Jet Propulsion Laboratory
California Institute of Technology

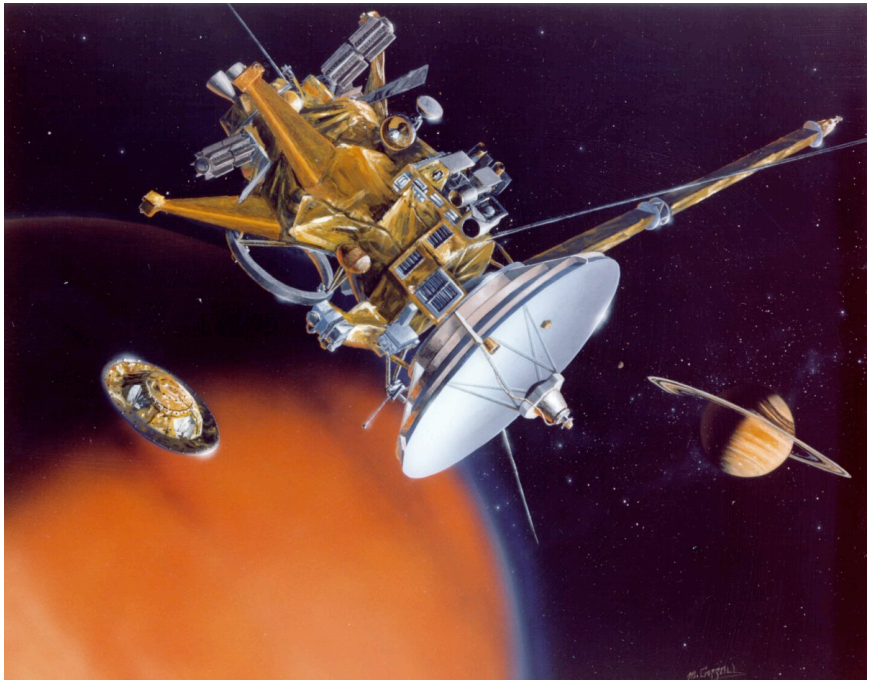
Interplanetary Internet

Joseph Lazio

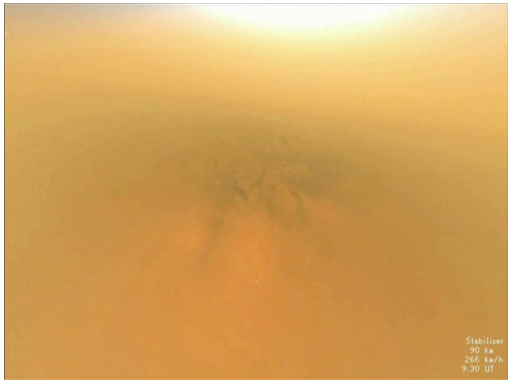
Relays and Networks

Scientific Importance

Galileo Probe



***Cassini* with Huygens Probe**



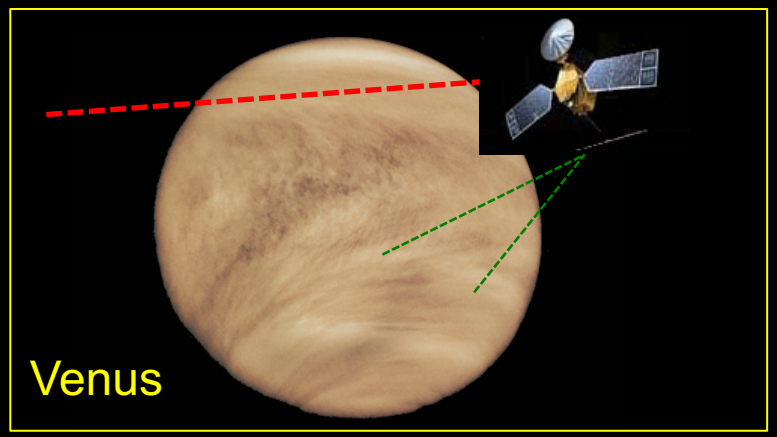
Credit: NASA

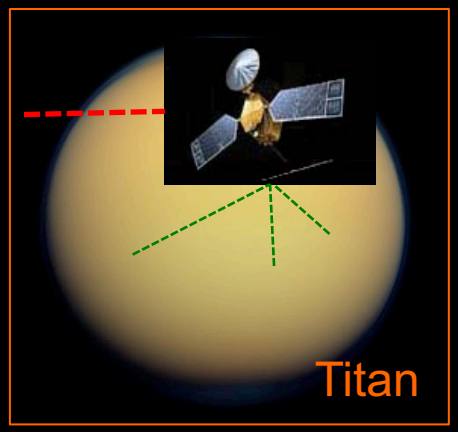
Strata at Base of Mt Sharp

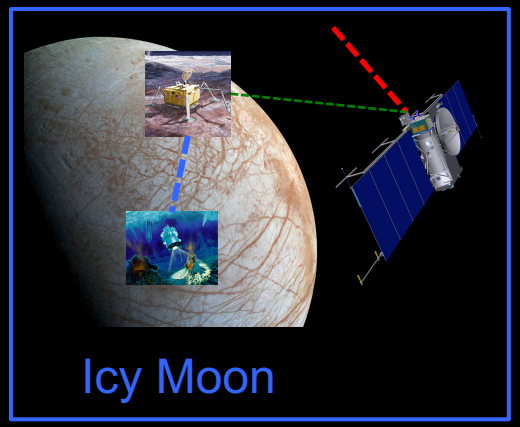
Indicates flow of water before the mountain formed

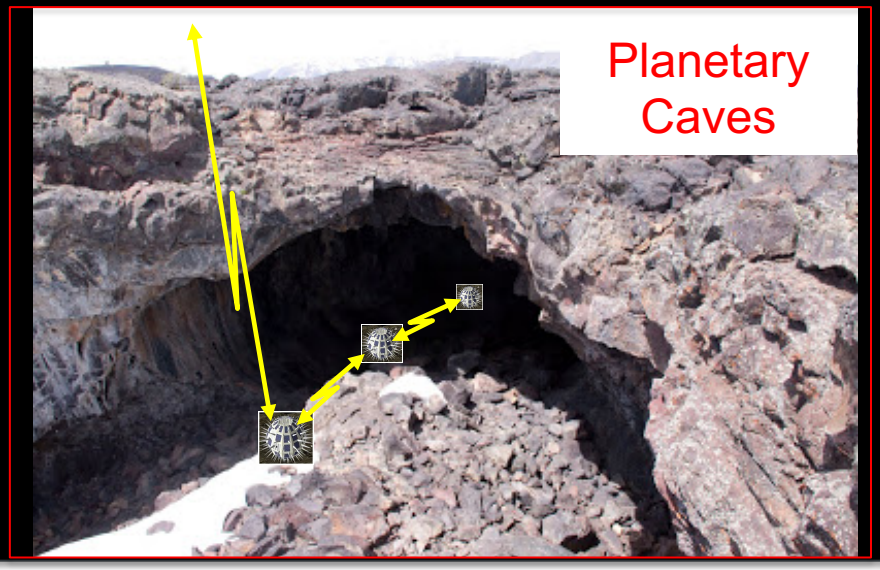
Interplanetary Internet

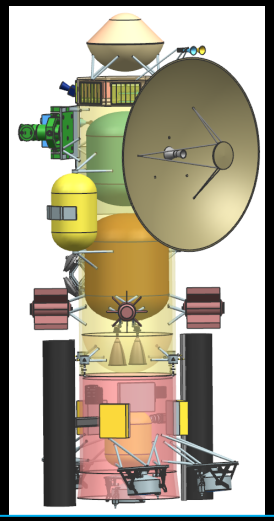
Extends today's Internet across the Solar System

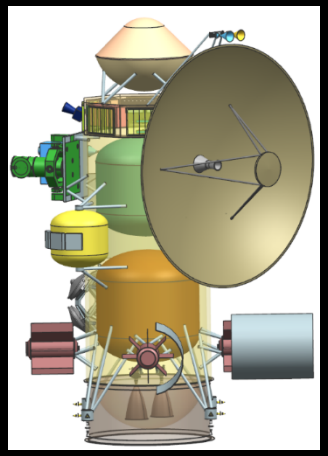








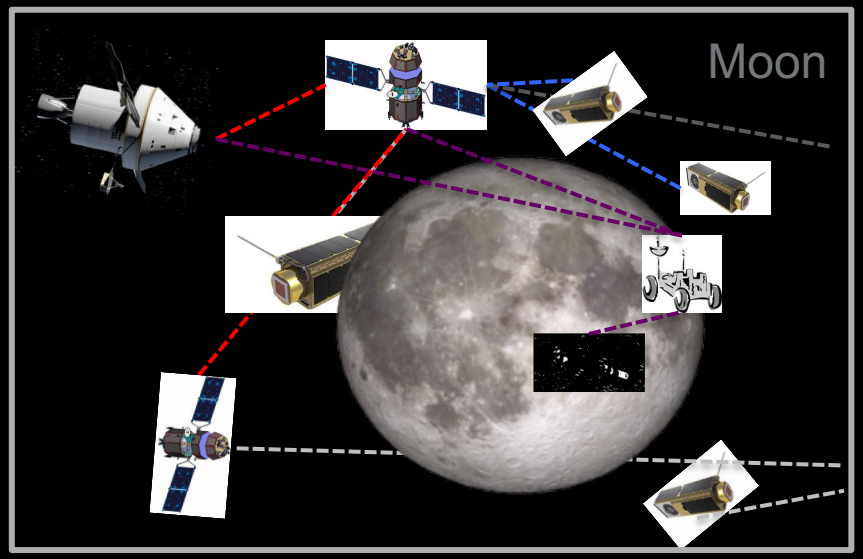


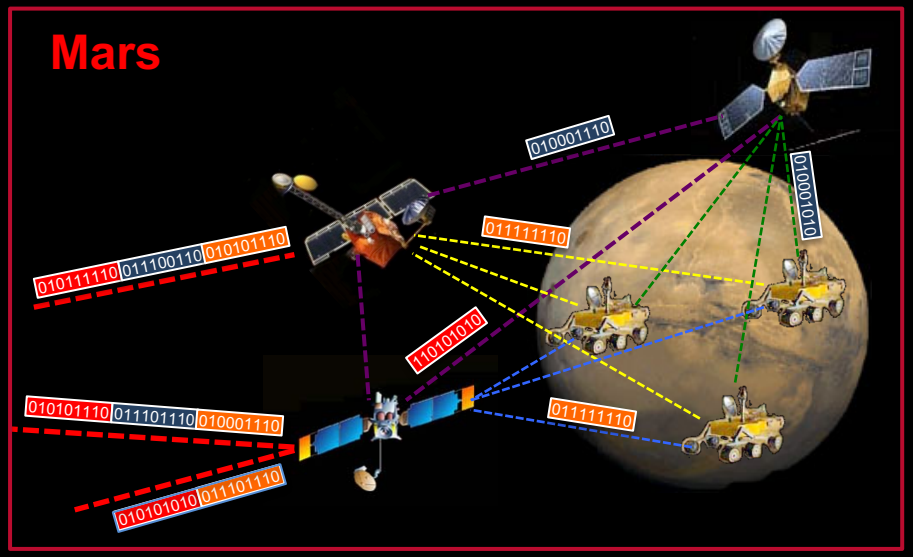


Ice Giant Mission Concepts

Interplanetary Internet

Extends today's Internet across the Solar System





Physical Layer

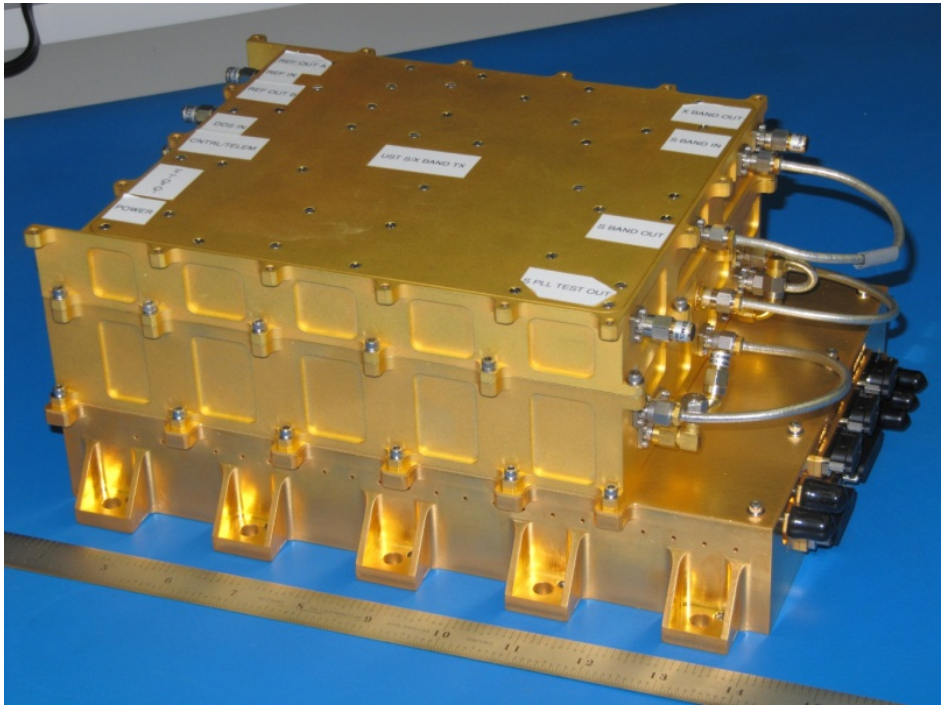
Don’t design in bottlenecks

- **Design in relays and networking**
- **Modular designs**

  e.g., Universal Space Transponder (UST)

➢ **Transponders vs. Command & Data Handling (C&DH)**

  ➢ **Plan for disruption/delay-tolerant networking (DTN)**

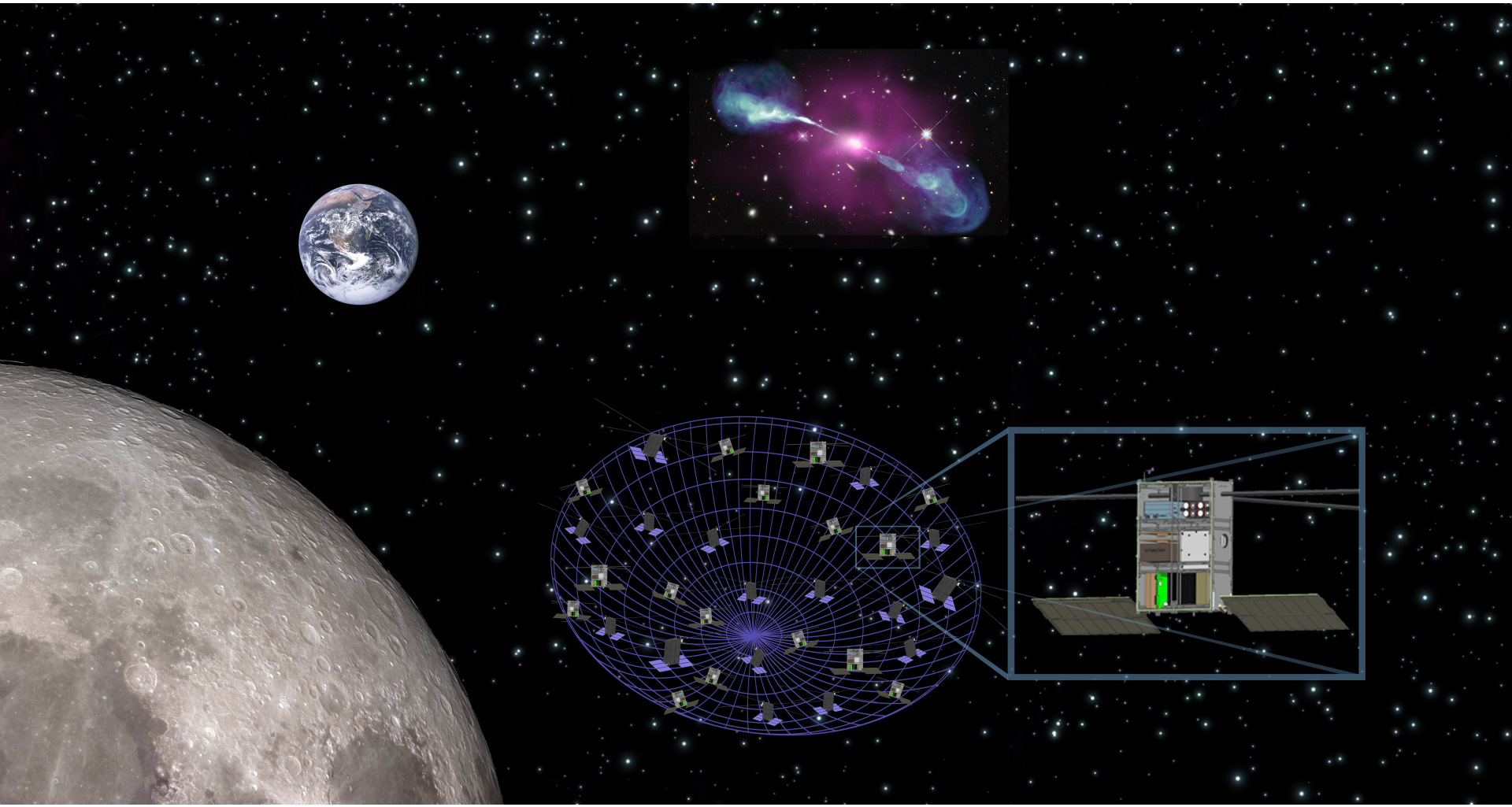


Lunar Communications Architecture

Link	Frequency	Comment
Earth to Moon	RF-low: 7.19--7.235 GHz RF-high: 22.55--23.15 GHz Laser: 1064 nm	➢ Plan for the future: Data rates and data volumes will grow! • High-def imaging • Teleoperations ➢ Inter-operability, inter-operability, inter-operability ✓ Already paid dividends at Mars ✓ Standards
Moon to Earth	RF-low: 8.45--8.5 GHz RF-high: 25.5--27.0 GHz Laser: 1550 nm	
Cross-link	22.55--23.55 GHz 25.6--27.225 GHz Laser: 1550 nm	
Proximity Link (to lunar surface)	RF-low: 390--405 MHz RF-low: 2.025 GHz--2.11 GHz RF-high: 22.55--23.55 GHz Laser: 1550 nm	
Proximity Link (from lunar surface)	RF-low: 435--450 MHz RF-low: 2.2 GHz--2.29 GHz RF-high: 25.5--27 GHz Laser: 1550 nm	
Lunar Surface	2.4--2.48 GHz	IEEE 802.11

Cautionary Tale

Relaying data makes a lot of sense, except if it does not.



BACKUP

Deep Space Network

Relays and Networking

Some of these capabilities will not be practical on smaller spacecraft

Communications capability can be provided to these more capable relay spacecraft

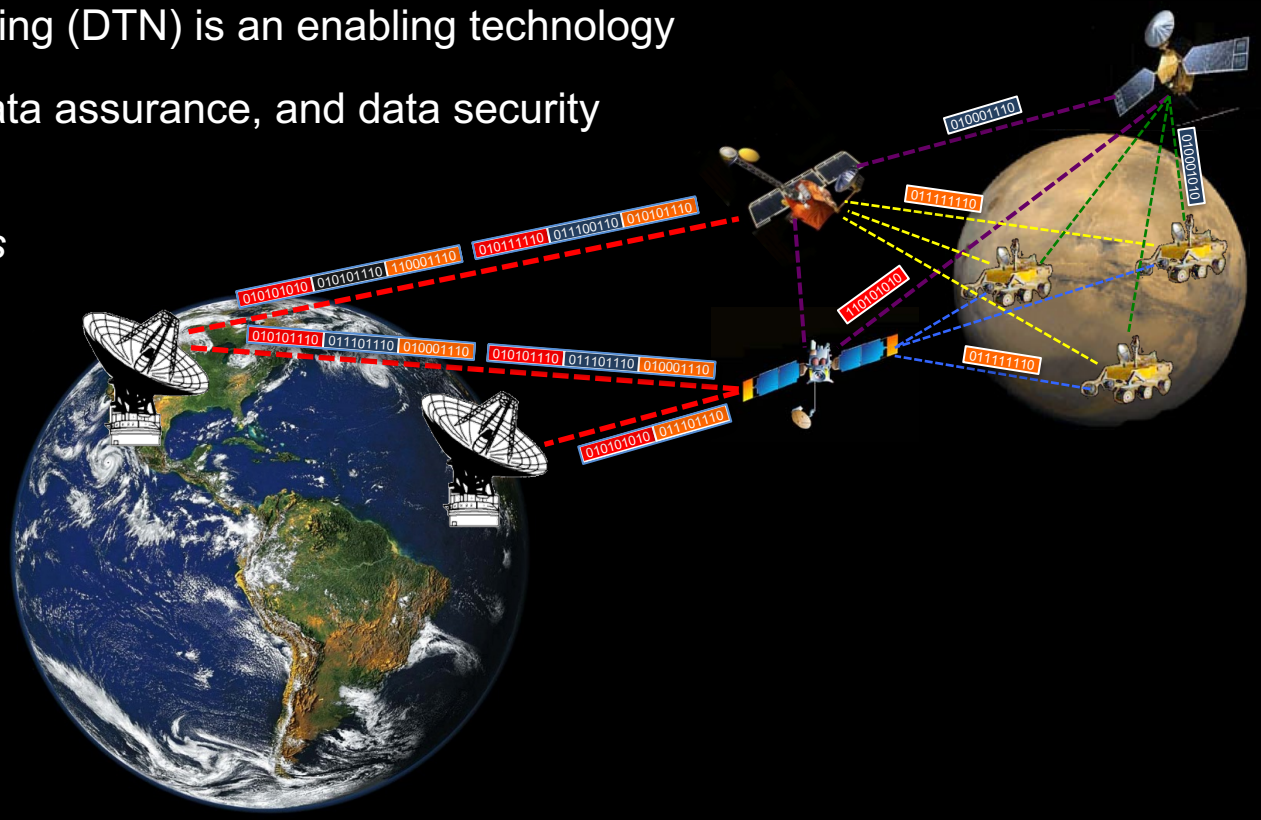
- Viking, Galileo Probe, Huygens, and Philae have taken advantage of this architecture

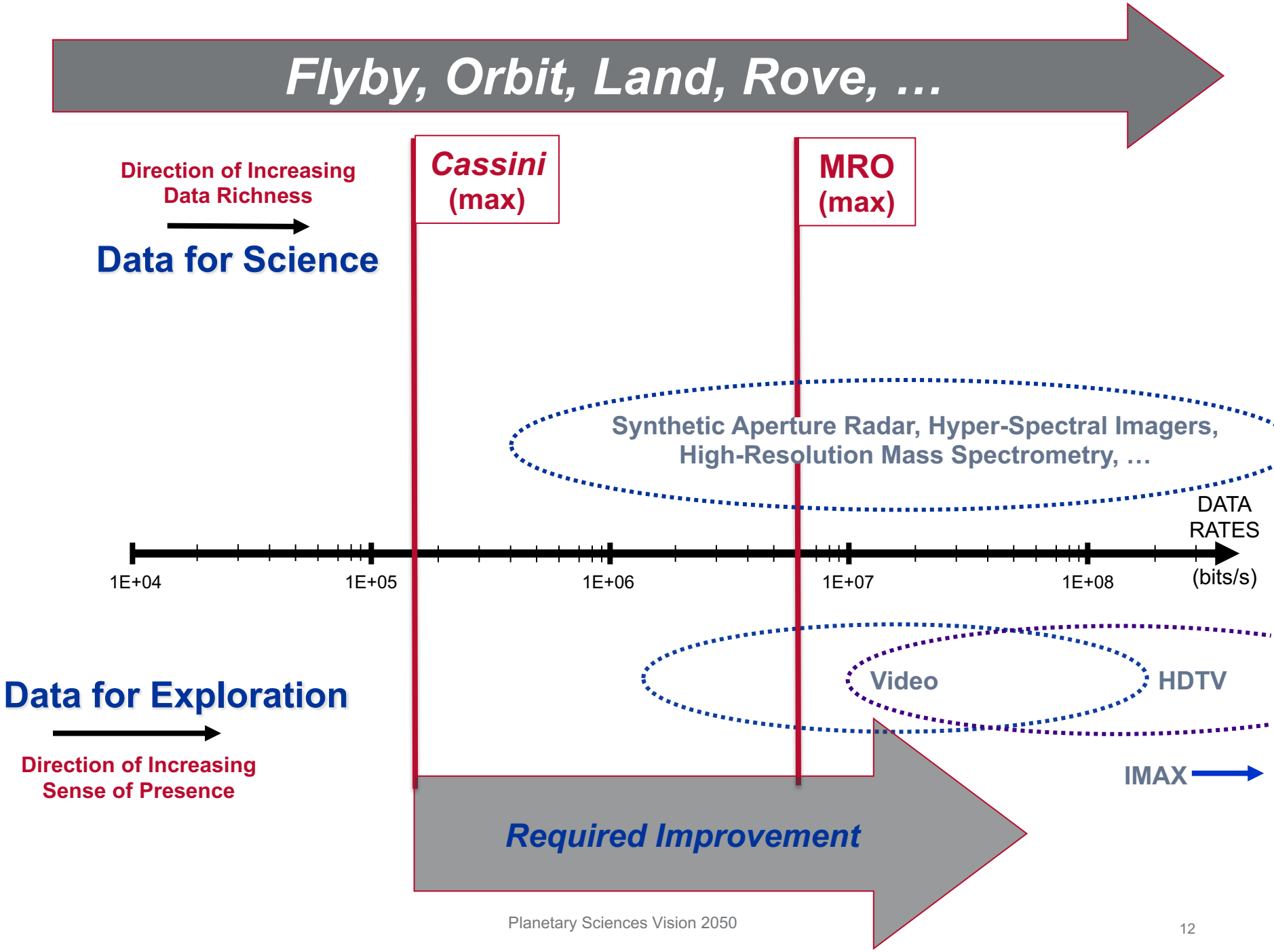
Disruption Tolerant Networking (DTN) is an enabling technology

- Provides automation, data assurance, and data security

NASA and our partners will emplace *planetary networks* to support areas of future intense exploration

- Today's *Mars Network* provides these services to landers and rovers




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, …
DATA RATES (bits/s)
1E+04
1E+05
1E+06
1E+07
1E+08
Video
HDTV
IMAX
Data for Exploration
Direction of Increasing Sense of Presence
Required Improvement