Deep Space Network (DSN) Update

NASA Planetary Science Advisory Committee (PAC) Meeting

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December 5, 2022

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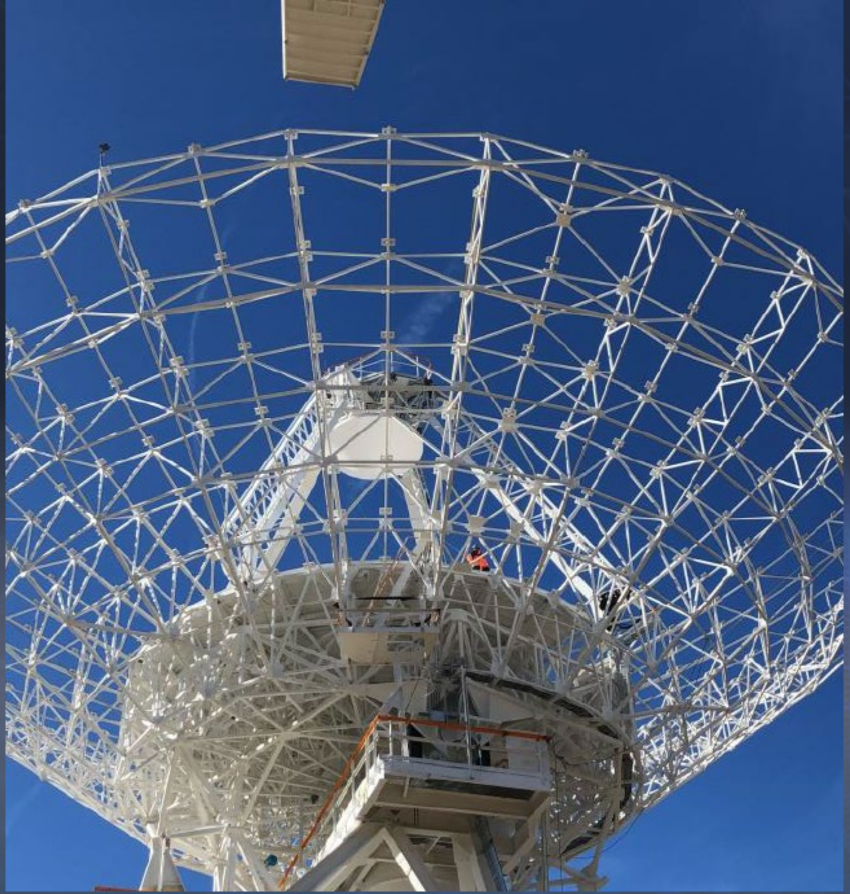
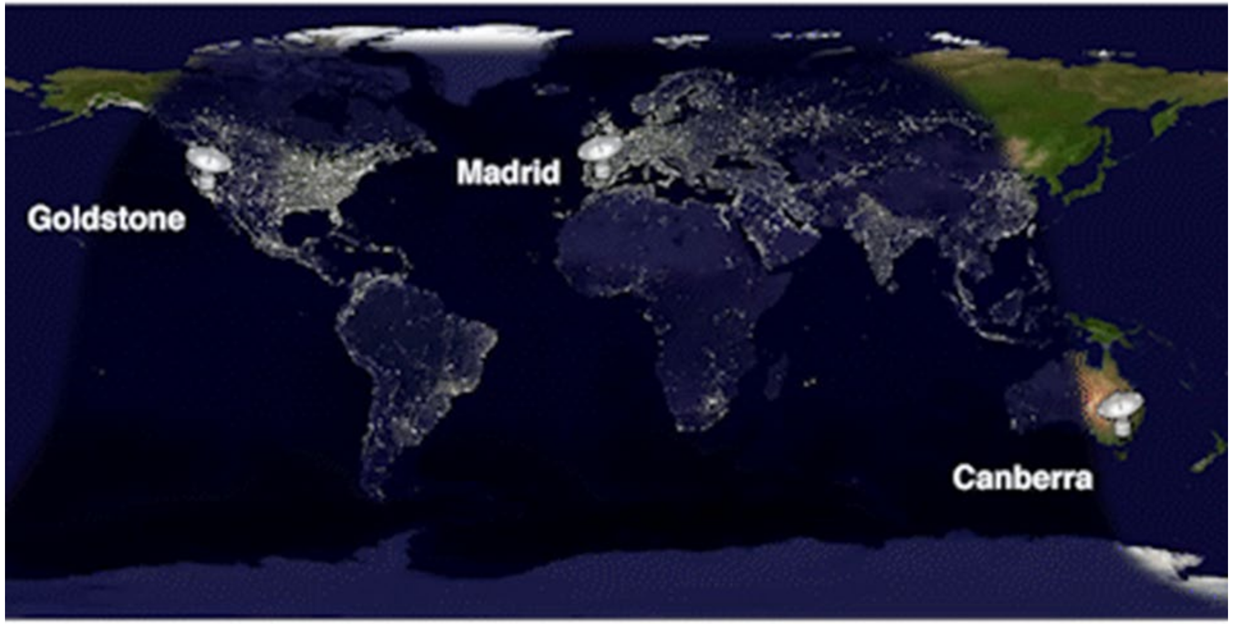


Deep Space Network Overview

Deep Space Network (DSN) Background

- NASA’s Deep Space Network (DSN) was established in December 1963 to provide a communications infrastructure for all of NASA’s robotic missions beyond Low Earth Orbit (LEO)
- The NASA Headquarters Space Operations Mission Directorate (SOMD) oversees the DSN through the SCaN Program
- Responsibility for development, operations, and management of the DSN is assigned to the Jet Propulsion Laboratory (JPL) Interplanetary Network Directorate (IND)
- The DSN’s prime responsibility is telecommunications for NASA missions, but its also supports many international spacecraft as well as scientific investigations through radio astronomy, radio science, and radar activities

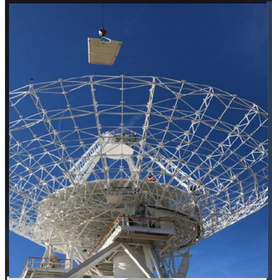


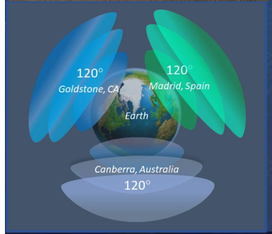
Canberra Deep Space Communications Complex, Australia

Goldstone Deep Space Communications Complex, California

Madrid Deep Space Communications Complex, Spain

Deep Space Network Users and Components



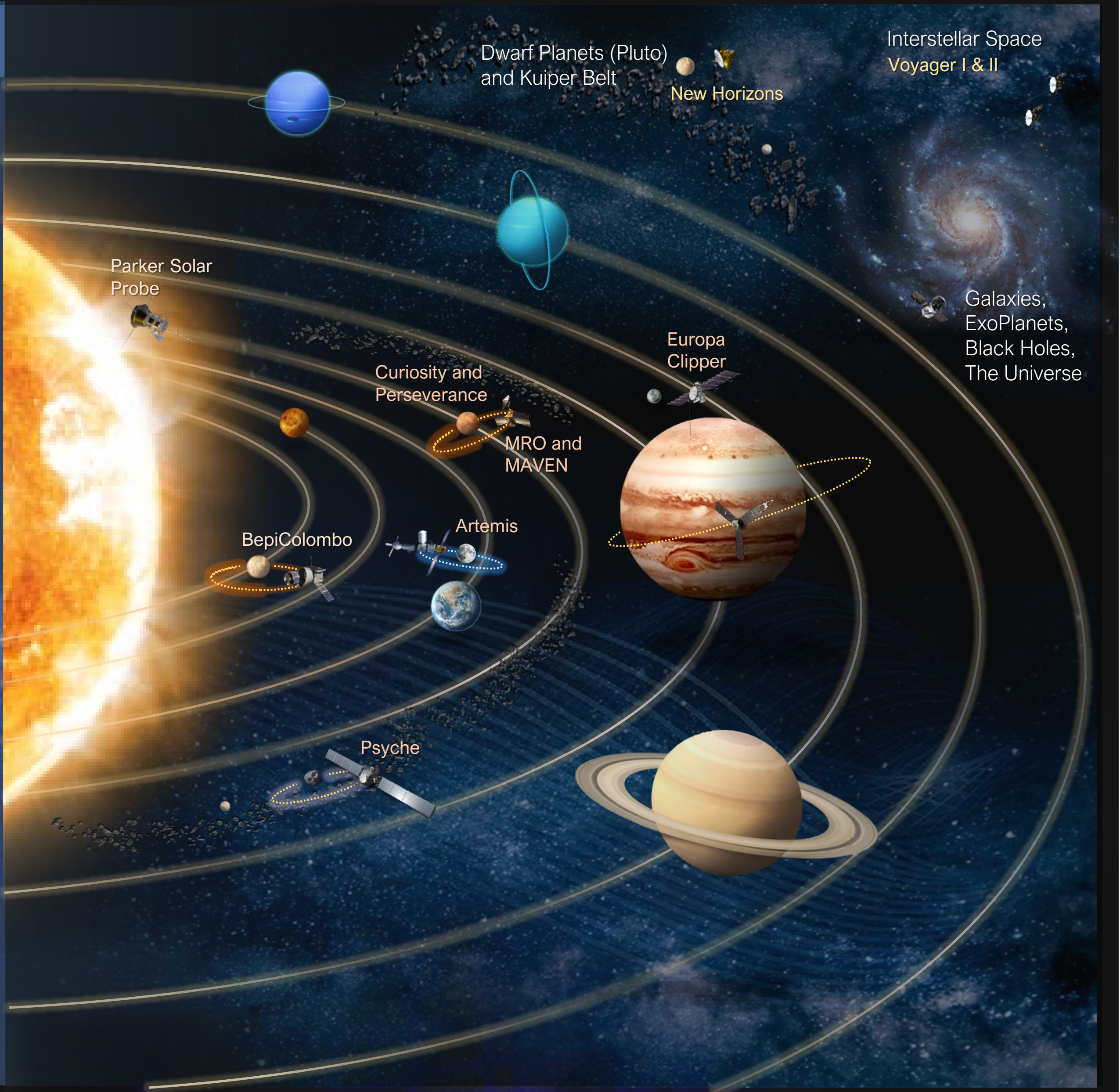


Deep Space Network — 98.5% FY21 Proficiency

- Consists of three deep-space communications facilities placed approximately 120 degrees apart, hosting 34- and 70-m antennas
- Operates, maintains, and upgrades the 3 tracking complexes around the world, along with centralized operation at Jet Propulsion Laboratory (JPL)

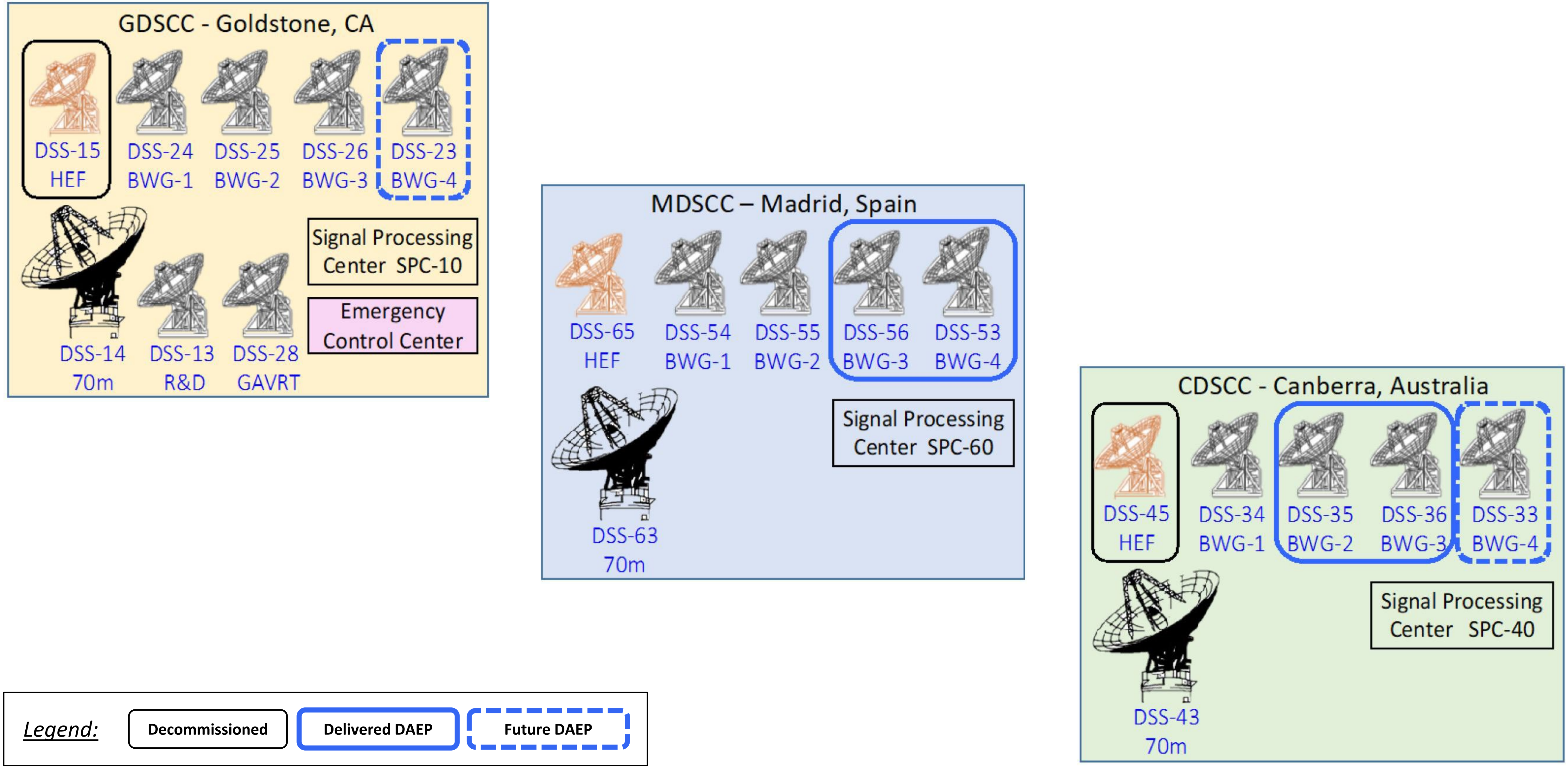
DSN Missions

- DSN was designed to communicate with spacecraft located 16,000 km (10,000 miles) from Earth to beyond the edge of the solar system
- Interplanetary spacecraft missions
- Radio and radar astronomy observations
- Key Missions: Artemis, JUNO, JWST, New Horizons, Mars Rovers and Orbiters, Mars Perseverance, Mars Science Laboratory, Voyager



NASA's Communications Networks

DSN Current & Planned Assets & Capabilities



Deep Space Network Demand and Loading

DSN Loading and Utilization Studies

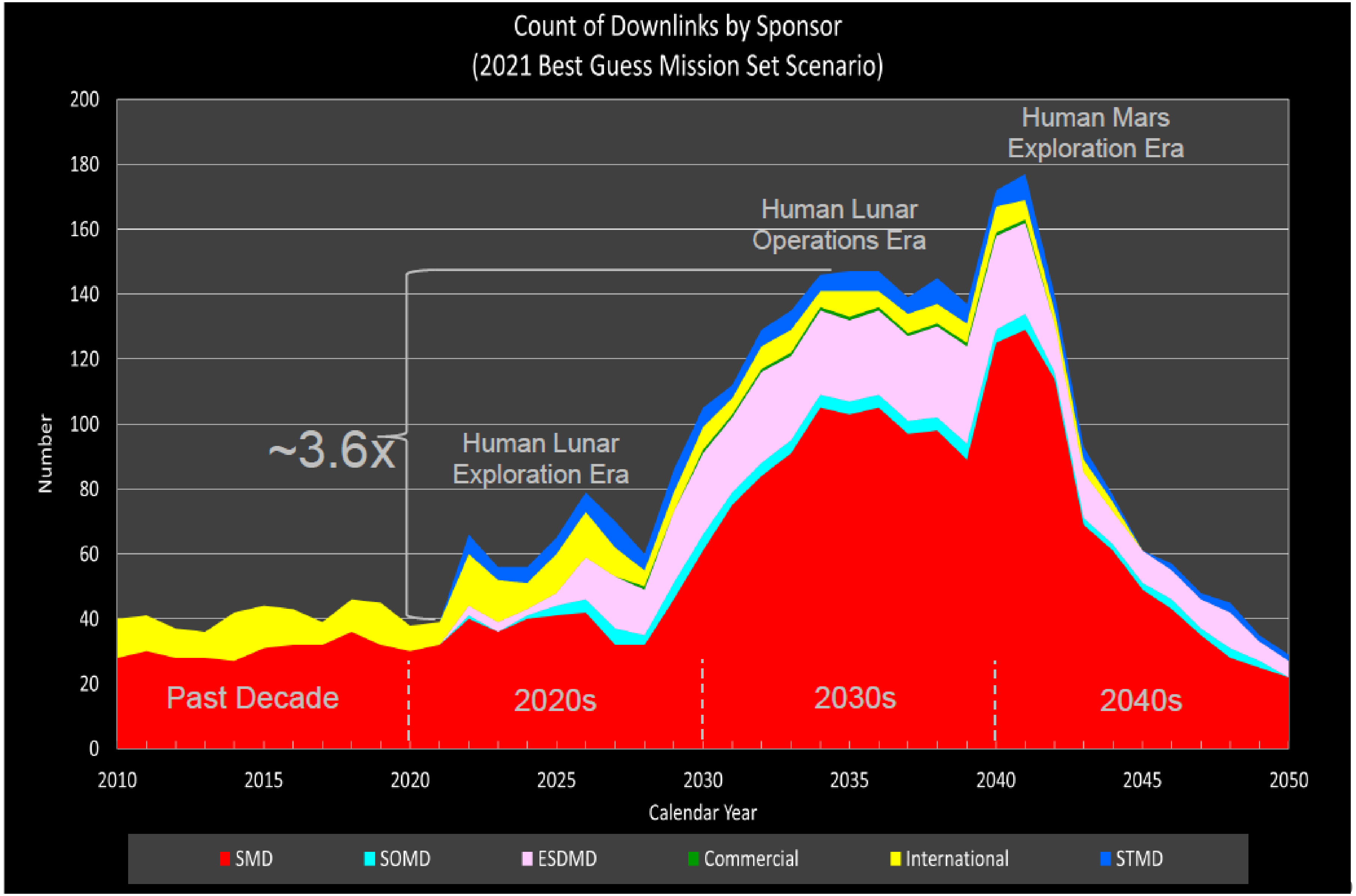
- The DSN regularly conducts capacity/loading studies to quantify projections for future “supply” from networks vs “demand” for services from missions using the following data:
  - Number of antennas and tracking hours available versus requested
  - Uplink frequencies, data rates, data volume capacity
  - Downlink frequencies, data rates, data volume capacity
  - G/T and EIRP metrics to characterize the capabilities of antennas for downlink and uplink
- Additionally, SCaN and the DSN complete ad-hoc studies to investigate any concerns with support/services
  - Most recently it completed a study to investigate communications issues discovered with key missions
  - The study recommended that SCaN/DSN increase network capacity at each complex beyond the current DSN Aperture Enhancements Project (DAEP) plans, which is in line with the overall regular loading study that was conducted

Importance to the Agency

NASA has a strategic and tactical interest in understanding upcoming demand for deep space communications and tracking services and if or when this demand will exceed its capacity in future years

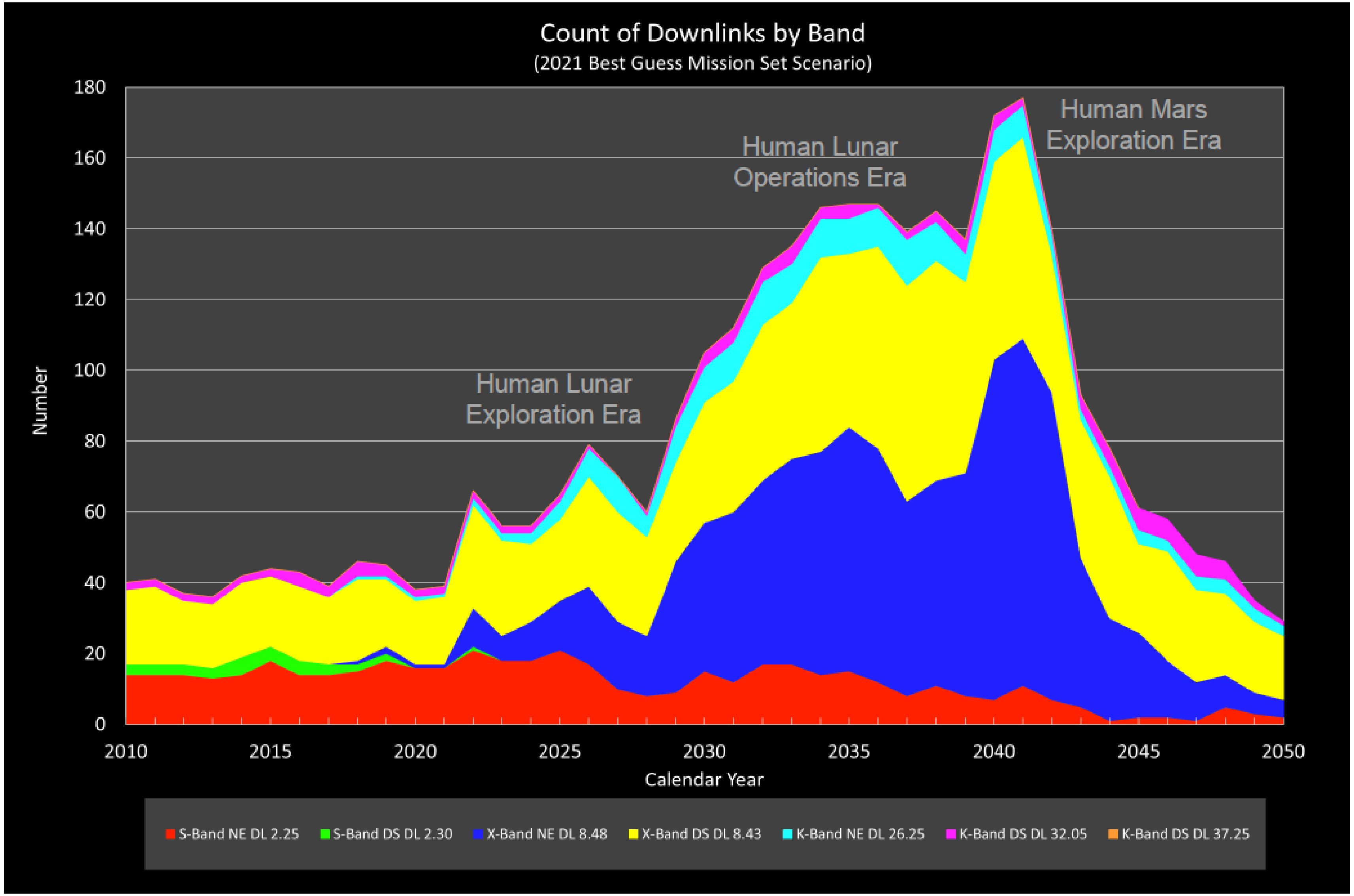
Projected DSN Use by Sponsor

- The downlink count more than triples in the next 15 years
- SMD remains the dominant beyond-GEO customer in these projections



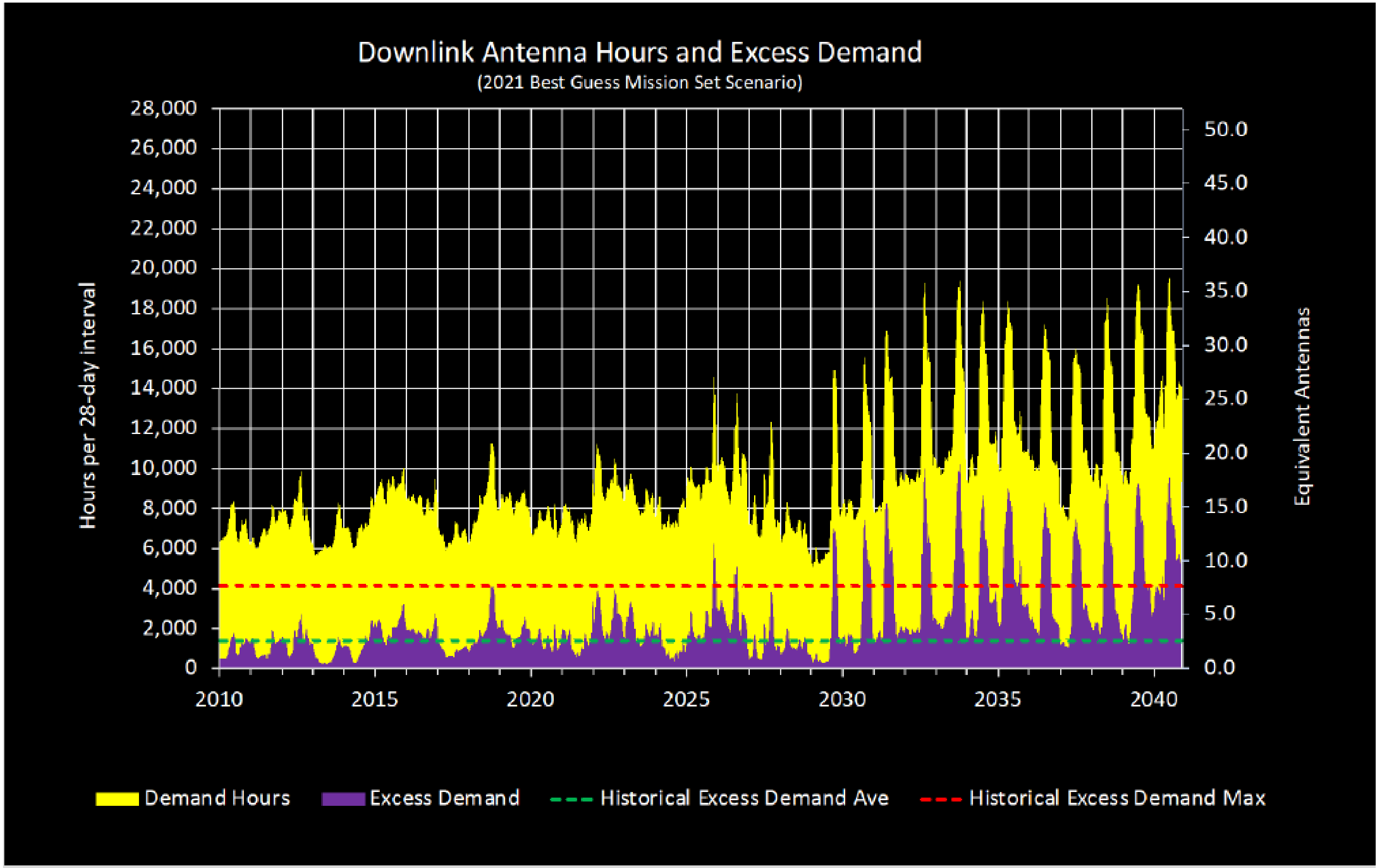
Projected DSN Use by Band

- Human lunar exploration and operations will drive a substantial increase in X-band and Ka-band 26 GHz utilization.
- S-band use is projected to decrease over time if NASA adopts the IOAG Lunar Comm. Architecture recommendations.
- X-band deep space use increases substantially as the number of deep space robotic users increases as well.



Review of DSN Excess Demand

- Steady-state excess demand during 2030s is projected to be 50%
- Steady-state excess demand during Artemis in 2030s is projected to be 100%
- Average data rate increase in 10 years is: 6x downlink, 690x uplink
- Data volume increase in 10 years is: 36x downlink, 1600x uplink



Causes:

1. Unparalleled growth in robotic and crewed missions
2. Unparalleled growth in uplinks and downlinks
3. Human exploration missions especially demanding

Excess Demand and Capacity Constraints Mitigation

- Present-day loading studies project large increases in DSN demand in the 2020s and 2030s that, at times, will significantly exceed the supply of DSN antennas

Possible Mitigations being Investigated	
1	Enhance DSN tracking, telecom, or operational techniques
2	Equip DSN antennas with more frequencies to minimize shortages
3	Engage with missions to move towards higher RF frequencies
4	Utilizing additional antennas -- DSN or non-DSN
5	Relay assets at Moon (and Mars) with crosslinks so that all local data can be sent through a single relay to one Earth antenna
6	Optical communications

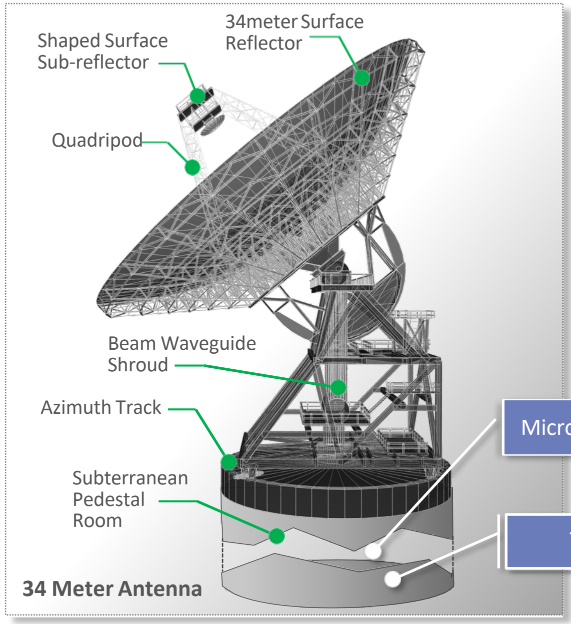
Deep Space Network Sustainment of Current Assets

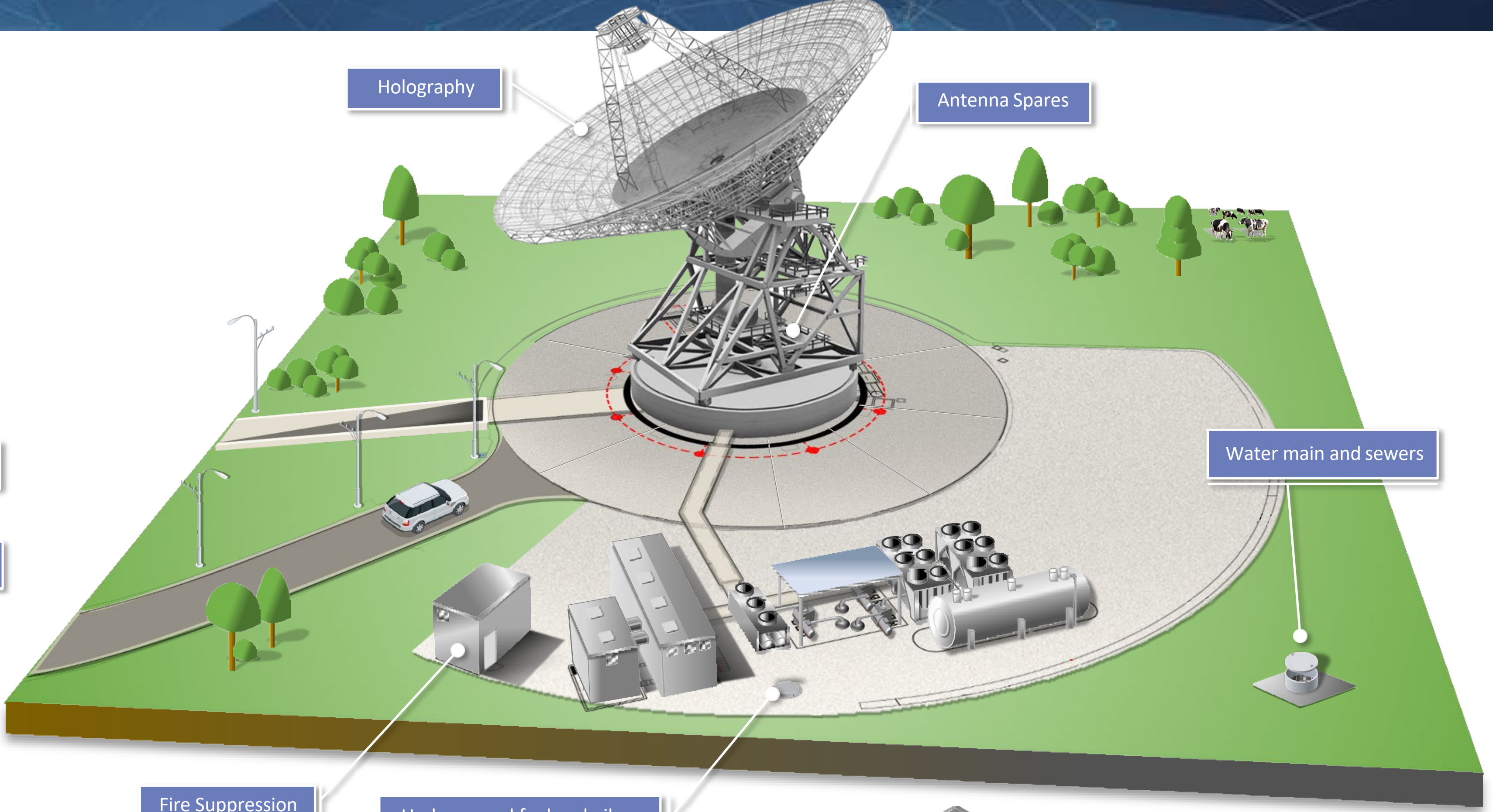
Sustainment of Current Assets

In addition to studying the assets and capabilities needed to meet future mission demand, SCaN and the DSN are taking steps to improve current network assets

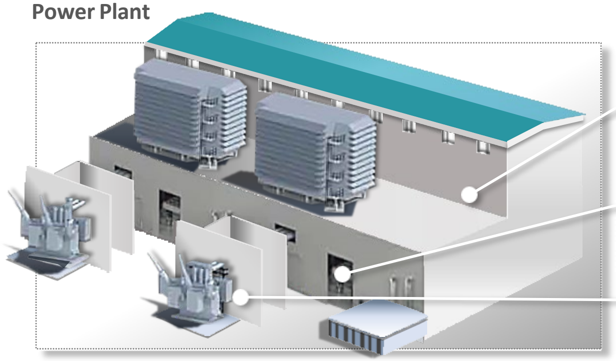
- The Road to Green Initiative:
  - SCaN began the “Road to Green” initiative in September 2020
    - Examine the current state of health of the DSN
    - Determine concrete steps SCaN could implement to improve the DSN’s reliability and robustness
  - Additional funding allowed SCaN to prioritize areas directly related to:
    - Health and safety
    - IT security vulnerabilities
    - Facility infrastructure
    - Antenna vulnerable components
- 70m Transmitter Sustainment:
  - There are no near-term plans to retire the 70m antennas, instead transmitter modernization efforts will take place

Road to Green Depiction of Focus Areas

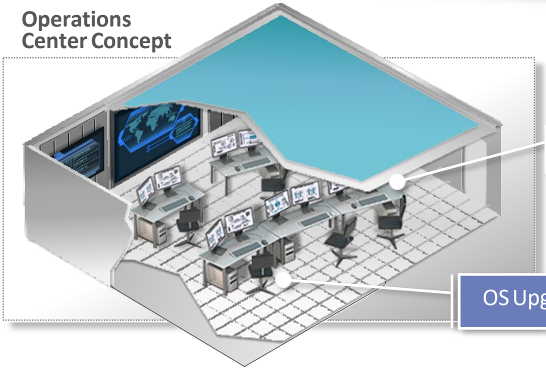




Power Plant



Operations Center Concept



70-meter Transmitter Modernization

- Transmitter modernization project
  - Revitalizes the 70m antennas by addressing the highest risk subsystems, the transmitters and associated power/facilities
  - Retired a DSN Red Risk associated with DSS-43 High Power S-Band Transmitter, the only uplink capable of supporting Voyager-2 commanding
- Goals:
  - Modernize the designs in the 20kW workhorse transmitters
  - Add wideband 80kW X-Band capability to all 70m antennas
  - Improve reliability and remove obsolete components
  - Improve maintainability by replacing multiple transmitter designs with the one transmitter design throughout the DSN
  - Replace obsolete Power Distribution equipment and Cooling Equipment
  - Replace cooling towers and retire the risk regarding MDSCC cooling towers
  - Replace and update transmitter, servo and hydrostatic bearing cooling equipment

S400 klystron cabinet removal

S400 klystron Lift

Alidade Pump House removal

New Access Gate at Apex

Australia 70-meter Sustainment Activity

- The first of three 70m sustainment activities have been completed on DSS-43 in Canberra
- Antenna downtime originally scheduled Feb 2, 2020 – Jan 17, 2021
  - DSS-43 is the only antenna in the world that can communicate with Voyager 2; downtime closely monitored
  - Start delayed six weeks due to Voyager 2 spacecraft emergency;
  - DSN Service Readiness Review successfully completed in Feb 2021
- DSS-43 is operational as of February 12, 2021
  - Supported early uplink with Voyager 2 in October 2020, after delay due to COVID-19 during the downtime

DSN 70-meter upgrades planned to take place Goldstone ~2025-2026 and Madrid 2028

Deep Space Network Future Assets and Upgrades

SCaN 3-Part Network Capacity Plan for Artemis and Lunar Science

What and Why

34-Meter Antenna Upgrades

- Upgrades to two Deep Space Network (DSN) antennas at each of the three complexes (totaling six upgraded antennas) to increase capability

18-Meter Antenna Subnet Development (LEGS)

- A dedicated new set of antennas, designed to support lunar missions, to help alleviate the user load on the current 34-meter subnet, to allow for a focus on deep space support. Beginning with 3 sites spaced around the Earth.

Lunar Relay and Interoperable Lunar Network

- Removes DTE line-of-sight communication constraint and reduces user burden
- Continuous communication during HLS descent is easier supported through a relay link than a DTE link

DSN Lunar Exploration Upgrades

- Upgrades to DSN's 34-m subnet represent a low-risk option to help meet Artemis program and Lunar science needs
- **Modifications will be made to two antennas at each DSN complex – total of six antennas**

Simultaneous Operations

S+Ka-band or X+Ka-band
Simultaneous Ka-band ↑↓

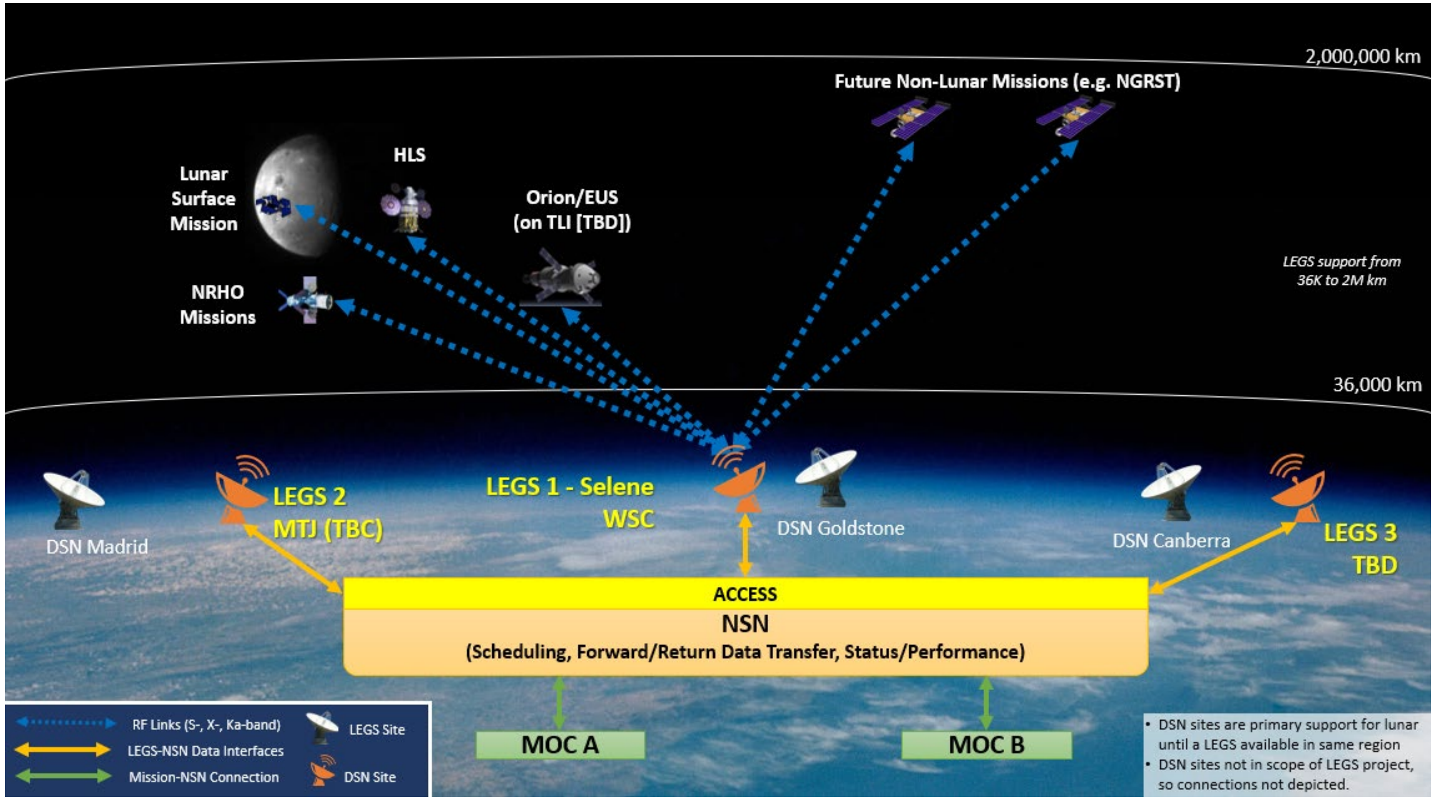
LOW Latency data processing >150Mbps

HIGHER DATA RATES

Ka-band	X-band
>100Mbps ↓	>2Mbps ↓
>20Mbps ↑	>5Mbps ↑

LEGS Overview

- Lunar Exploration Ground Sites (LEGS) will provide Direct to Earth (DTE) RF comms to users ranging from the GEO orbit, to Lunar surface and orbit, to Sun-Earth-Lagrange orbits
- A key objective is to offload Deep Space Network (DSN) 34m antenna assets for “near space” missions such as:
  - Lunar Missions: Gateway, HLS, Orion, SLS EUS, CLPS, Cubesats
  - Gateway, HLS, LTV contracts will design for LEGS compatibility
  - Other compatible Near Space missions from 36,000 to 2,000,000 km
  - SMD Lagrange missions
- Minimum three LEGS sites located around the Earth to provide continuous coverage
  - Ability to add further assets as demand grows



DSN User Flexibility

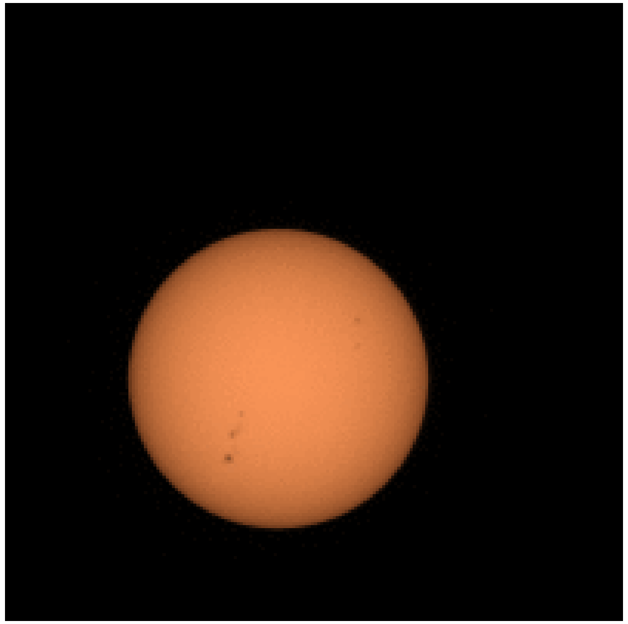
- SCaN provided a recommendation to the mission community to:
  - Limit DSN hot back-up use by Artemis missions for critical events only
  - Develop a strategy to deal with the expected demand increase from lunar SmallSats
  - Increase utilization of Ka-band to meet science data return requirements in the short term
- Future missions that need data return rates beyond the capability of a single Ka-band antenna will be required to investigate alternate solutions, which may include:
  - Maximizing Ka-band throughput via higher-order modulation and coding via ground system receiver and flight system transceiver upgrades (common in industry practice but not leveraged at NASA)
  - Arraying multiple Ka-band antennas, allowing for high antenna gain which increases data rates
  - Utilization of optical communications

Summary

- SCaN is committed to studying future mission requirements and demand in order to make informed decisions about Network improvements
- SCaN remains prepared to support all future NASA missions, from the Moon to Mars and beyond

SCaN's goal is to continue to be proactive and ensure the needs of the Agency will be met with a robust, reliable, and cost-effective network.

Orion Capsule at maximum distance from Earth



Picture of solar eclipse taken on Martian surface by Perseverance Rover

Picture of Carina Nebula taken by JWST

DART Launch

Acronyms

Acronym	Definition
ASF	Alaska Satellite Facility
BWG	Beam-Waveguide
CDSCC	Canberra Deep Space Communications Complex
CLPS	Commercial Lunar Payload Services
DAEP	DSN Aperature Enhancement Project
DLEU	DSN Lunar Exploration Upgrades
DSN	Deep Space Network
DSS	Deep Space Station
DTE	Direct to Earth
EIRP	Equivalent isotropic radiated power
EUS	Exploration Upper Stage
FtSO	Follow the Sun Operations
GAVRT	Goldstone-Apple Valley Radio Telescope
GDSCC	Goldstone Deep Space Communications Complex
GEO	Geosynchronous Equatorial Orbit
HEF	High-Efficiency Antenna
HLS	Human Landing System
IND	Interplanetary Network Directorate
IOAG	Interagency Operations Advisory Group

Acronym	Definition
JPL	Jet Propulsion Laboratory
JWST	James Webb Space Telescope
KUS	Kennedy Uplink Station
LEGS	Lunar Exploration Upgrades
LEO	Low Earth Orbit
LTV	Lunar Terrain Vehicle
MAVEN	Mars Atmosphere and Volatile EvolutioN
MDSCC	Madrid Deep Space Communications Complex
MRO	Mars Reconnaissance Orbiter
NSN	Near Space Network
PDL	Ponce de Leon
R&D	Research and Development
SCaN	Space Communications and Navigation
SLS	Space Launch System
SMD	Science Mission Directorate
SOMD	Space Operations Missions Directorate
SPC	Signal Processing Center
SSC	Swedish Space Corporation