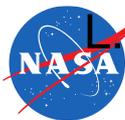




The Deep Space Network

Committee on the Review of Progress toward Implementing
the Decadal Survey Vision & Voyages for Planetary Sciences

Joseph Lazio



Benner, A. Bhanji, A. Biswas, W. Klipstein, S. Lichten, J. Statman, S. Townes
Jet Propulsion Laboratory
California Institute of Technology

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Government sponsorship acknowledged.

Deep Space Network

Topics

- Deep Space communications and navigation
- Planetary radar
- Future planning



Canberra



Goldstone



Madrid

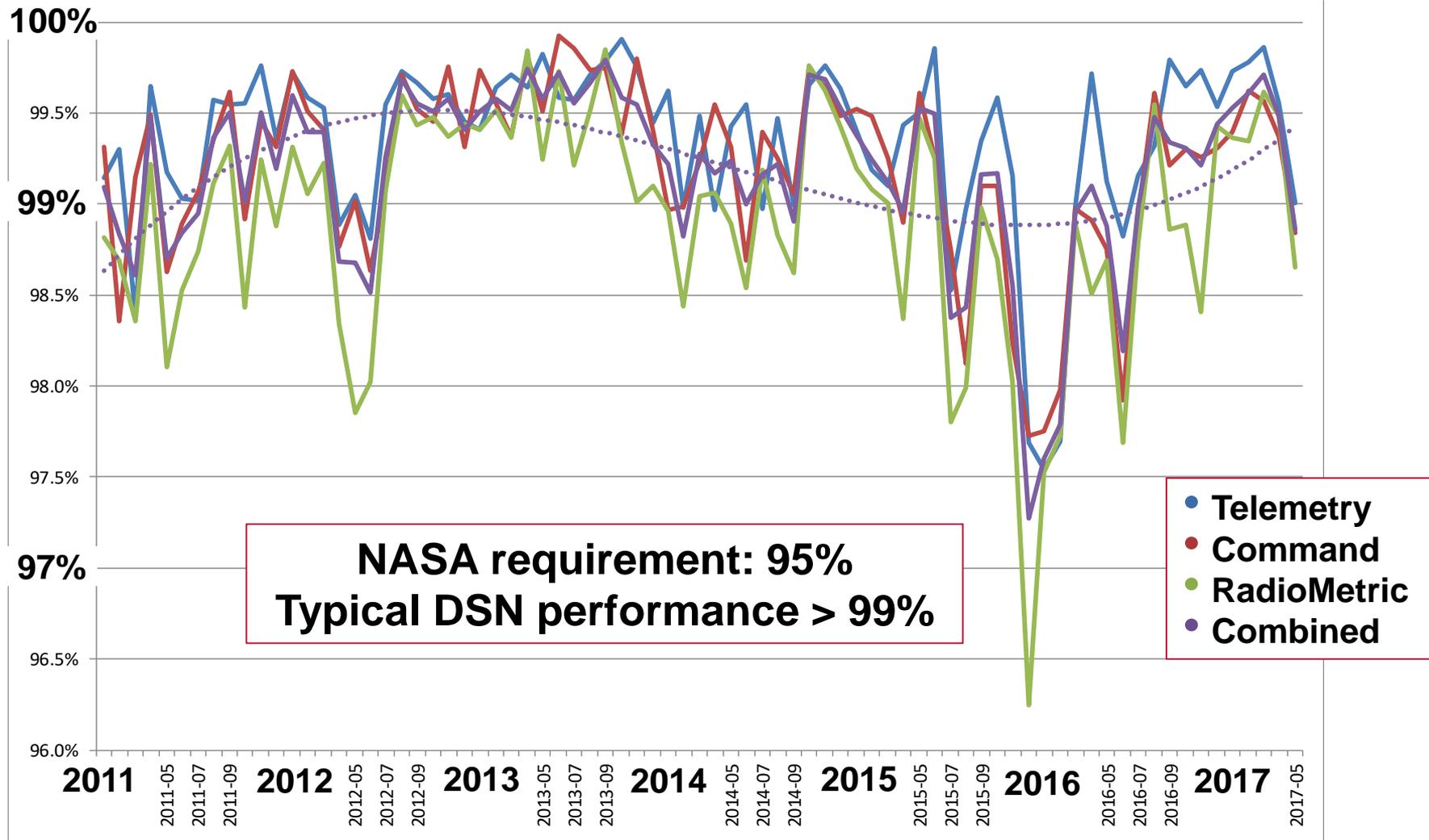
Planetary Sciences-DSN Partnership

Don't Leave Earth Without Us!

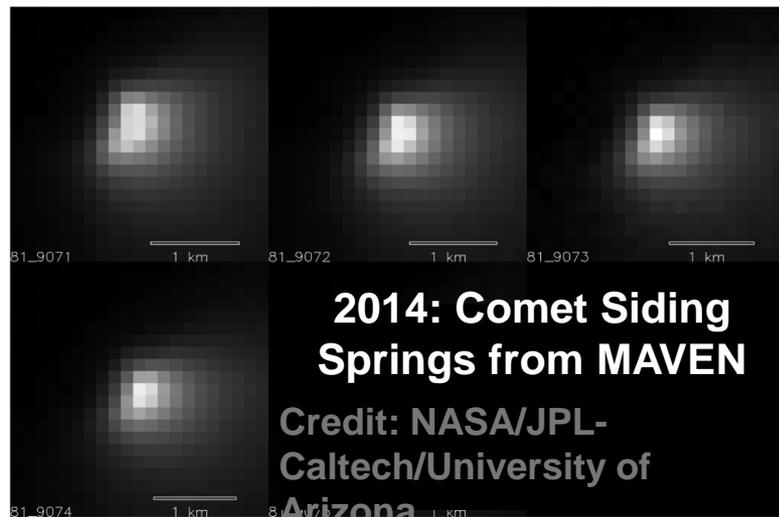


Telemetry, Tracking, & Command: 5 Year

Monthly Data, Averaged over All Missions



DSN and Planetary Science



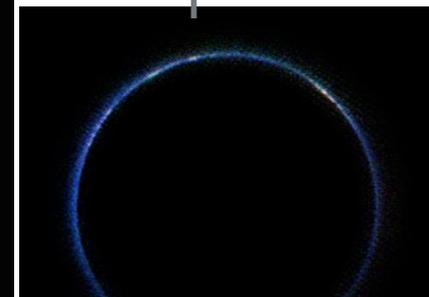
2014: Comet Siding Springs from MAVEN

Credit: NASA/JPL-Caltech/University of Arizona



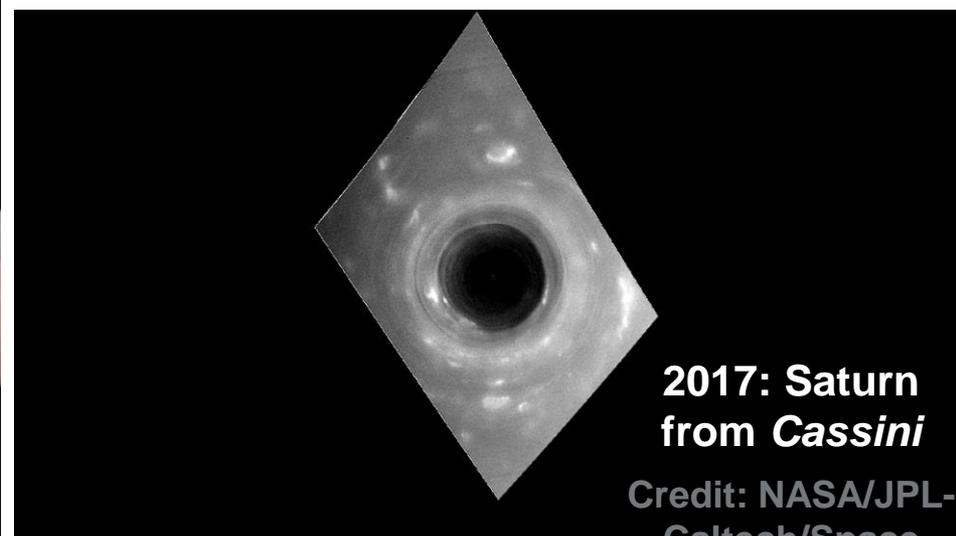
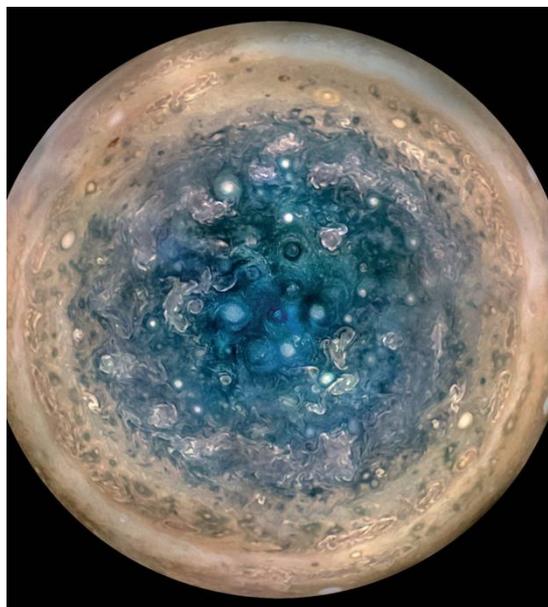
2015: Pluto from New Horizons

Credit: NASA/JHUAPL/SwR



2016: Jupiter from Juno

Credit: NASA/JPL-Caltech/SwRI/MSSS/Betsy Asher Hall/Gervasio Robles



2017: Saturn from Cassini

Credit: NASA/JPL-Caltech/Space Science Institute

Planetary Radar

The Primitive Bodies

Earth-Based Telescopes

The Arecibo and **Goldstone radar** telescopes are powerful, complementary facilities that can characterize the surface structure and three-dimensional shapes of the near-Earth objects within their reach of about one-tenth of the Earth-Sun distance. Arecibo has a sensitivity 20 times greater than Goldstone, but Goldstone has much greater sky coverage than Arecibo. Continued access to facilities for the detailed study of near-Earth objects is essential to primitive bodies studies.

National Radar Assets



Goldstone DSS-14 (DSN)
70 m antenna, 500 kW
transmitter, 4 cm
wavelength (X band)



Arecibo (NAIC)
300 m antenna, 1 MW
transmitter, 13 cm
wavelength (S band)

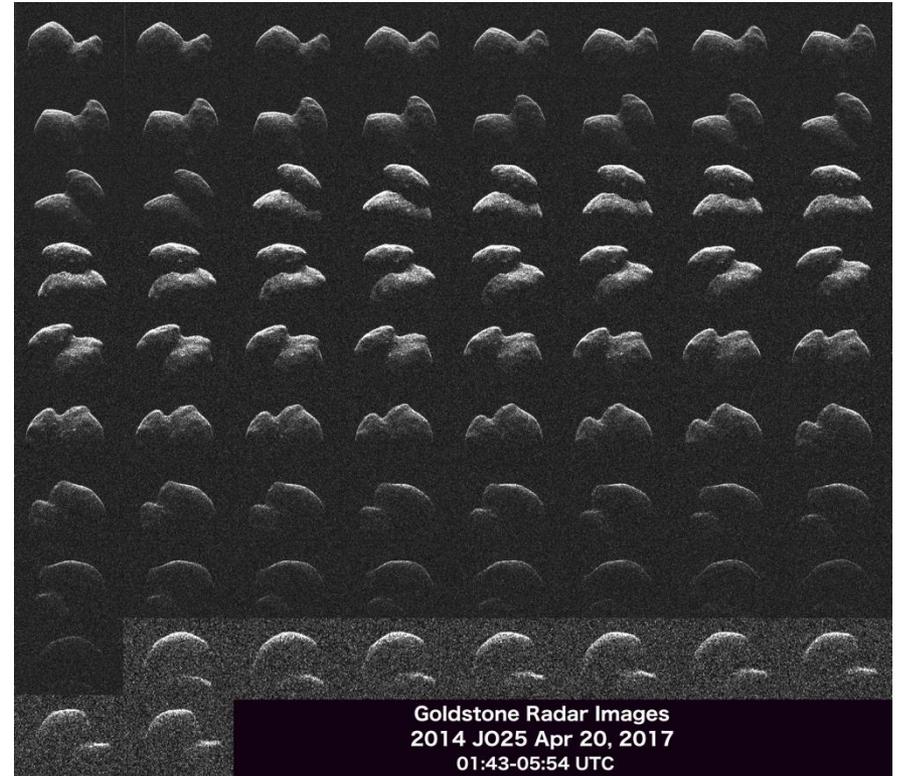


**Green Bank Telescope
(GBO)**
100 m antenna, no
transmitter

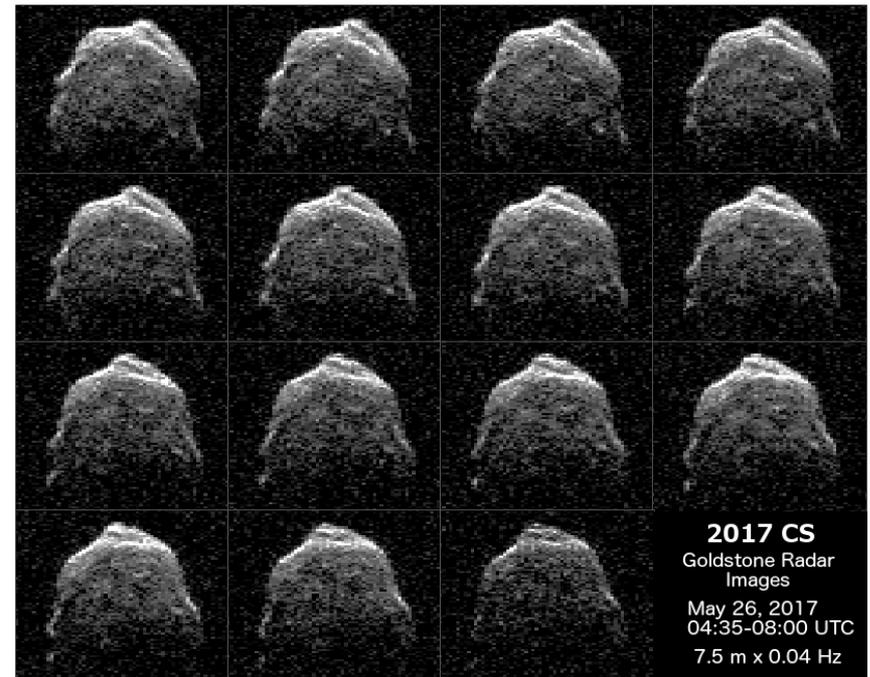
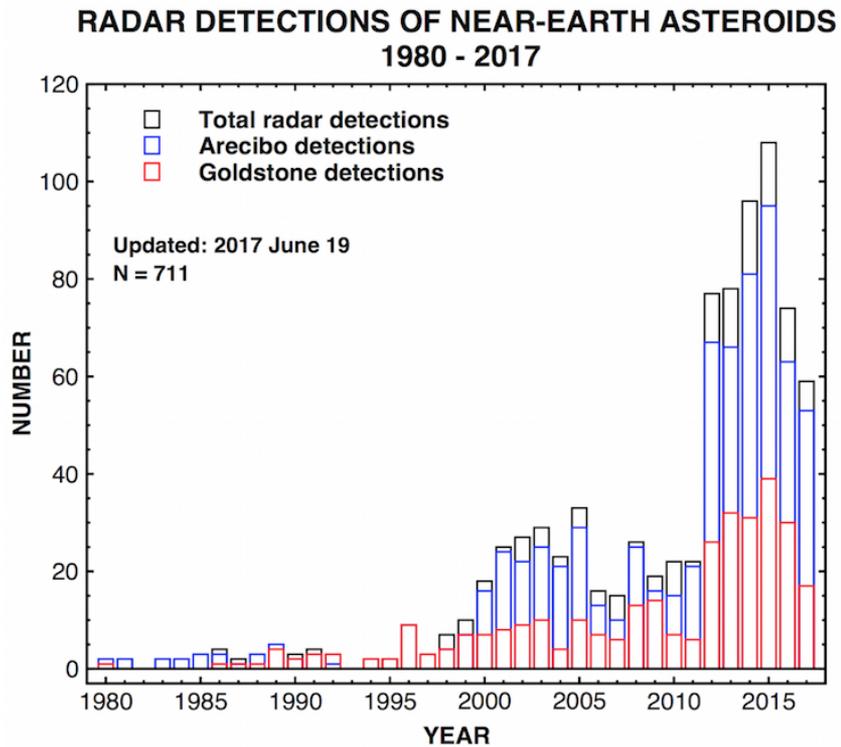
Goldstone Solar System Radar



**DSS-14: 70 m antenna at Goldstone
Deep Space Communications
Complex**



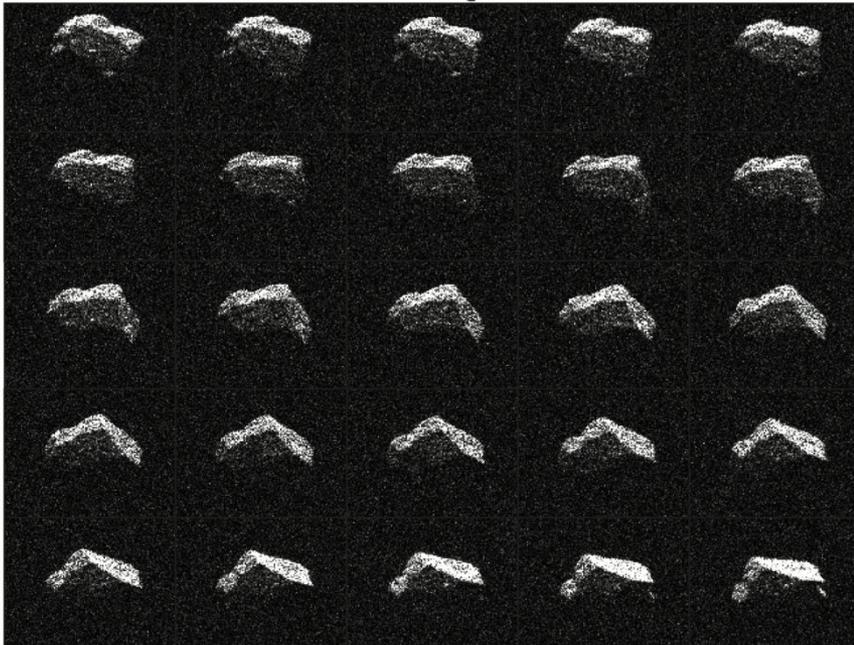
Goldstone Solar System Radar



Goldstone Solar System Radar

2017 BQ6

3.75m x 0.07 Hz



Goldstone Radar Images
Feb 7, 2017 04:39-05:50 UTC



New klystron!

Vision and Voyages for Planetary Science in the Decade 2013-2022

The Deep Space Network

“The DSN is a critical element of NASA’s solar system exploration program. It is the only asset available for communications with missions to the outer solar system, and is heavily subscribed by inner solar system missions as well. As instruments advance and larger data streams are expected over the coming decade, this capability must keep pace with the needs of the mission portfolio. Future demands on the DSN will be substantial. Missions to the distant outer solar system requires access to either 70-meter antennas or equivalent arrays of smaller antennae. The DSN must also be able to receive data from more than one mission at one station simultaneously. If arrays can only mimic the ability of one 70-meter station and nothing more, missions would still be downlink constrained and would have to compete against one another for limited downlink resources.

“Although Ka-band downlink has a clear capacity advantage, there is a need to maintain multiple band downlink capability. For example, three-band telemetry during outer planet atmospheric occultations allows sounding of different pressure depths within the atmosphere. In addition, S-band is required for communications from Venus during probe, balloon, lander, and orbit insertion operations where other bands cannot penetrate the atmosphere. X-band capability is required for communication through the atmosphere of Titan, and also for emergency spacecraft communications. **The committee recommends that all three DSN complexes should maintain high power uplink capability in X and Ka-band, and downlink capability in S, Ka, and X-bands. NASA should expand DSN capacities to meet the navigation and communication requirements of missions recommended by this decadal survey, with adequate margins.**

2020--2021 Mars Contention Period Planning

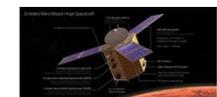
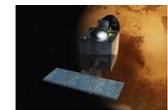
New Mars missions launch in mid-2020 and arrive in early 2021
~ 8-week window

Current Mars Missions

- TGO 2016 (orbiter) – operating
- MAVEN (orbiter) – operating
- Curiosity (rover) – operating
- InSIGHT (lander) – operating
- MRO (orbiter) – likely operating
- MOM-1 (orbiter) – likely operating
- MER (rover) – possibly operating
- ODY (orbiter) – possibly operating
- MEX (orbiter) – possibly operating?

2020--2021 New Mars Missions with DSN Support

- NASA Mars 2020 (Rover) (EDL)
- ESA ExoMars Rover and Surface Platform (RSP) (EDL)
- SpaceX Red Dragon lander 1 (EDL)
- *SpaceX Red Dragon lander 2 (EDL)*
- ISRO MOM-2 orbiter (MOI)
- UAE EMM orbiter (MOI)

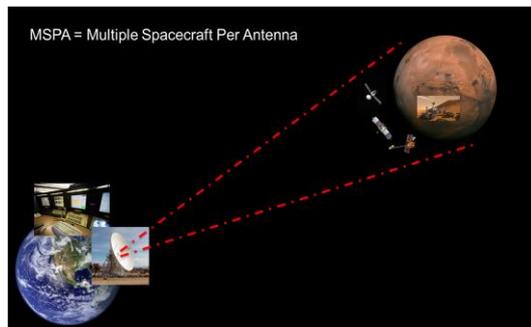


2020--2021 Mars Contention Period Planning

Preliminary Findings I

Deep Space Network will be supporting unprecedented volume of missions and data at one planetary body

- **DSN planning for Mars and 30+ non-Mars missions**
- **Longer term impacts from Mars mission “surge” persists**
 - Does not “go away” later --- overall mission load increased
- **Mitigating actions also long-term strategies: in 2020s--2030s, growth in planetary, crewed missions expected to continue ...**



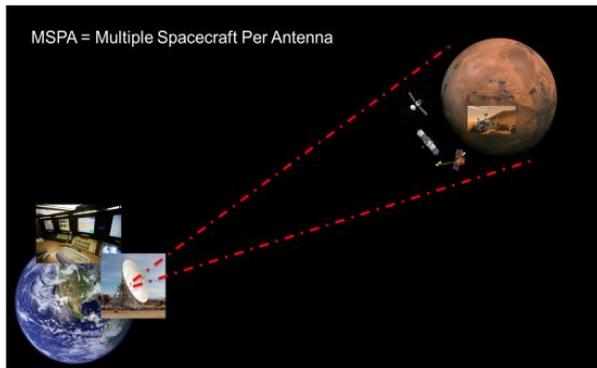
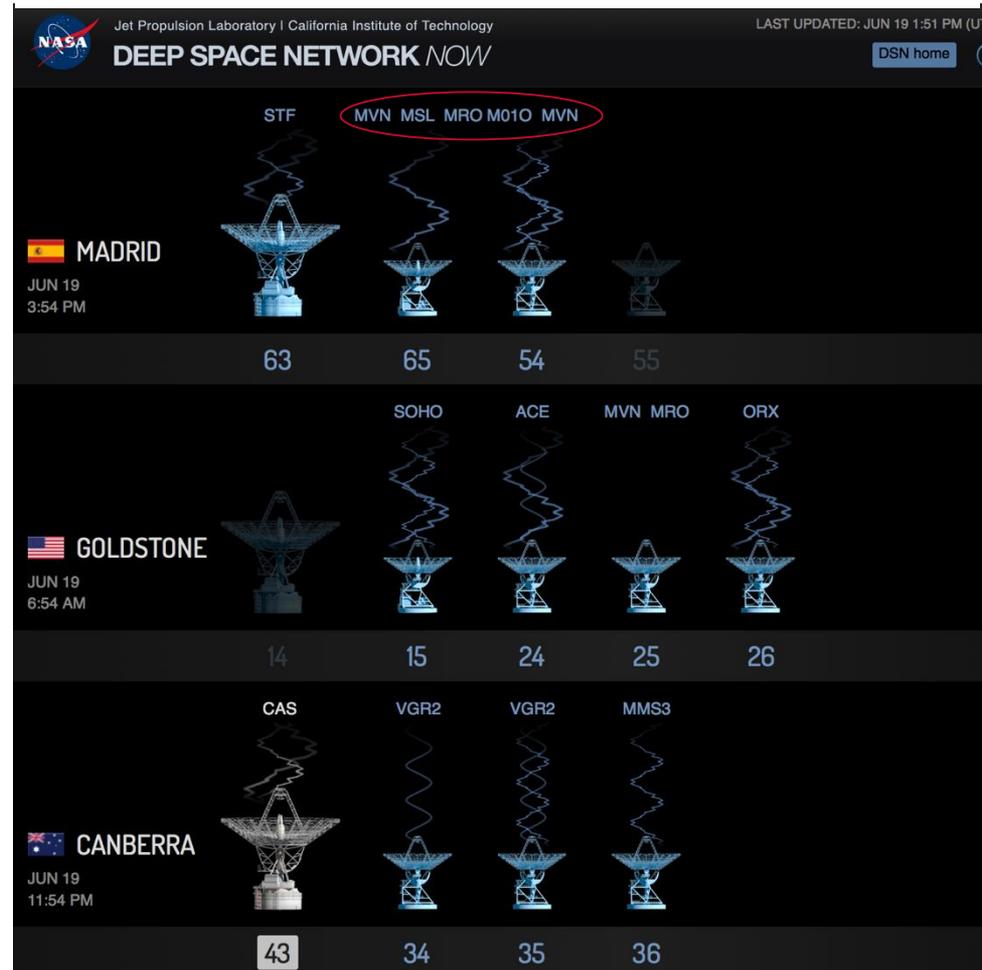
DSN Futures

Mitigation and Strategy I

Maximize use of Multiple Spacecraft Per Aperture (MSPA)

- up to four at once (downlink)
- Investigating multiple uplink per aperture
Likely requires changes to on-board radios

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



DSN Futures

Mitigation and Strategy II

DSN Aperture Enhancement Project

- DSN identified efficiencies to enable construction of additional 34 m antennas
- Provides multiple mission coverage at each Complex
- Addressing Decadal Survey recommendation

Maximize use of non-DSN large antennas

ESA, Sardinia, JAXA, ISRO,
Morehead State

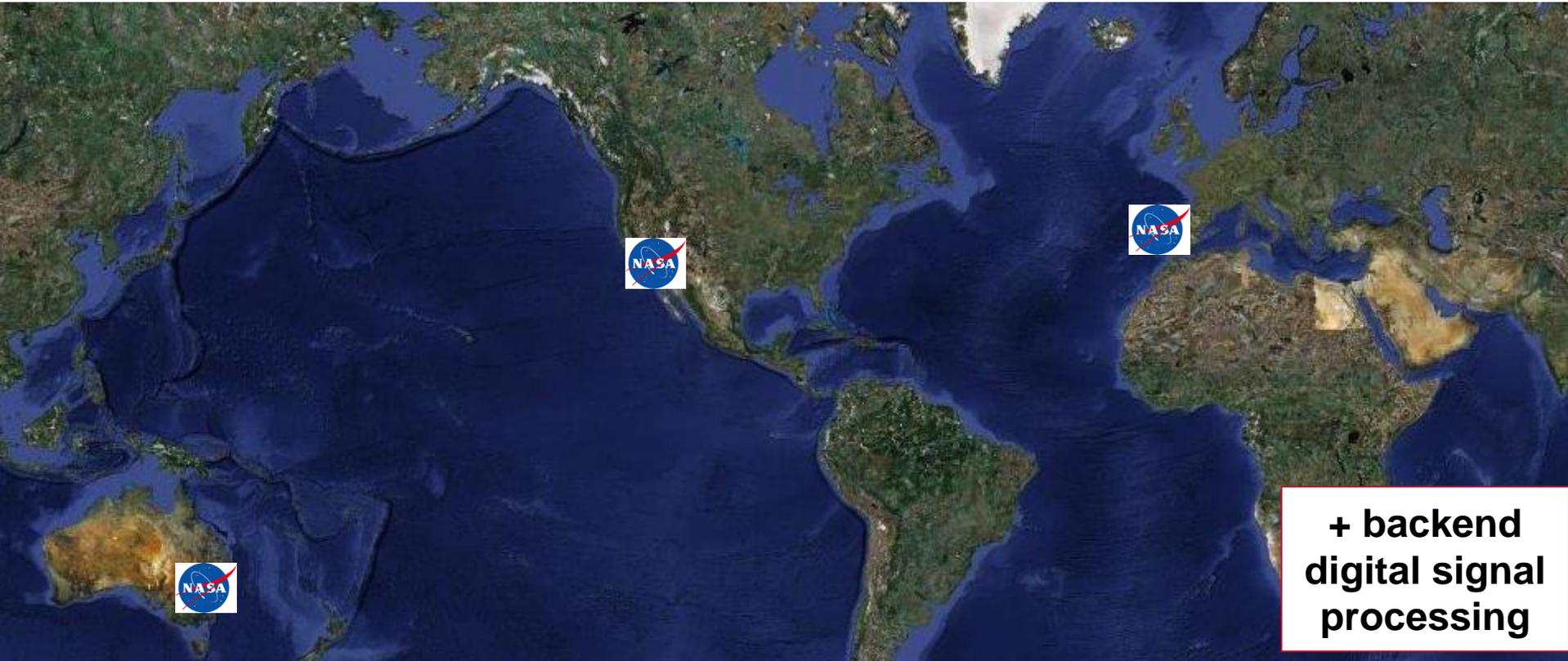


DSS-56 foundation
in Madrid



Deep Space Network

DSN Aperture Enhancement Project (through 2025)



Canberra



Goldstone



Madrid

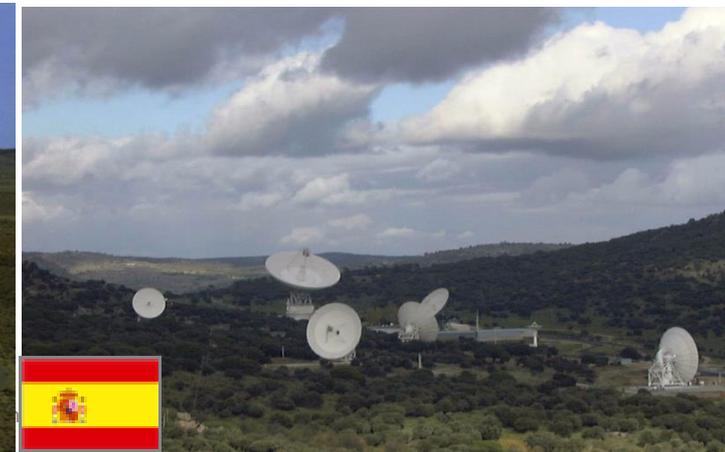
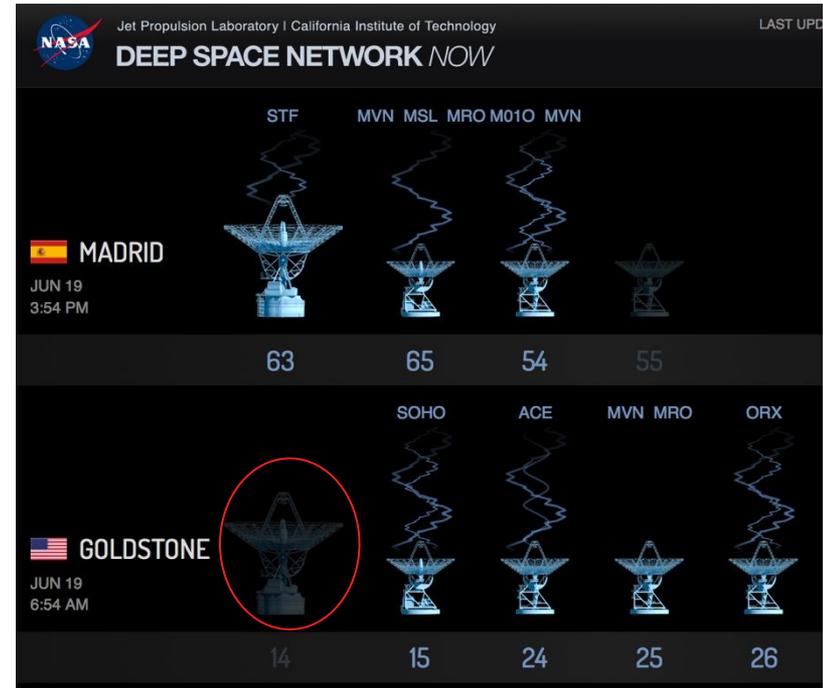
DSN Futures

Mitigation and Strategy III

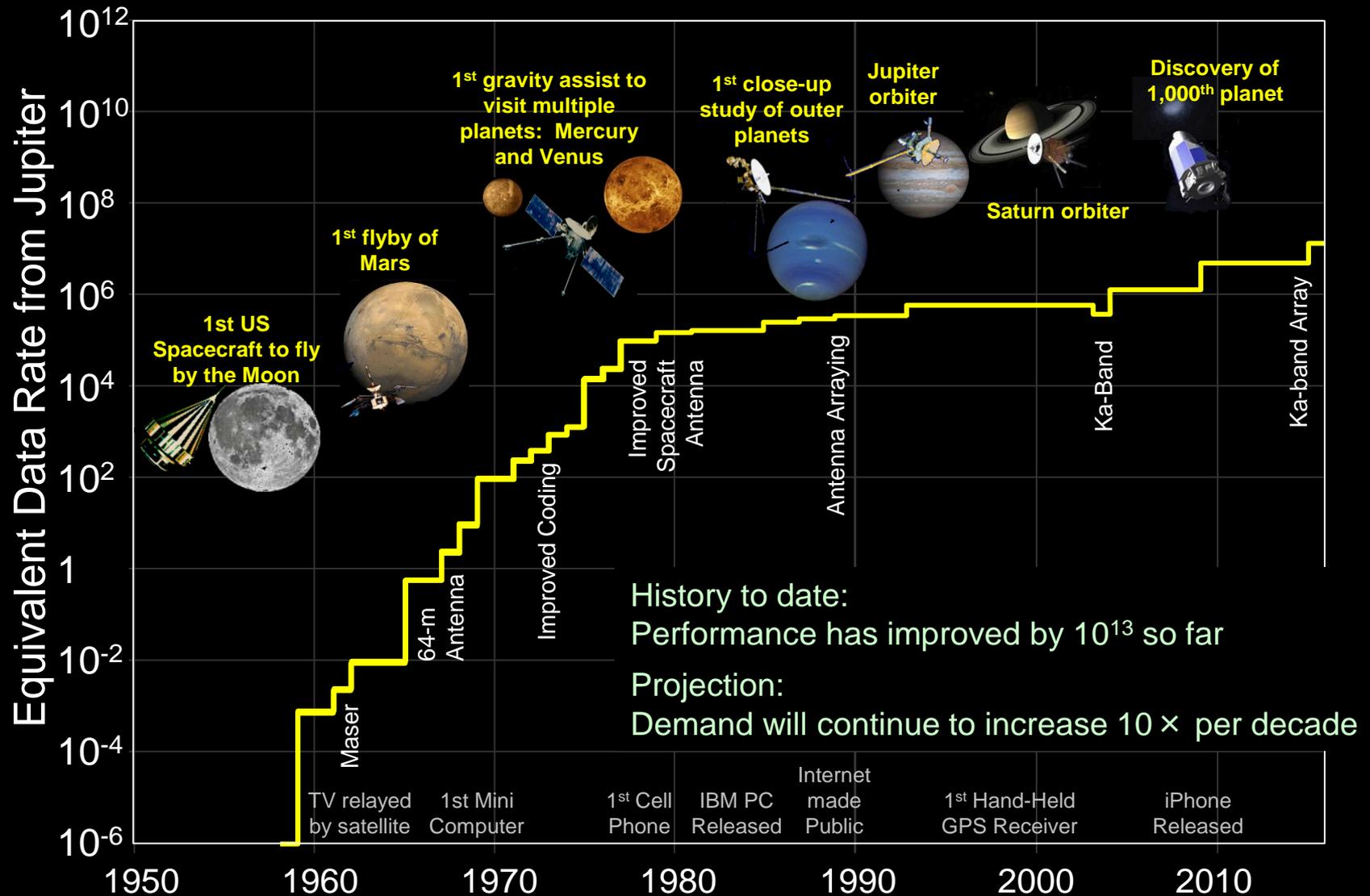
Modify maintenance schedule to maximize DSN availability during critical periods

(launches, Mars arrivals)

- **Accelerate some antennas, defer others**
cf. change car's oil before embarking on long road trip



History of Downlink Performance

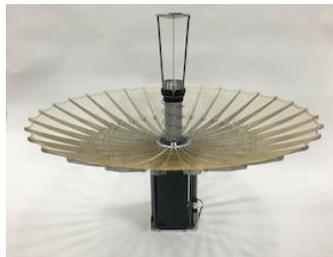


DSN Future Technologies



Solid-state power amplifiers for higher uplink rates

New, software-defined radios, associated technologies
Including for smallsats

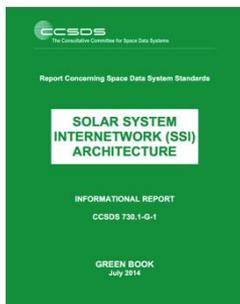


Next-generation clocks

Standards for cross-agency support and interaction



Quantum communications?



Decade 0--1: 10× Improvements over Today

Vision for the DSN's Future

Make upgrades to enhance future Mars orbiter relay capabilities

... and other spacecraft

- On-board → software-defined radios
 - Universal Space Transponder (UST)
 - Iris smallsat transponder
- On the ground
 - Common Platform signal processor
- On board and ground → Ka band



Universal Space Transponder (UST)



new digital backends

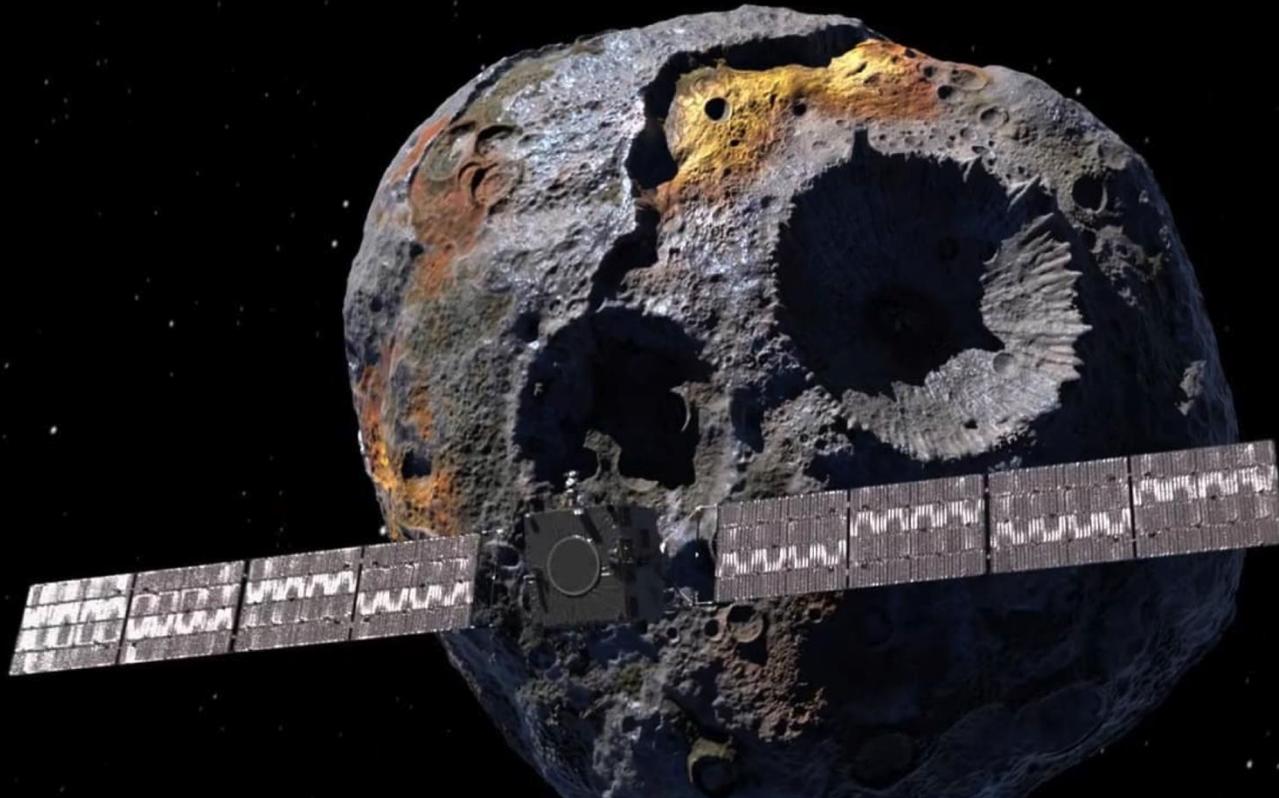
Decade 2+: 100× Improvements over Today

Vision for the DSN's Future



Psyche: Journey to a Metal World

from School of Earth & Space



Decade 2+: 100× Improvement over Today

Vision for the DSN's Future

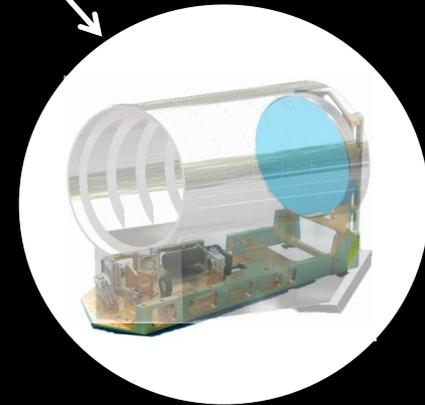
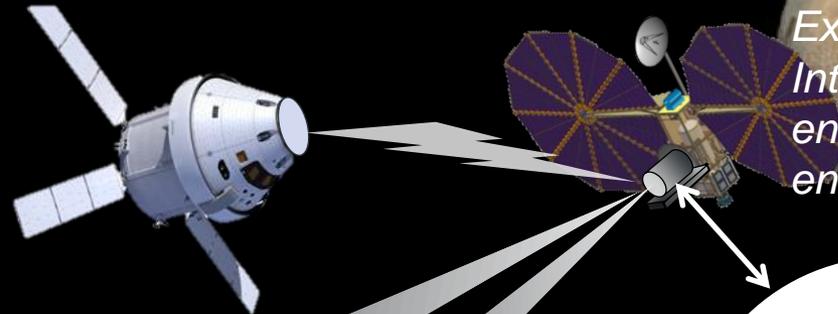
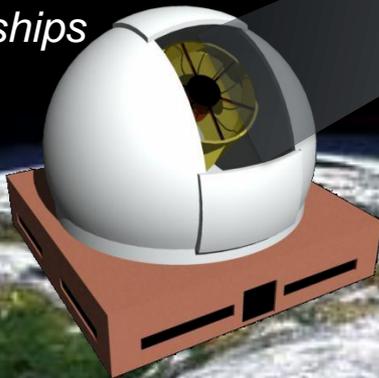
Human and robotic users
*100× today's data rates
from Mars – up to 1 Gbps*

Dedicated
Comm Relays
*Extend the
Internet to Mars,
enabling public
engagement*

Dedicated 12m
Stations
*NASA + International
partnerships*

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

High Performance
Optical Terminal:
*To be demonstrated
on Psyche*



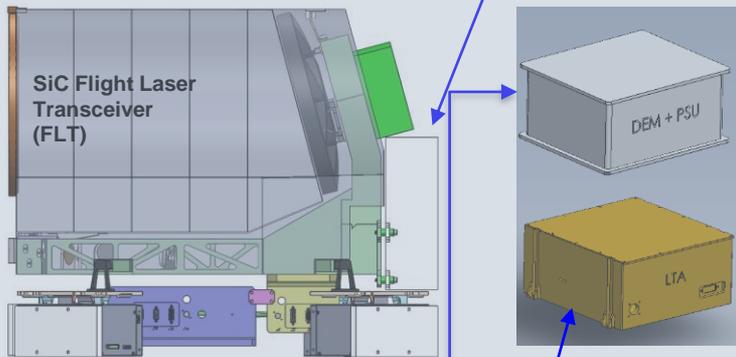
DSOC Technologies & Advances

FLIGHT LASER TRANSCEIVER (FLT)

Aluminum Optical Transceiver Assembly



Photon-Counting Camera



Point-Ahead Mirror



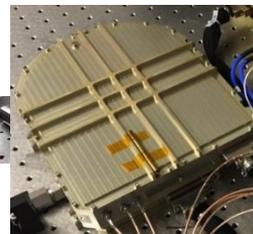
Single strut photo



Isolation Pointing Assembly

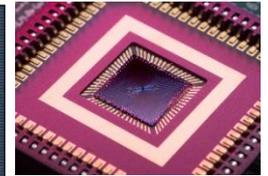


flight-like electronics



Laser Transmitter
Average Power 4 W

GROUND TECHNOLOGY



Packaged Nanowire Array

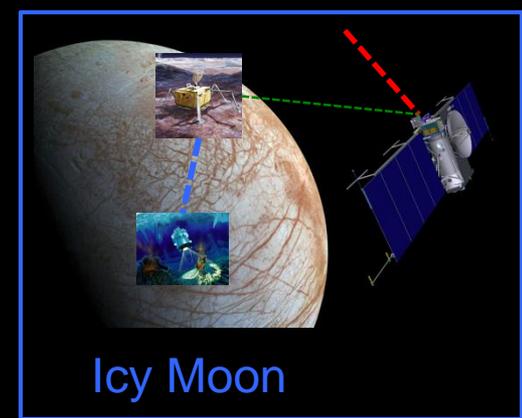
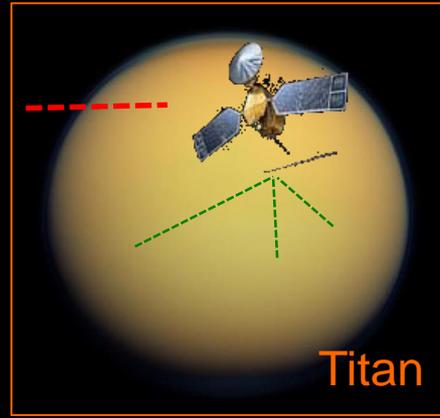
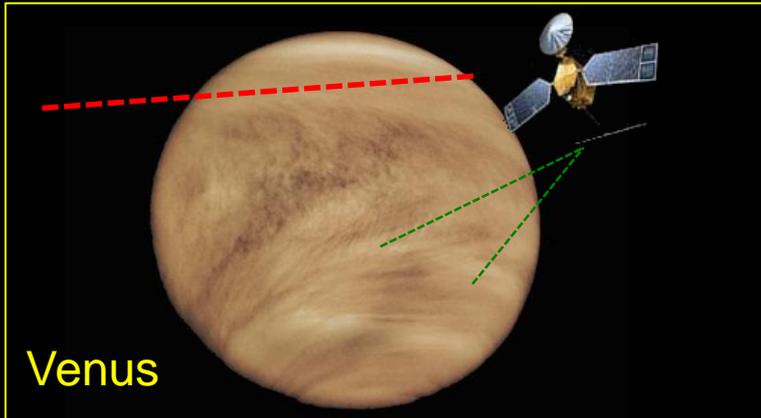
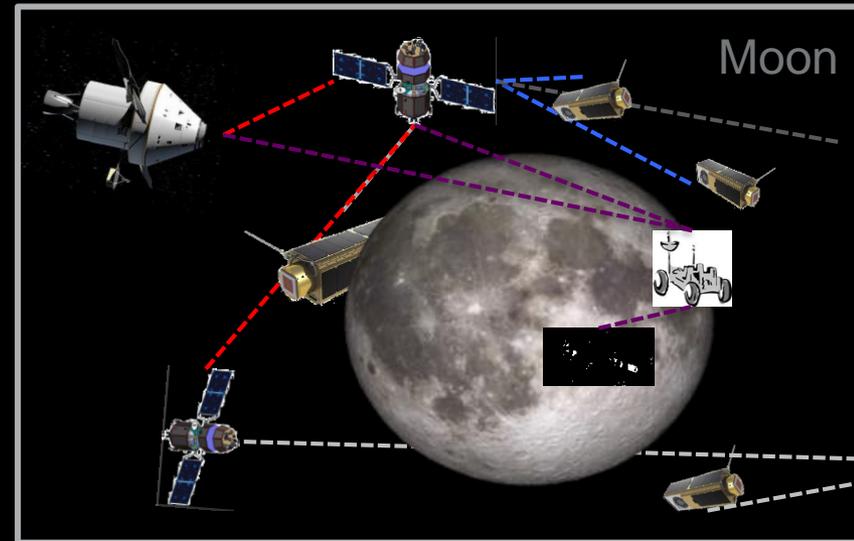
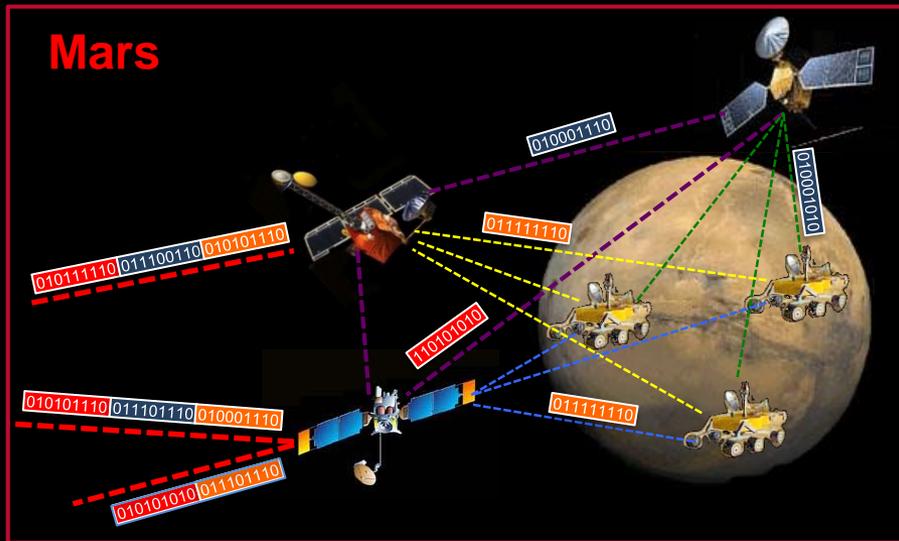
Electron microscope detail of 320 μm active area tungsten silicide (WSi) superconducting nanowire single photon detector (SNSPD) array



Palomar Observatory/Hale Telescope 5 m

The DSN and the Interplanetary Internet

Vision for the DSN's Future



The Deep Space Network



- ✓ Enabling 35+ missions
- ✓ Maintaining 99% reliability
- ✓ Radar contributing to planetary science and planetary defense
- ✓ Implementing strategies to continue performance into 2020s and beyond

