Interplanetary Network Directorate

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Director
The Interplanetary Network: Enabling NASA’s Exploration

Lunar Exploration

Astronomy Missions

Planetary Exploration

Radio Links

Optical Links

Mission Services, Data Distribution
Attributes of the Interplanetary Network

- Reliable
- High Performance
  - Minimum of 1000x performance gain by 2030
- Cost-Effective
  - Standard, inexpensive interfaces
- Architecture for growth
  - Communication and navigation assets operating seamlessly across the solar system
  - Planetary local area networks with relay assets at places of intense exploration
  - Intelligent network management
Low-Earth-orbit solar and astrophysical observatories.

Single, large spacecraft for solar and astrophysical observations.

Preliminary solar system reconnaissance via brief flybys.

In situ exploration via short-lived probes.

Observatories located farther from Earth.
(e.g., SIRTF, JWST)

Constellations of small, low-cost spacecraft.
(e.g., MMS, MagCon)

Detailed Orbital Remote Sensing.
(e.g., MRO, JIMO)

In situ exploration via long-lived mobile elements.
(e.g., MER, MSL)
Today’s DSN

Global coverage of Deep Space
Current state of the art

Goldstone
Madrid
Canberra

Large Array of Small Antennas

Modular and expandable
Low cost manufacturing and operations
x100 performance

High bandwidth communications
Low mass spacecraft components
Beginning of technology growth curve

Optical Communications

High reliability
High Performance: ≥x1000 by 2030
Cost effective
Planetary networks & seamless connectivity

Interplanetary Network

Lunar Exploration
Missions in cruise, Astronomy Missions
Planetary Exploration
Mission Services, Data Distribution

Bringing the sensors to the scientists and the universe to the public.
Responding to the Future Challenges

- Pioneer deep space optical communications
- Build large arrays of small antennas
- Advance flight hardware capabilities
- Evolve local networks around Mars and possibly at the Moon
- Develop network and multi-mission ops systems and tools
- Advance mission design, navigation, and science/public user tools
Spacecraft Antennas

- Large (>10 m) deployable spacecraft antennas
  - Initial technology developments and lab demonstrations underway
  - Demonstration in space in the 2008 time frame

- Critical system and component needs
  - High efficiency reflectarray panels for X/Ka-band signals
  - Reliable and controllable deployment systems
  - Self-rigidization after deployment
Optical Communications: A New Element of the DSN

Deep space optical communications will enter a new age with the 10+ Mbps demo on MTO in 2009
Technology development has been underway for 20 years and continues. Flight demonstration planned for 2009. Critical system and component needs:

- Low-cost, large aperture (e.g. 10m) ground telescopes and enclosures
- Low-cost, high performance flight terminals
- Efficient (>30%) single photon detectors
- Strategies/systems to mitigate effects of atmospheric turbulence and daytime skylight
- High-power (kW-level) optical uplink transmitters
Mars LaserCom Demonstration

**MLCD Important Features**
Demonstrate optical communications from Mars.
Flight Terminal will be a payload on the Mars Telecom Orbiter
Launch Date: October 2009
Demonstration Lifetime: 2 years, Extended lifetime TBD yrs

**Demonstration Requirements**
Downlink rate of at least 10 Mbps (goal of 30 Mbps); minimum of 1 Mbps down to 3 degrees from the sun.
Uplink of at least 10 bps to Mars.
Measure, characterize, and model the system performance
Demonstrate weather mitigation techniques and handover strategies

**Programmatics**
Goddard Space Flight Center: project lead responsibility (PM), systems engineering, delivery of flight terminal and co-investigator
JPL: deputy PM, operational ground terminals, mission operations, principal investigator, data analysis, provide deputy project manager
Lincoln Laboratory: flight terminal, systems engineering, co-investigator
MLCD System Block Diagram

MTO/MLT

Optical downlink

Optical beacon / uplink

Array at TBD

Link Development And Evaluation System, LDES

DSN

OCTL at Table Mountain

Hale Telescope at Mt Palomar

MTO Operations Center at JPL

CMD/TLM

Demo Coordination Center (DCC) at JPL

CMD/TLM

MLCD Mission Analysis Center (MMAC) at MIT/LL

CMD/TLM/Monitor
Detectors

- Links are "photon starved", thus need photon counting approach
- Avalanche Photodiode (APD) is detector of choice
  - Important parameters are detection efficiency and bandwidth
- Also considering Hybrid Photomultiplier Tube
- Detector must match flight transmitter wavelength
  - Presently 1064 nm
- Must meet PPM link operational requirements
  - 1 ns minimum slot width
  - Must operate in presence of high optical background
Arrays of Smaller Antennas: Another New Element in the DSN

We will increase the RF capability of the DSN by at least a factor of 100 in the next 25 years.
Arrays of Smaller Antennas

- Expected to be more cost-effective than large monolithic antennas
  - Studies and technology developments underway
  - Large-scale prototype possible start in 2008
  - Deployment of network sites could follow quickly

- Critical system and component needs
  - Low-cost, easily-produced antenna surfaces
  - Low-cost, precision steerable antenna mounts
  - Low cost, low-noise amplifiers and cryocoolers
  - Array signal combination and calibration techniques
50% Scale Antenna

First 6m antenna set at 45° elevation for RMS measurement
Industry Opportunities

- Arrays will require large scale production (by JPL standards)
  - 1200 12-m antennas with associated front-end electronics
  - Must be manufactured in a cost-effective manner
  - Will dominate the development cost

- Prototyping is underway
  - Industry contracts for full-scale and partial scale antennas and components
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.
A Decade of Mars Exploration

- **2001**: MARS ODDYSEY
- **2003**: MARS EXPRESS (ESA)
- **2005**: BARS RECONNAISSANCE ORBITER
- **2007**: MARS TELESAT ORBITER
- **2009**: MARS SCIENCE LABORATORY

**BEAGLE 2 LANDER**
**MARS EXPLORATION ROVERS**
**PHOENIX**
Interplanetary Network

Three Layers to the Stack

The applications that create information

IPN Applications

The middleware that processes data and routes and shares information

IPN Middleware

The communications that move data

IPN Communications
Virtual sense of presence techniques could include:

- Immersive Visualization
- 3-D Acoustic Imaging
- Force and Touch
- Odor Reproduction
EO-1 Autonomous Sciencecraft Experiment

Image taken by Spacecraft (Hyperion) & appropriate bands extracted

Cloud Detection

Clouds Sparse → Downlink Image

Extensive Cloud Cover

No feature Detected

Feature Detected → Downlink Image

Retarget for New Observation Goals

New Science Images

Onboard Replanning
System engineering methodology
- Structured, disciplined process
- Model-based design for estimation and control

Architectural patterns
- State architecture
- Component architecture

Frameworks and adapter’s guides
- Reusable building blocks in object-oriented design
- Guides for how to adapt it for concrete tasks
- Examples of framework usage
Computing, Modeling, Simulation and Visualization to develop *modeling frameworks* and seed new high-end *applications*

- Common Earth Science models
- Common engineering subsystem models
- Computationally intensive parallel and distributed processing for science, engineering and outreach applications

Populate computing environment with an engineer *tool suite*

- Tools for modeling, analysis, simulation, and visualization
- Interactive and scalable high-capability computing

Upgrade high-capability *computing* capability

- Modernize existing institutional supercomputing
- Add Teraflops-class Beowulf clusters
- Add JPL Grid to sweep up unused cycles
- Purchase cycles from external supercomputing facilities
## Information Technology

### Industry Opportunities

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### Partnership Example: CMU and Sun Microsystems

![JavaOne](image)