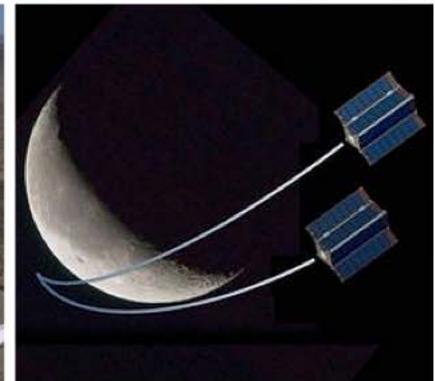
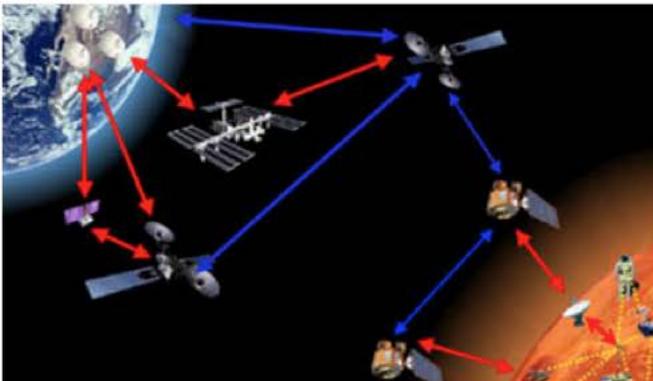
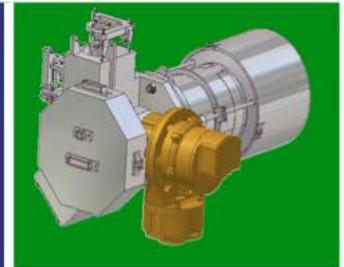
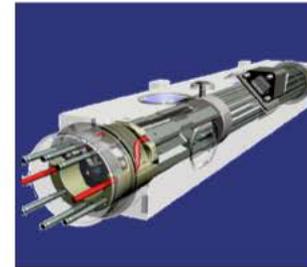


Panel Discussion: *DSN of the Future*

Bill Weber, Moderator
Phil Liebrecht, NASA SCAN
Les Deutsch, IND
Steve Townes, IND
Joe Lazio, IND/Div 33
Chad Edwards, IND/Mars





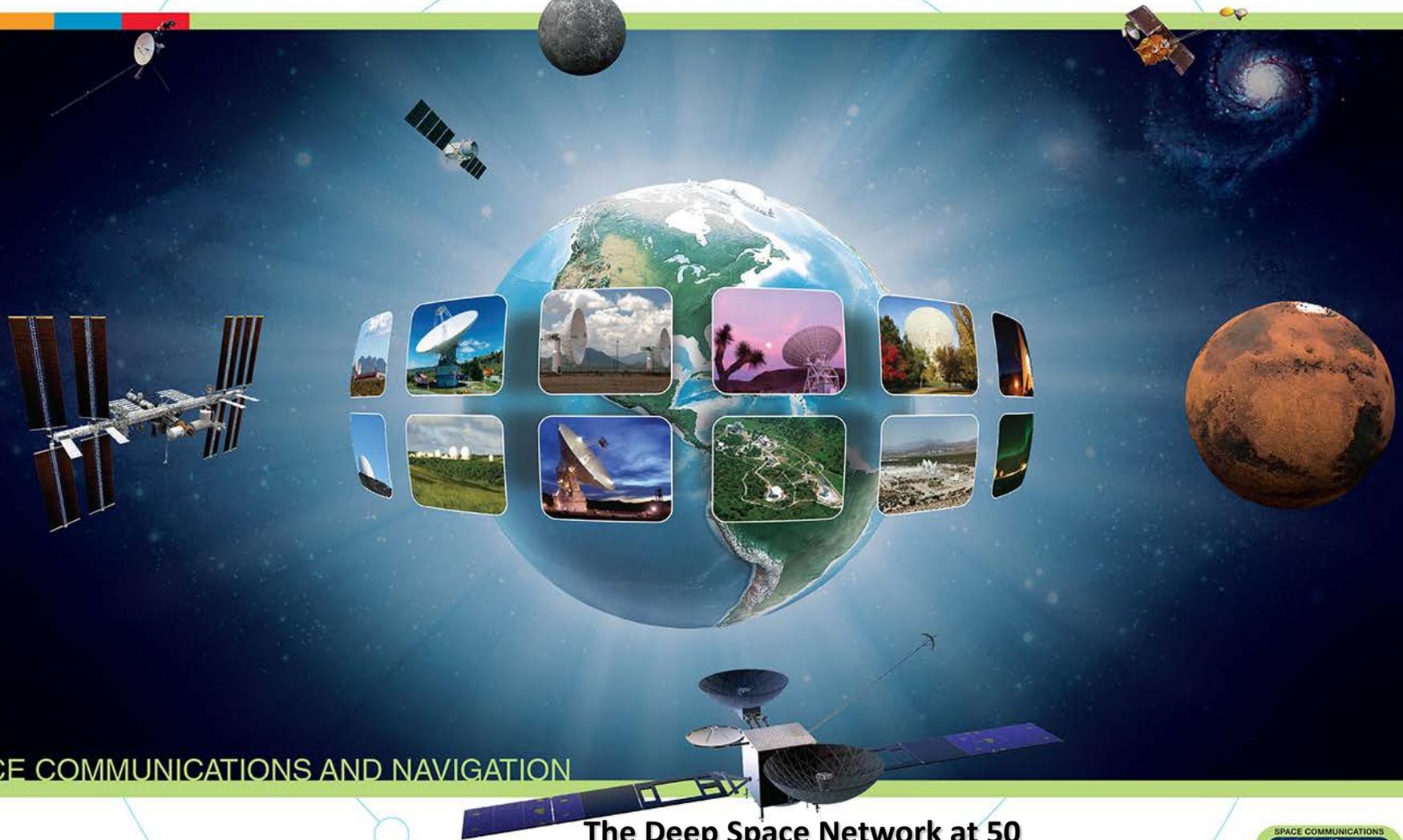
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Introduction Agenda



- **Phil Liebrecht** **NASA perspective; hi-level architecture**
- **Les Deutsch** **DSN from the user perspective**
- **Steve Townes** **Enabling technology**
- **Joe Lazio** **DSN Science**
- **Chad Edwards** **Mars Network; Interplanetary Network**

Top level Mission and Agency Drivers and Architecture Plan



SPACE COMMUNICATIONS AND NAVIGATION

The Deep Space Network at 50

Phil Liebrecht, Deputy Program Manager, SCaN
February 2014





Agency and Mission Drivers



Human Exploration beyond Low Earth Orbit

Unified interfaces for all SCaN Networks

Increasing International Collaboration

Internationally Interoperable Standards

Space Internetworking

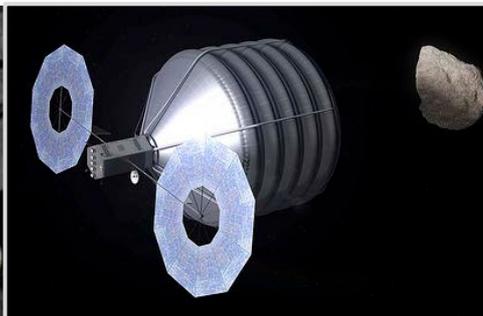
Sensor webs & increased automation

Seamless Human & Robotic Exploration

Increased data transmission

Increased resolution & productivity

Bring the public along for the Adventure

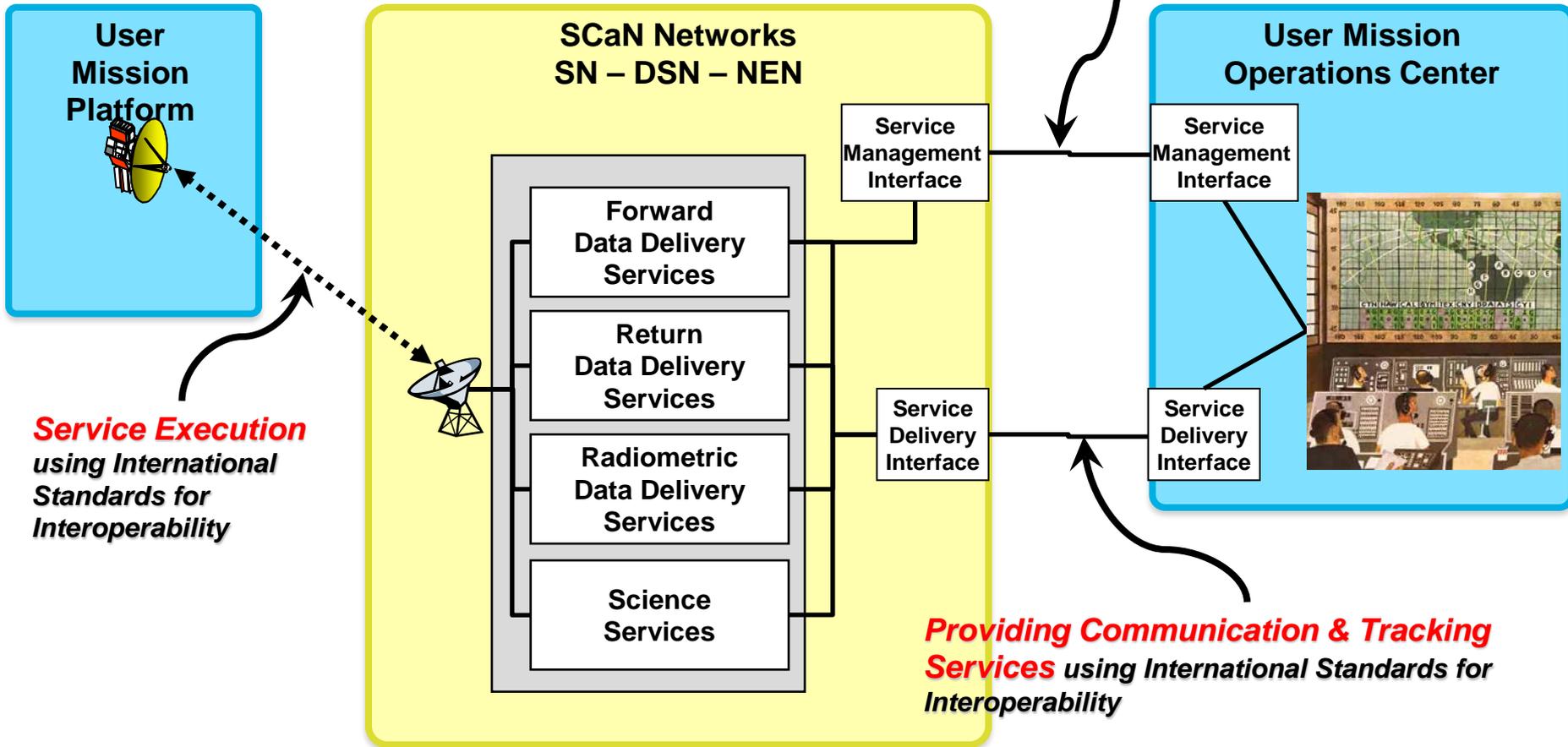




Unified Interfaces to Users & Internationally Interoperability



Scheduling & Monitoring Services using International Standards for Interoperability





Architecture and Agency Drivers



2010

2015

2020

2025+

Driving Requirements

Provide space communications and navigation services to existing and planned missions.

Develop a unified space communications and navigation network infrastructure

Implement internationally interoperable communication protocols

Provide the highest data rates technically and financially feasible

Implement a networked communication and navigation infrastructure across space

Provide communication and navigation infrastructure and services for Lunar and Mars human missions

Mission Drivers

- Shuttle/ISS 
- Mars Landers
- Great Observatories
- Coordinated Earth Observation
- LRO 

- ISS 
- Mars – Coordinated and Complex Science Missions
- SAR Earth Observation
- Curiosity rover 

- ISS
- MPCV/Orion
- SLS 
- Asteroid Sample Return
- High Data Volume Hyper Spectral Missions

- Hyper spectral imaging at Mars and beyond
- Human Near Earth Object Missions
- Earth Sensor Web
- Mars Exploration 
- Mars Sample Return

Capabilities

- Up to 300 Mps (EBRE/NEE)
- Up to 6 Mbps at 1 AU (DSE)
- Radiometric Services

- Up to 1.2 Gbps (EBRE)
- Up to 13 Mbps at 1 AU (DSE)
- Standard Services
- Integrated Mission Commitment
- Radiometric Enhancements

- Up to 50 Mbps at 1 AU
- Integrated Network Management
- Integrated Service Execution
- Space Internetworking

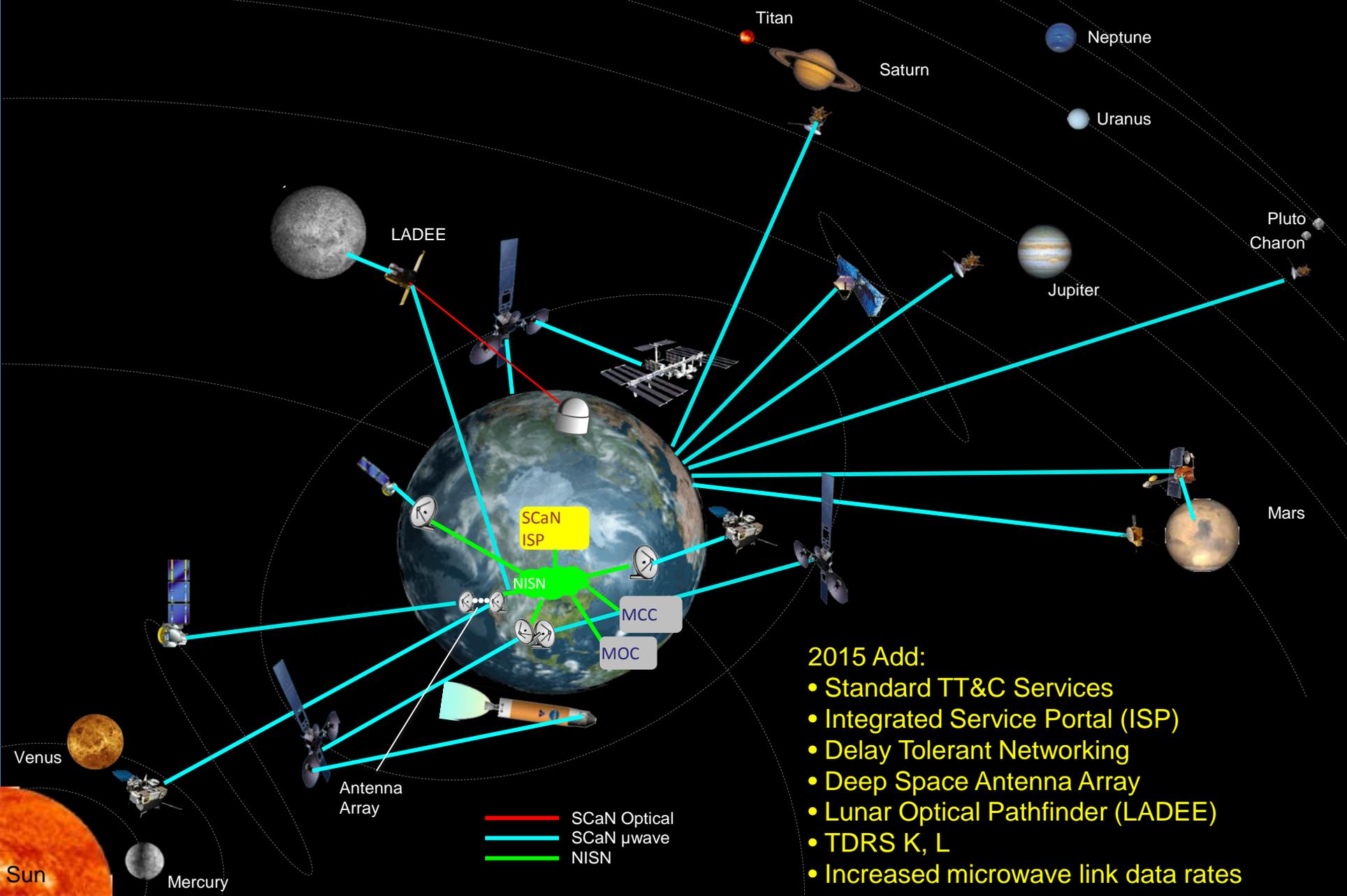
- Up to 1.2 Gbps from the moon (optical)
- Optical Communications to 100 Mbps (planetary)
- Lunar far side coverage
- High capacity multi-node
- Inter-networking interoperability



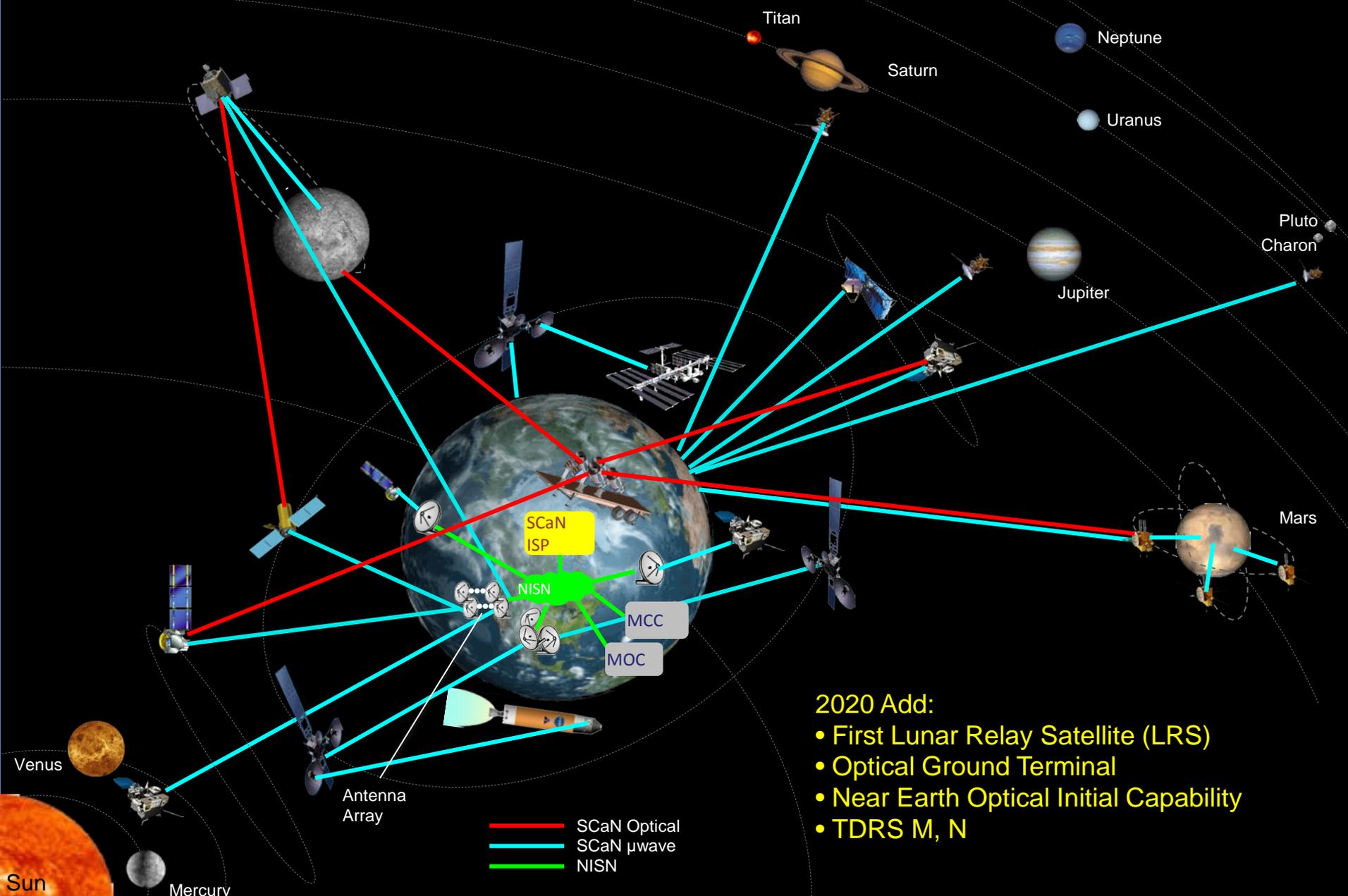
SCaN Notional Unified Communication Architecture

2009 SCaN Architecture Baseline will transition to an Integrated Network Architecture which follows...

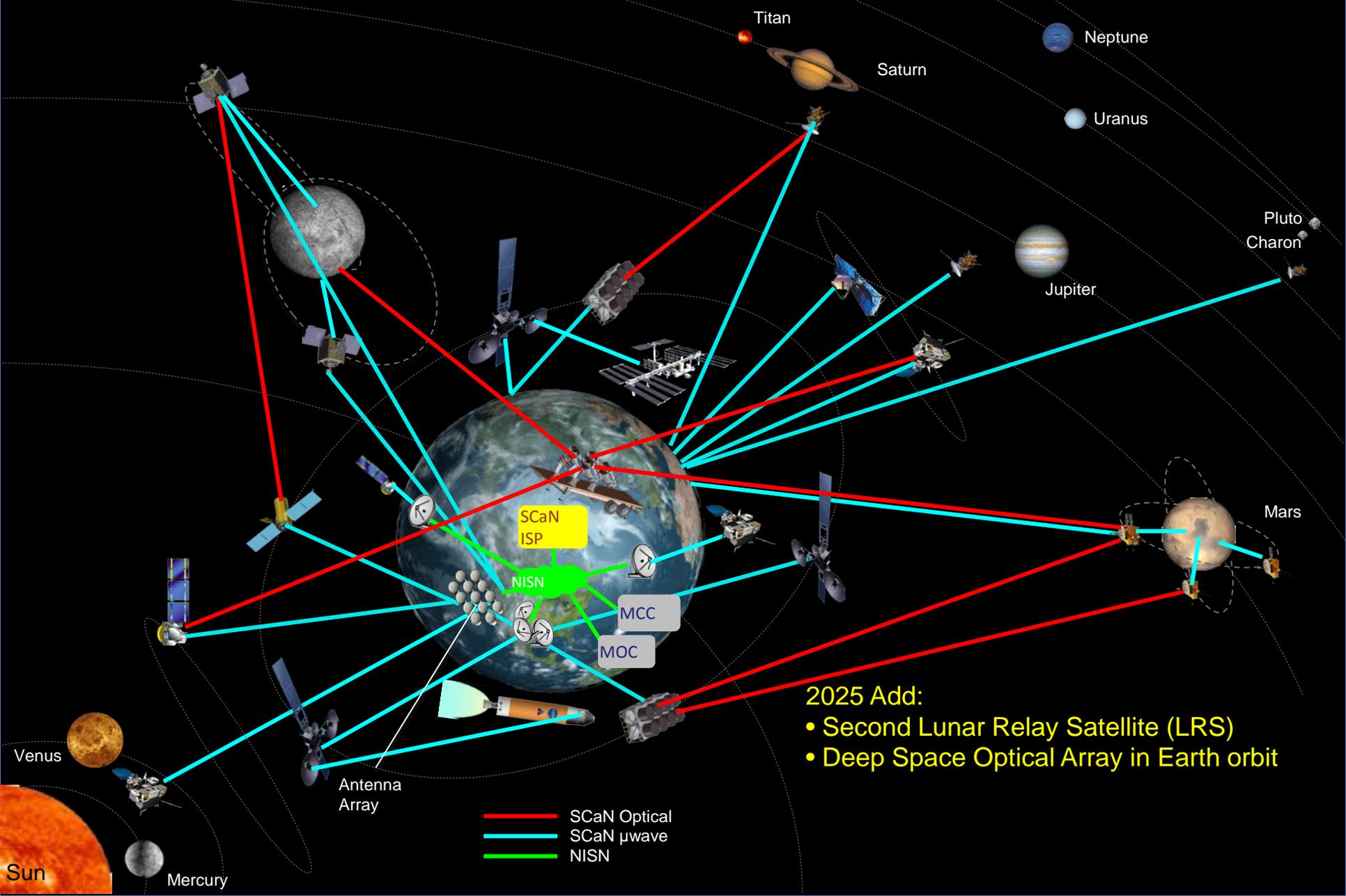
SCaN Notional Unified Communication Architecture



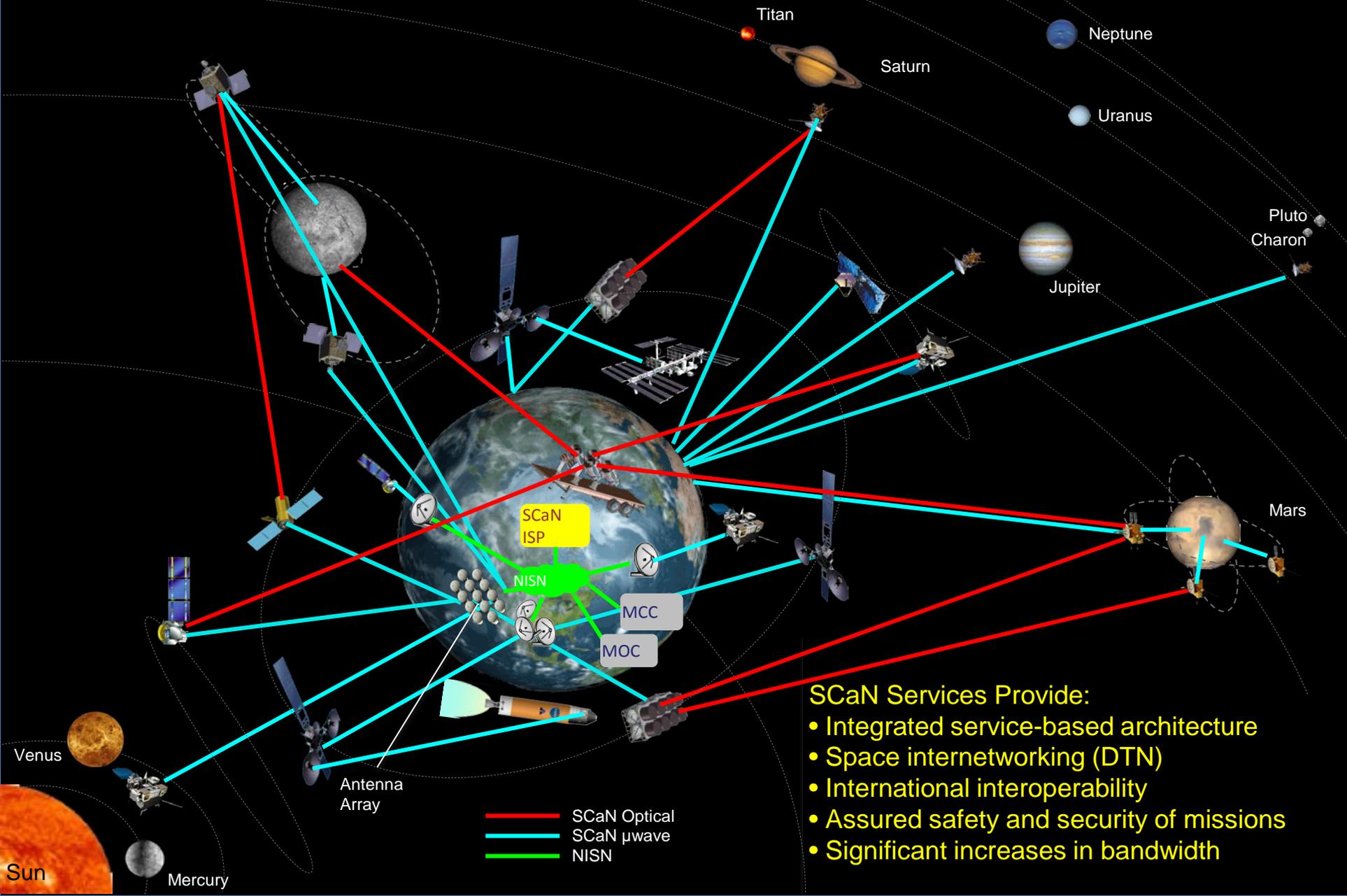
SCaN Notional Unified Communication Architecture



SCaN Notional Unified Communication Architecture



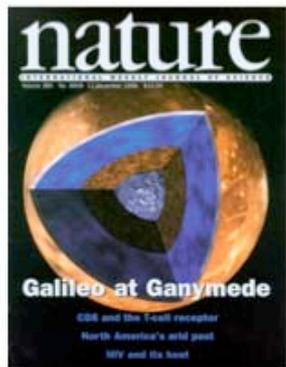
SCaN Notional Unified Communication Architecture



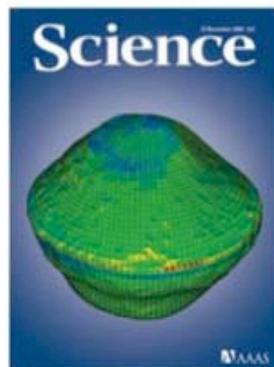
DSN's Impact on Exploration and Science



Communications and navigation support and *Radio and Radar* science has enabled a continuing torrent of forefront discoveries



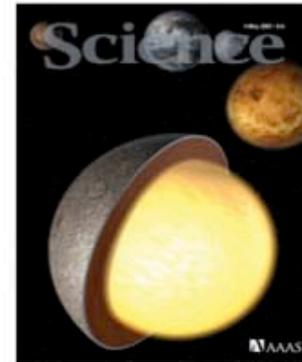
Interior of Ganymede



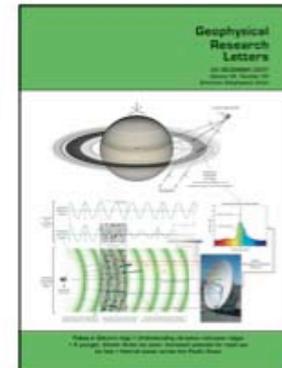
Asteroids in 3-D



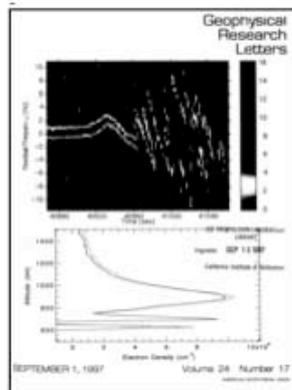
Oceans on Europa?



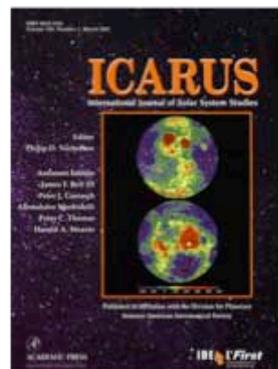
Mercury Liquid Core



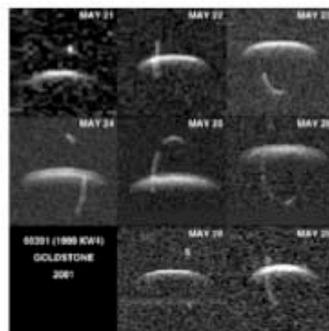
Saturn's Rings



Mars Ionosphere



Moon Gravity Field



Binary Asteroids



Student Study of Juptier Radio Emission



Saturn's Rings



For more information, visit NASA:

www.nasa.gov

or

Space Communications and Navigation (SCaN):

www.nasa.gov/scan

www.facebook.com/NASASCaN

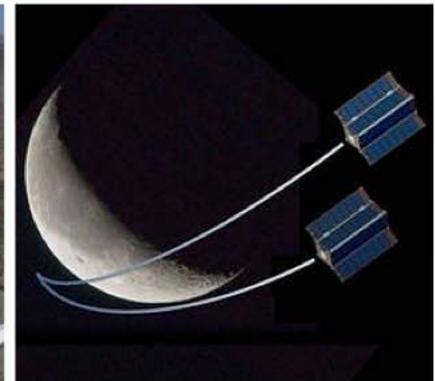
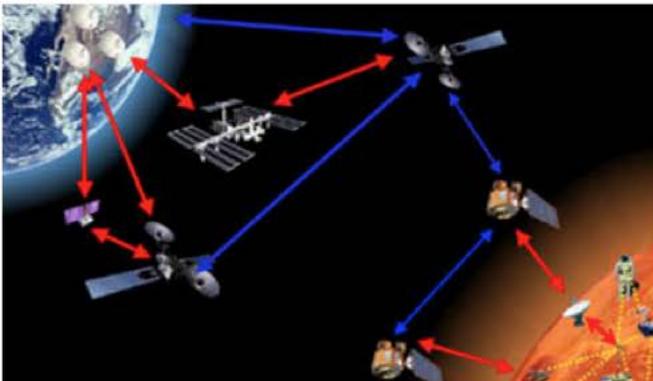
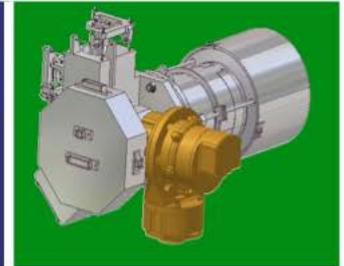
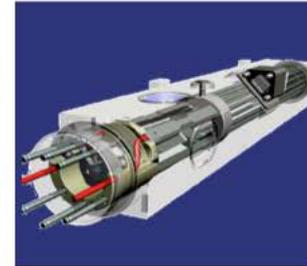
Twitter: [@NASASCaN](https://twitter.com/NASASCaN)



DSN Future: A User Perspective

Dr. Les Deutsch
Deputy Director For
Interplanetary Network Directorate
Jet Propulsion Laboratory
California Institute of Technology

February 20, 2014



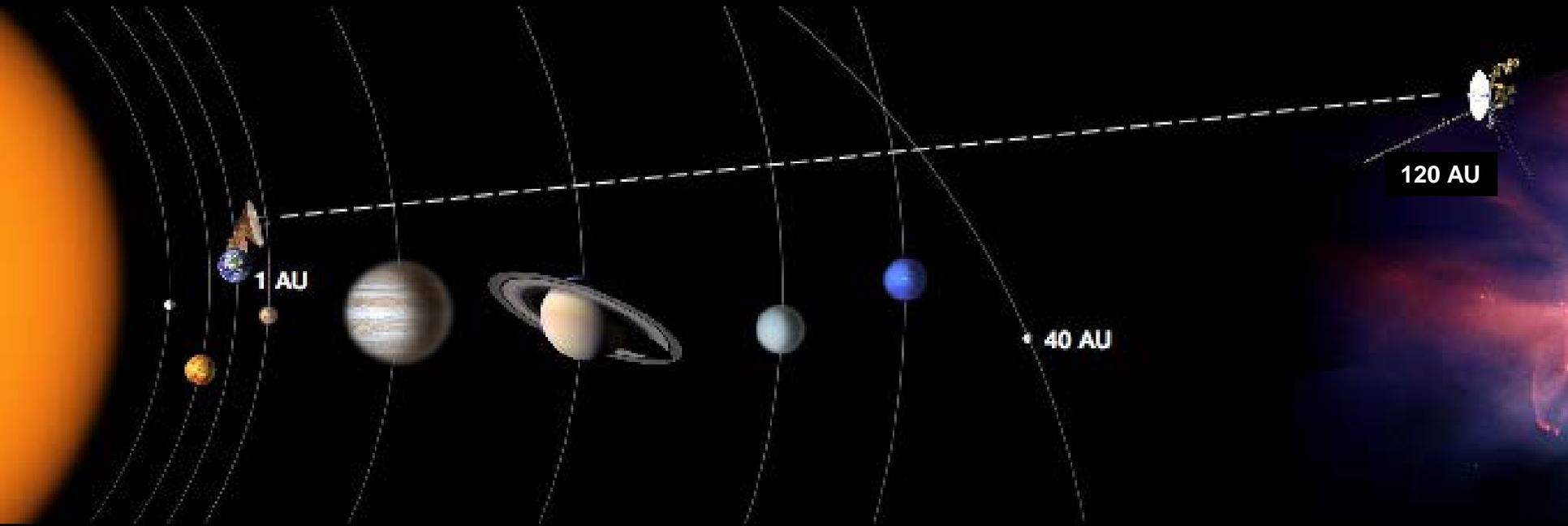


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Ultimate Long Distance Carrier



Power received by 70 m DSN antenna from Voyager is so small that, if accumulated for 10 trillion years, it could power a refrigerator light bulb for one second!!!

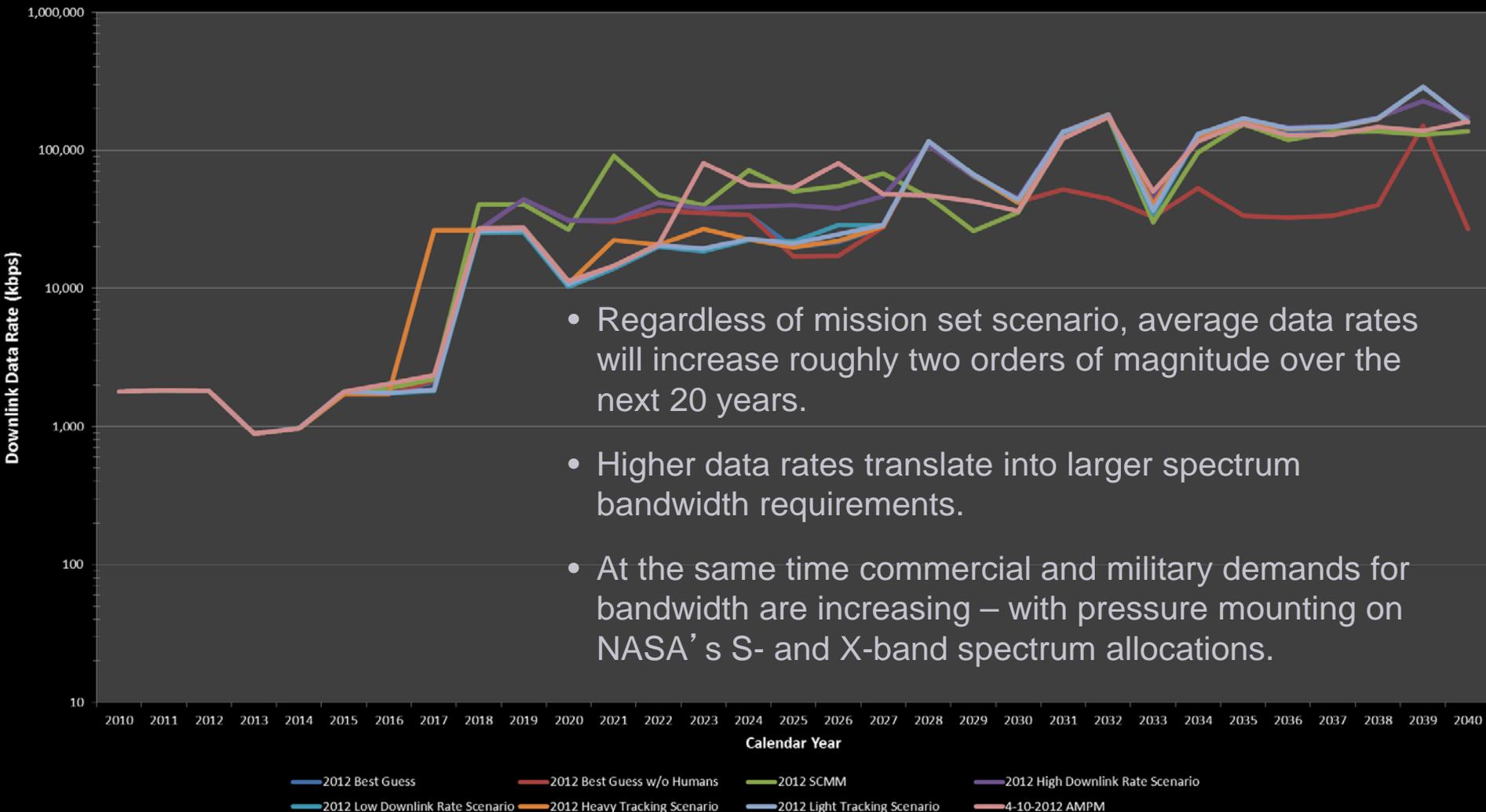




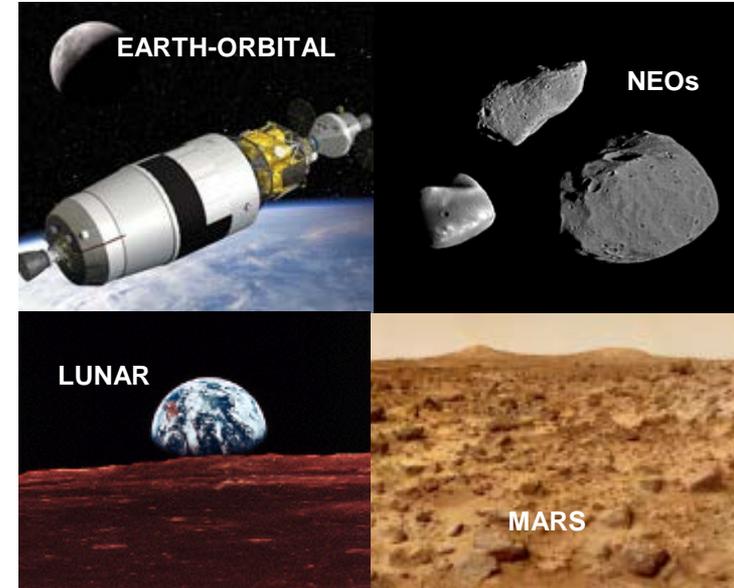
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Increasing Bandwidth Demand

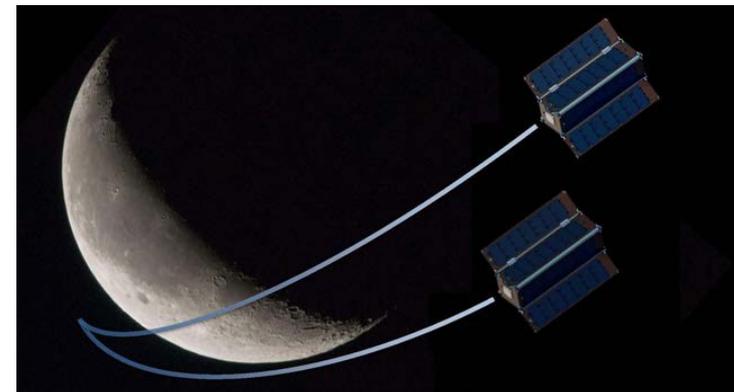
Average Downlink Rate as a Function of Time
(Comparison of Alternative Mission Set Scenarios)



- **The DSN enables astronauts to explore beyond low-Earth orbit**
 - Over the last two years, DSN has become a key participant in HSF planning

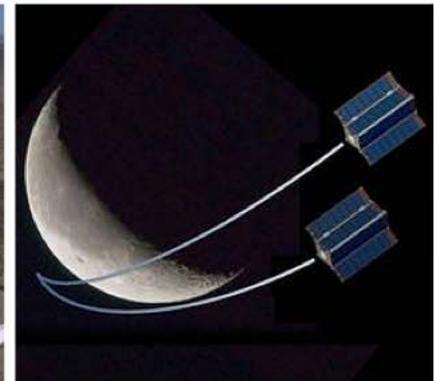
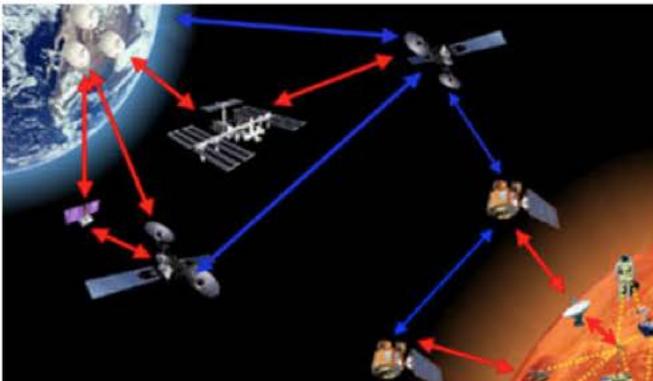


- **The DSN and AMMOS enable deep space smallsats – including CubeSats**
 - Large DSN antennas, Optical communications, Clever navigation and trajectory design, Low-cost multimission ground systems
 - New IND R&TD investments are focused on smallsats



Enabling Technology

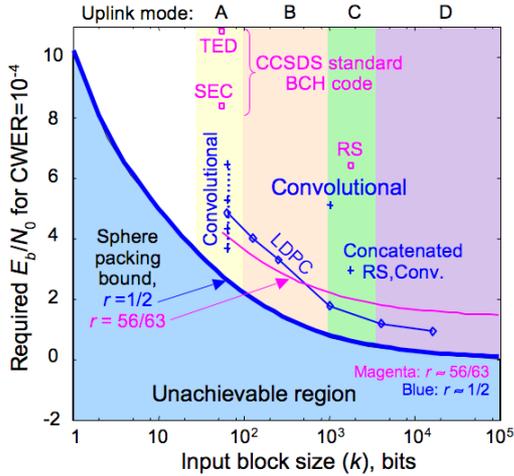
Steve Townes
Chief Technologist
Interplanetary Network Directorate





Jet Propulsion Laboratory
California Institute of Technology

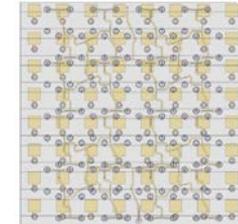
Improved Performance



Efficient Coded Up/Downlinks



Arrayed Antennas for Uplink and Downlink
X-band and Ka-band



1 Kilowatt Ka-Band
Solid State
Amplifier Array

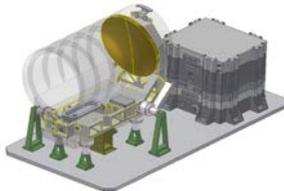
100 kW X-Band
Klystron



High-Power Uplinks



Combined RF/optical
Ground Station



Optical Terminals

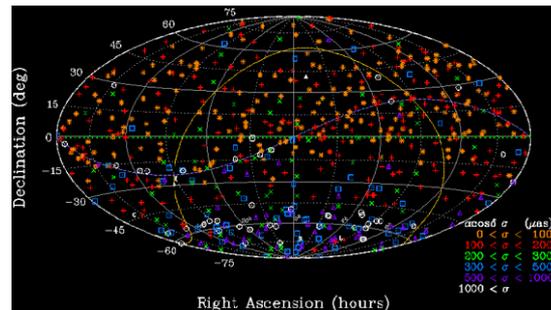


Software Defined Radios

Flight Hardware

Improved Navigation

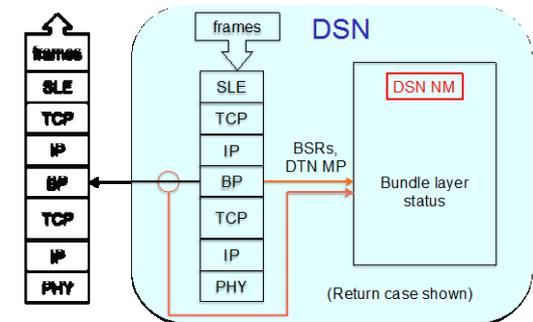
Ka-Band Quasar Reference Source Catalog—Filling in
Southern Declinations



Advanced Communications Protocols

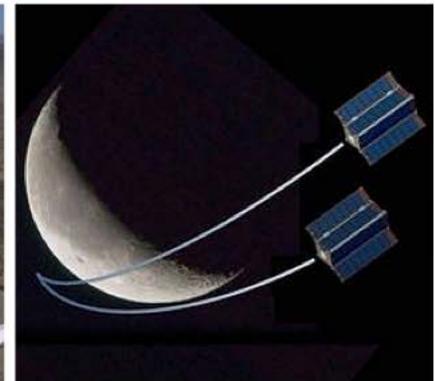
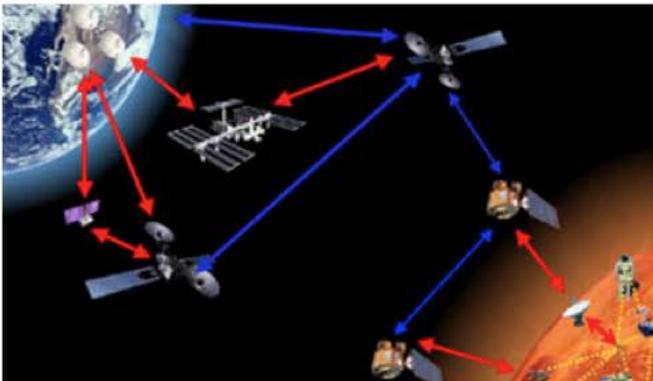
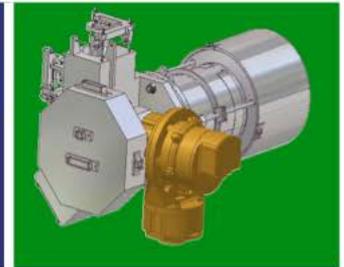
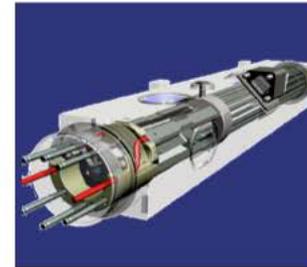
Protocols

Delay Tolerant Networking



DSN Science

Joseph Lazio
Chief Scientist
Interplanetary Network Directorate



Next 50 Years?



Complete catalog of Near Earth Objects

Gravitational wave astronomy

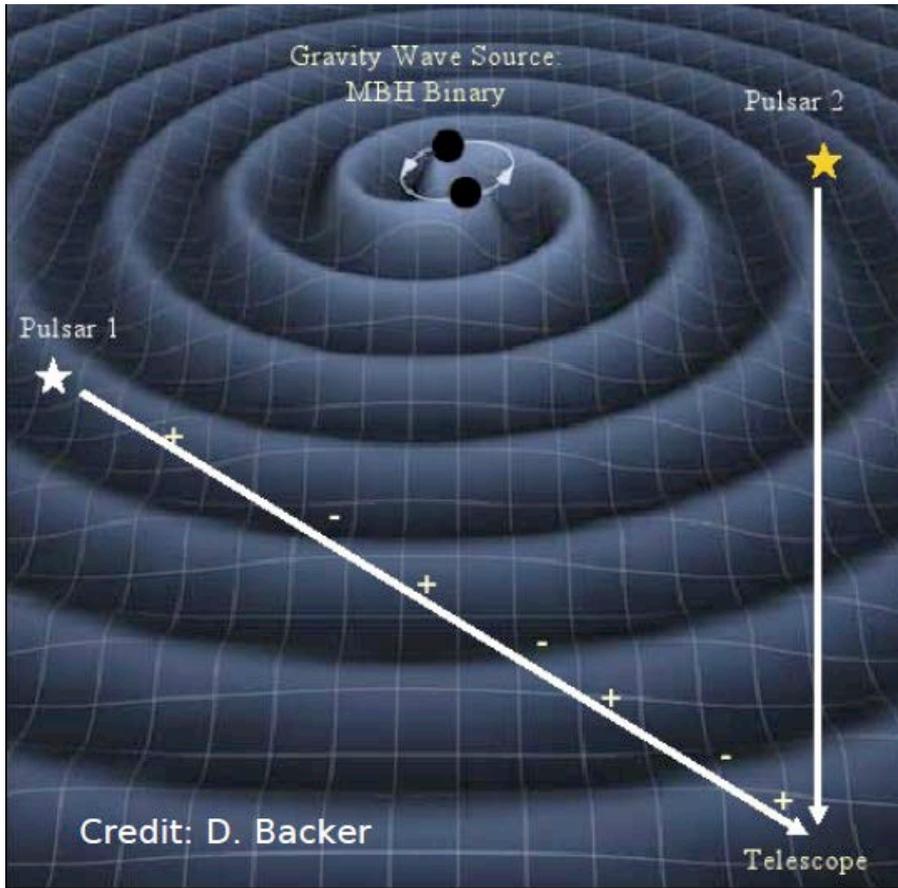
Planetary spacecraft fleets

Extrasolar planets

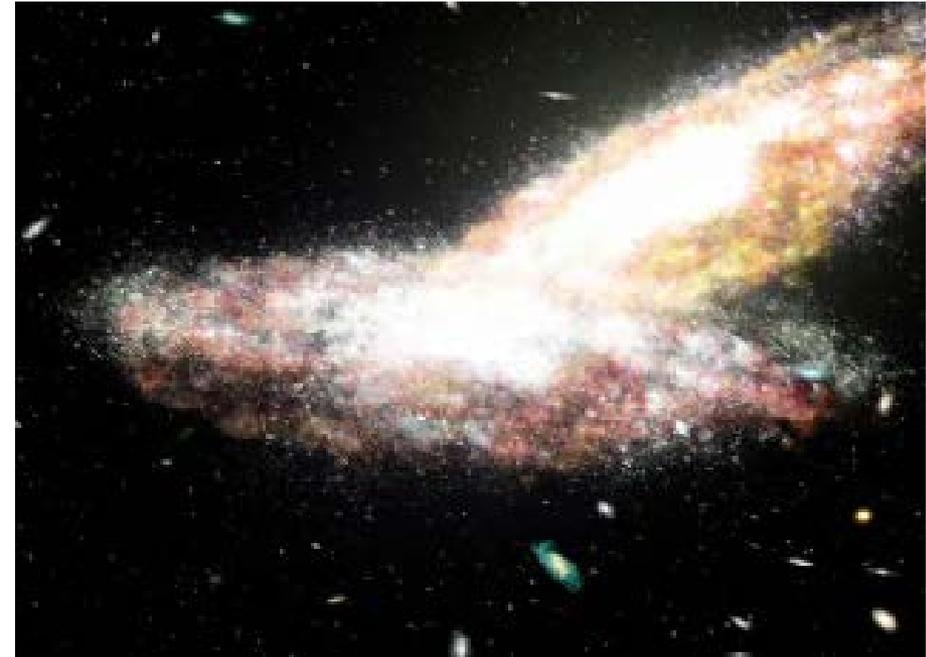
Extraterrestrial life



Radio Pulsars, DSN, and Gravitational Waves



Technique first proposed by Hellings & Downs (JPL)



Searching for gravitational waves emitted by supermassive black holes at centers of galaxies as they in-spiral together

Deep Space SmallSat Constellations



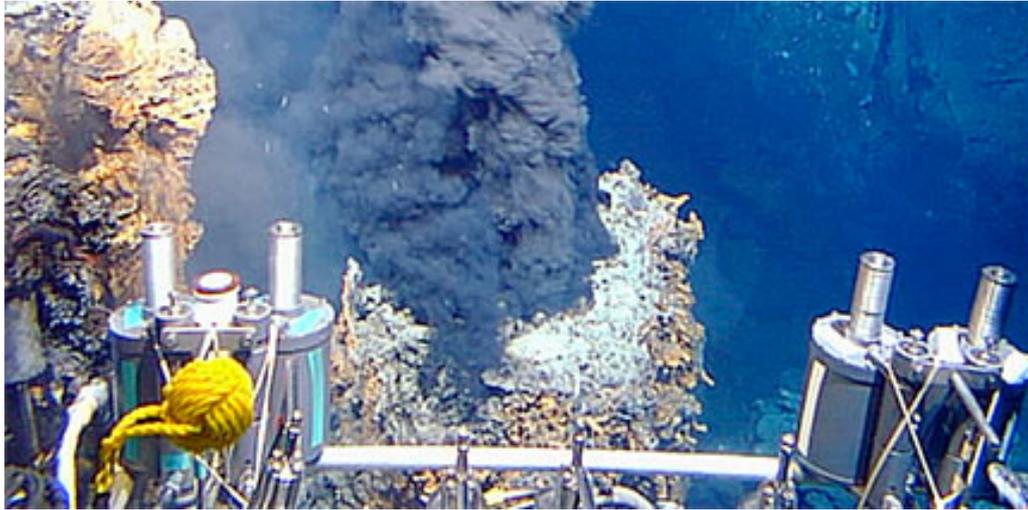
- Imagine fleets of spacecraft at other planets
- Imagine dropping many probes into a planet's atmosphere ...
- May be possible with "smallsats"
- Requires whole new way to operate the DSN ...





BACKUP

Non-DSN Science?



19. 1977 – Deep-Sea Life

Honorable mention:

When John Delaney was forming UW's Neptune Project to study life around thermal vents on the ocean floor, he contacted JPL's DSN engineers because their expertise in communicating in hostile environments.

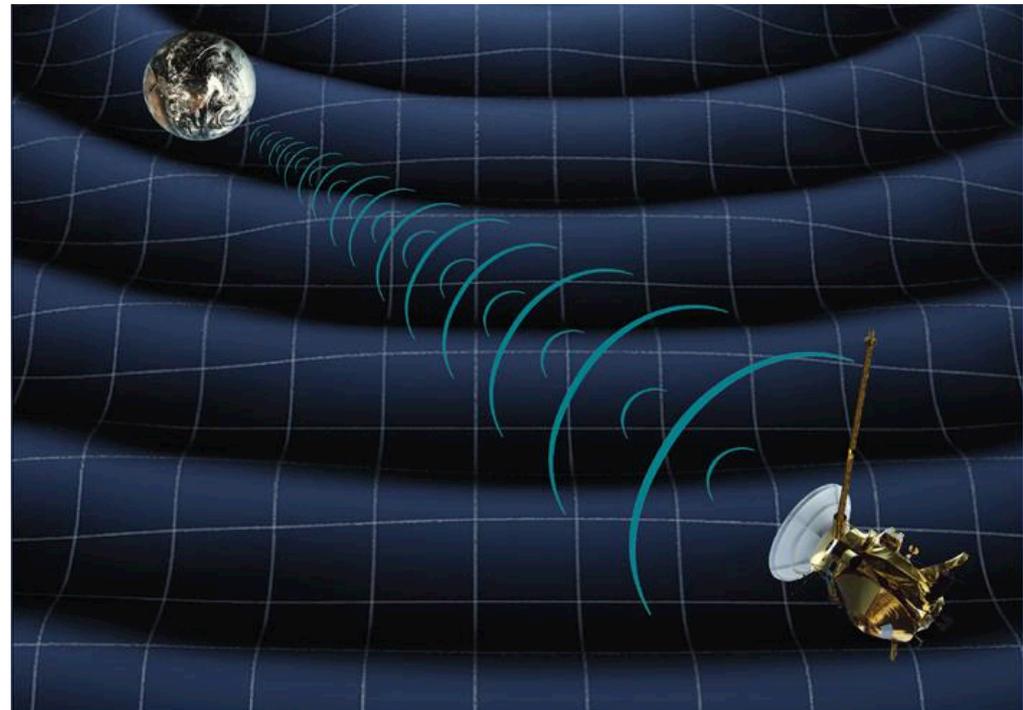
What about Europa?

Spacecraft Tracking and Gravitational Waves



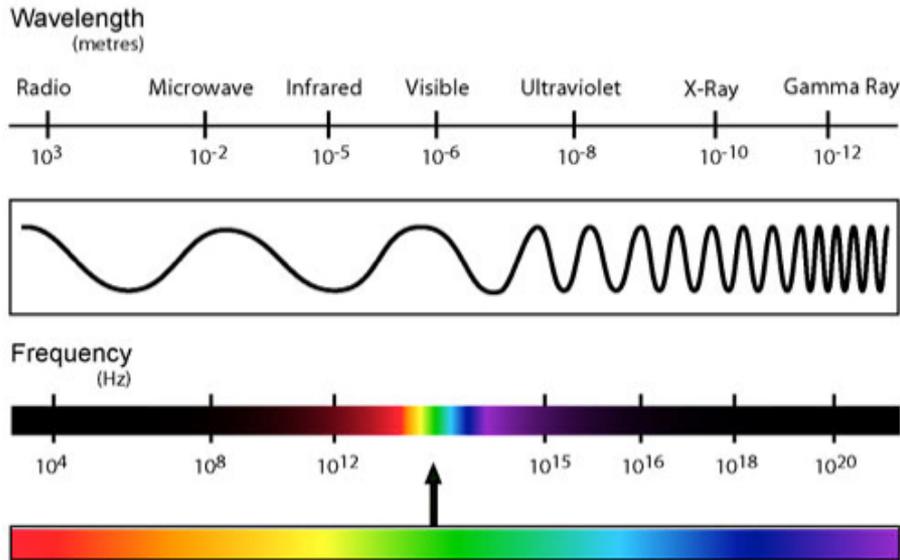
Spacecraft-Earth forms gravitational wave detector

- First suggested by Estabrook & Wahlquist (1975), both JPL
- DSN has long history --- Pioneer, Viking, *Cassini*
- DSN-*Cassini* limits $\sim 1000 \times$ better than previously obtained

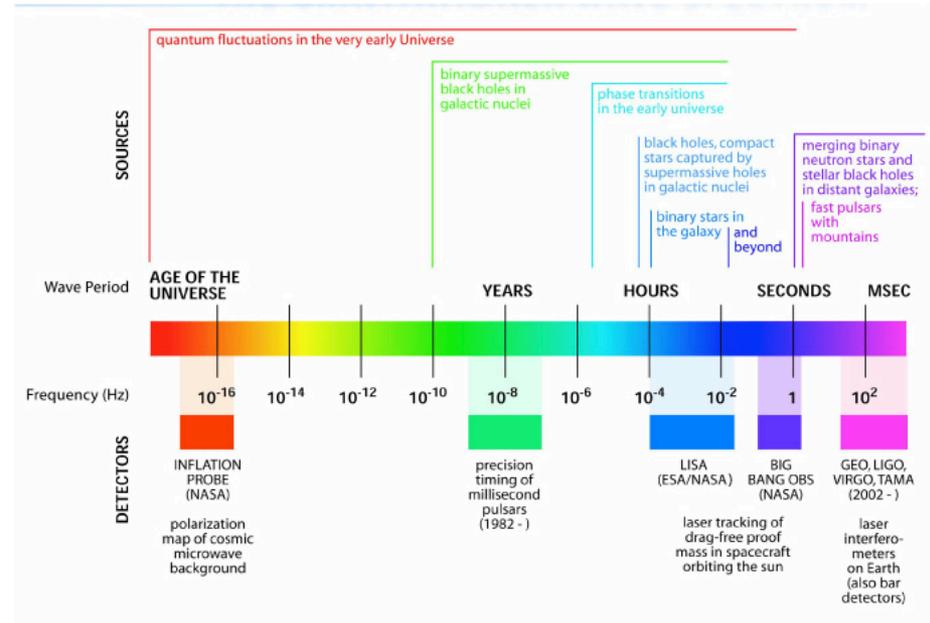


Gravitational Waves

Electromagnetic Spectrum



Gravitational Wave Spectrum

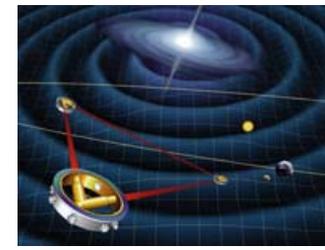
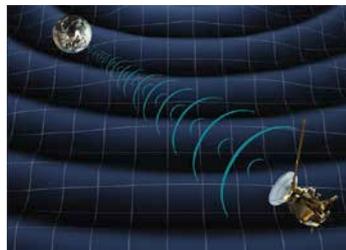
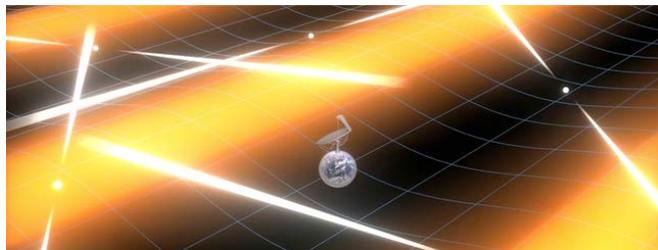
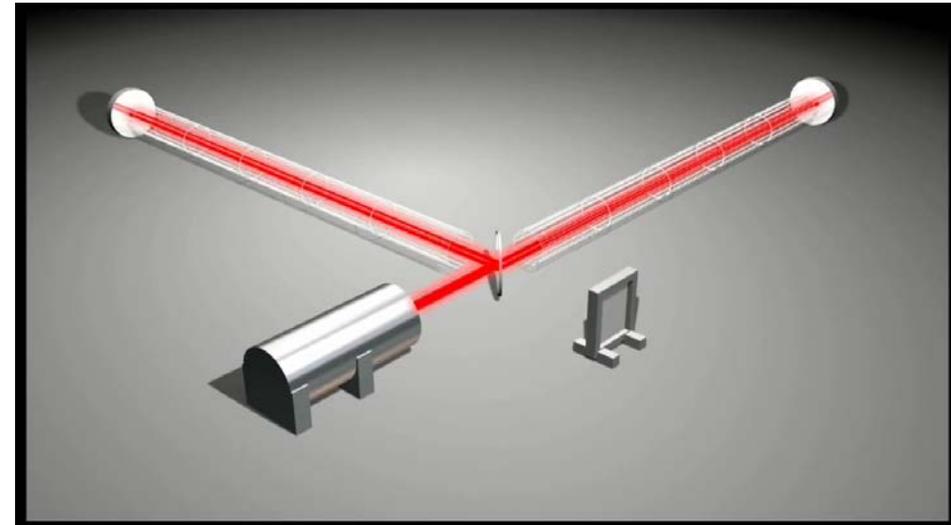


Gravitational Wave Detectors



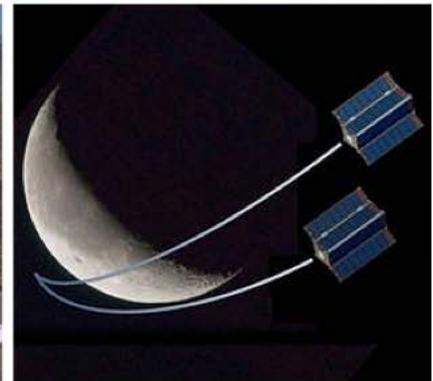
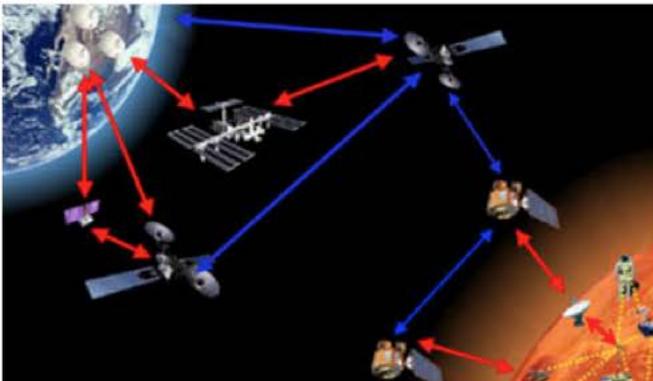
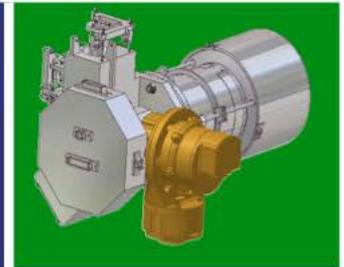
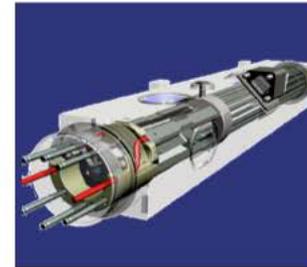
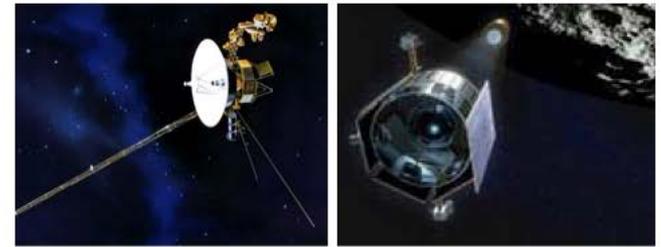
All modern gravitational wave detectors use same principle

- Gravitational wave modifies distance (a.k.a. spacetime metric)
- Measure distances between collection of objects (test masses)
- Changes result from passing gravitational waves



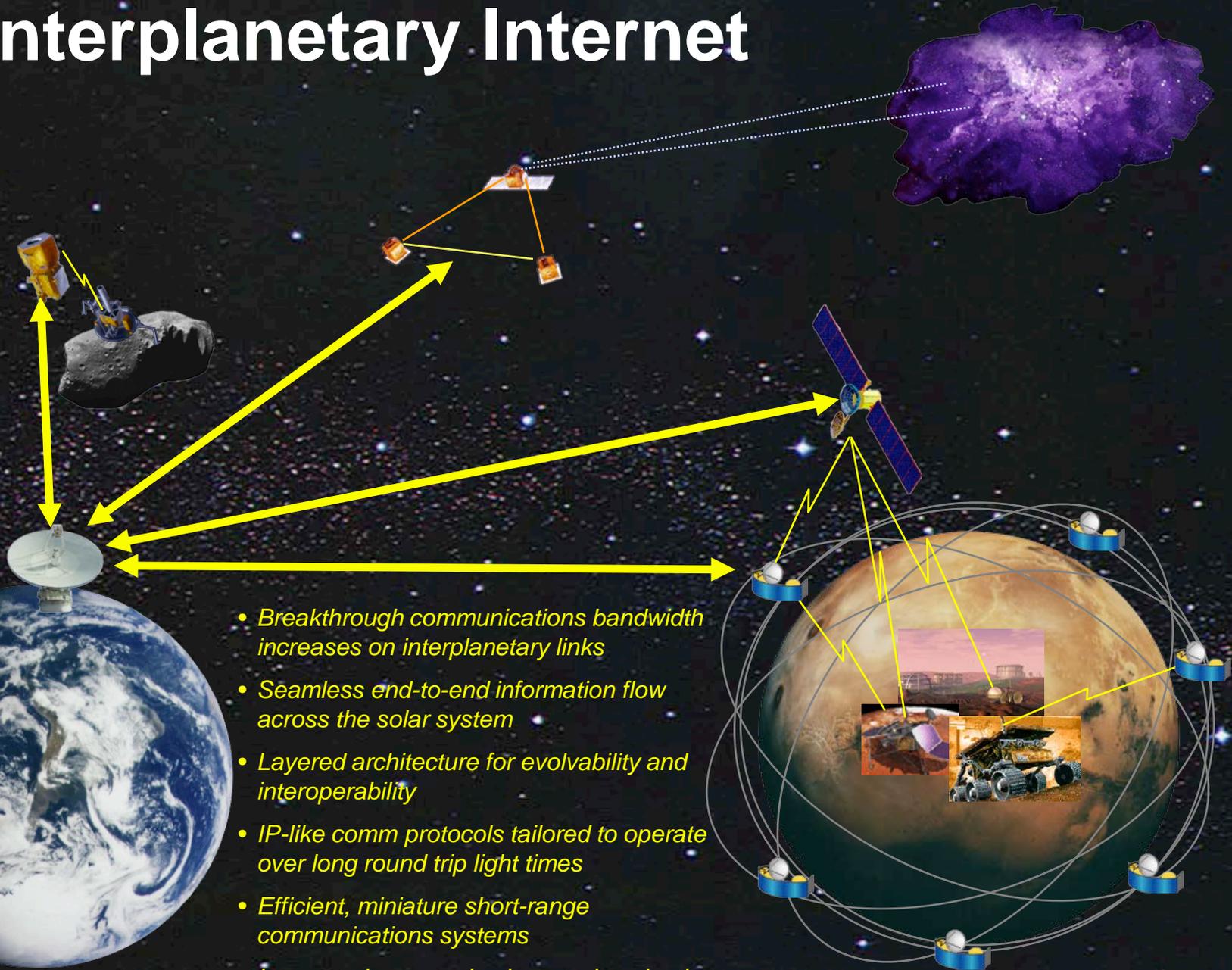
Mars Relay Network

Chad Edwards
Chief Telecommunications Engineer
Mars Exploration Directorate
Jet Propulsion Laboratory

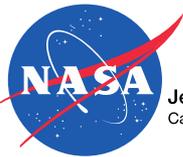




Interplanetary Internet

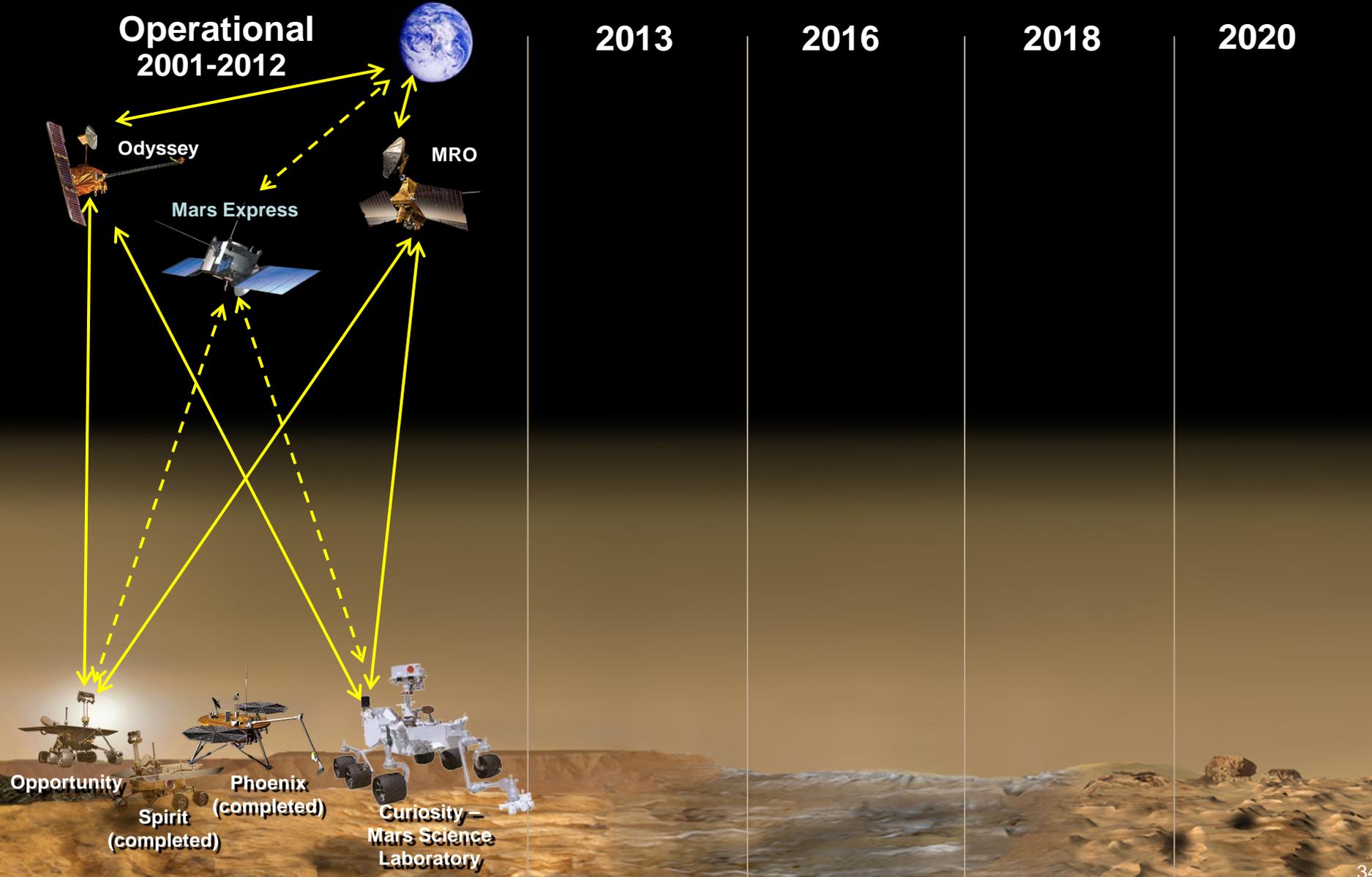


- *Breakthrough communications bandwidth increases on interplanetary links*
- *Seamless end-to-end information flow across the solar system*
- *Layered architecture for evolvability and interoperability*
- *IP-like comm protocols tailored to operate over long round trip light times*
- *Efficient, miniature short-range communications systems*
- *Integrated communications and navigation services*



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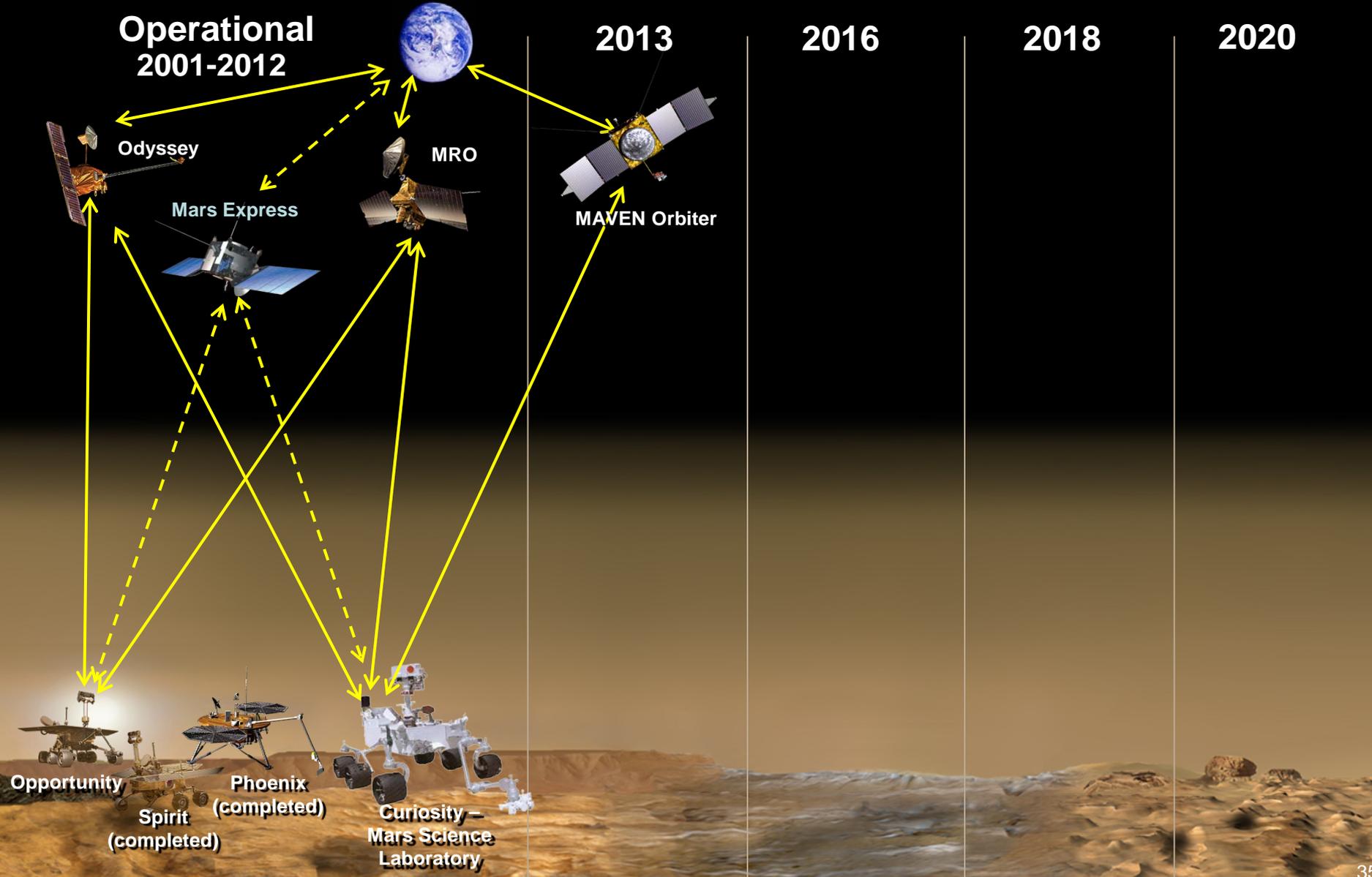
Mars Relay Network Evolution

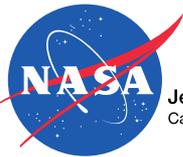




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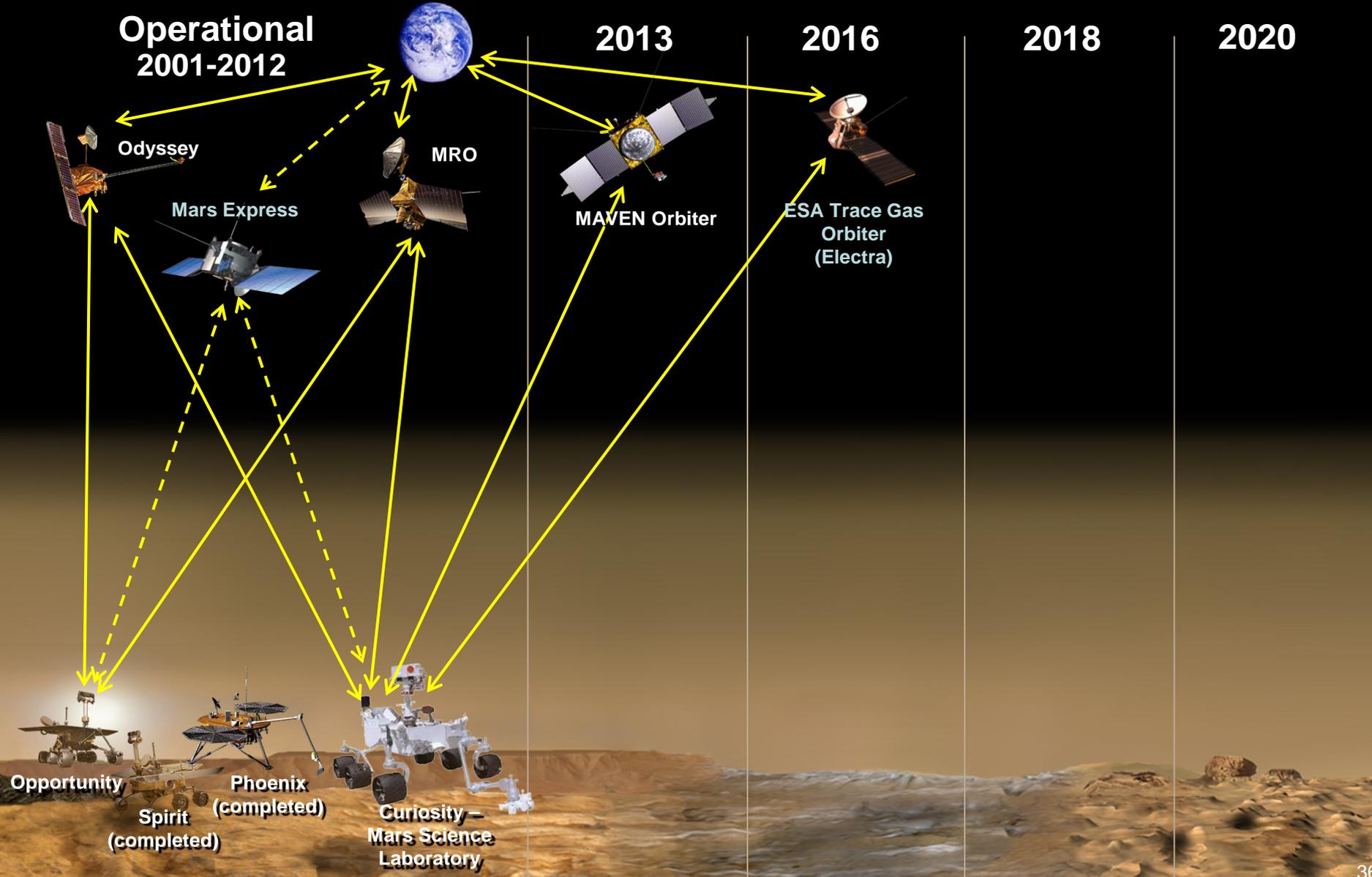
Mars Relay Network Evolution





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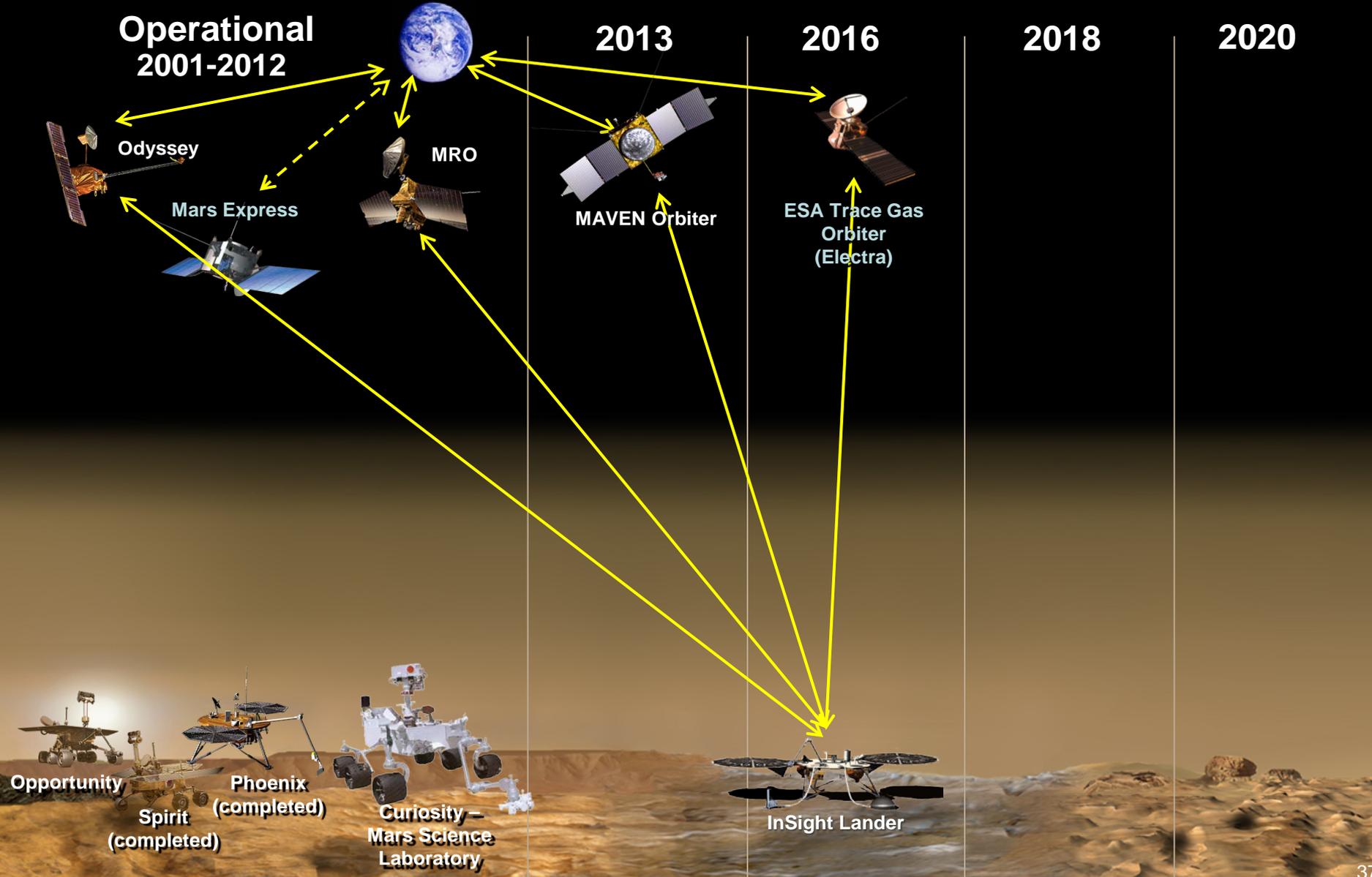
Mars Relay Network Evolution

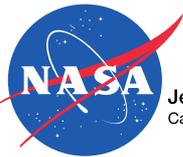




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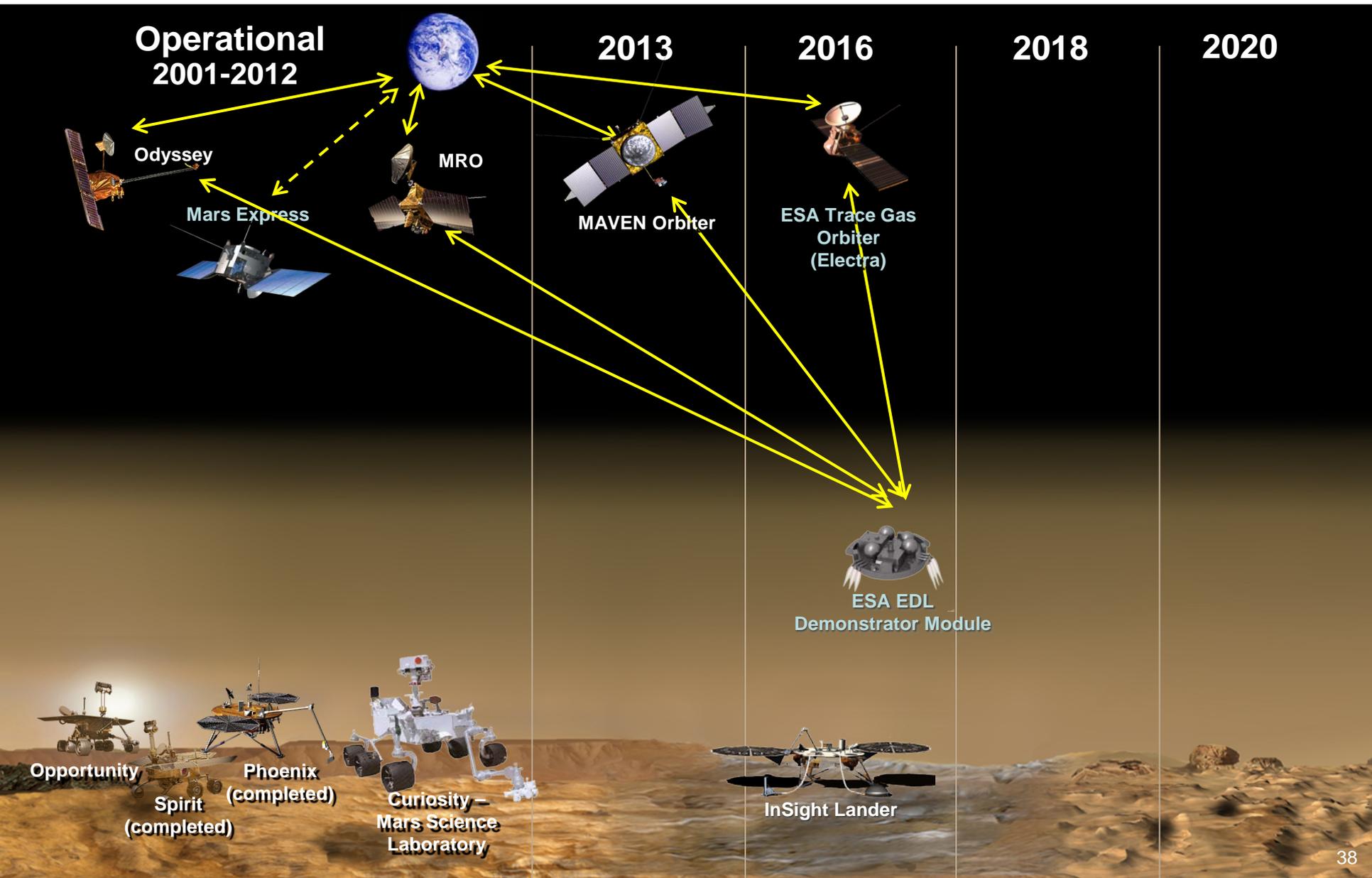
Mars Relay Network Evolution

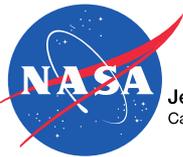




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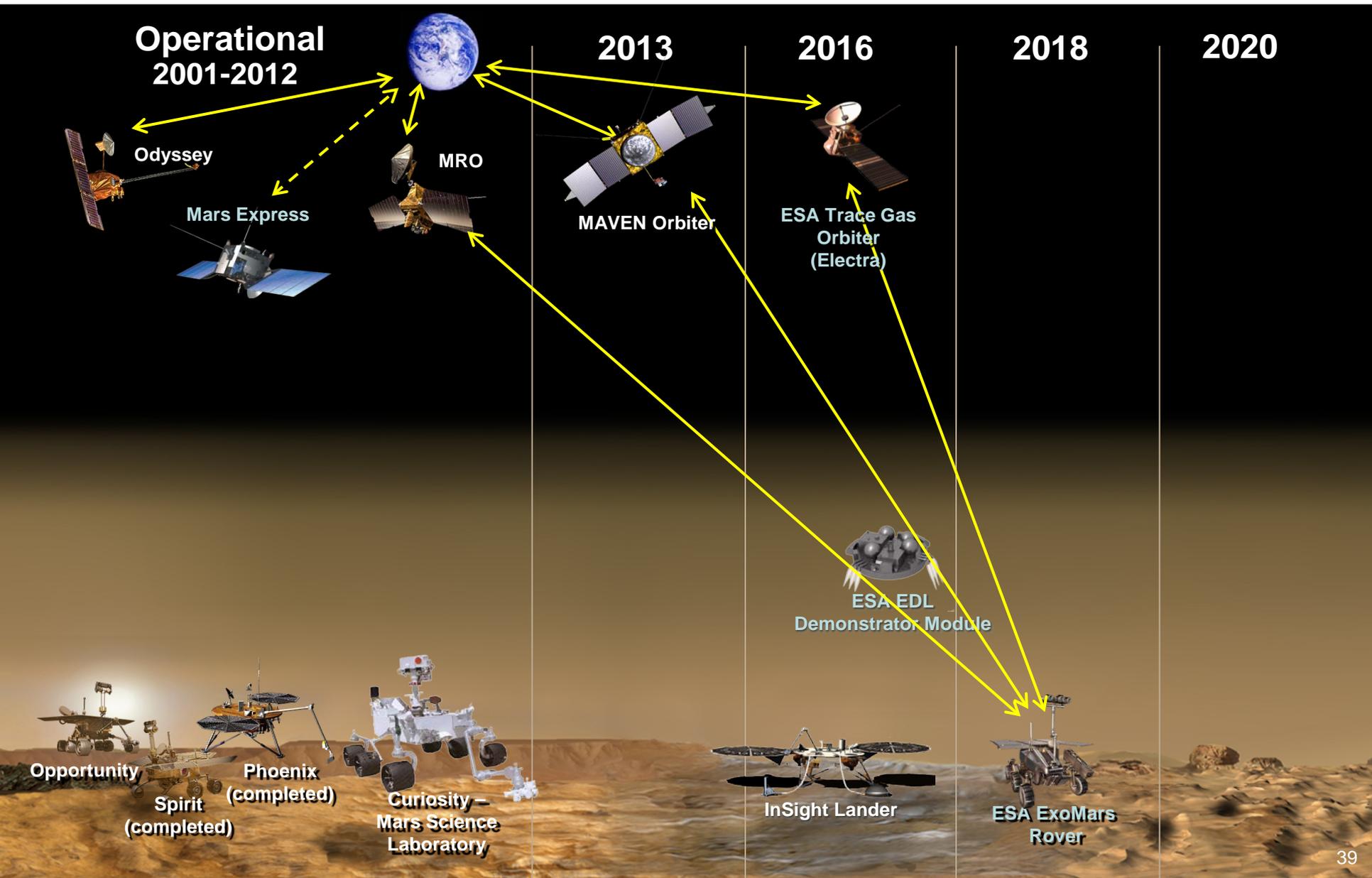
Mars Relay Network Evolution





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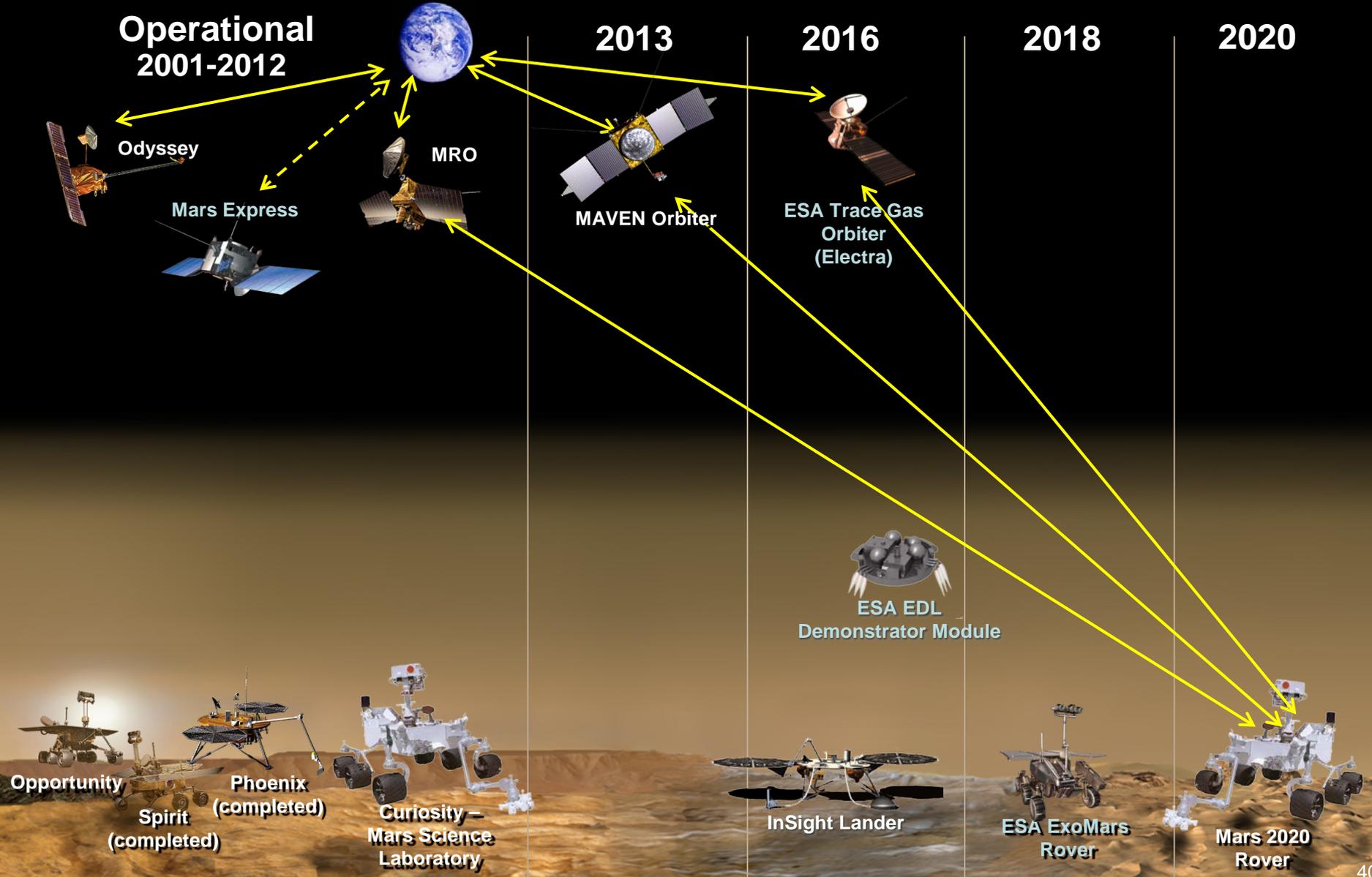
Mars Relay Network Evolution





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Mars Relay Network Evolution





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A Long-Term View: Human Mars Exploration

