

Low mass spacecraft components



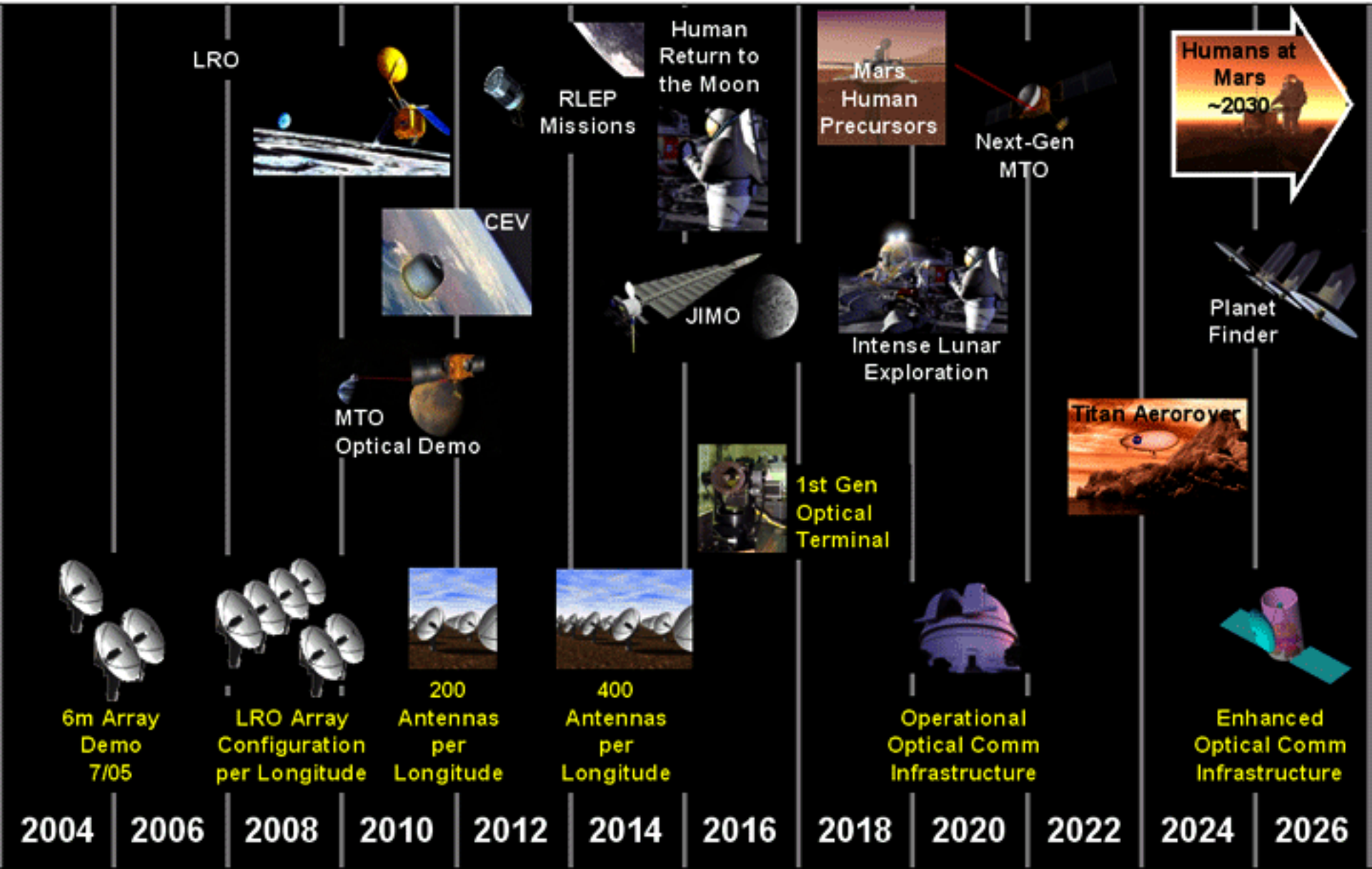
High reliability

High Performance: ≥ x1000 by 2015

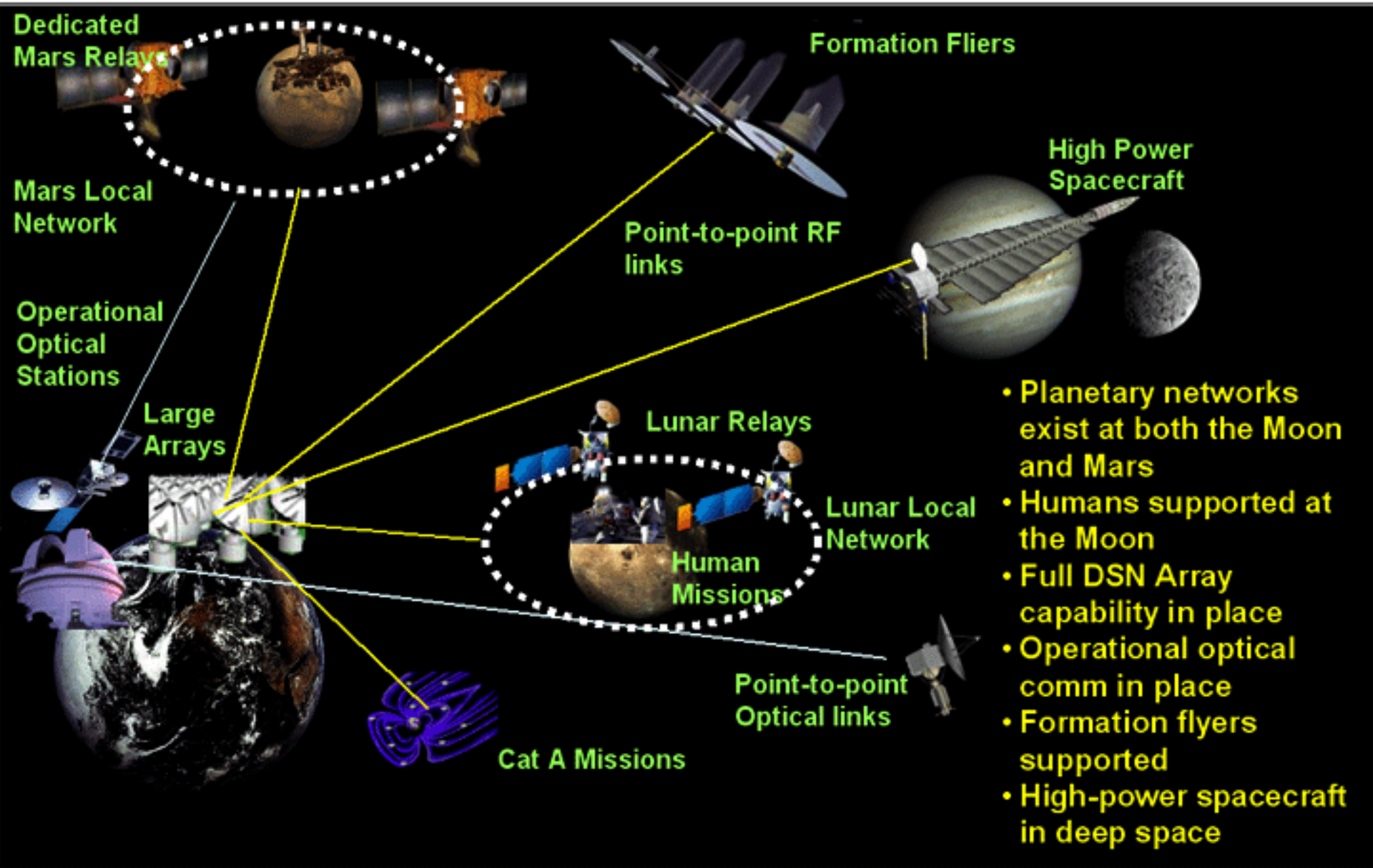
Cost effective

Ubiquitous and seamless connectivity

DSMS Roadmap Overview



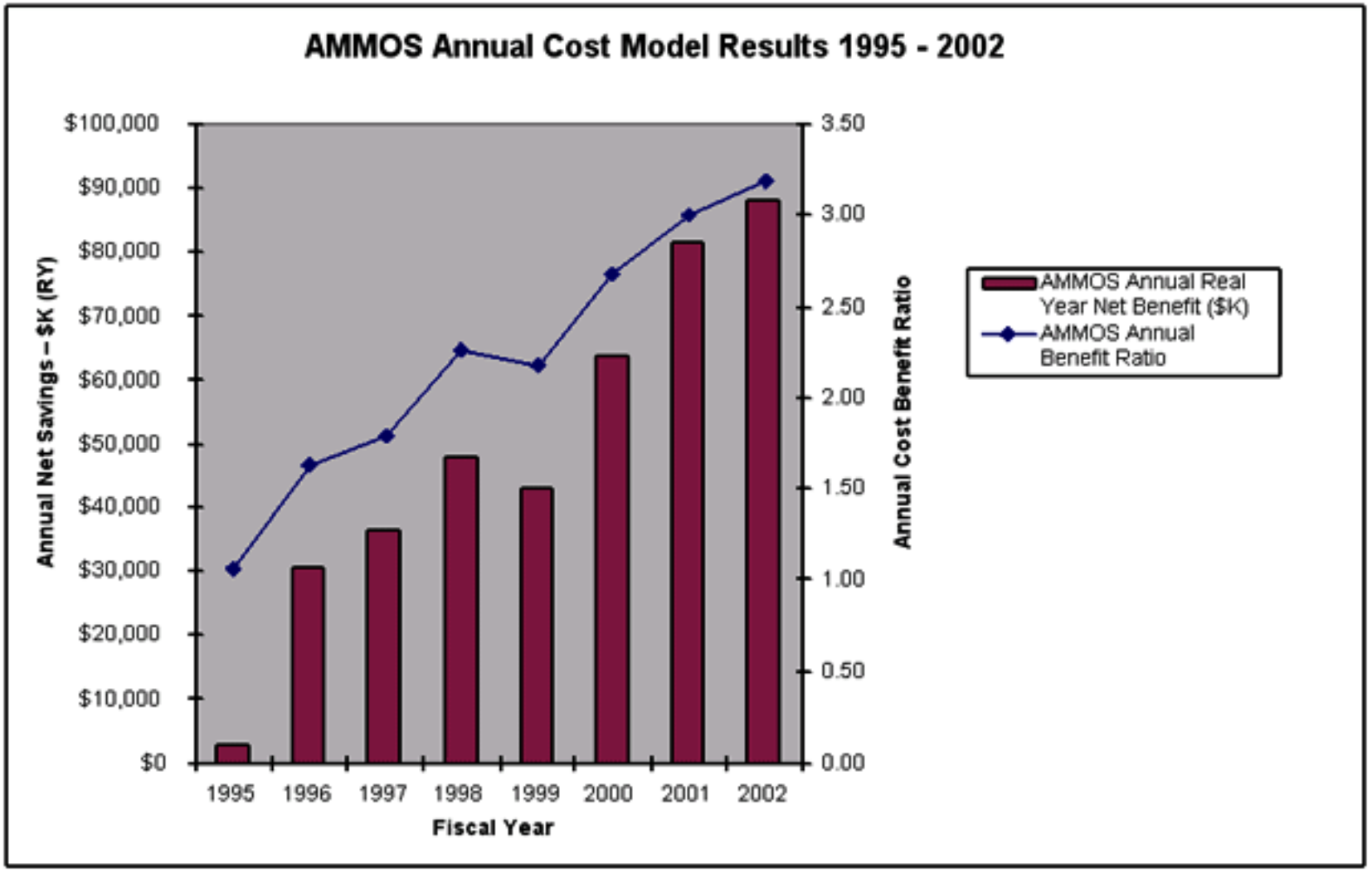
Interplanetary Network Architecture: 2020



- Planetary networks exist at both the Moon and Mars
- Humans supported at the Moon
- Full DSN Array capability in place
- Operational optical comm in place
- Formation flyers supported
- High-power spacecraft in deep space


Network and Mission
Operations Services

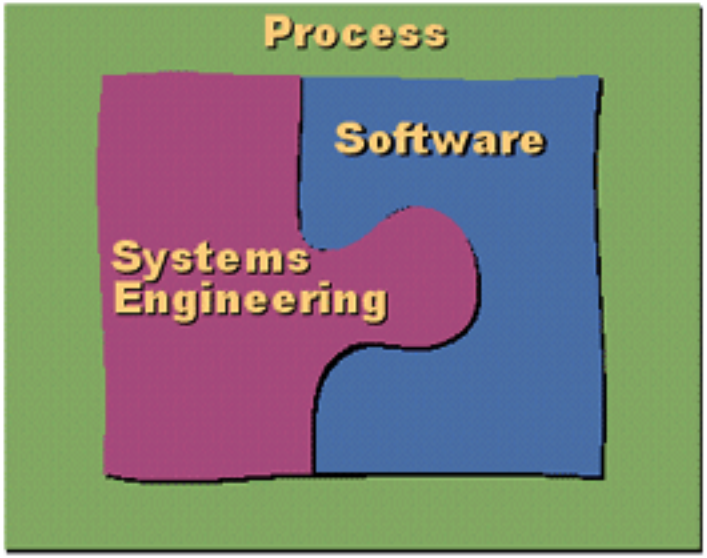
Return on Investment



* Does not account for capitalization or cost savings prior to 1995

Mission Data System

A Unified Flight, Ground, &Test Data System Architecture for Space Missions



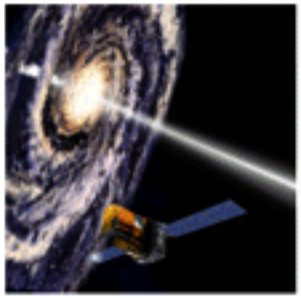
MDS Products

- ☑ Unified flight, ground and test architecture
- ☑ Orderly systems engineering methodology
- ☑ Frameworks
- ☑ Processes, tools, and documentation
- ☑ Reusable software

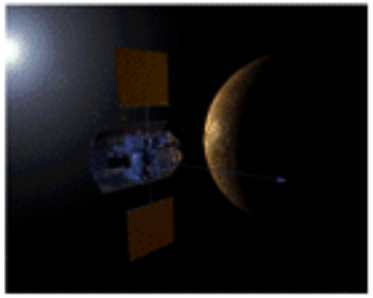
MDS provides a cradle-to-grave, end-to-end system solution

Standards

Space Link Extension



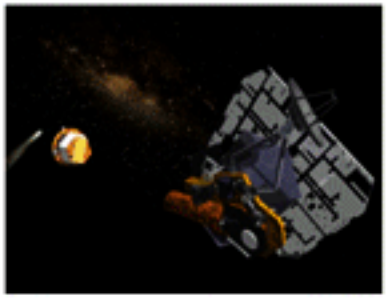
Turbo Codes



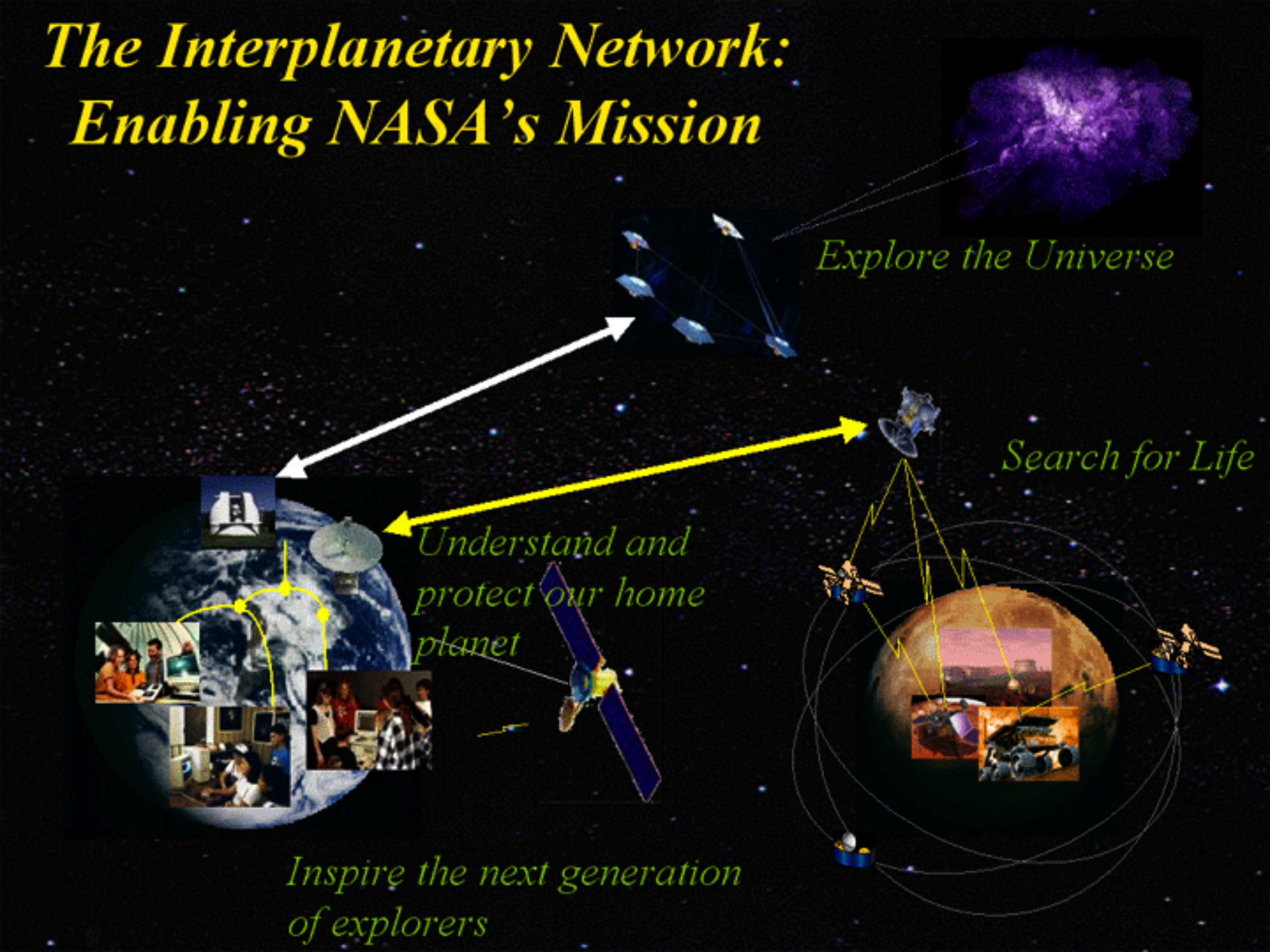
- Reduce costs
- Enable interoperability and cross-support services
- Increase reliability and reduce risks

Proximity Links at Mars

CCSDS File Delivery Protocol



The Interplanetary Network: Enabling NASA's Mission



Explore the Universe

Search for Life

Understand and protect our home planet

Inspire the next generation of explorers