



National Aeronautics and Space Administration



SCaN Updates, Deep Space Network Updates and Technology

Presented to:
National Academy of Sciences Space Studies Board
Presented by:
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Acting Deputy Associate Administrator and Program Manager
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Space Operations Mission Directorate, NASA
November 14, 2023

SCaN

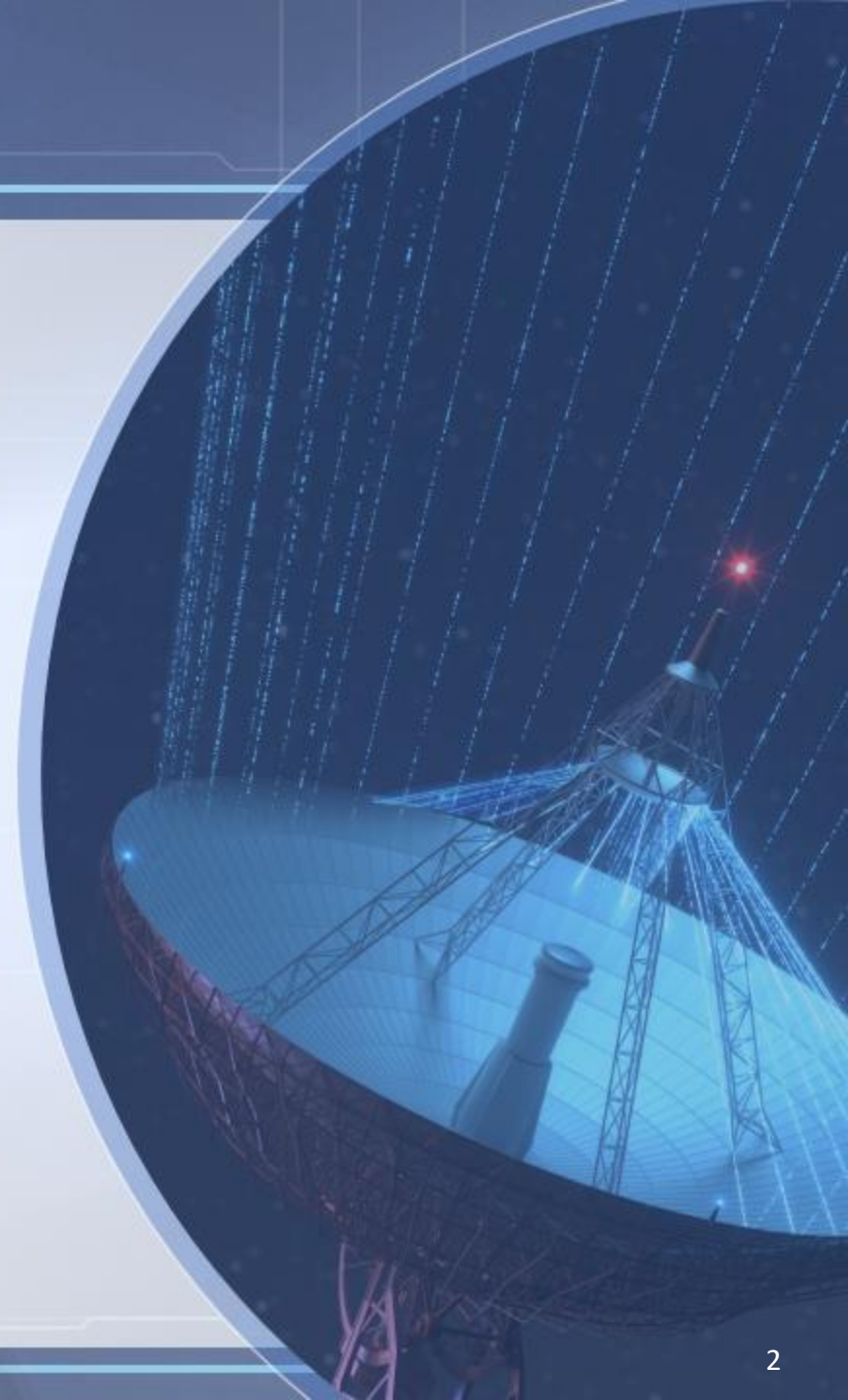
Space Communications
and Navigation
Exploration, **enabled.**

Outline

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- 1 About SCaN and Our Major Initiatives**
- 2 Deep Space Network Overview**
- 3 DSN Status, Challenges, and Plans**
- 4 Optical Communications and Other Technologies**

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Enabling Human Space Exploration and Science

1

Develop, operate and manage all NASA space communications capabilities



2

Develop technologies to enable and enhance future mission experience



3

Manage NASA spectrum; represent NASA on national and international spectrum management forums



4

Develop space communication standards as well as positioning, navigation, and timing policies



5

Represent and negotiate on behalf of NASA on all matters related to space communications and navigation



Space Communications and Navigation (SCaN) serves as the Program Office for all of NASA's space communications activities

24/7 Global Near Earth and Deep Space Communications and Navigation Services

100+ Missions currently supported by SCaN

SCaN is Adapting to Rapid Changes in the Space Sector

Commercialization

- Growth of commercial space sector has created robust non-governmental demand for space support services like communications
- OMB and National Space Policy encourage NASA SCaN to draw upon these commercial services wherever possible

Cis-Lunar Developments

- Artemis and Commercial Lunar Payload Services (CLPS) will dramatically increase near Space network demand
- DSN will require support for upgrades
- Commercial services will also be part of the solution for fulfilling mission needs

2022 Satellite Service Industry Trends*

Mobile voice and data revenue **growth**

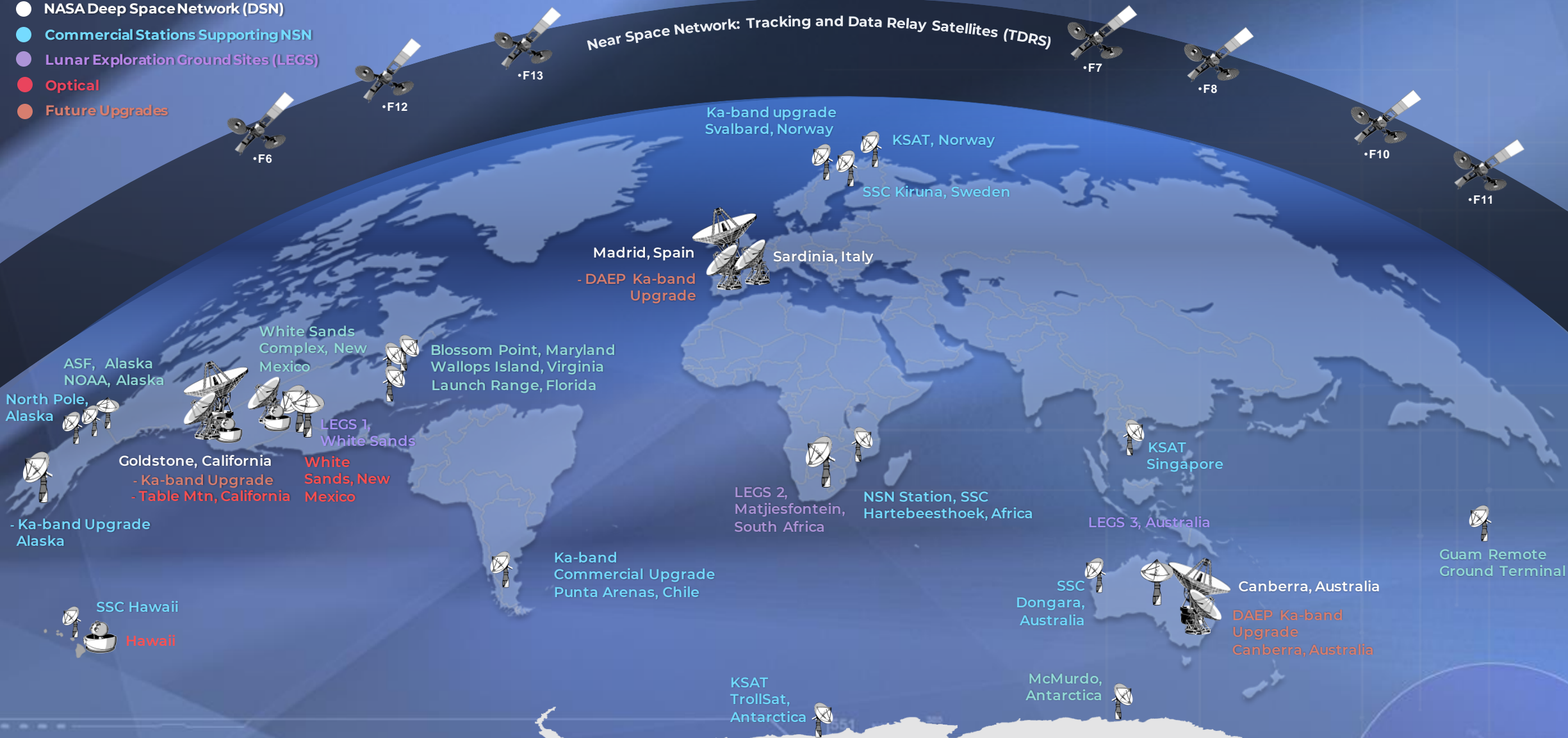
Managed network services revenue **increased**

High Throughput Satellite **capacity** increasingly available



NASA's Communications Networks

- NASA Near Space Network (NSN)
- NASA Deep Space Network (DSN)
- Commercial Stations Supporting NSN
- Lunar Exploration Ground Sites (LEGS)
- Optical
- Future Upgrades



Progress in Pursuing Commercial Services

- Commercial Geosynchronous Orbit (GEO) L-band relay network

inmarsat

- Optical Low Earth Orbit (LEO) network

amazon | project kuiper

- GEO C-band and Medium Earth Orbit (MEO) Ka-band networks

SES
GOVERNMENT SOLUTIONS

- Optical LEO network

SPACEX

- RF relay networks offering C-band and Ka-band services for high

TELESAT

- GEO Ka-band relay network

Communications Services Project (CSP)

June 2022, six NASA CSP Funded Space Act Agreement awards were made totaling **\$278.5 million**

- Commercial will offer NASA users a variety of capabilities
 - 2024 Agency Program Management Council will review and decide on future mission commitments, including TDRS flyout

Direct-to-Earth Communications Expansion

- NASA has tapped into a growing market of commercial Direct to Earth (DTE) vendors, which now provide over 63% of NASA's DTE service hours
 - Request for Proposals (RFP) released in 2023 with goal to expand level of commercial services to 100%

Wideband Multilingual Terminal

NASA is supporting APL's development of a wideband/multilingual user terminal to unlock interoperability across commercial SATCOM systems

Supports government and commercial Ka-band allocations (17.7 – 31.0 GHz)

Key Milestones:

- APL was selected (end of FY21) to proceed to flight demonstration activity
- A flight demonstration terminal has been integrated into a York Space Systems S-Class bus for launch on Transporter-11 (estimated Q4 2023)
- Flight demo operations (~6 months) targeted to start February 2024

Post flight demo actions:

- Leverage existing partnerships to transfer wideband design / technology to industry
- Include resultant wideband terminal options in NSN services catalog

Inmarsat Global Xpress

- GEO Constellation
- 28 Steerable Antennas in orbit
- 7 new satellites



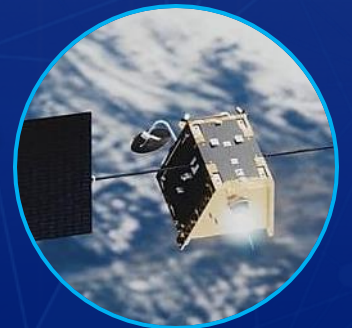
O3b mPOWER

- MEO Constellation
- Thousands of beams per satellite
- 11 satellites



Telesat Blackjack

- LEO Constellation
- 2 steerable antennas per satellite
- 2 satellites in DARPA mission



Deep Space Network (DSN)

DSN's Role and Structure

DSN is the only US network dedicated to providing telecommunications services for missions beyond LEO

DSN also supports international spacecraft and scientific investigations (radar, radio astronomy and radio science)

DSN has three complexes, spread across the world to ensure 24/7 coverage

The NASA Jet Propulsion Laboratory (JPL) develops, operates, and manages DSN



Canberra



Goldstone

Madrid

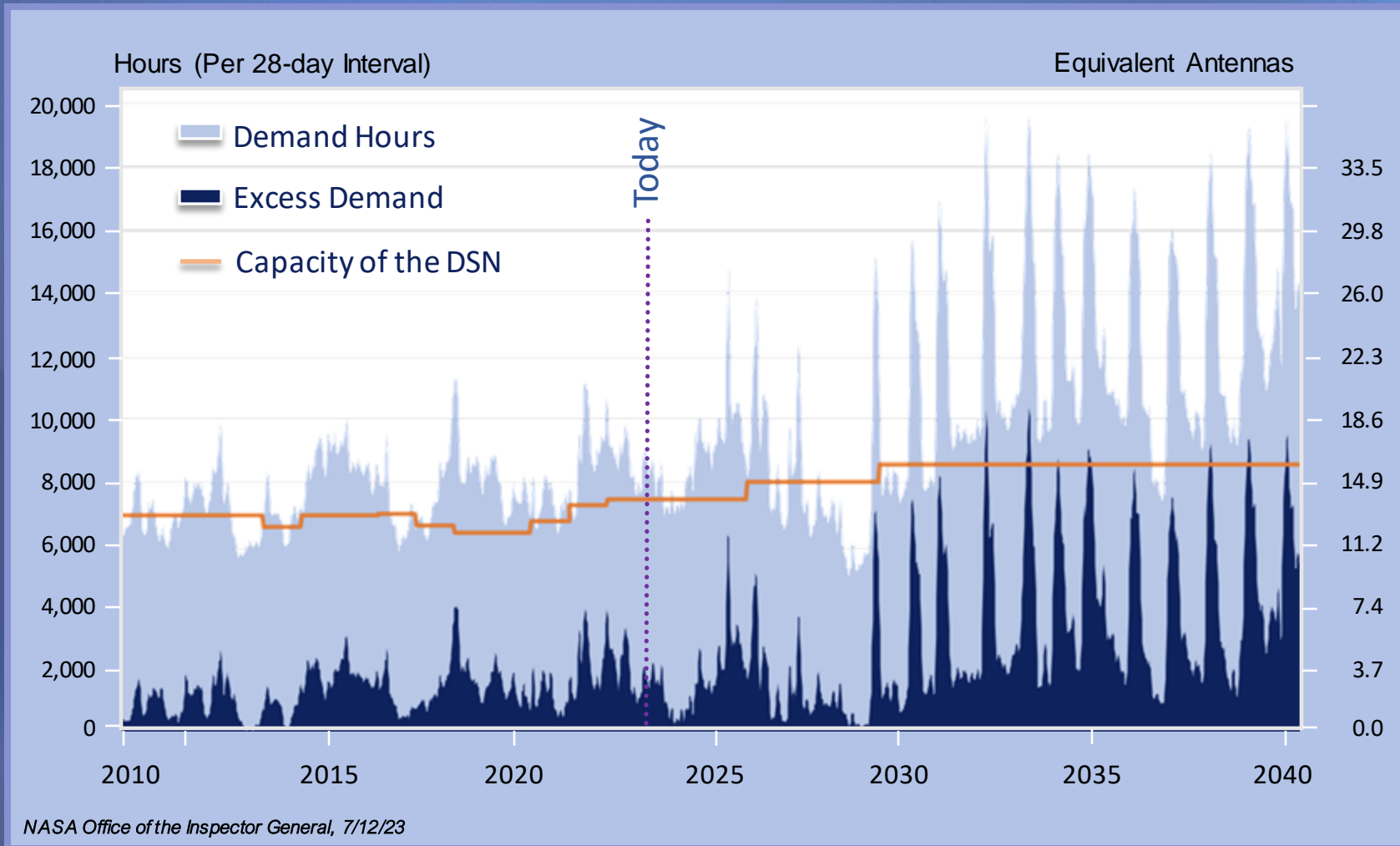


Deep Space Network Missions

+ DSN Mission Dashboard October 2023 (Updated Monthly -- Contact S. Asmar)					
#	Completed Since 2019	Current 20+22 = 42		Future 15+26 = 41	
		Deep Space	Cis-Lunar, Lagrange, ...	Deep Space	Cis-Lunar, Lagrange, ...
1	InSight Mars	Juno Jupiter	Lunar Recon. Orb. Lunar	VERITAS Venus	SunRISE
2	Mars Cube One InSight Cube	Lucy Asteroids	SOHO Helio L1 NASA-ESA	DAVINCI+ Venus	GOES U
3	DART Asteroid	Perseverance Mars	ACE Helio L1	Dragonfly Titan	SWFO L1
4	LICIA (ASI) DART Cube	Mars Odyssey Mars	Wind Helio L1	Europa Clipper Jupiter 2024	IMAP L1
5	GOES T	Mars Recon. Orb. Mars	MMS 1 Earth Ellip. Orb.	ESCAPADE Blue Mars	Carruthers L1
6	Geotail	MAVEN Mars	MMS 2 Earth Ellip. Orb.	ESCAPADE Gold Mars	Astrobotic Peregrine Lunar
7	Artemis 1 Lunar	Curiosity Mars	MMS 3 Earth Ellip. Orb.	Sample Return Land. Mars	Astrobotic Griffin Lunar
8	NEA Scout Cube	New Horizons	MMS 4 Earth Ellip. Orb.	Earth Return Orb. (ESA) Mar	Lunar Node-1 CLPS Lunar
9	CuSP Cube	OSIRIS-REx (APEX)	Themis B Helio L1	Rosalind Franklin (ESA) Mars	Lunar Trail Blazer Mar 2024
10	LunaHMAP Cube	Parker Solar Probe Helio	Themis C Helio L2	EnVision (ESA) Venus	VIPER Lunar
11	Lunar Ice Cube	Voyager 1 Helio	DSCOVR L1	HERA (ESA) Asteroid	Artemis-2 Orion
12	Team Miles Cube	Voyager 2 Helio	Chandra HEO	DESTINY+ (JAXA) Asteroid	Artemis-3 Orion
13	ArgoMoon (ASI) Cube	STEREO A Helio	JWST L2	MMX (JAXA) Mars (L 2024)	Exploration Upper Stage
14	Omotenashi (JAXA) Cube	Akatsuki (JAXA) Venus	TESS Earth Ellip. Orb.	Emiratres Asteroid (UAE)	Gateway Lunar
15	Equuleus (JAXA) Cube	Hayabusa-2 Ext (JAXA) Astero	CAPSTONE Cube	Rocket Lab Venus	Human Landing Sys 1
16	INTEGRAL (ESA)	BepiColombo (ESA)	TDRS 6-13 emergency		Human Landing Sys 2
17	Hayabusa-2 Prime (JAXA)	Trace Gas Orb. (ESA) Mars	Biosentinel Cube		Human Landing Sys 3
18	Beresheet (Israel) Lunar	Mars Express (ESA)	Lunar Flash Light Cube		Blue Origin Mark-1 SN-1
19	Mars Orb. Mission (ISRO)	Emirates Mars (UAE)	XMM (ESA) Earth Ellip. Orb.		Blue Origin Mark-1 SN-2
20	Chandrayaan 2 Land. (ISRO)	Psyche Asteroid	Gaia (ESA) L2		Lunar Terrain Vehicles
21	Chandrayaan 2 Orb. (ISRO)		KPLO (KARI) Lunar		Beresheet-2 (Israel) Lunar
22	Chandrayaan 3 Land. (ISRO)		SLIM & LEV (JAXA) Lunar		Roman Telescope L2 2027
23					NEO Surveyor L1 2027
24					Oracle-P Air Force L1 2025
25					Astrobotic third lander
26					LUPEX (JAXA/USRO)

DSN Challenge: Growing User Needs

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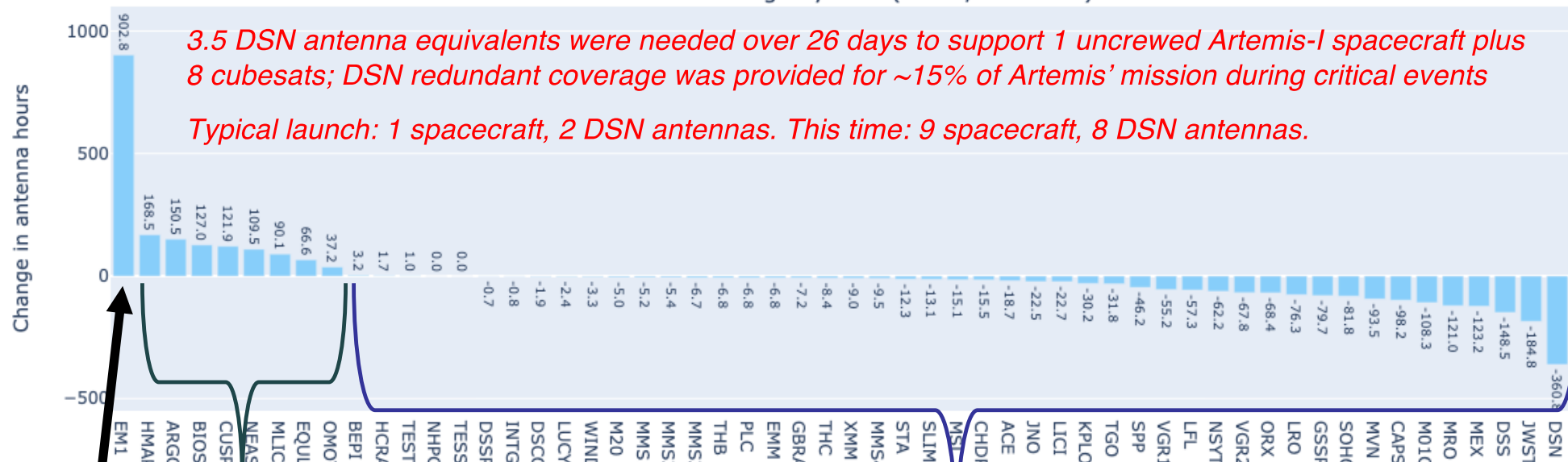
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Artemis 1 and CubeSat Experience

Artemis-I + Deep Space CubeSat Support: DSN Impacts

Impact (antenna hours by mission) of EM1 Nov16 launch schedule on 2022 weeks ['2022-46', '2022-47', '2022-48', '2022-49']

Total time change by user (hours, all weeks)



3.5 DSN antenna equivalents were needed over 26 days to support 1 uncrewed Artemis-I spacecraft plus 8 cubesats; DSN redundant coverage was provided for ~15% of Artemis' mission during critical events

Typical launch: 1 spacecraft, 2 DSN antennas. This time: 9 spacecraft, 8 DSN antennas.

Artemis I:
+903 hrs
(1.8 antennas)

CubeSats:
+871 hrs
(1.7 antennas)

Existing SMD missions: -1585 hrs
DSN Maintenance: -509 hrs

DSN maintenance deferral – not a sustainable approach

How SCaN Plans to Support DSN Users



New Deep Space Network (DSN) Capacity & Upgrades

1

- Building six 34m antennas across all three DSN complexes
- Upgrading two DSN antennas at each complex to enable simultaneous operations, enhance uplinks, and increase data rates



Lunar Exploration Ground Segment (LEGS)

2

- Network of new 18-meter class antennas to support lunar missions
- Starting with three government owned, commercial operated sites around the Earth, offering continuous coverage
- Commercial services will add additional capacity as demand grows



Lunar Communications and Navigation Relay Services

3

- Creating lunar relays to reduce user PNT burden and remove DTE line-of-sight constraints (enabling South Pole and Far-Side operations)
- Using a commercial service procurement approach

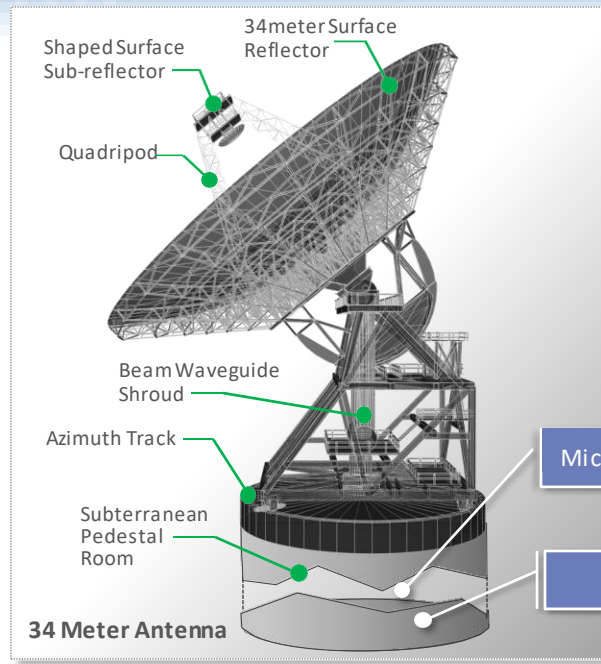


International Partnerships and Contributions

4

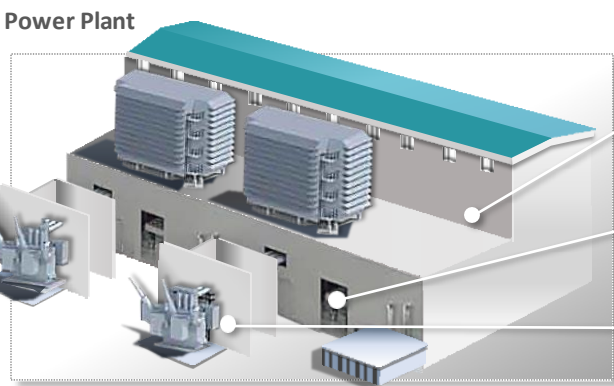
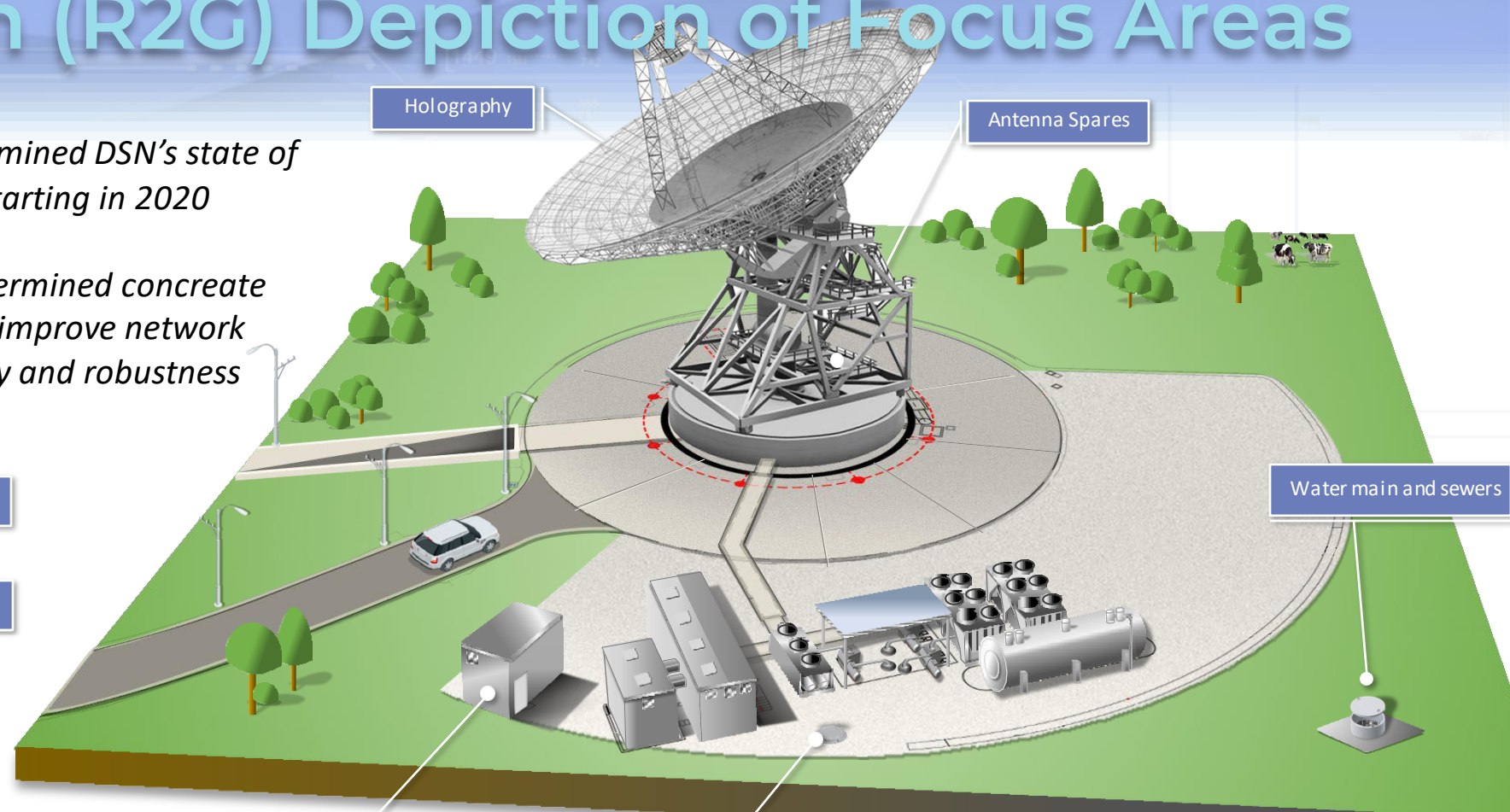
- Seeking contributions for both Earth based and Lunar C&N assets
- Priority 1: Direct-to-Earth assets that meet or exceed LEGS performance
- Priority 2: Lunar relay comm and PNT services
- Priority 3: Lunar surface comm and PNT capabilities

Road to Green (R2G) Depiction of Focus Areas



R2G examined DSN's state of health starting in 2020

R2G determined concrete steps to improve network reliability and robustness



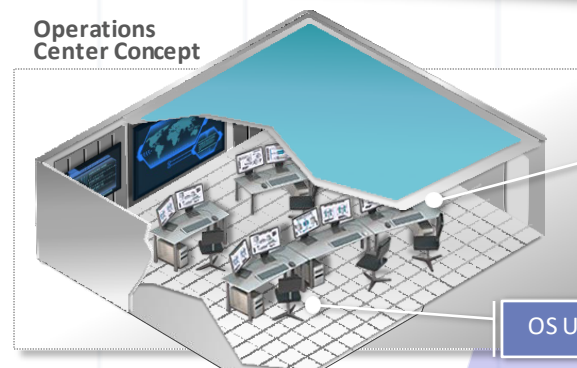
- Generators
- Uninterruptible Power Supply
- Transformers and Switchgear

Fire Suppression

Underground fuel and oil tank (move to above ground)

Funds prioritized to address:

- Health and safety
- IT security
- Facility infrastructure
- Vulnerable antenna components

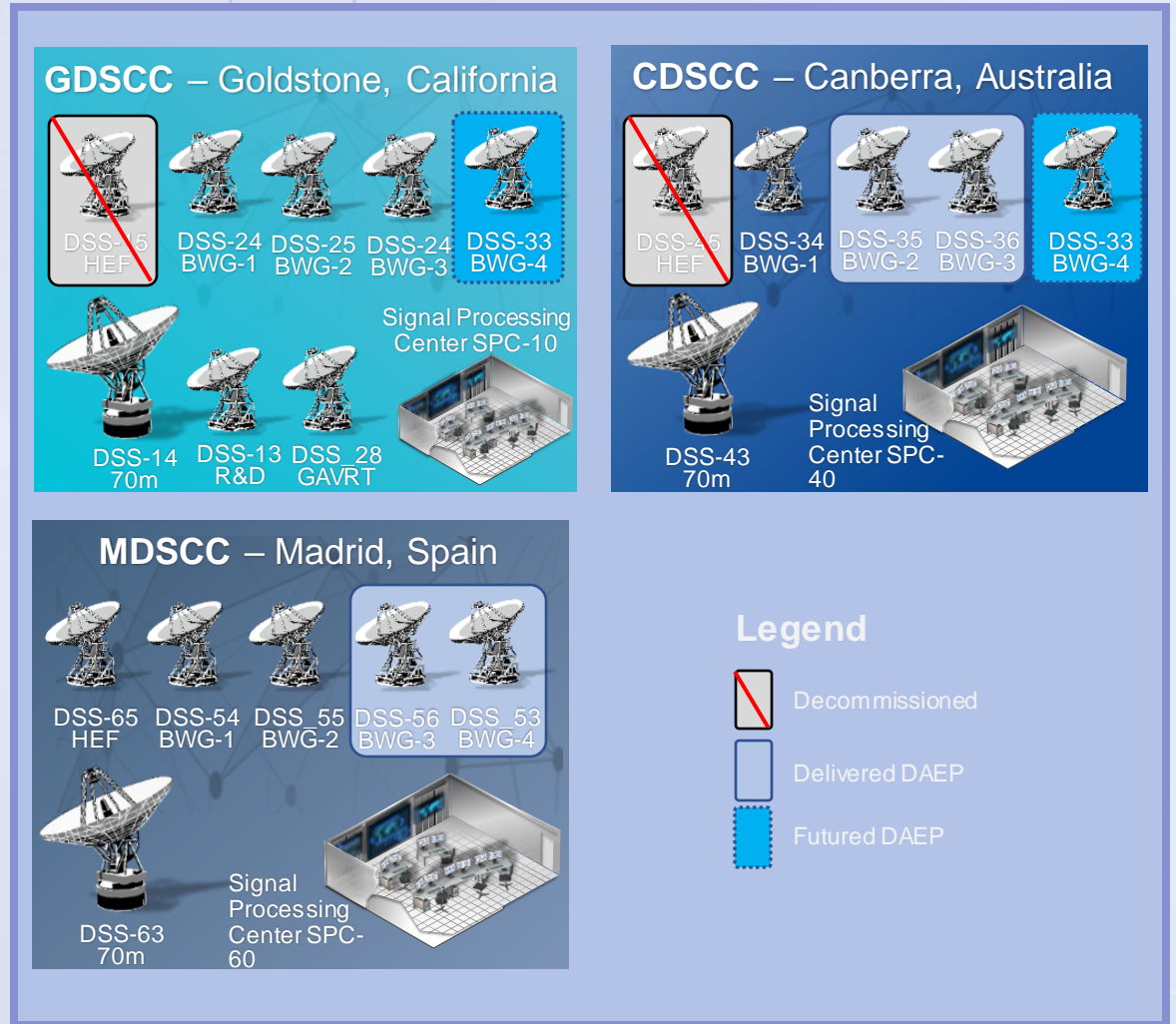


General Cyber Security

OS Upgrades

Capacity Increases: DSN Aperture Enhancement Project (DAEP)

- DAEP is building six 34m Beam Wave Guide (BWG) antennas across all three DSN complexes to provide additional capacity
- FY2024 DAEP STATUS SNAPSHOT:
 - Four 34m BWG deliveries completed (Two in Canberra and two in Madrid)
 - One 34m BWG in process in Goldstone; Delivery to service April 2026
 - One 34m BWG in the future at Canberra; Delivery to service expected October 2029
- Further expansion after FY30 will be based on a *DSN Futures Study* and Agency requirements, and available support
 - May include higher power transmitters, HEF antenna refurbishments, and site diversity measures
 - Post-FY30 development work is funding dependent



DSN Lunar Exploration Upgrades (DLEU)

Upgrading six DSN antennas (two at each of the three complexes)

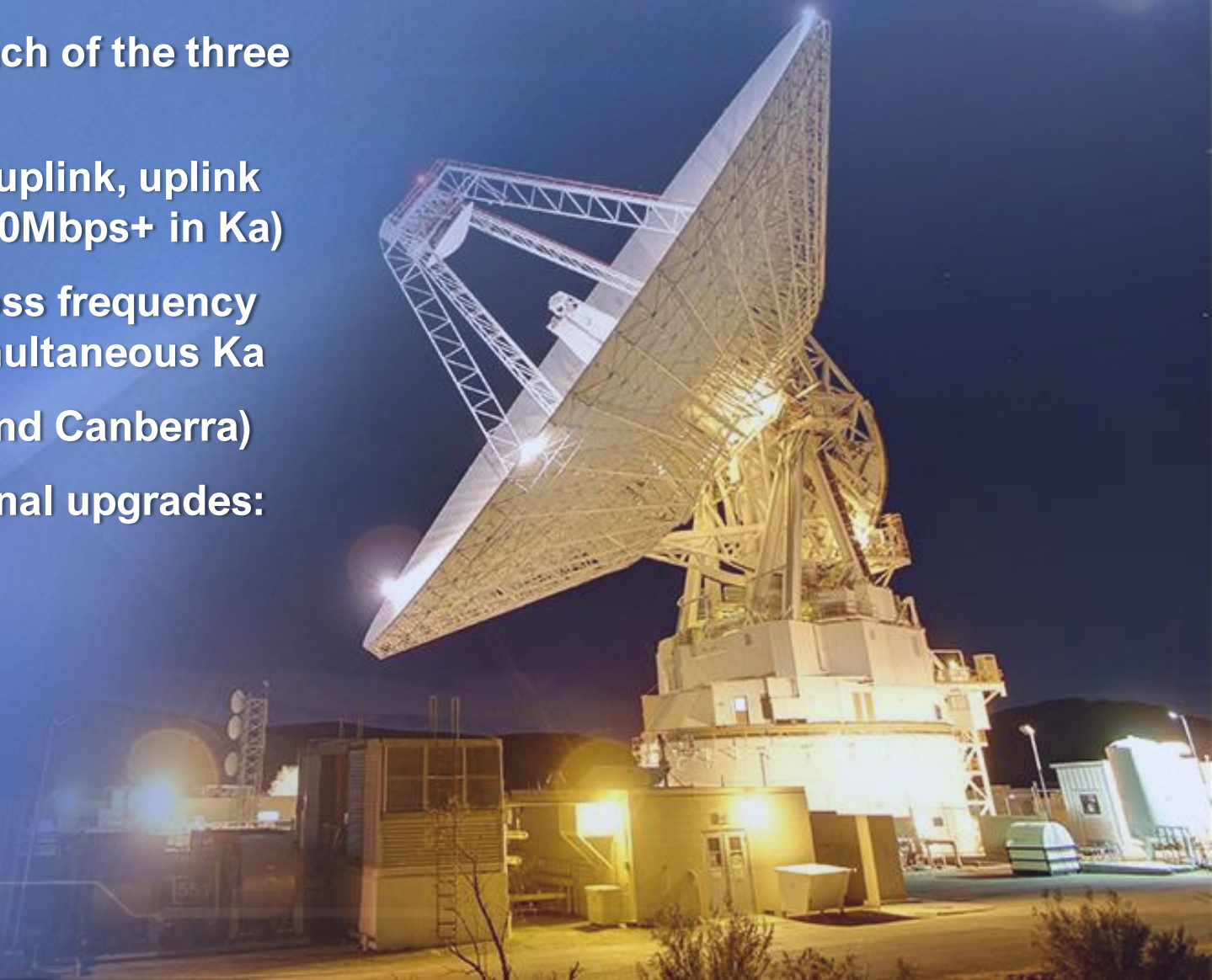
Adds capability for near-earth K-band uplink, uplink encoding, and increased data rates (100Mbps+ in Ka)

Provides simultaneous operations across frequency bands – S+Ka-band, X+Ka-band, or simultaneous Ka

Two upgrades completed (Goldstone and Canberra)

Estimated completion dates for additional upgrades:

- ❑ Goldstone: December 2023
- ❑ Canberra: July 2024
- ❑ Spain (DSS-56): April 2025
- ❑ Spain (DSS-54): March 2028



Lunar Exploration Ground Segment (LEGS)

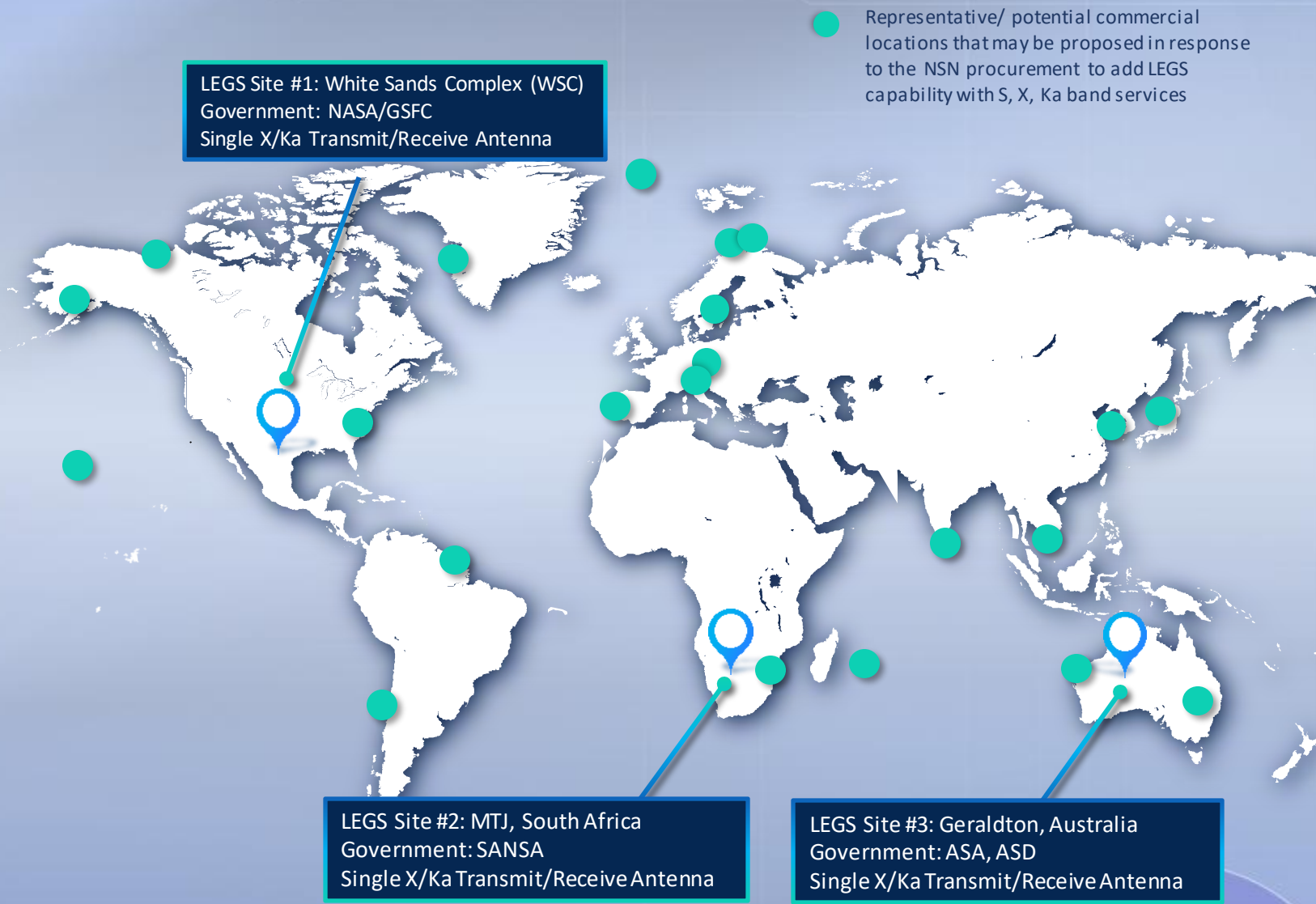
LEGS is a new network of DTE antennas that reduce contention for DSN by absorbing new Artemis demands

LEGS 1 to 3:

- Cover three geographically diverse sites, offering continuous lunar coverage
- 18-meter class performance in X and Ka
- Government-owned / contractor operated

LEGS 4+:

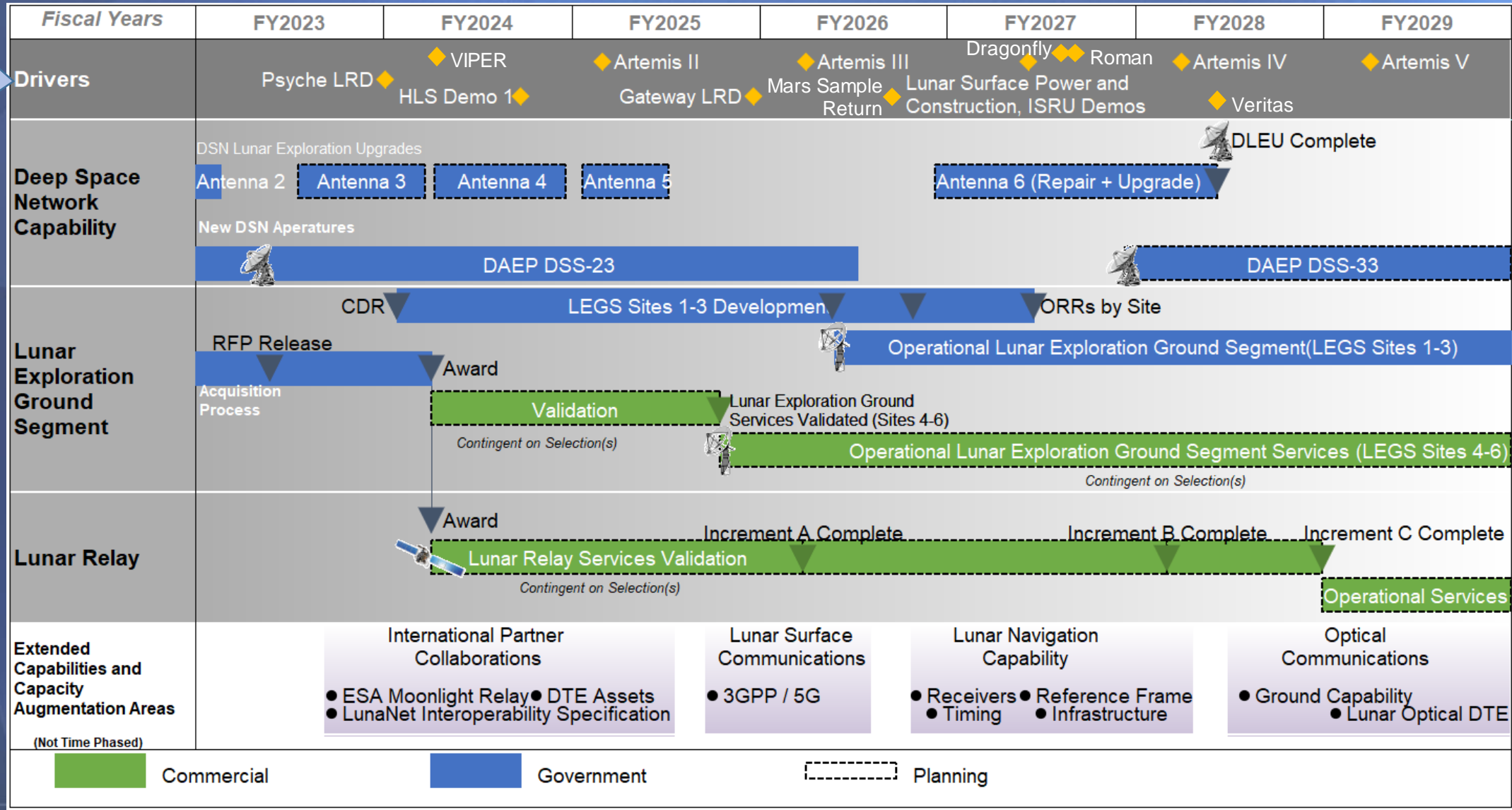
- Locations TBD
- 18-meter class performance in X, Ka and S
- Being pursued under full commercial services procurement



Orchestration of Supply

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Examples only... critical event list is significant



O&M and sustainment must be orchestrated around mission demands and capability variance is 1:1 with funding variance

DSN Futures Study

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DSN Futures Study objectives:

- Look at near-term issues (network scheduling efficiency, network and element brittleness, and fragility), and projected capability needs through 2050
- Understand what probable technology will be available, when it could be infused into the DSN, and the required costs

Incorporating SMD (Decadals) and ESDMD (Lunar and Mars architectures) as long-term planning inputs

Study Team members include NASA stakeholders from ESDMD, SMD, and SOMD that are asked to review study progress on a quarterly basis



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Optical Communications Technology Demonstrations

From Near Earth/Moon



LCRD

1.244 Gbps
Optical Relay
(622 Mbps RF down)

O2O

Lunar: 250/20 Mbps
(Gen2 Rates)

ILLUMA-T on ISS

1.244 Gbps / 155 Mbps
Relay User (ISS)

TBIRD

2U CubeSat Payload
2TB On-board Storage
200 Gbps LEO to Earth

LCRD
2021

TBIRD
2022

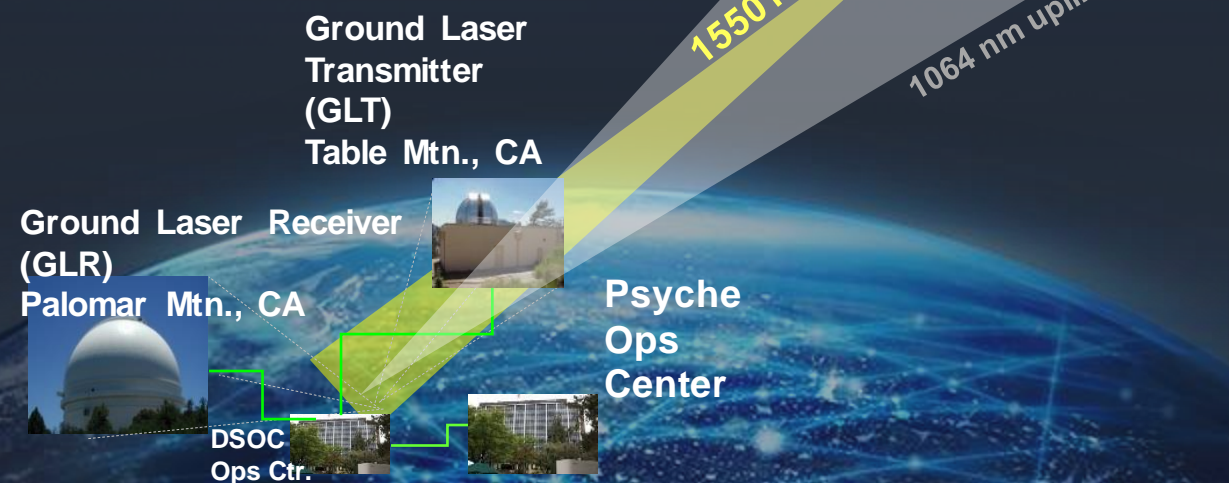
ILLUMA-T
2023

O2O
2024 (Artemis II)

To Deep Space

DSOC Gen-1 User Terminal

DSOC on Discovery Psyche
Asteroid Mission
267 Mbps / 1.6 kbps maximum
1 Mbps @ 2.6 AU to Palomar
~2 Mbps @ 2.6 AU w/ RF/optical



Ground Laser Transmitter (GLT)
Table Mtn., CA

Ground Laser Receiver (GLR)
Palomar Mtn., CA

Psyche Ops Center

DSOC Ops Ctr.

Psyche/DSOC Optical User Terminal
(2022*-2023)

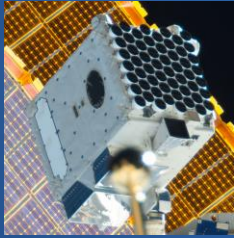
1550 nm downlink

1064 nm uplink beacon

Opportunity for mission community to identify interest in use of optical capability and partner with SCan to implement

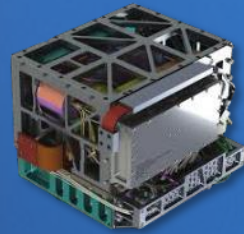
SCaN Technology Investments Driven by Mission Needs

Galactic Positioning System: XNAV



- Autonomous navigation and timing via X-ray emitting Millisecond Pulsars (XNAV)
- Enables long-duration independent operations and reduces Earth-based tracking

Deep Space Atomic Clock



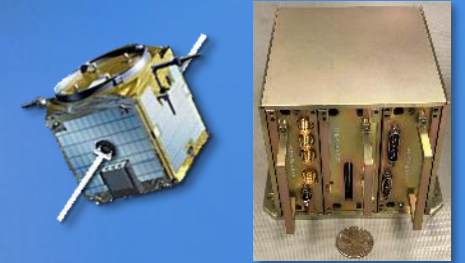
- Advanced prototype mercury-ion (Hg+) atomic clock (TRL 7) demonstrated in space
- Enables next gen space navigation, radio science, and navigation autonomy

Lunar Surface 3GPP



- Build on Nokia 4G lunar demo tipping point award
- Leverage existing 3GPP/5G commercial standards to accelerate deployment of lunar surface capabilities

Lunar Weak-Signal GNSS: NavCube3 Mini



- Leverage always-on, Earth-based radiometric navigation and timing signals in cislunar space and at the Moon
- Reduces network burden
- Enables autonomous PNT
- Small-sat form factor

Synopsis: The Future of SCaN

New Challenges and New Opportunities

Use of Commercial Vendors for Communication and Navigation Services

- ❑ Success in commercialization of DTE services since the 1990s provides roadmap
- ❑ Phasing out of TDRS services over the coming decades provides opportunities for commercial LEO, MEO, GEO relay services
- ❑ Through lunar relay service procurements and 18m class DTE LEGS, commercial providers can also support lunar activities

Human Spaceflight Beyond LEO:

- ❑ Growing DSN demand is putting flagship SMD and SOMD missions at risk
- ❑ Investment in reliability, robustness, and capacity will be necessary to secure DSN's future
- ❑ LEGS government and commercial investments can also offload some Artemis and CLPS requirements from DSN, alongside international partnerships
- ❑ Lunar relay is necessary to send crewed missions to the South Pole region

Technology Infusion of Optical Communication

- ❑ Current demonstrations cover LEO DTE, LEO/GEO relay, Lunar and Deep Space, applications
- ❑ Future optical infrastructure investments will require commitment by Human Spaceflight and Science Missions

Future Technology Investments

- ❑ Focus on establishing user driven technology investments and priorities



SCaN

Space Communications and Navigation

Exploration, enabled.

National Aeronautics and
Space Administration



Mr. Jeffrey Volosin

Acting Deputy Associate Administrator
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