The Role of Wideband Multilingual Terminals in NASA’s Transition to Commercial Space Communications Services

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NASA’s Near Space Network and Supported Missions

Space-based Relay Component
- Constellation of geosynchronous Tracking and Data Relay Satellites (TDRS) and various ground terminals; designated National Asset
- Provides scheduled, on-demand and emergency support services to users for telemetry, tracking, and command
- ~57 missions currently supported: Key Missions: International Space Station, Commercial Crew, OGA, Hubble Space Telescope, Artemis

Direct to Earth (DTE) Component
- Global coverage via a mix of government, university, and commercially operated ground stations
- ~45 missions currently supported. Key Missions: Artemis, LRO, SMAP, Landsat, NISAR, PACE

NSN provides critical support to users:
- Launch vehicles
- Human space flight
- Earth science missions
- Heliophysics missions
- Astrophysics missions

Diverse locations and characteristics:
- Latency tolerant
- Real-time and near-real-time service
- LEO to Lagrange points nearly 100,000 miles from Earth
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 limited 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.

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

Potential for NASA to be one of many buyers.

*Companies listed are illustrative of market activity, not indicative of NASA preference or commitments.*
Objective: Extend Commercial Capabilities to Space Users

- Commercial Space Relay
- Human Space Flight
- Small Satellites
- Launch
- Land, Sea, and Air User Terminal
- Commercial Ground Stations
- Science Missions
- Existing Market
- Emerging Market
Plan for Commercial Communications Services

“Divide and Conquer” approach is tailored to market capabilities and risks...

- Time required to gradually transition
- Commercial SATCOM capability used for new missions; legacy missions fly out on current government capability
- NASA has no plans to build/deploy Tracking and Data Relay Satellites (TDRS); current network can support users into the early 2030's
- Significant U.S. commercial SATCOM infrastructure exists, however... industry capability tailored to non-space users
- Glenn Research Center & the Communications Services Project (CSP) focused on demonstrating the feasibility of commercial SATCOM
- Rolling wave approach of demonstrating new/expanded services over the 2020s

- In 2020, ~36% of mission passes were provided by commercial partners
- Near-term increase in services provisioned by current commercial & partner ground sites
- Targeting 2023 for 100% commercial service; applies to existing and new missions
- Infuse new vendors drawing on vibrant and growing market
- Targeting 2023 for 100% commercial service; applies to existing and new missions
- Responsibility assigned to Goddard Space Flight Center; team realigned to better support commercial service through virtual network management

TDRS: Commercialization Target

Ground Stations: Commercialization Target
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

Challenges Along the Way
Cognitive Framework Building Block: Broadband and Agile RF Components

Example: 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

- Pursue Wideband Multi-Lingual User Terminals
Wideband Multilingual Terminal Overview & 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
  > Commercial SATCOM has capacity in L, C, Ku, and Ka bands
  > SCaN is targeting Ka-band, in accordance with larger spectrum strategy
    ▪ 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, development of technology gap areas toward realization of a flight product
> Conduct 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)
### “Wideband 1.0” Terminal Specifications

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Comment</th>
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<tbody>
<tr>
<td>The Wideband Terminal shall interface and be interoperable with multiple Ka-Band space assets (commercial, government, and military)</td>
<td>RF Interface</td>
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<td>The Wideband Terminal shall operate over the following frequency assignments: 25.25 GHz – 31 GHz (RTN), 17.7 GHz – 23.55 GHz (FWD)</td>
<td>Spectrum</td>
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<tr>
<td>The Wideband Terminal shall interface with at least one government and two commercial space data networks, as a user, to demonstrate interoperability between a commercial and government network provider.</td>
<td>RF Interface to Government and Commercial systems</td>
</tr>
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<td>The Wideband Terminal shall be able to track commercial, government, and military satellites operating in LEO, MEO or GEO</td>
<td>Service Provider Architecture</td>
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<td>The Wideband Terminal shall be capable of full link management including connecting, maintaining connection, and disconnecting, as well as allowing the Host to fully manage the link.</td>
<td>Link Management</td>
</tr>
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<td>The Wideband Terminal shall support autonomous network management of multiple space assets, such as seamless handover</td>
<td>Network Management</td>
</tr>
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<td>The Wideband Terminal and its components shall be packaged in a form-factor that is compatible with the specified spacecraft and mission class.</td>
<td>Host Packaging</td>
</tr>
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<td>The Wideband Terminal shall be designed for spacecraft and missions with a dry mass &gt;100kg</td>
<td>Host Packaging</td>
</tr>
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<td>The Wideband Terminal shall be capable of reconfiguration in flight to support communication with future space data networks</td>
<td>Re-programmability</td>
</tr>
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<td>The Wideband Terminal shall support the cryptography necessary to support connection with specified networks and protection of mission command stack per NASA Space System Protection Standard (NASA-STD-1006)</td>
<td>Security</td>
</tr>
<tr>
<td>The Wideband Terminal shall receive navigation information from the ground or host to perform pointing</td>
<td>Pointing</td>
</tr>
<tr>
<td>The Wideband Terminal shall interface with the Host using modern standard interfaces to maintain compatibility with the specified spacecraft and mission class. This includes power, command, telemetry, time, and data.</td>
<td>Interface</td>
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<tr>
<th>Terminal Performance</th>
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<tr>
<td><strong>Frequency Bands</strong></td>
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<tr>
<td><strong>Bandwidth</strong></td>
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<td><strong>Antenna</strong></td>
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<td><strong>Axial Ratio</strong></td>
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<td><strong>Polarization</strong></td>
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<td><strong>EIRP</strong></td>
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<td><strong>G/T</strong></td>
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<td><strong>Power</strong></td>
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<td><strong>Mass</strong></td>
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<td><strong>Temperature</strong></td>
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<td><strong>Life, Radiation, EMC</strong></td>
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NASA Sponsored Wideband Demonstrations – FY21

GRC successfully completed ground demonstrations with NASA’s TDRSS and Inmarsat’s Global Xpress using prototype Wideband RF Terminal:

- TDRSS: Demonstrated peak data rates of ~540 Mbps with 8-PSK LDPC 9/10.
- Global Xpress: Demonstrated >100 Mbps bidirectional data using DVB-S2
- Successfully demonstrated service roaming from TDRSS to Global Xpress with <30 sec transition time
- Demonstrated CCSDS and IP-compatible data flow
- Emulated realistic channel impairments (e.g. Doppler) to provide confidence that system works in LEO environment

APL team completed a Test Readiness Review (TRR)

- Rooftop terminal integrated and ready for testing
- O3b beam and TDRSS time secured
- Up to ~100 Mbps forward and return with O3b, >200 Mbps return on TDRSS
- Demonstration will run from June 21 – Aug 2021
- Optional bonus testing with Telesat
Wideband Progress In the Cognitive Framework Context

Cognitive Communications Framework

- Machine-Based Decision Making
- Data Semantics, Languages, Ontologies
- Dynamic Spectrum Access
- Cognitive Networking
- Cross-Layer Protocol Interactions
- Delay/Disruption Tolerant Networking
- Context Data, Info Models, Data Availability
- Data Storage
- Adaptive Rates and Auto-Configuration
- Signal Processing and SW Defined Radios
- Broadband and Agile RF Components
- Data Analytics, Mining and BI
- Context-Aware Routing

Development to Date

“Wideband 1.0”

- Broadband and Agile RF Components
- Signal Processing and SW Defined Radios
- Adaptive Rates and Auto-Configuration

Wideband 1.0 Capability

- Roaming between networks
- Requires “manual” / operator intervention and direction

William D. Horne; Therese Suaris; Raymond T. Gilstrap; Ryan Rogalin
Looking Ahead to “Wideband 2.0”

**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.
Moving Forward with Cognitive: Improving Networks

- SCaN expects communications in the near-Earth regime to be supplied by a set of heterogeneous services providers, both government and commercial.
- The legacy operational model is broken, can cognitive technologies be applied in this new era?

Cognitive building blocks applied to the network

A “must have” as we move further toward multi-provider networks
Moving Forward with Cognitive: What Do Missions Need?

Cognitive communications and network capabilities are multi-faceted – different components and building blocks to create a more complex / capable architecture

But are all capabilities or building blocks equal?
> Missions are the ultimate arbiters of value

NASA’s investment in cognitive needs to be driven by mission needs going forward
> NASA SCaN is already challenged to improve mission adoption of other enabling operational approaches and capabilities including:
  > Migration from X-band to Ka-band
  > Integration of Delay/Disruption Tolerant Networking protocols, CCSDS File Delivery Protocol (CFDP)
  > Variable Coding and Modulation

> Realistic assessments need to be made moving forward
  > Current roadmap to interoperability is long – interdependent pieces, which may not all have equal value from the mission perspective
  > What can we accomplish with the components that missions perceive to have a need for, what is the killer app?
  > How will this shape our prioritization? → Might autonomy be of greater importance than cognition?
THANK YOU

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