The Interplanetary Network View
Exciting and Ambitious!

We Have a Challenge …
Remote Sensing at Other Planets as at Earth

DATA RATES (bits/s)

1E+04 1E+05 1E+06 1E+07 1E+08

Data for Science

Direction of Increasing Data Richness

Cassini (max)

MRO (max)

Synthetic Aperture Radar, Hyper-Spectral Imagers, High-Resolution Mass Spectrometry, …

Required Improvement

✔ ✔

OPAG Technology Forum
History of Downlink Difficulty

History to date: Performance has improved by $10^{13}$ so far
Ice Giant Mission Concepts

Cassini with Huygens Probe

Neptune Orbiter with Probe, SEP, and 50 kg payload

Uranus Orbiter with Probe and 50 kg payload
Why Do I Care?
Ice Giant Mission Concepts

• More capable instruments
  Higher spectral resolution spectrometers, higher spectral resolution mass spectrometers, higher angular resolution imager
  30 km spatial resolution on a moon vs. 100 km spatial resolution

• More capable missions
  Stereo vision on a moon via multiple looks
Decade 0.5+: 10× Improvement over Today

- Remove bottlenecks on spacecraft and DSN
  - Universal Space Transponder (UST)
  - Common Platform DSN signal processor

- Increase use of Ka band (32 GHz) over X band (8 GHz)
  - Factor ~ 4× improvement
    cf. Cassini, Juno Radio Science
Decade 0.5+: 10× Improvement over Today

- Antenna arraying
  - DSN Aperture Enhancement Project emplacing additional 34m antennas
  - Provides backup for 70 m as well as arraying beyond 70 m
Deep Space Network
DSN Aperture Enhancement Project (through 2025)

+ backend
digital signal
processing
International Deep Space Network

New Norcia
Cebreros
Malargüe
Canberra
Goldstone
Madrid
Usuda
Uchinoura
Byalalu
Strata at Base of Mt Sharp

Indicates flow of water before the mountain formed
The DSN and the Interplanetary Internet

Extends today’s Internet across the Solar System
Decade 2+: 100× Improvement over Today

Dedicated 12m Stations
NASA + International partnerships

Hybrid RF/Optical Antenna
Potential reuse of existing infrastructure, in development today

Dedicated Comm Relays
Extend the Internet to Mars and enable public engagement

High Performance Optical Terminal
To be demonstrated on Pysche
Laser Communication

- Deep Space Optical Communications (DSOC) to be demonstrated!
DSOC Technologies & Advances

**FLIGHT LASER TRANSCEIVER (FLT)**
- Aluminum Optical Transceiver Assembly
- Photon-Counting Camera
- SIC Flight Laser Transceiver (FLT)
- Point-Ahead Mirror
- Single strut photo
- flight-like electronics
- Laser Transmitter Average Power 4 W

**GROUND TECHNOLOGY**
- Ground Technology
- Silicon Carbide (SiC) Flight Laser Transceiver (FLT)
- Electron microscope detail of 320 µm active area tungsten silicide (WSi) superconducting nanowire single photon detector (SNSPD) array
- Packaged Nanowire Array
- Palomar Observatory/Hale Telescope 5 m
Decade 2+: 100× Improvement over Today

High Performance Optical Terminal To be demonstrated on Pysche

... In the Inner Solar System

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In the Inner Solar System
Decade 2+: 100× Improvement over Today

... In the Outer Solar System

Increased Data Volume

Radio Frequency Communication
- Diameter (6 m?)
- Mass
- Surface accuracy
- Pointing and stability
- ...

Laser Communication
- Diameter (50 cm?)
- Pointing
- Laser power?
- Spacecraft isolation
- ...

SMAP 6 m antenna (NG Astro.)
Radio Science

Apparent even with early missions that occultations by planetary atmospheres would affect radio communications

• Mio dio! Tragedy!

• Or one person’s annoyance is another’s data --- Study atmospheric properties!

  “Occultation Experiment: Results of the First Direct Measurement of Mars's Atmosphere and Ionosphere” (Kliore et al. 1965, Science)

• Can also study planetary interior!

  ➢ Turn the DSN+spacecraft into one giant science instrument
Radio Science in the Outer Solar System
Future Radio Science

“We have identified 12 priority science objectives for ice giant exploration. […] The two most important objectives relate to the formation, structure, and evolution of ice giants (...):

• Constrain the structure and characteristics of the planet’s interior, including layering, locations of convective and stable regions, and internal dynamics.

• Determine the planet’s bulk composition ….

Ice Giants Pre-Decadal Study Final Report

Technologies

• Simultaneous dual frequency links (Cassini, Juno use X- and Ka bands) to difference the Doppler and cancel dispersive noise effects

• Water vapor radiometer to calibrate Earth’s tropospheric noise contribution
Radio Science

Interiors of Moons: Earth’s Moon

GRAIL mission made precise measurements of separation between two spacecraft orbiting the Moon
• Changes in separation due to acceleration of one of the spacecraft

• Changes in acceleration result from changes in mass along spacecraft trajectory
• Could also use small spacecraft to study planetary atmospheres

➢ Role for small spacecraft in outer solar system?
Conclusions

Ambitious science missions realized iff sufficient data returned
Communication technologies improvements possible over next decades
Radio Science making and will continue to make valuable contributions
The DSN as a Science Instrument

http://eyes.nasa.gov/dsn/dsn.html