NASA'S EVOLVING KA-BAND NETWORK CAPABILITIES TO MEET MISSION DEMAND

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Ka and Broadband Communications Conference

Science Drivers

NASA's science and exploration capabilities – the instruments, payloads, and operational needs – are driving significant increases in data volume demand and network support.

James Web Space Telescope (JWST) — 458 Gb/day

- Infrared observatory with improved sensitivity and capability as compared to Hubble

Plankton, Aerosol, Cloud and Ocean Ecosystem (PACE) — 5 Tb/day

- Primary instrument - hyperspectral scanning radiometer to study Earth's atmospheric and oceanographic responses to climate change

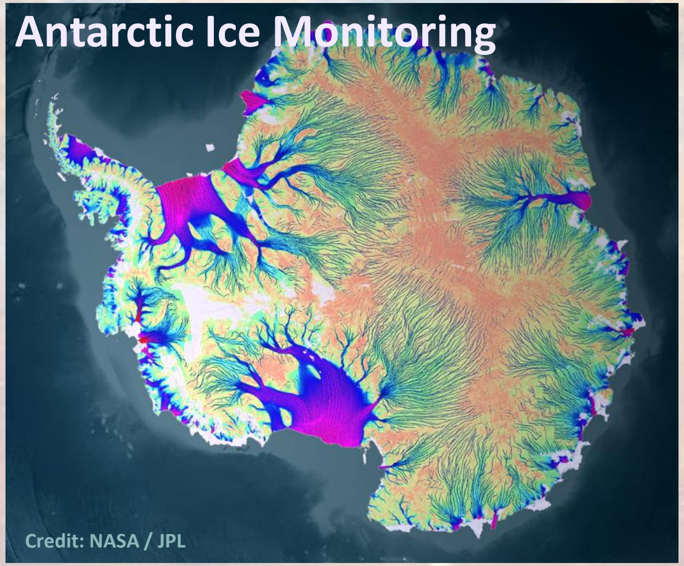
NASA-Indian Space Research Organization (ISRO) Synthetic Aperture Radar (NISAR) — 26 Tb/day

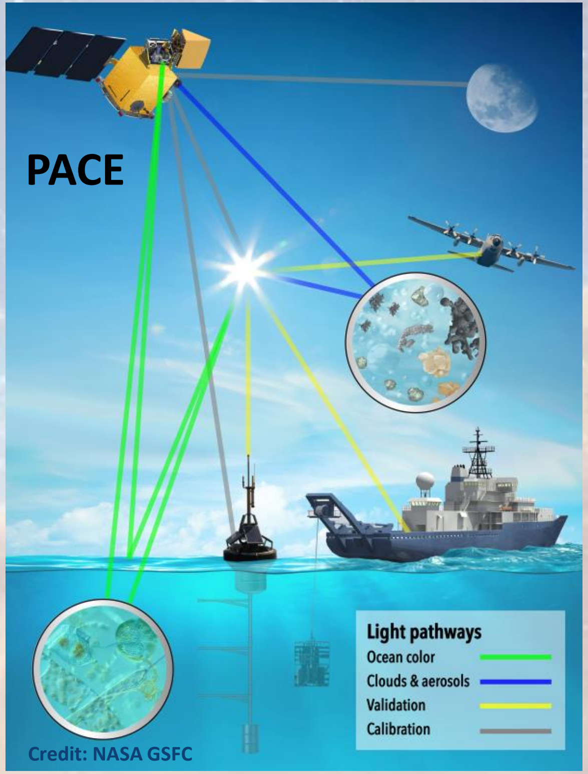
- Earth ecosystems, surfaces, ice masses, and sea level investigation

Nancy Grace Roman ("Roman") Space Telescope — 11 Tb/day

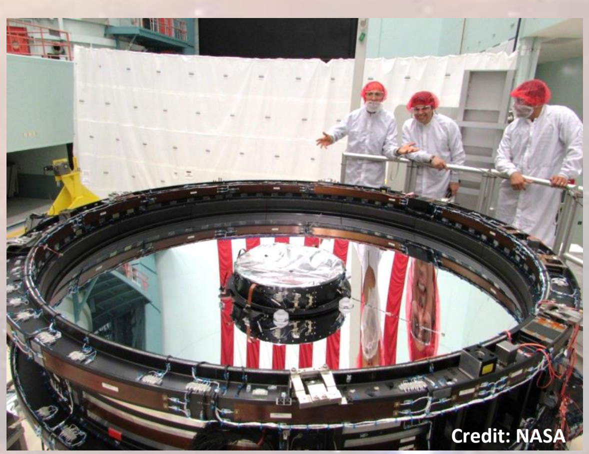
- 2.4m primary mirror, Wide Field and Coronagraph instruments to support investigations of dark energy, exoplanets, and infrared astrophysics

JWST





Roman Optical Telescope Assembly



Background image: "Cosmic Cliffs" in the Carina Nebula – JWST NIRCam Image https://www.nasa.gov/press-release/nasa-reveals-webb-telescope-s-first-images-of-unseen-universe

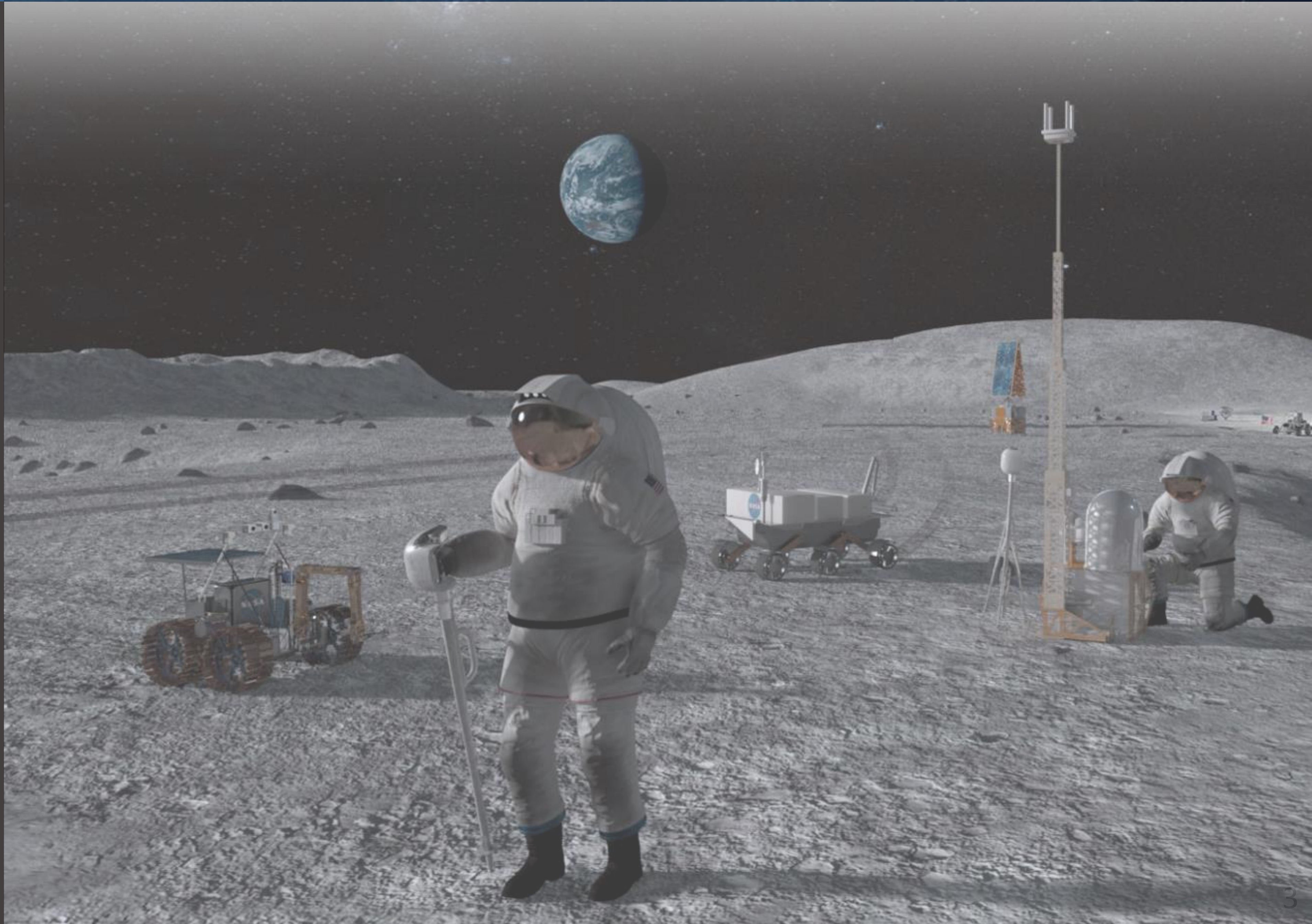
Exploration Drivers (Artemis)

Return to the Moon with international and commercial partners

- Landing the first woman and first person of color on the lunar surface
- Longer duration, sustainable presence – stepping-stone to Mars

Drivers for high data volume include:

- Complex human and robotic operations
- 4k video
- Telemedicine
- Remote operations



NASA's Communications Networks

NASA Near Space Network (NSN)
NASA Deep Space Network (DSN)
Commercial Stations Supporting NSN
Optical
Future Upgrades

Deep Space Network Aperture Enhancement

Objectives: expand capacity, improve flexibility to support customer missions, and reduce operational risks by augmenting the capabilities of the existing antennas

New beam waveguide (BWG) antennas being deployed as part of DAEP span all three Deep Space Communications Complexes (DSCC)

Canberra – New Antennas

- ✓ DSS-35 complete
- ✓ DSS-36 complete
- DSS-33 – planned 2029

Madrid – New Antennas

- ✓ DSS-56 – completed January 2021
- ✓ DSS-53 – completed February 2022

Goldstone – RF/Optical Hybrid Development

- New antenna (DSS-23) –target delivery late 2025, with later upgrade to provide 8-m optical reception as a hybrid RF/optical antenna

Completion of the new DSS-53 BWG antenna in Madrid, Spain

34-m BWGs can be arrayed to create equivalent capability to backup NASA's aging 70-m apertures

One BWG at each complex will be upgraded with an 80kW X-band transmitter which will provide the equivalent EIRP of the 70-m antenna's 20kW transmitter, providing full backup of the 70-m antenna at a complex

Deep Space Lunar Exploration Upgrades

Objectives: increase data rates through low-risk methods to address lunar science and Artemis program near-term needs

Two antennas at each DSN complex with be upgraded with near Earth K-band uplink, totaling six antennas

Capabilities for the upgraded antennas will include:

- Concurrent antenna operations with configurations of either S+Ka-band or X+Ka-band (simultaneous S+Ka-band or X+Ka-band uplinks and downlinks)
- Low latency processing for data up to 150Mbps
- Increased X-band uplink data rates: 5 Mbps
- Increased Ka-band data rates: over 100Mbps downlink, and 20Mbps uplink
- New uplink modulation formats – QPSK/OQPSK, filtered BPSK/QPSK/OQPSK
- Uplink data error correction coding – Reed-Solomon, LDPC

Status:

✓ DSS-26 complete
- DSS-36 underway
- Three of the four remaining antennas to be finished by Artemis III human lunar landing mission

Network Initiative for Ka-band Advancement (NIKA)

Objectives: evolve and modernize the NASA's Near Space Network to provide increased capbility primarily for polar orbiting missions

- Four new 11-m tri-band antennas (Virginia, Alaska, Norway, Chile)
- Integrated high-speed cloud and data services

Leveraged heritage designs and components; new design focused on:

- Radome
- Antenna Ka-band components
- High data rate receiver

Cloud-based storage and data access leverages Amazon Web Service Capability

- 1G WAN
- Data collection to science ops center in minutes

Status:

- Three of the four NIKA stations (Svalbard, Chile, and Alaska) are operating and taking (S-band) passes from legacy missions
- Successfully completed shadow passes on Ka-band for the Joint Polar Satellite System (JPSS) mission
- Wallops antenna in Virginia is scheduled to be completed by the end of calendar year 2022

Alaska – NIKA-Enabled Antenna (AS4)

Radome Installation – Wallops Virginia (WG5)

High Data Rate Receiver

Characteristic	Specification
Storage	20 TB (option)
Demodulation	High speed, up to 6 channels
Aggregate bit rate	Up to ~10 Gbps
Intermediate Frequencies	720 MHz 1.2 GHz 2.4 GHz
Modulations	BPSK, QPSK, OQPSK, 8PSK, 16QAM, 16APSK, 32 APSK, 64APSK
Decoder	Viterbi, Reed-Solomon, LDPC 7/8, DVB-S2

Lunar Exploration Ground Segment (LEGS)

Objectives: development of “18-m class” performance (or better) apertures and/or associated services at multiple ground stations to provide direct-to-Earth (DTE) radio frequency communications support for lunar missions

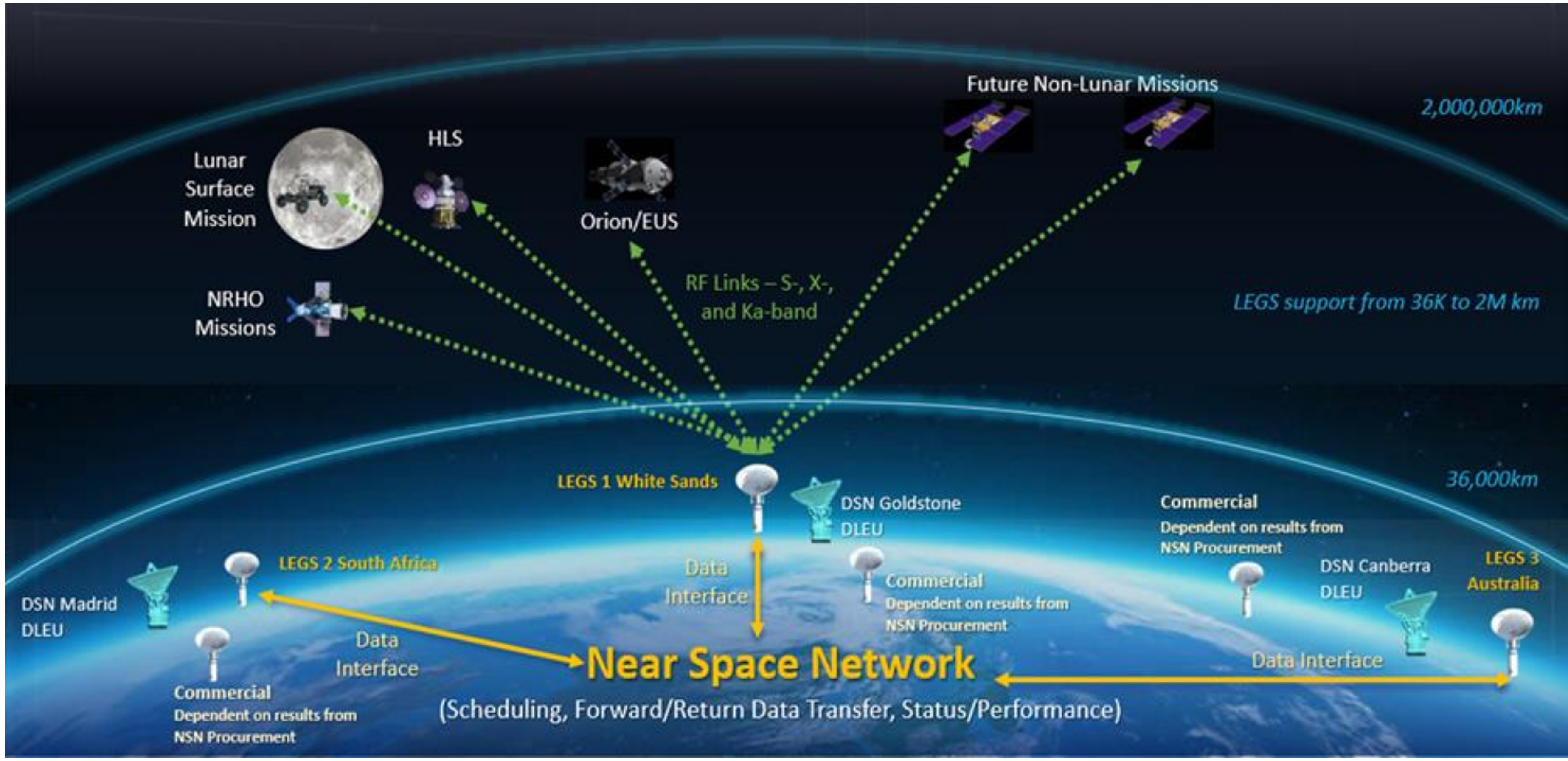
- Three government-owned contractor operated sites – White Sands, NM - USA; South Africa; Australia
- Three commercially owned/operated sites; NASA will purchase services; locations to be determined by outcome of active acquisition process

Sites 1-3 Capability:

- X/Ka-band
- Dedicated to the Artemis Gateway

Sites 4-6 Capability:

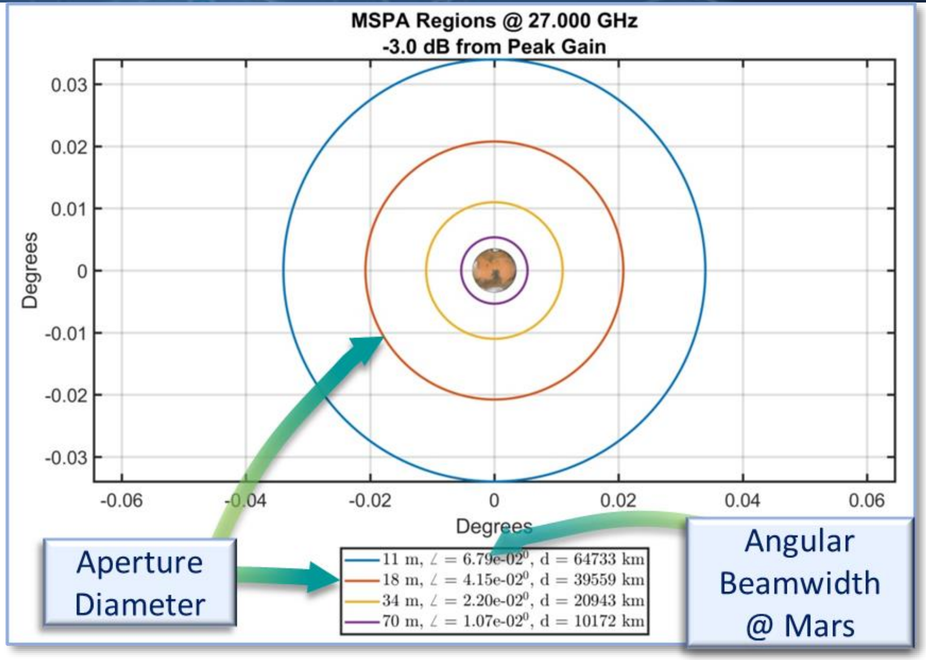
- Tri-band - S/X/Ka-band
- Support for Artemis vehicles/systems – relieve the DSN



Performance Enhancement Technology and Techniques

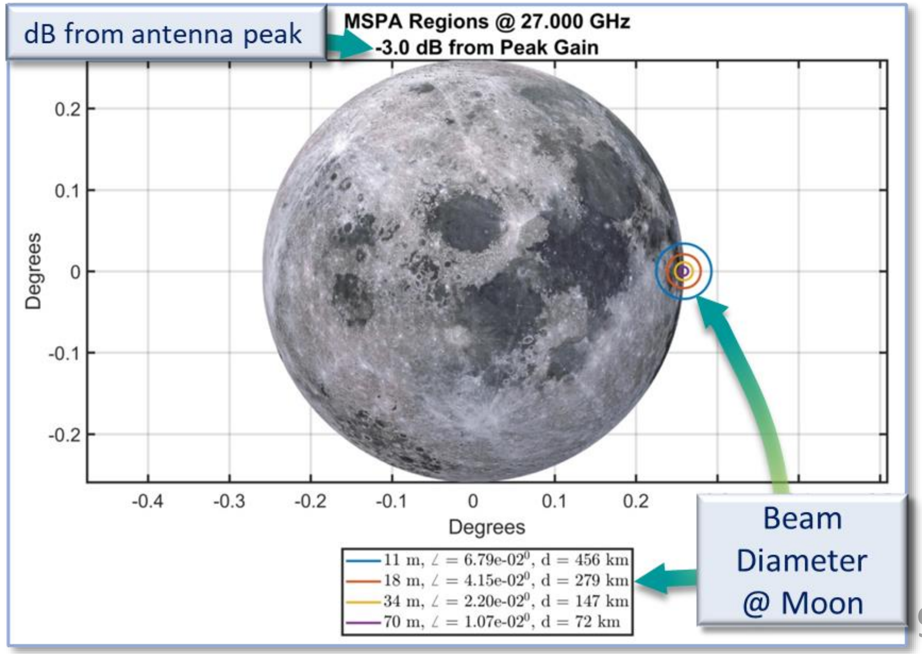
Advanced and Variable Coding and Modulation (ACM / VCM)

- Significant benefit at higher frequencies like Ka-band where power-to-noise ratio over a downlink varies substantially
- Maximizes throughput, provides flexibility to operate at moderate to high-speed data at low elevation, very high speed for medium to high elevation
- NASA Cognitive Communications Project inclusive of cognitive radios capable of ACM/VCM
  - Work in progress to develop cognitive radio applications on CubeSat form-factor software-defined radios
- Advocated by Interagency Operations Advisory Group
- Extensible to lunar communications – VCM included in proximity link interface specifications as part of the “LunaNet” draft Interoperability Specification



Multiple Spacecraft Per Aperture (MSPA)

- NASA DSN capable of 4-MSPA at S/Ka or X/Ka (two bands at a given time)
- Research underway to enable n-MSPA, n > 4
- Beneficial to multi-mission environments in the same region – such as lunar SP – but beamwidth at Ka-band is challenging



Challenges

NASA missions have historically relied on S- and X-band

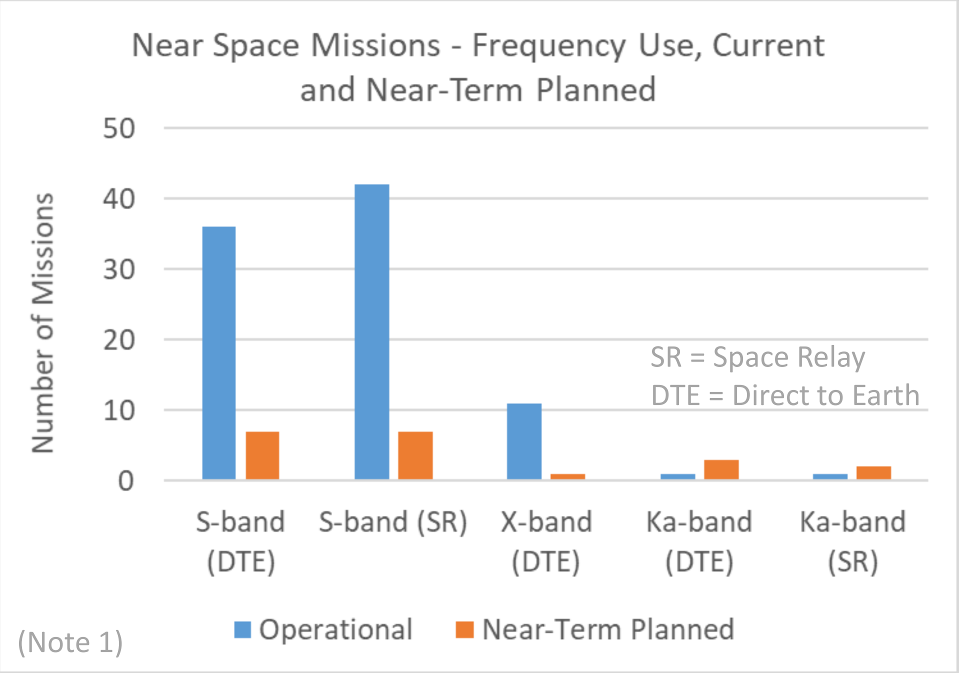
Challenge in part is confidence in, and historical reliability of S- and X-band terminals by NASA missions, and its lack in Ka-band

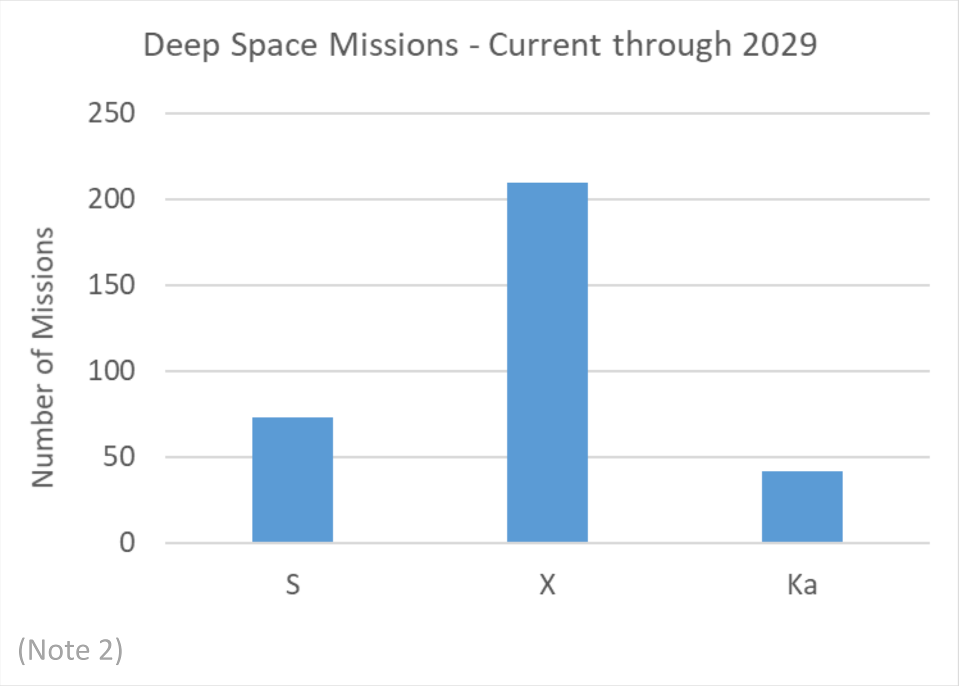
Opportunity to provide pathway for reliable Ka-band user terminals via:

- NASA investment in wideband (22.25-31 GHz return link) multilingual user terminals
  - > Flight demo preparations in work – target 2024
- Investment in SmallSat Ka Operations User Terminal (SKOUT)
  - > Modular communications solution, electronically steered antenna, sized to meet smaller spacecraft mission needs

Operational challenge with Ka-band – atmospheric/ propagation attenuation

- Design to higher link margins, which reduces data rates
- Use of higher-level data transfer protocols supporting retransmission of lost data



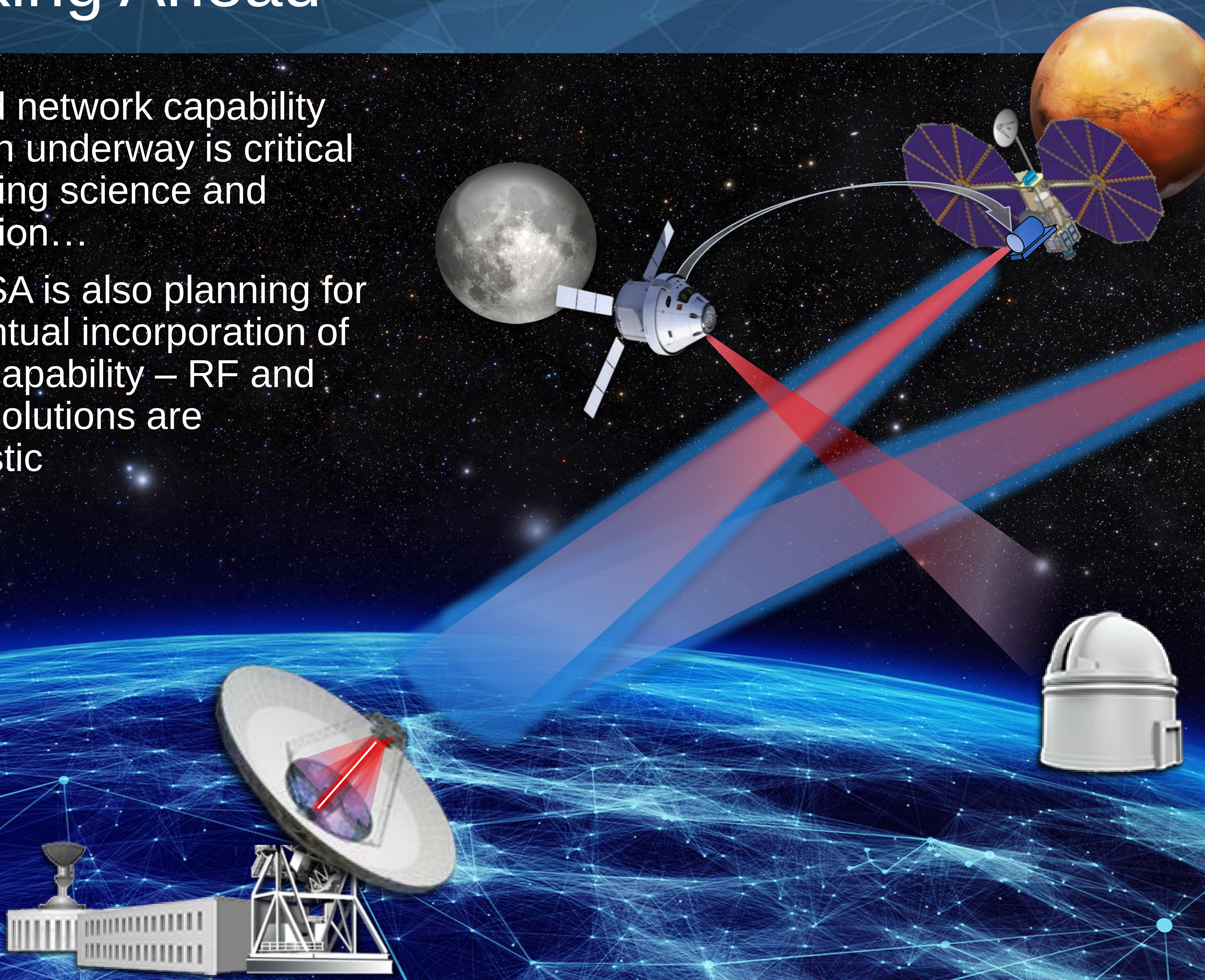


1. Excludes lunar. Data from 2021.
2. Includes lunar. Large mission count in part driven by cubesats associated with multiple Artemis missions.

Looking Ahead

Ka-band network capability evolution underway is critical to enabling science and exploration…

But NASA is also planning for the eventual incorporation of optical capability – RF and optical solutions are synergistic



Past and current investments:

- Low-cost optical ground terminal (LCOT)
- Deep Space Optical Capability (DSOC) – user terminal
- Hybrid optical / RF antenna – integration of 8-m optical aperture in 34-m BWG DSN antenna

Thank you

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