



# Outer Planet Communication Technologies and Radio Science

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**Jet Propulsion Laboratory**  
California Institute of Technology

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# Exciting and Ambitious!

We Have a Challenge ...



✓ ✓/2 ✓

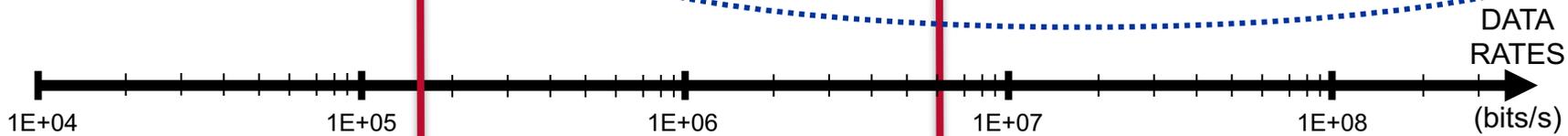
# Flyby, Orbit, Land, Rove, ...

Direction of Increasing  
Data Richness  
→  
**Data for Science**

**Cassini  
(max)**

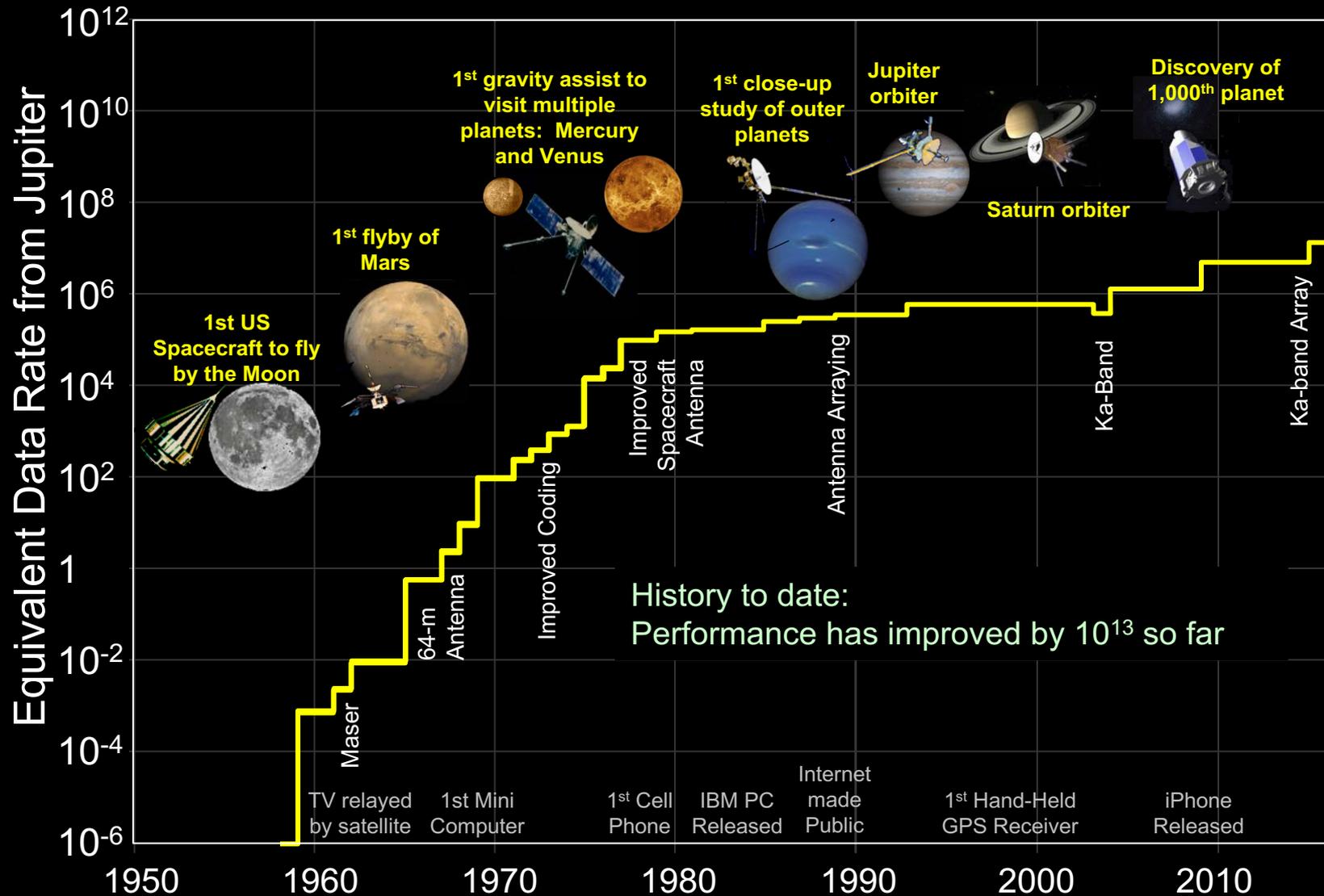
**MRO  
(max)**

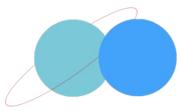
Synthetic Aperture Radar, Hyper-Spectral Imagers,  
High-Resolution Mass Spectrometry, ...



**Required Improvement**

# History of Downlink Difficulty

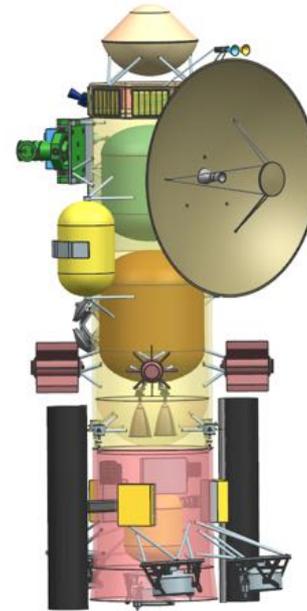




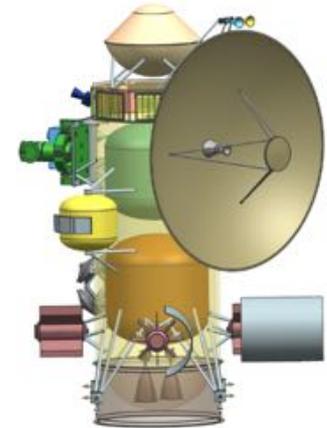
# Ice Giant Mission Concepts



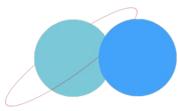
***Cassini* with Huygens Probe**



**Neptune Orbiter  
with Probe, SEP,  
and 50 kg payload**



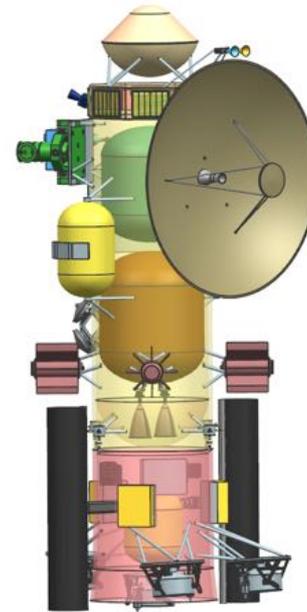
**Uranus Orbiter with  
Probe and 50 kg  
payload**



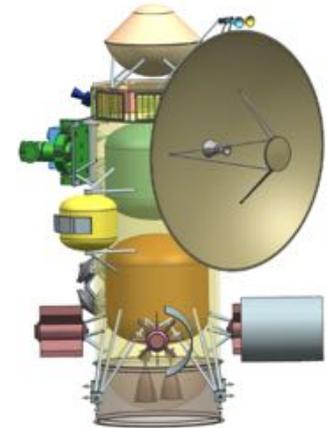
# Why Do I Care?

## 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



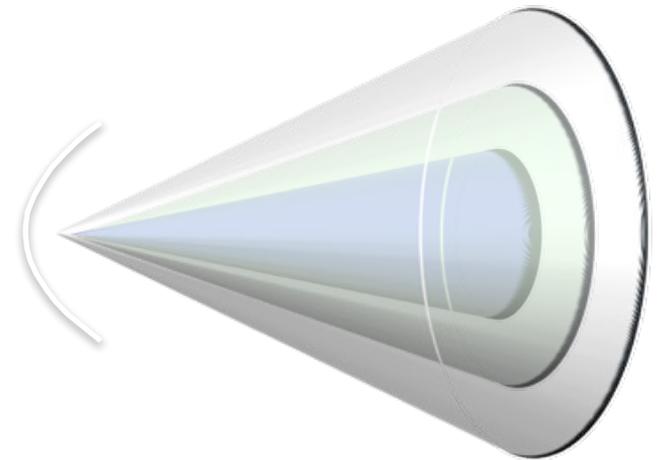
Neptune Orbiter with Probe, SEP, and 50 kg payload



Uranus Orbiter with Probe and 50 kg payload

# 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**



**DSS-56 foundation  
Madrid**

# Deep Space Network

DSN Aperture Enhancement Project (through 2025)



+ backend digital signal processing



Canberra

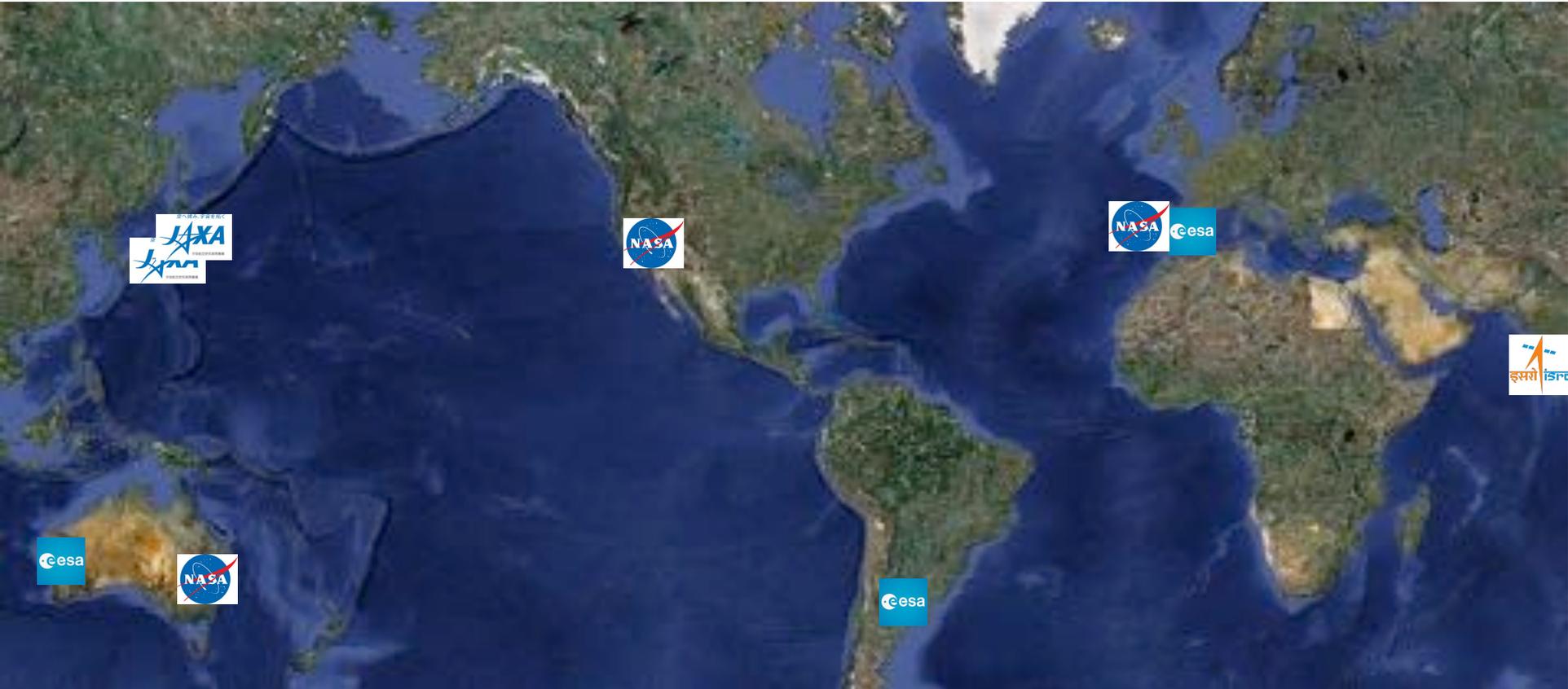


Goldstone



Madrid

# International Deep Space Network



New Norcia  
Cabreros  
Malargüe



Canberra  
Goldstone  
Madrid



Usuda  
Uchinoura



Byalalu



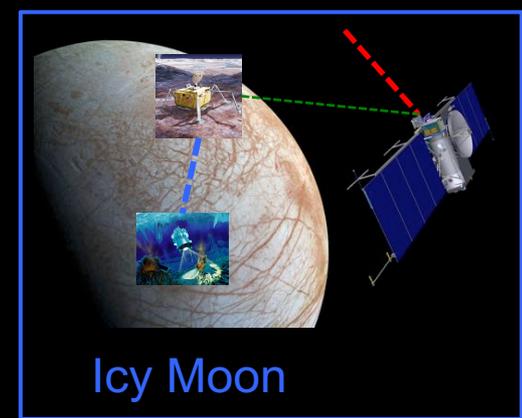
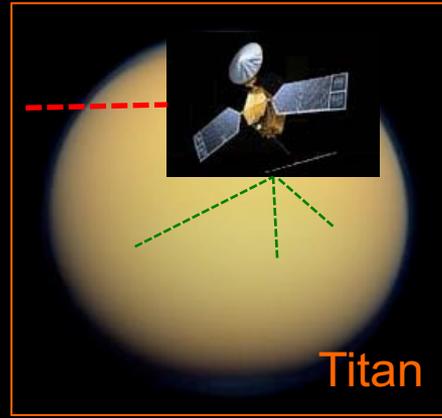
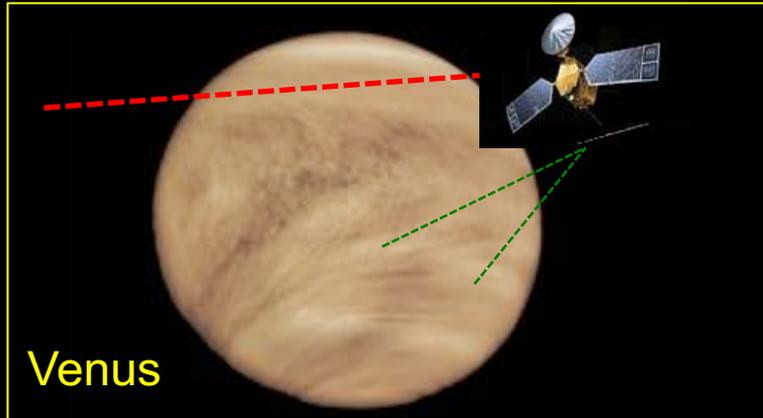
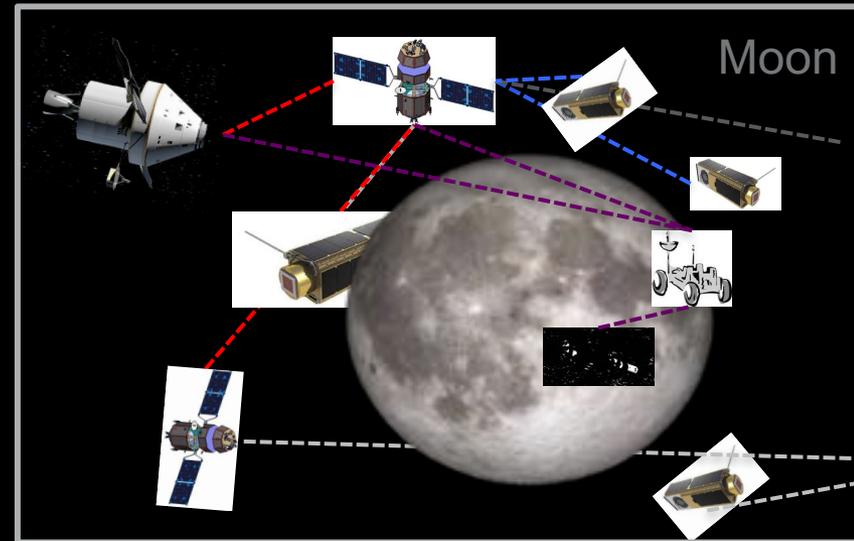
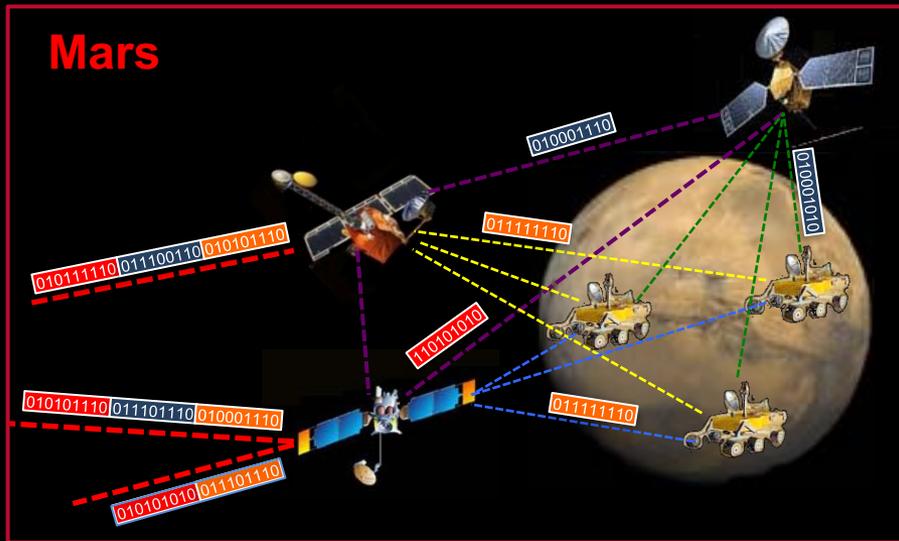
# Strata at Base of Mt Sharp

Indicates flow of water before the mountain formed



# The DSN and the Interplanetary Internet

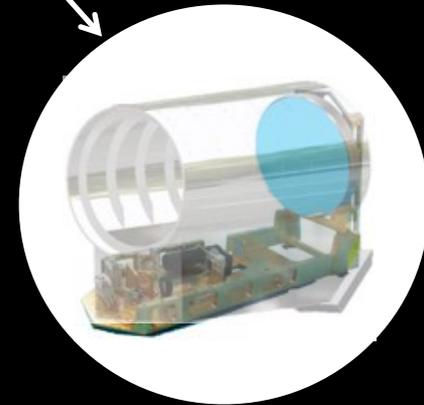
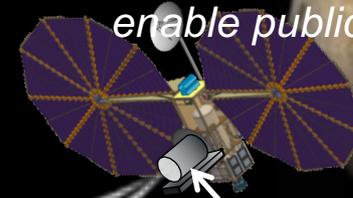
Extends today's Internet across the Solar System



# Decade 2+: 100× Improvement over Today

## ... In the Inner Solar System

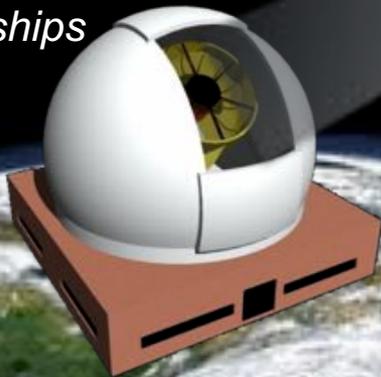
Dedicated Comm Relays  
*Extend the Internet to Mars and enable public engagement*



High Performance  
Optical Terminal  
*To be demonstrated  
on Psyche*

Dedicated 12m  
Stations

*NASA + International  
partnerships*



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

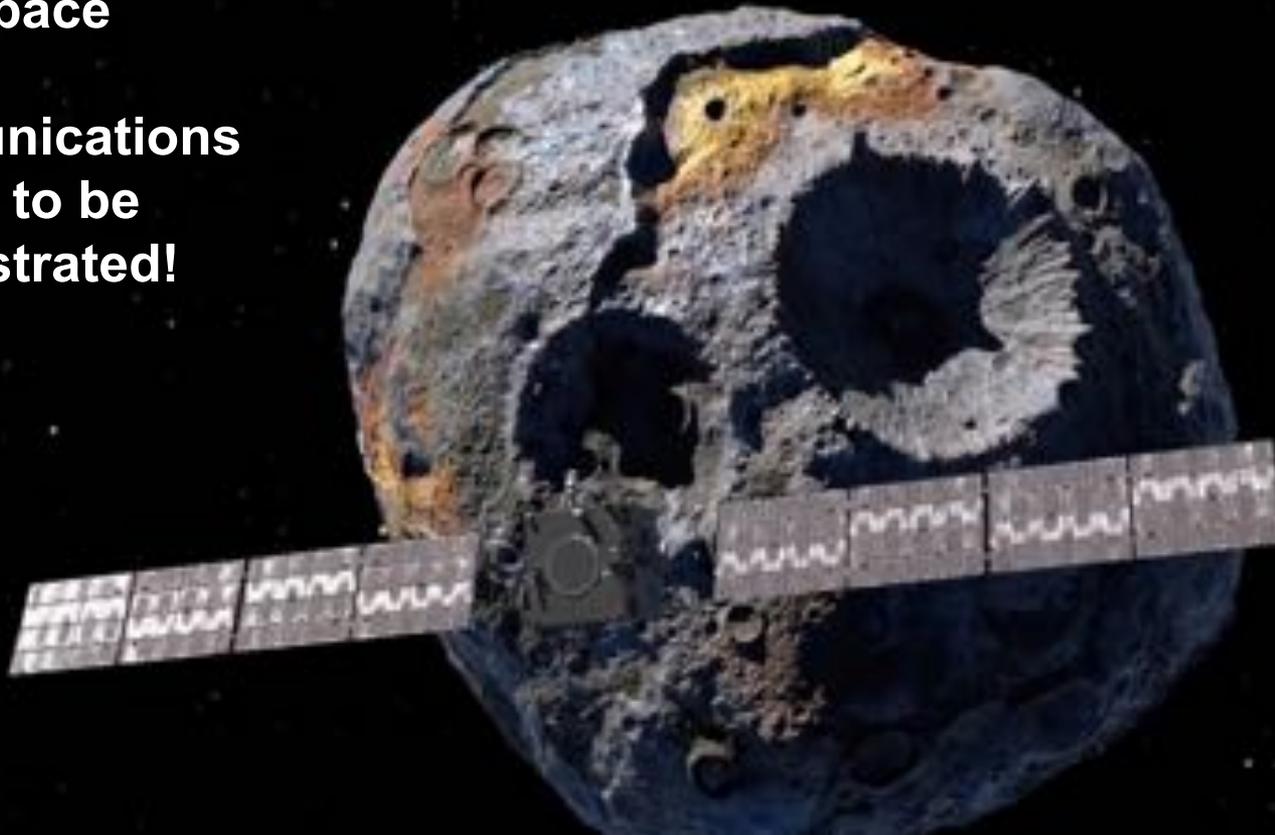


# Laser Communication



Psyche: Journey to a Metal World  
from School of Earth & Space

- **Deep Space Optical Communications (DSOC) to be demonstrated!**

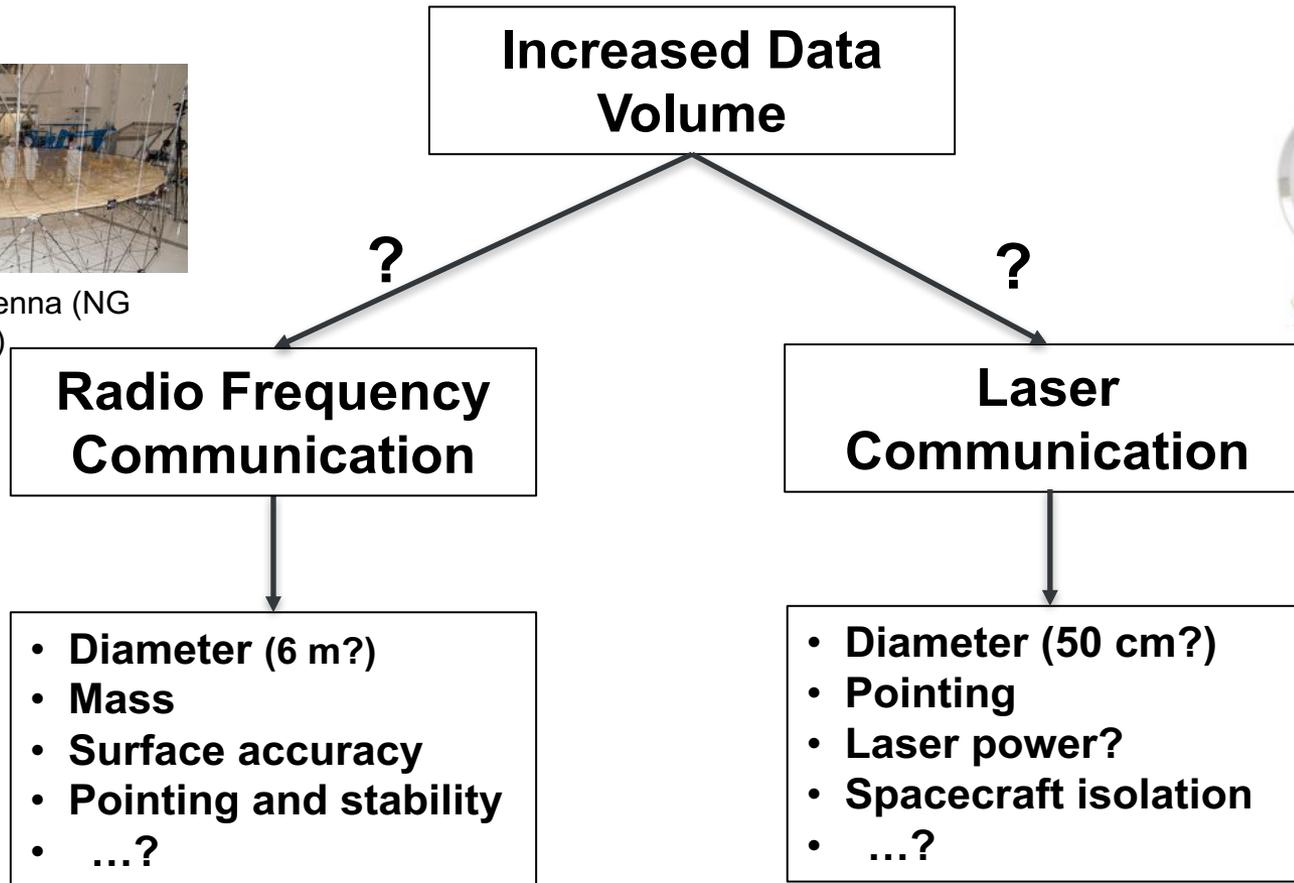
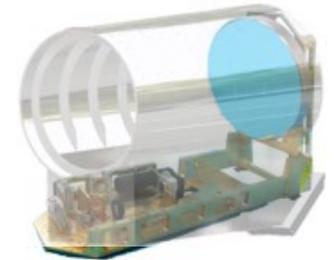


# Decade 2+: 100× Improvement over Today

... In the Outer Solar System



SMAP 6 m antenna (NG Astro.)



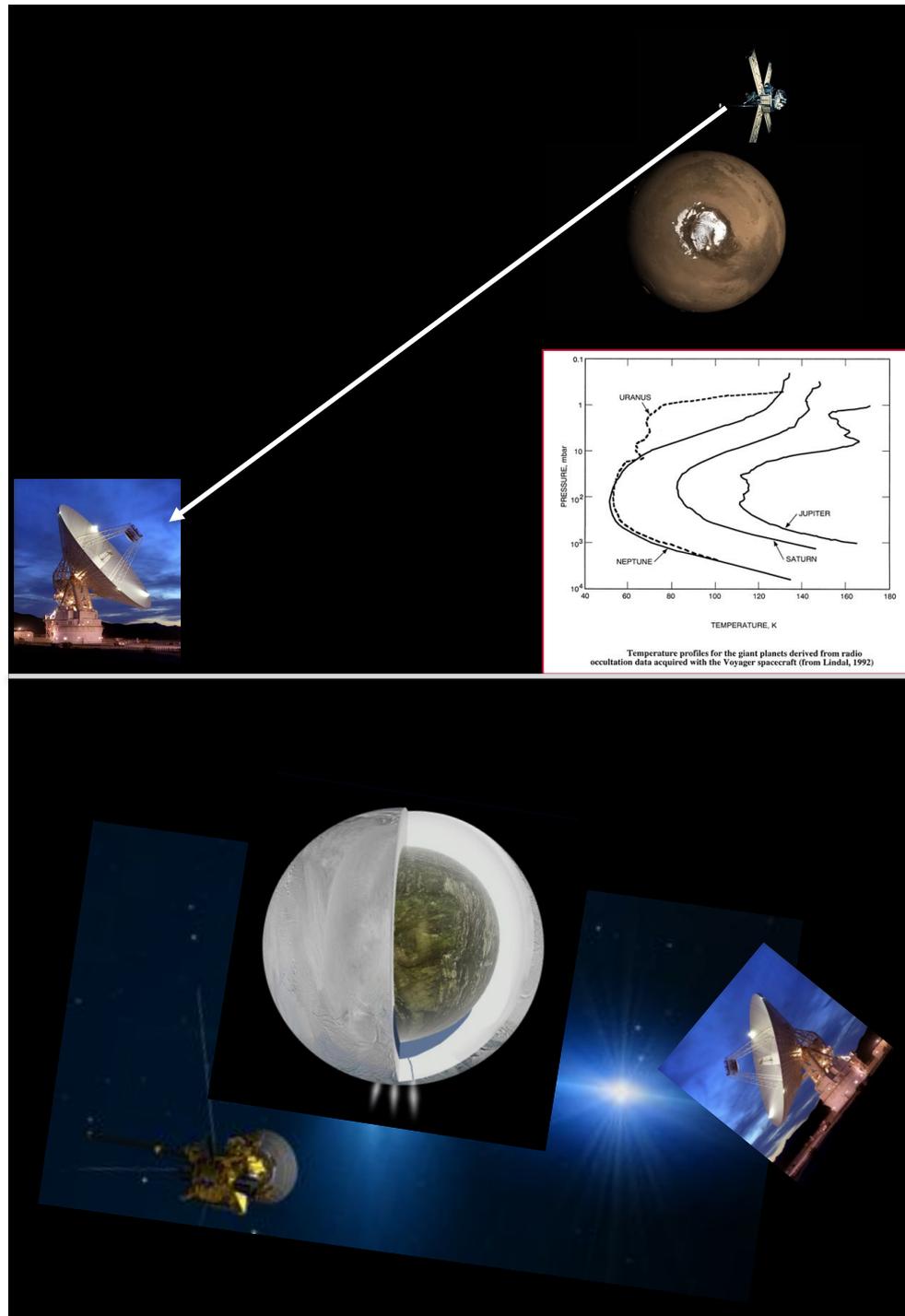
# Radio Science

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

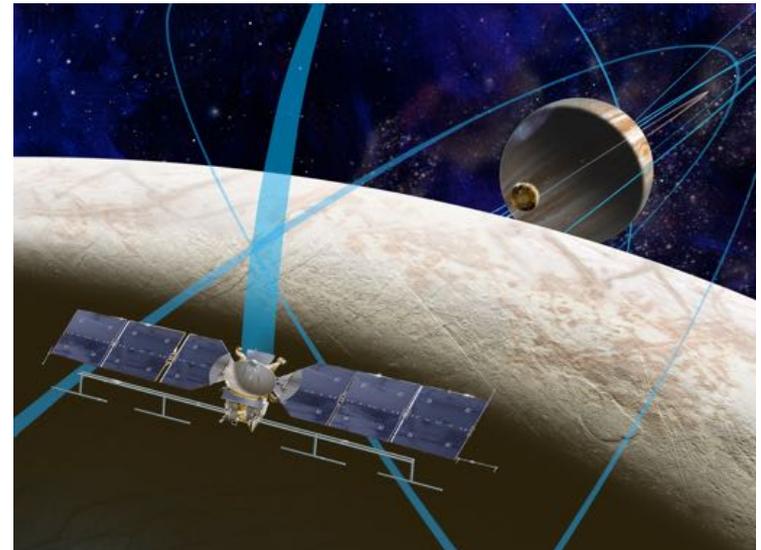
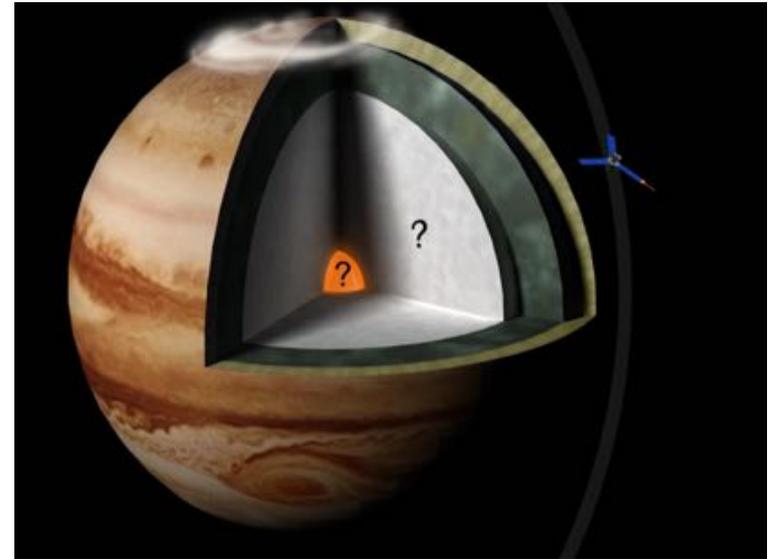
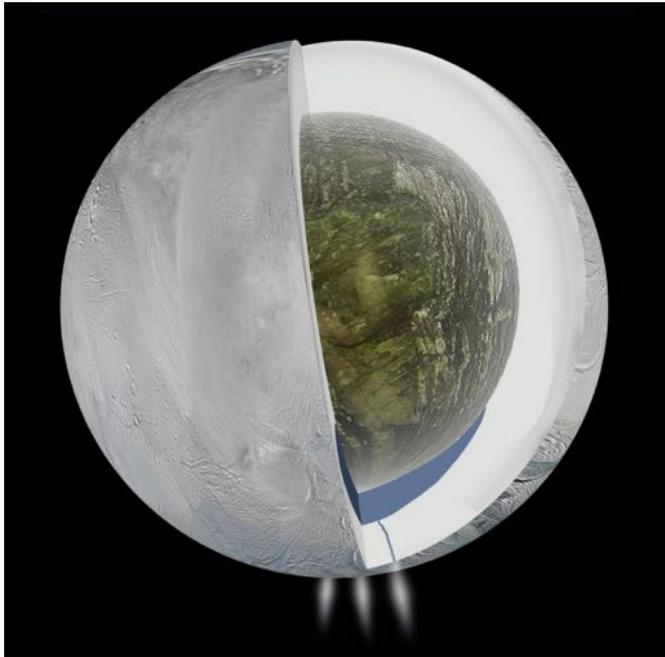
- Mio dio! Tragedy!
- Or one person's annoyance is another's data --- Study atmospheric properties!

“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

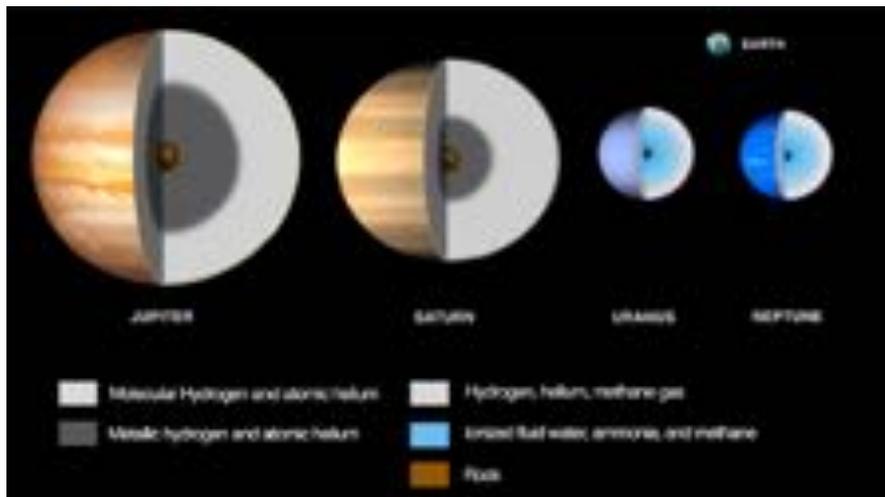


# Future Radio Science

“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

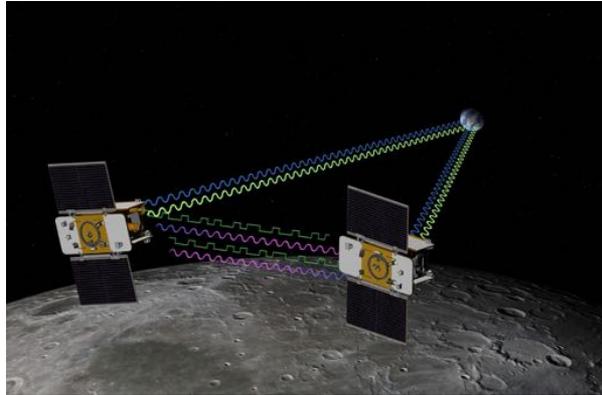


## Technologies

- 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

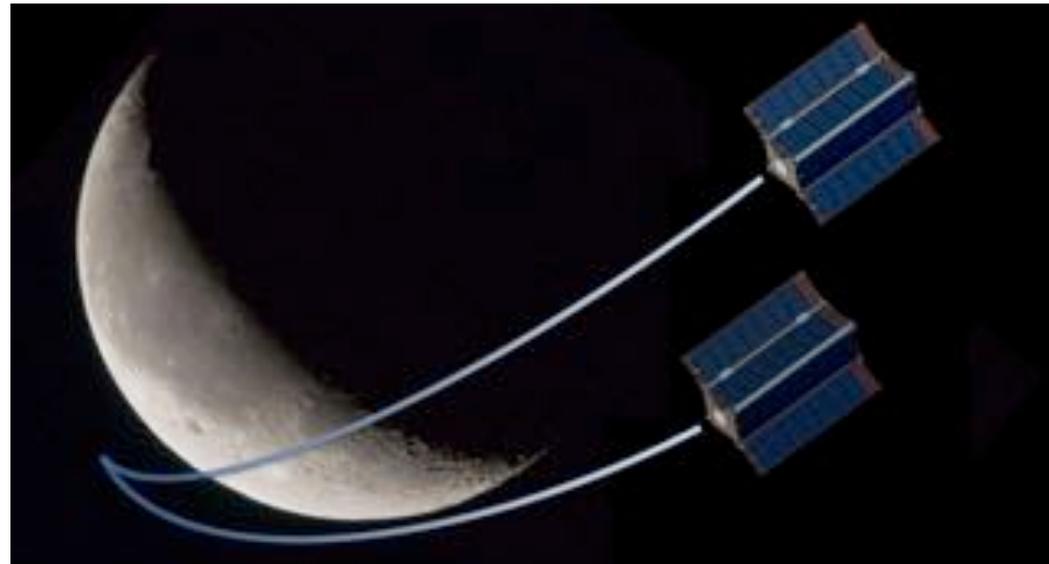
## Interiors of Moons: Earth's Moon



**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**





# DEEP SPACE NETWORK NOW

[DSN Home](#)



TARGET

## GROUND BASED RADIO ASTRONOMY



- [VIEW ANTENNA](#)
- [VIEW SPACECRAFT](#)
- [VIEW WORLD MAP](#)

GBRA

### ANTENNA

NAME  
DSS 43

AZIMUTH  
86.01 deg

ELEVATION  
52.43 deg

WIND SPEED  
3.71 km/hr

[+ more detail](#)

[credits](#) [contact us](#)

### MADRID

APR 21  
10:06 AM



63

SOHO



65

STA



54

DAWN



55

### GOLDSTONE

APR 21  
1:06 AM



14

JNO



15

MOM MEX



24

CAS



25

M010 MPO



26

### CANBERRA

APR 21  
6:06 PM



43

GBRA



45

THC



34

ROSE



35