NASA's Wideband Multilingual Terminal Efforts as a Key Building Block for a Future Interoperable Communications Architecture

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Ka and Broadband Communications Conference

NASA Communications Today

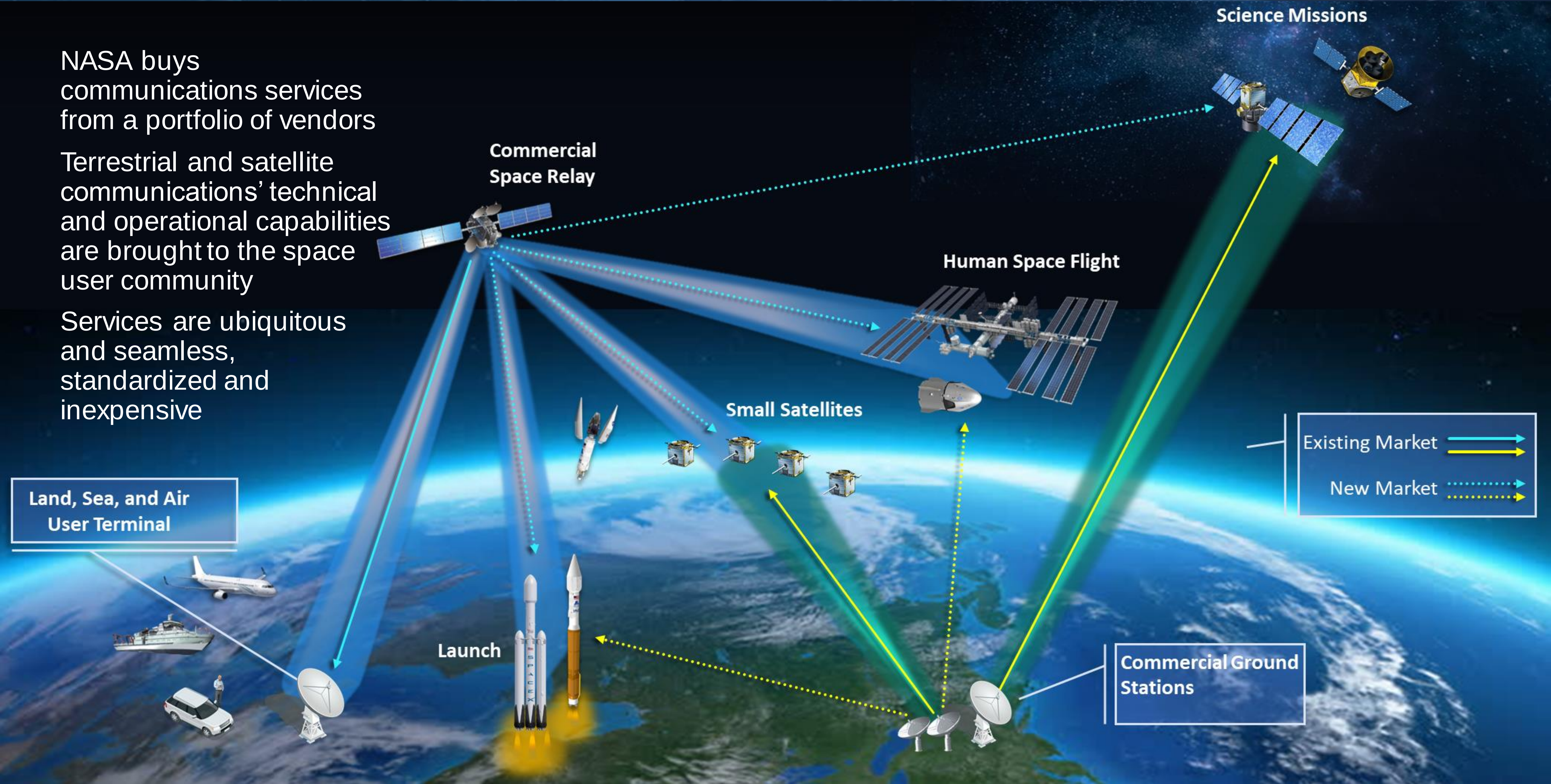
- The National Aeronautics and Space Administration (NASA) owns and operates significant infrastructure to support space mission communications and tracking
- Commercial partnerships for ground services address only about 30% of mission needs in near-Earth space

Communications Vision for Tomorrow

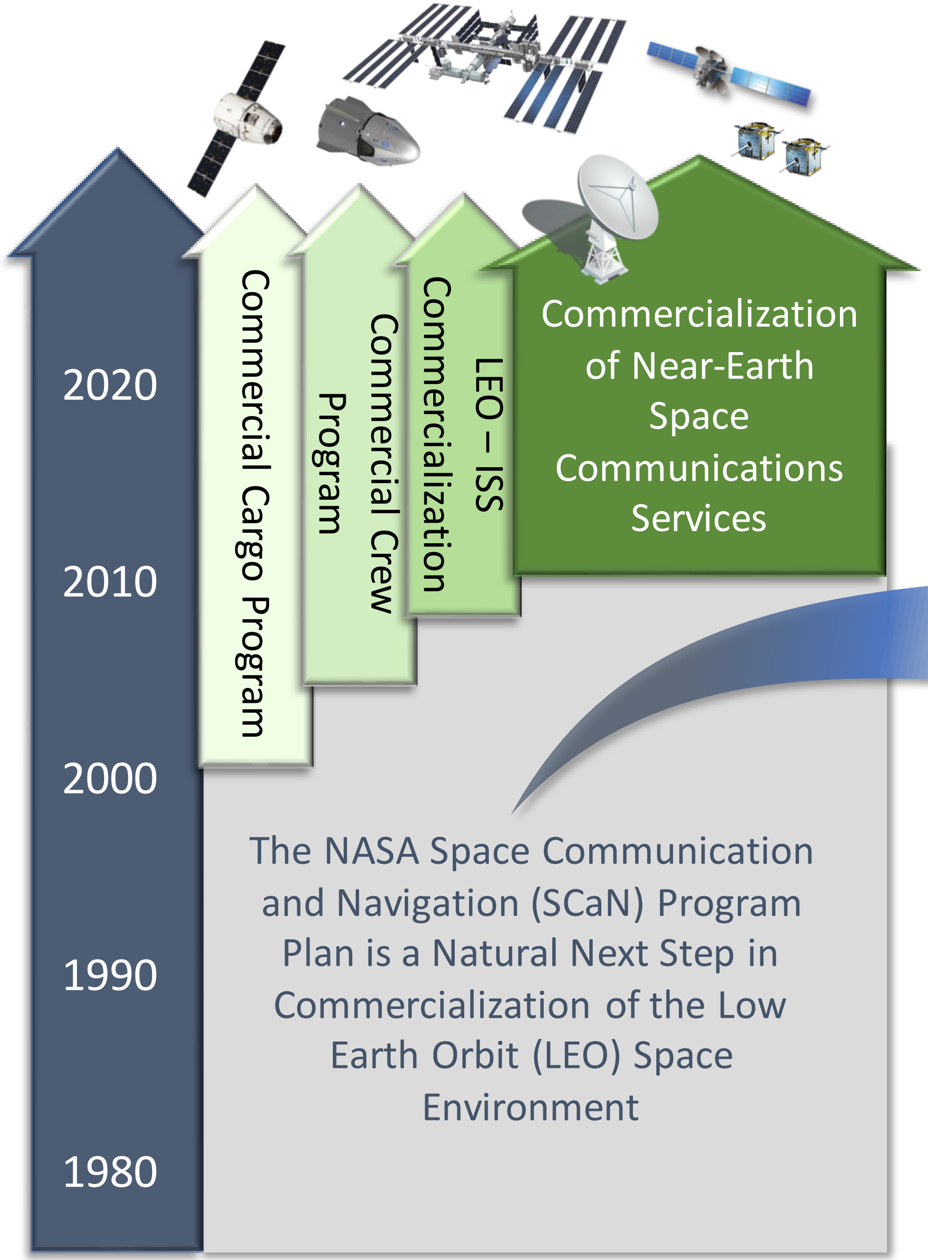
NASA buys communications services from a portfolio of vendors

Terrestrial and satellite communications' technical and operational capabilities are brought to the space user community

Services are ubiquitous and seamless, standardized and inexpensive



Market Opportunity



The global space economy in 2019 generated $366B in revenue, of which $123B was associated with satellite services, and $130.3B was associated with the satellite ground segment market

- Early ground networks were limited to government and a small number of commercial entities
- Significant expansion of ground network service providers in the last decade

- 1980's there were six commercial satellites and 200 transponders on orbit.
- Today there are over 500 satellites and approximately 6,000 transponders.
- Mobile and fixed satellite service industry represents ~$20B in annual revenues

aws, KSAT Kongsberg Satellite Services, Leafspace, SSC, RBC Signals, Infostellar, Atlas Space Operations, Telesat, OneWeb, Iridium NEXT, SpaceX, Globalstar, inmarsat Global Xpress, O3b Networks, SES, Intelsat Epic, Viasat

New companies flying satellites in low earth orbit for commercial purposes are selling a variety of products and services, including imagery, radio occultation data, radio frequency mapping data, and derivative analytics —altogether a $2.3B market.

NASA can be one of many buyers rather than a unique customer!

**Companies listed are illustrative of market activity, not indicative of NASA preference or commitments*

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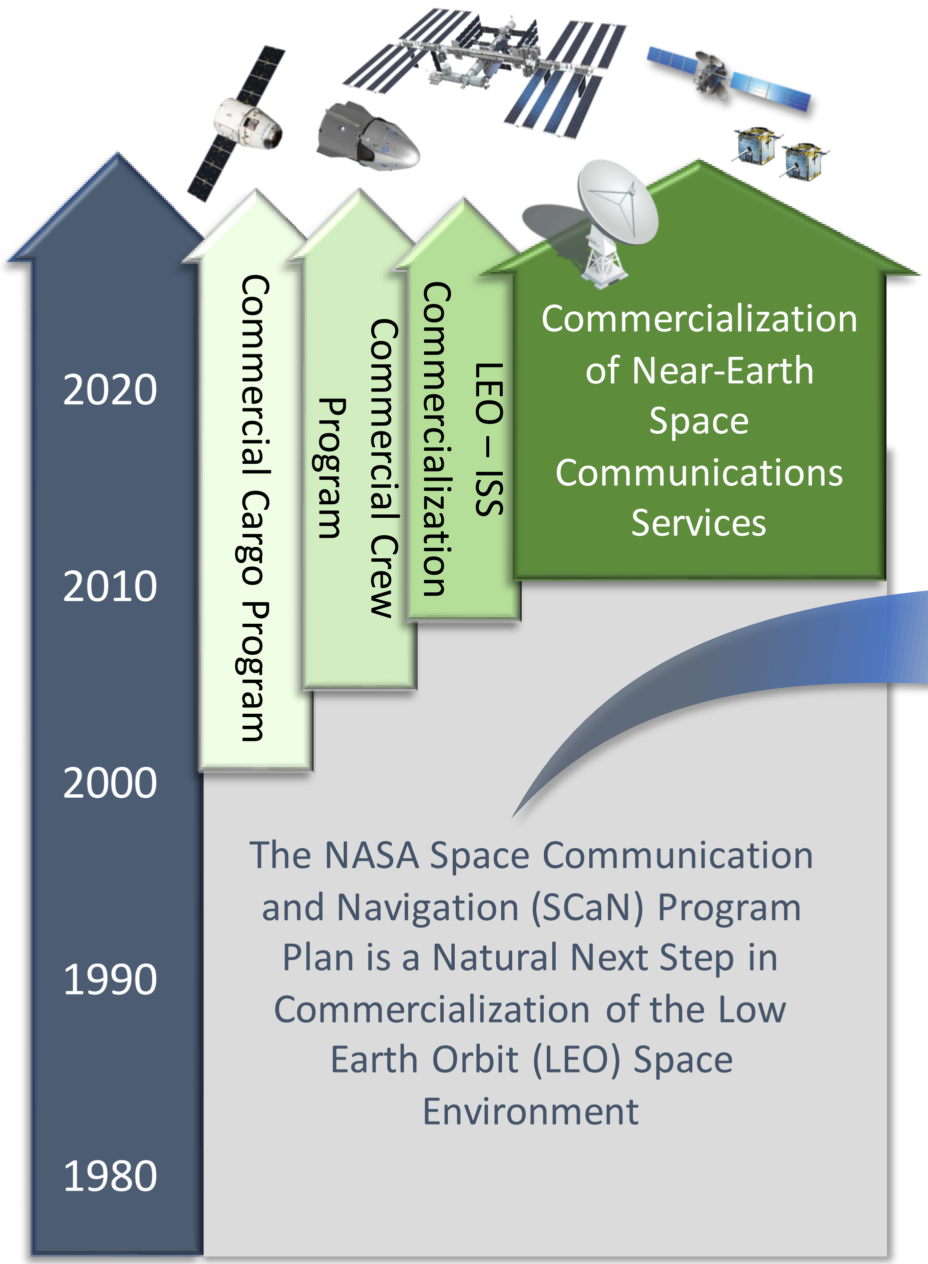

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Amazon Web Services
Kongsberg Satellite Services
Leaf Space
RBC Signals
Swedish Space Corporation
Atlas Space Operations
Infostellar

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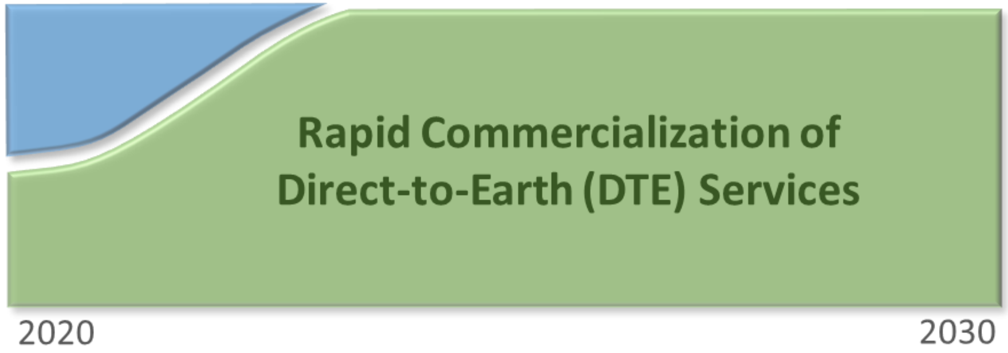
Plan for Commercial Communications Services

"Divide and Conquer" approach is tailored to market capabilities and risks…

TDRSS: Commercialization Target

- NASA will no longer build/deploy Tracking and Data Relay Satellites (TDRS); the current network can support users into the early 2030's
- Time required to validate SATCOM capability for space users and gradually transition future NASA users
- New commercial SATCOM capability used only for new missions; legacy missions fly out on the Space Network

Ground Stations: Commercialization Target



- Near-term increase in services provisioned by current commercial and partner ground sites
- Infuse new vendors drawing on a vibrant and growing market
- Targeting 2023 for 100% commercial service; applies to existing and new missions

NASA-owned service capability

Commercially-provided

Challenges Along the Way

Addressing a New Operational Paradigm

- Quality of Service
- Network insight
- Legacy / Backward Compatibility
- Navigation Gap
- IT Security
- Cost

Achieving Interoperability across networks and providers

- Continue to support civil space standards
- Adopt commercial standards
- Engage with industry
- Pursue Wideband Multilingual User Terminals
- 5G opportunity

Address Spectrum Regulatory Challenges

- Pursue changes within the International Telecommunication Union (ITU) Radio Regulations
- Seek regulatory recognition for space-to-space operations in frequency bands currently allocated to the Fixed and Mobile Satellite Services

Mission Adoption – Accepting change, mitigating risk

- Socialization
- Participation
- Phased transition

Wideband Multilingual Terminals

What:

- Radios that operate across wide ranges of spectrum → "wideband"
- "Multilingual" indicates the capability for the radio to communicate with different systems which may implement proprietary protocols and waveforms

Why:

- Long-term desire is to have interoperability challenge addressed through standards – coordinated with industry and OGAs – but a "breakthrough" on that front is likely not feasible in the near term; wideband multi-lingual terminals provide the means to achieve a form of interoperability in the interim
- Terminals allow missions to access communication services from multiple providers
- Provides for seamless, low risk transition and long-term sustainable service support
- Avoids missions being locked in to using a single vendor's spectrum allocation and waveform

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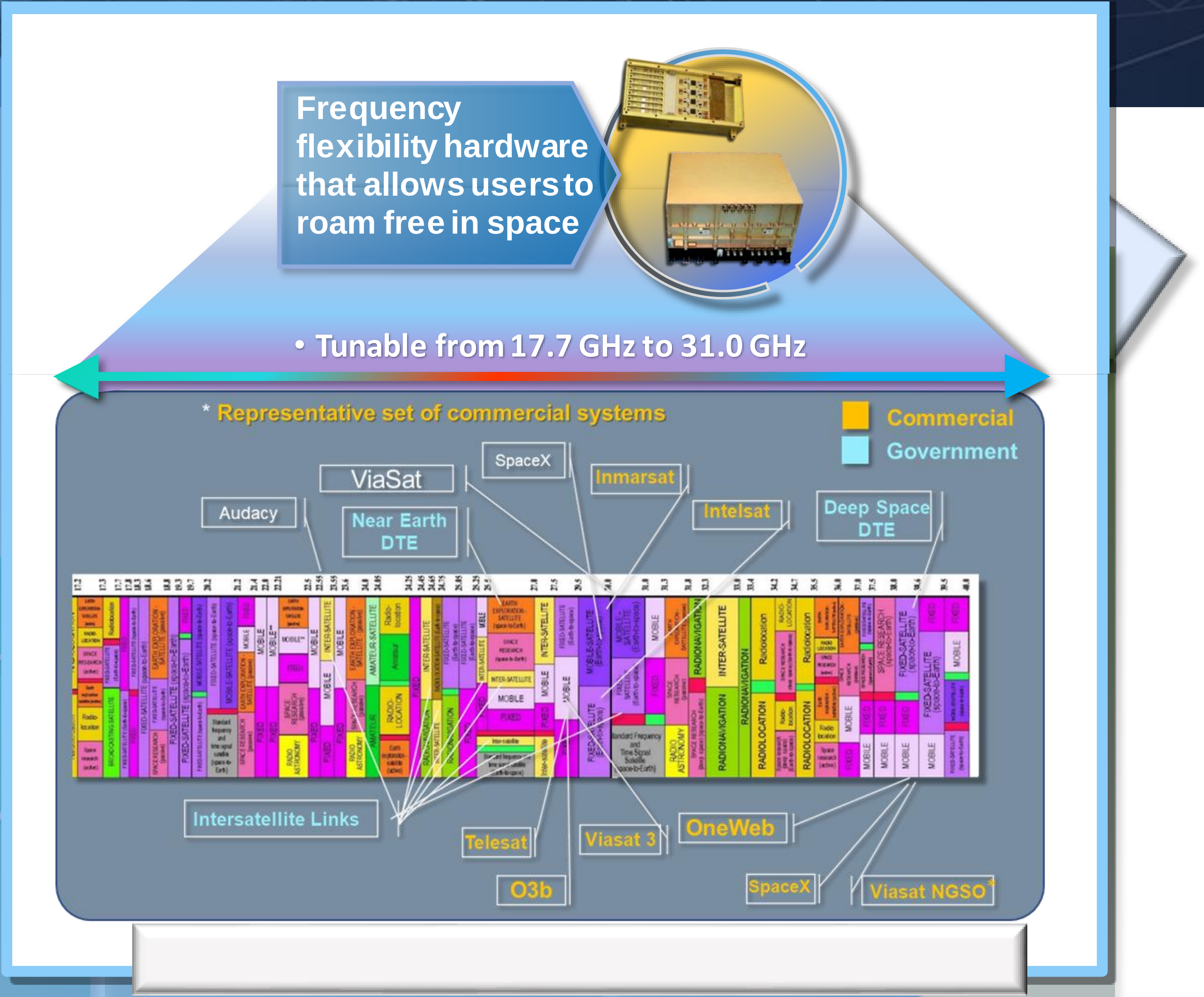


• Cost

Terminal Overview and Approach

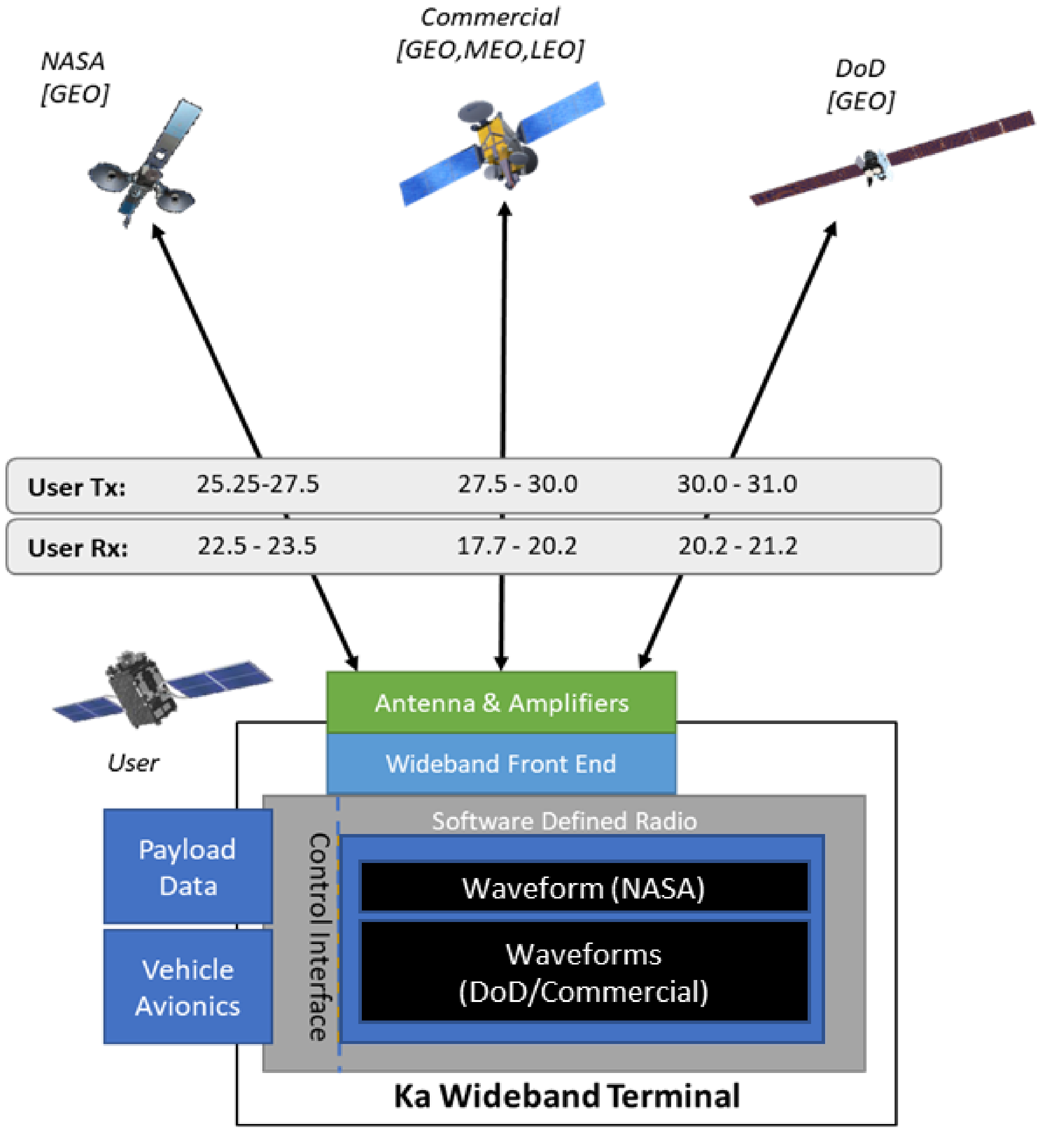
Goal: Support transition of NASA missions to use of commercial space relay services

Drivers / Timeline:

- NASA decision to cut off new TDRSS commitments represents a major transition point for the agency. Commercial capability needs to be established prior to cut-off date

Approach:

- Develop a prototype user terminal to support low latency space relay links across NASA/Commercial/DoD assets
- Operation from 17.7 – 31 GHz also captures TDRSS and near-Earth DTE Ka bands
- Focus on integration of commercially available product lines or, where products do not exist, focus on the development of technology gap areas toward the realization of a flight product
- Conduct a combination of early ground-based and space-based experiments to demonstrate proof-of-concept wideband terminal operations
- Invest in parallel development paths: Glenn Research Center (GRC) and Johns Hopkins Applied Physics Lab (APL)



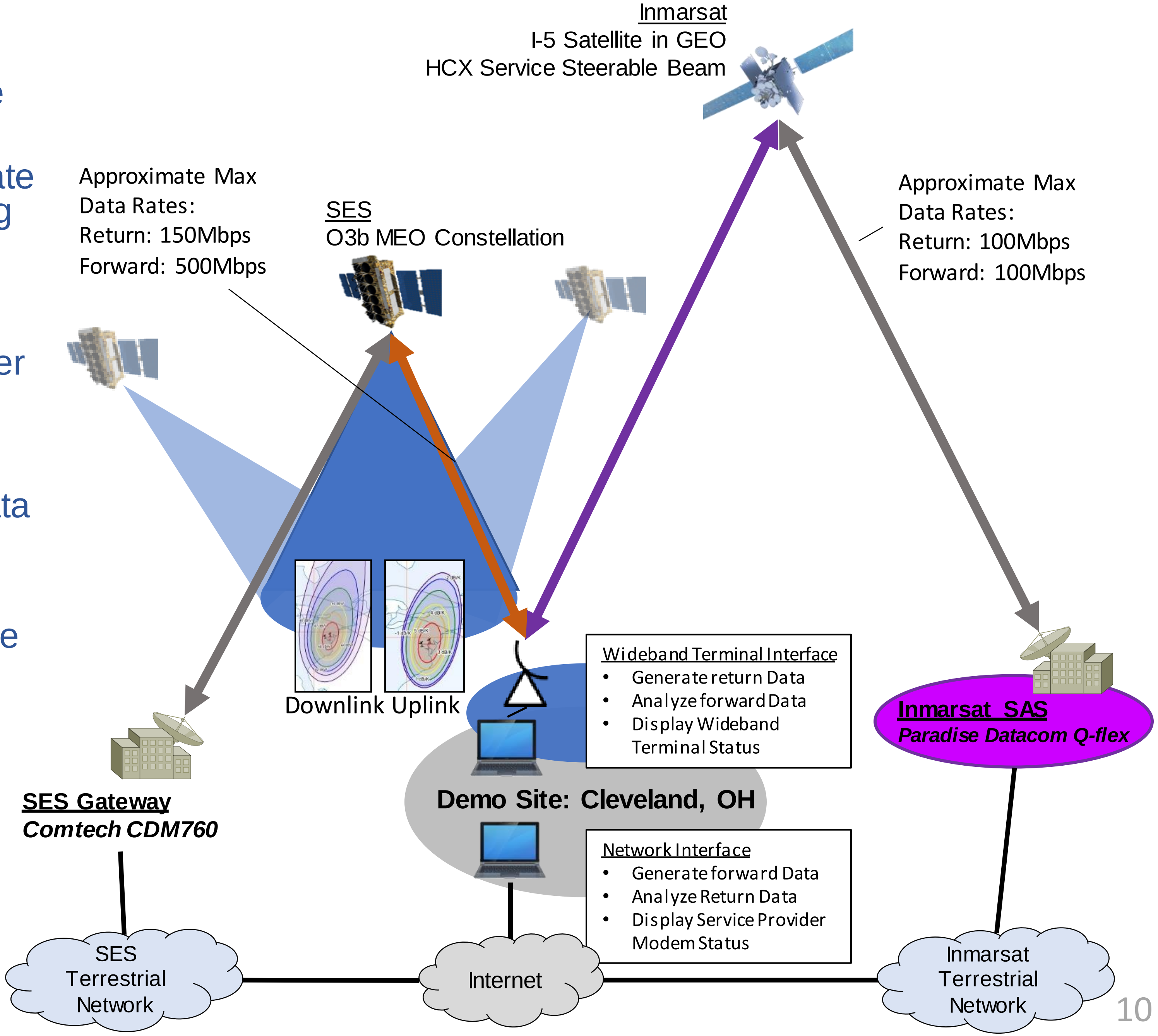
GRC: Test Objectives and CONOPS

Objectives to demonstrate:

1. Demonstrate DVB-S2 over the relay satellite service
2. Demonstrate end-to-end connectivity
3. Variable coding and modulation (VCM) to demonstrate on-the-fly reconfiguration of a modulation and coding (MODCOD) set
4. Emulate spacecraft dynamics for LEO spacecraft by measuring system with an inserted Doppler
5. Optimize performance of high-order modulations over a non-linear channel to determine the optimal drive level for high-order modulations
6. Demonstrate roaming between multiple services by switching between multiple services, establishing data connectivity with both services.

Key hardware components:

- L3Harris 2nd generation AppSTAR radio with heritage design currently in orbit and awaiting launch on numerous spaceflight missions
- Dual stage up/down converter design using COTS parts
- COTS 5G high power amplifier
- Moog QPT-130 antenna pointing system
- 1m Comtech dish antenna
- STRS framework to provide commonality among radio developments



GRC: FY21 Ground Demo Accomplishments

Successfully completed TDRSS testing with standard service and DVB-S2 modes

- TDRSS Legacy Modes: Demonstrated peak rates of 300 Mbps (uncoded) and 150 Mbps rate ½ convolutional encoded
- DVB-S2: Demonstrated peak data rates of ~540 Mbps over 225 MHz channel with 8-PSK LDPC 9/10

Completed Inmarsat-5 testing with 24 DVB-S2/S2X waveform modes including:

- Modulations: QPSK, 8-PSK, 16/32 and 64-APSK
- Forward Error Correction: LDPC code rates 1/4 to 9/10
- >100Mbps – forward and return

Additional tests included:

- Variable Coding and Modulation modes, HPA drive level optimization, Doppler emulation

Successful roaming experiment wherein services switched in real-time (less than 30 seconds of downtime)

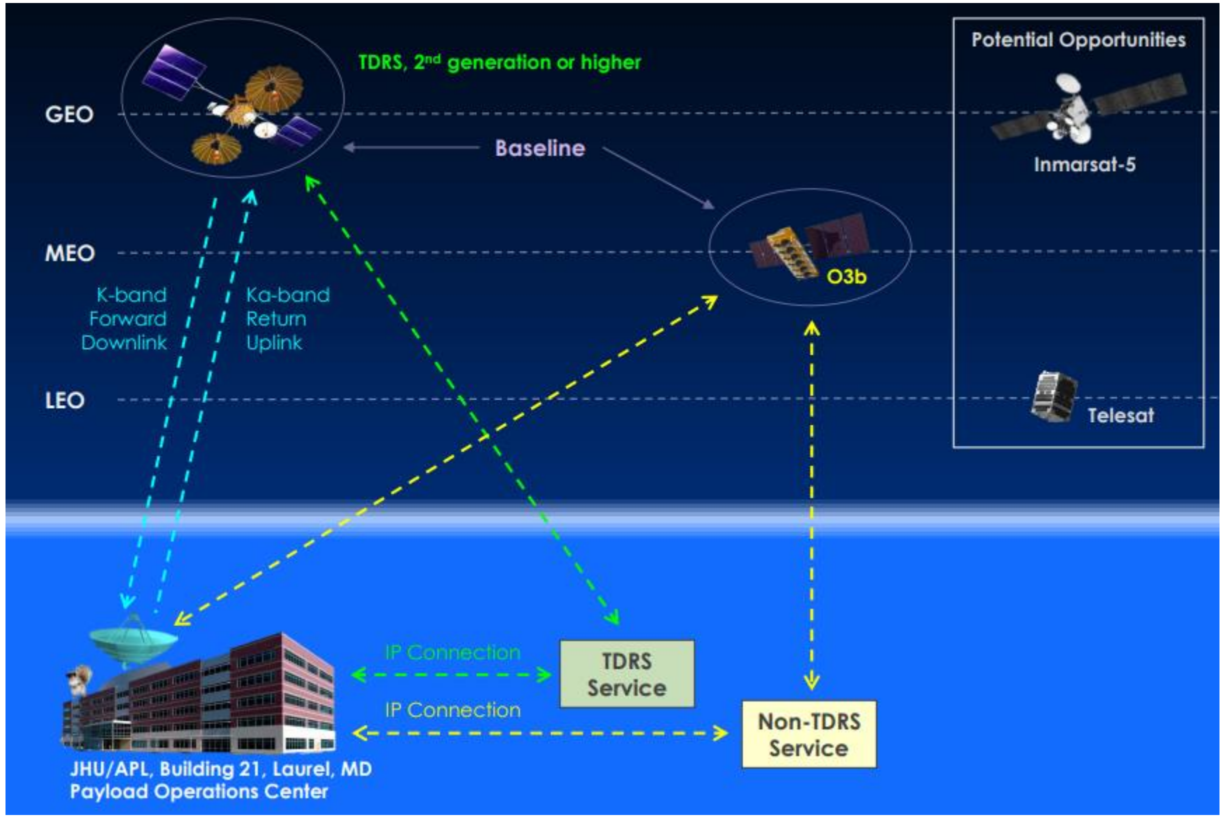
APL: Test Objectives and CONOPS

Objectives to demonstrate:

1. Contact and link management, as well as forward/return link data flow with TDRS, and at least one non-TDRS relay service:
   > TDRS Legacy Ka-band Single Access (KaSA) Forward.
   > TDRS DVB-S2 KaSA Return
   > O3b DVB-S2 Forward and Return
2. Peak symbol rates and link performance via on-orbit relay (Effective Isotropic Radiated Power (EIRP)-limited), and non-EIRP limited in lab environment
3. Demonstrate link performance optimization with radio enhancements (e.g., Digital Predistortion (DPD), equalization, Adaptive Coding and Modulation (ACM), Variable Coding and Modulation (VCM))

Key hardware components:

- APL Frontier Radio with flight heritage
- Stock O3b terminal produced by AvL (870-O3b 85 cm) – modified to include an APL broadband high-power amplifier (HPA)
- Swappable TDRS feed from AvL
- APL custom feed that covers the commercial and USG frequency allocations

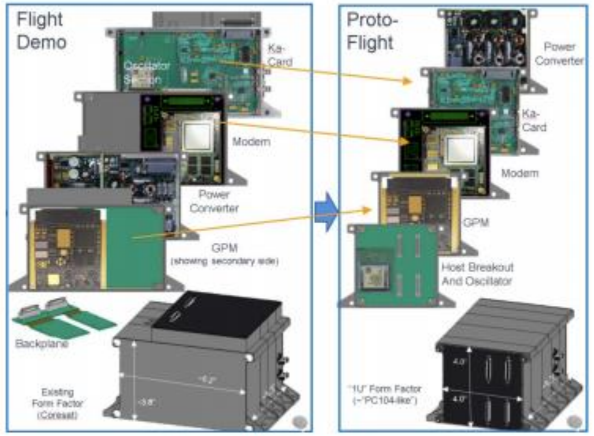


APL: FY21 Ground Demo Accomplishments

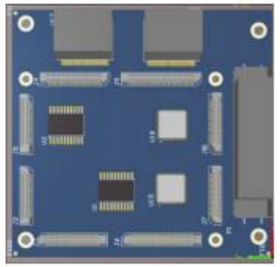
Final results of the demonstrations are forthcoming at the conclusion of the test period; however, initial results are positive:

- Compatibility with SN and O3b-configured COTS modems (CDM-760 and MDM-6000) has been established
- Testing with TDRS exceeded expectations –reaching 270 Mbps return bit rate for a subset of EIRP-limited cases
- Forward and return links with O3b have been exercised at each MODCOD and bit rates up to 74 Mbps (EIRP-limited) have been tested
- Lab-based compatibility tests (not EIRP-limited) with O3b ground hardware and APL prototype hardware have also demonstrated 375 Mbps (return) and 200 Mbps (forward) peak bit rate capability

Preparing for testing with O3b – APL rooftop



Radio Packaging Concept



APL RADSoM for Modem (left), Modem Carrier Board (right)

Ka-Band Front End Board

SpaceMicro CSP for GPM

Wideband 2.0

Notional Wideband 2.0 Build Up

Wideband 1.0 + **Broadband and Agile RF Components** + **GPS & On-Board Nav** + **Context Data, Info Models, Data Availability** + **Broadband and Agile RF Components** + **Cognitive Networking**

Wideband 1.0
- Build on 1.0 wideband terminal development and demonstration as base

Broadband and Agile RF Components
- Build on GRC SKOUT
- Pursue "SKOUT 2.0": more capable Electronically Steerable Array (ESA) capability

GPS & On-Board Nav
- Contributes ability to predict position – self and network assets

Context Data, Info Models, Data Availability
- Incorporate spectrum sensing capability
- Beacon detection

Broadband and Agile RF Components
- Incorporate L- and S-band frequency capability
- Greater resiliency, contingency support from alternate networks
- Omnipresent monitoring and control channel

Cognitive Networking
- Onboard ability to understand available network connections and make selections and execute

Wideband 2.0 Could Provide Seamless Roaming:
- Eliminates user interaction by adding the "intelligence" of state prediction, spectrum sensing, and automated decision making about network connections
- Mission users benefit from overall ease of operation – but impact is difficult to quantify and may challenge mission adoption

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Industry Engagement and Standards

Historically, interoperability among civil space agencies was achieved through collaboration within the Consultative Committee for Space Data Systems (CCSDS)

> Like-minded organizations – common objectives
> Cross-support of spacecraft reduces risk

Going forward: NASA is pushing to adopt more commercial standards as the LEO commercial space market matures:

> Engage with 3GPP
> Bring 5G communications capabilities to space missions
> Support “one of many” objective

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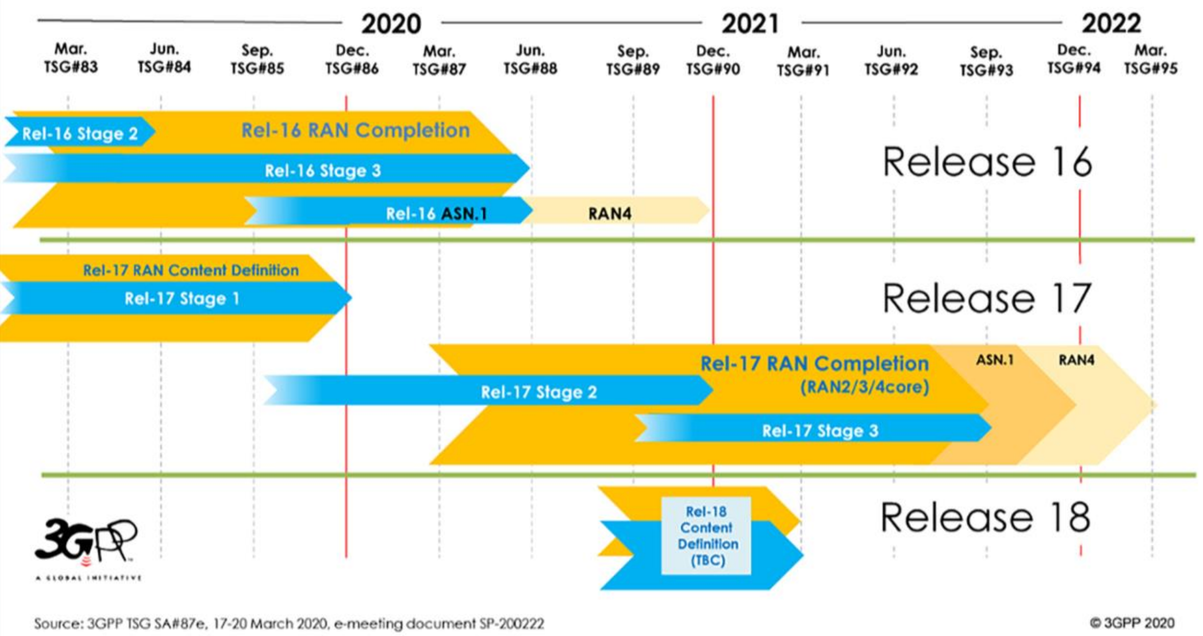


A GLOBAL INITIATIVE

3GPP and Non-Terrestrial Networking

3GPP is developing 5G Release 17, and planning Release 18, both of which will include non-terrestrial network (NTN), or satellite components

Convergence of satellite and terrestrial represents an opportunity for NASA and other space users

NASA became a guest member of 3GPP in 2020

Three objectives for NASA engagement in 3GPP:

- Understand scope of releases and implications for space users
- Make a case for inclusion of the space user as a unique use case for 5G
- Advocate for the evolution of 5G and NTN to support space user needs

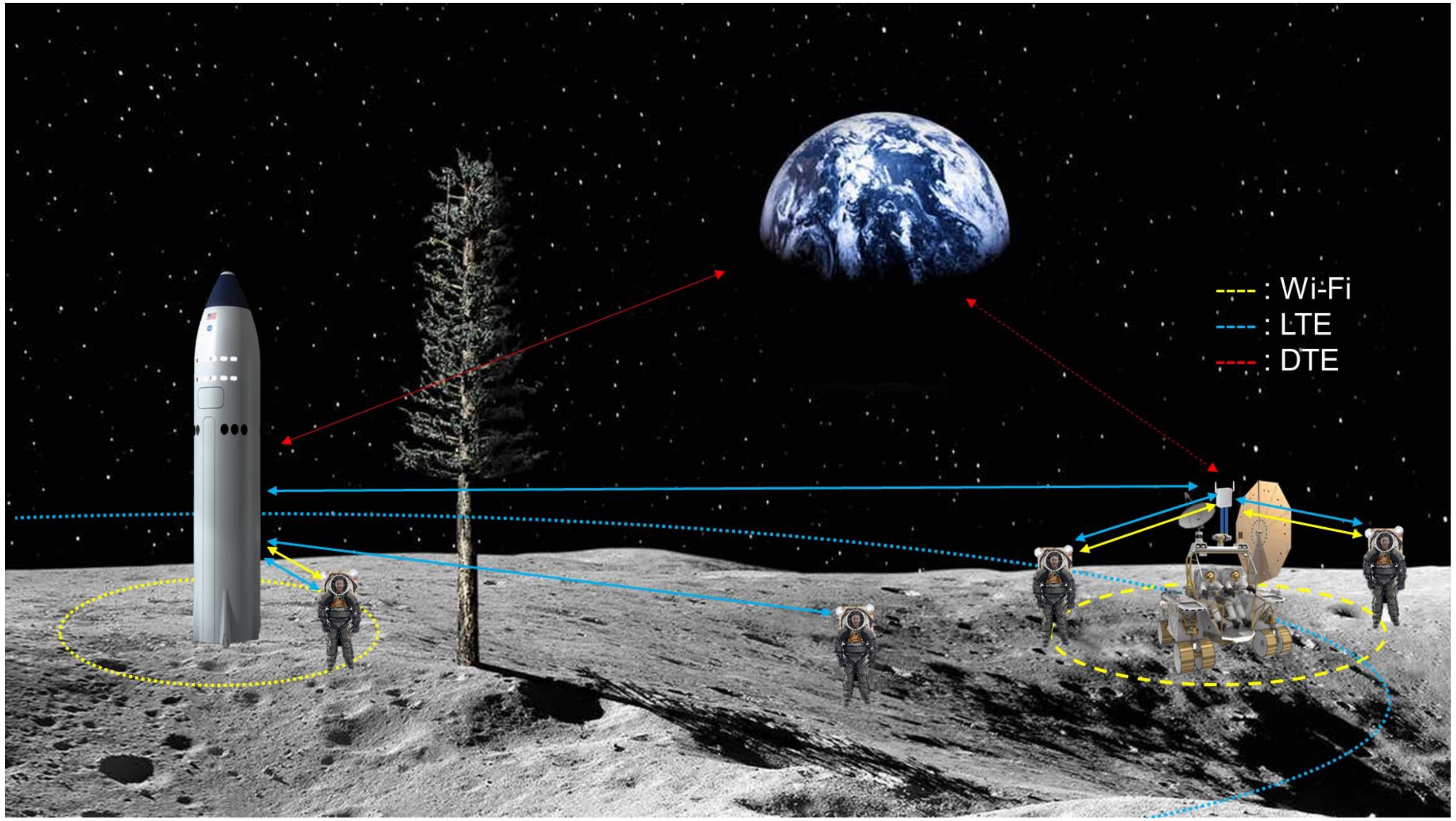
Beyond Earth…

NASA’s interest extends beyond NTN and near-Earth space to using 3GPP as part of future Lunar communication architectures

- Lunar surface use cases identified require kilometer+ distances exceeding 802.11 capability
- Analogous to terrestrial use cases that are supported by 4G/LTE standards

NASA awarded a Lunar Surface Innovation Initiative Technology Demonstration to Nokia, partnering with Intuitive Machines to demonstrate a 4G/LTE base station and user radio on the moon

Future 3GPP releases that address satellite-to-satellite and satellite-to-surface use could also be directly applied to future lunar relay systems



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Looking Ahead

NASA is continuing to focus on both wideband terminal development and engagement with standards bodies (3GPP) as key enablers in the path to commercialize communication services for NASA missions

Next steps include:

- Wideband multilingual user terminal flight demonstrations
- Planning for Wideband “2.0” capability
- NASA to join 3GPP as market representation or organizational partner in FY2022
    - Dedicate personnel / resources to better understand current activities and applicability to space users, advocate for space user use case
- Leverage wideband work, support testing of 5G NTN space-user concepts and capabilities, and help to space qualify commercial equipment
- Feed commercial standards into NASA architectures and plans as applicable

Thank you

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