National Aeronautics and Space Administration

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

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Contents

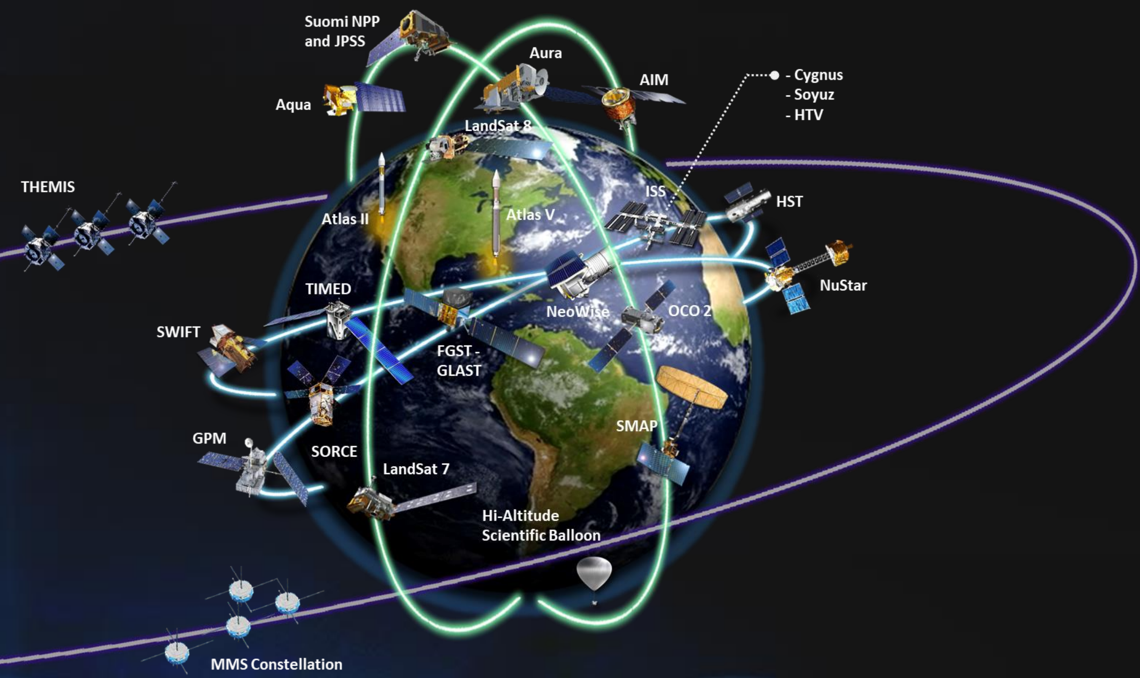
NASA's Near Space Network and Supported Missions

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



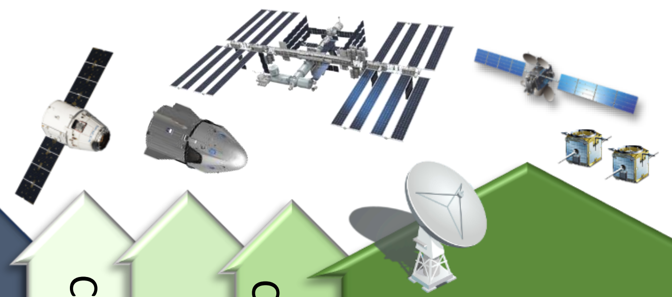
NSN provides critical support to users:

- 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

Market Opportunity



2020

2010

2000

1990

1980

Commercial Cargo Program

Commercial Crew Program

LEO – ISS Commercialization

Commercialization of Near-Earth Space Communications Services

The NASA Space Communication and Navigation (SCaN) Program Plan is a Natural Next Step in Commercialization of the LEO Space Environment

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

aws | KSAT KONGSBERG SATELLITE SERVICES | RBC SIGNALS | LEAFSPACE | SSC | ATLAS SPACE OPERATIONS | Infostellar

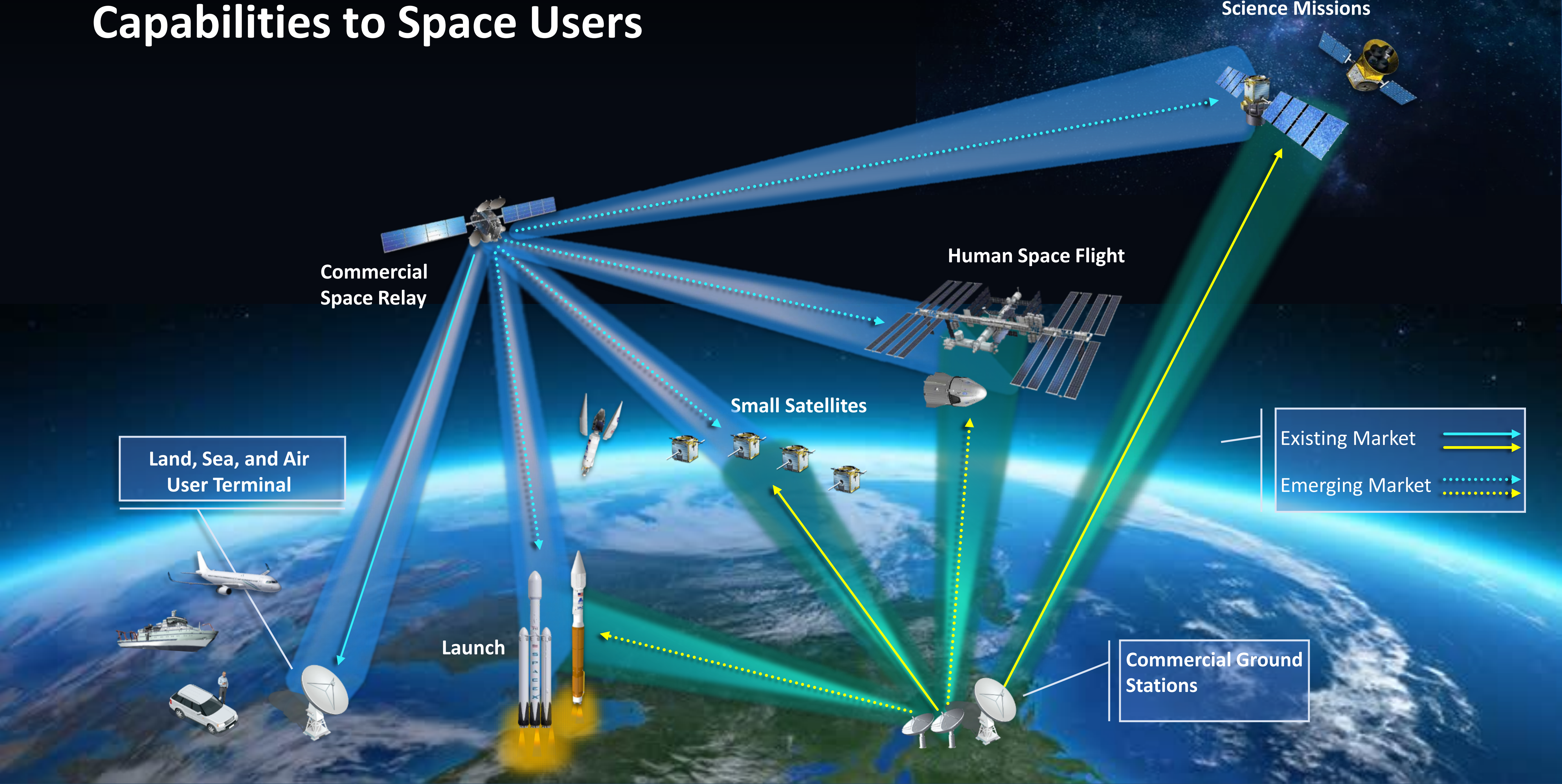
Telesat | OneWeb | Iridium NEXT | SPACEX | Globalstar | inmarsat Global Xpress | O3b Networks | SES | INTELSAT Epic NG | Viasat

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



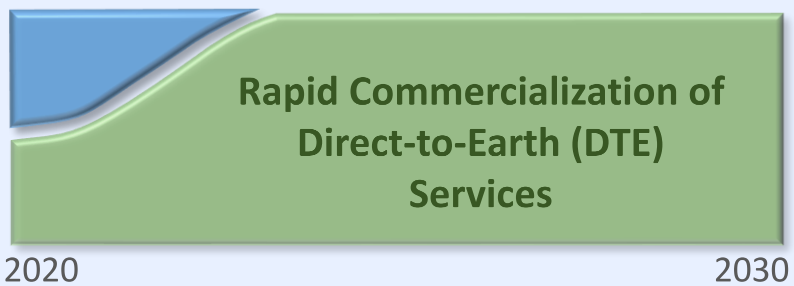
Plan for Commercial Communications Services

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

TDRS: Commercialization Target

- 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

Ground Stations: Commercialization Target



- 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

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

Cognitive Framework Building Blocks: Part of the Solution

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:

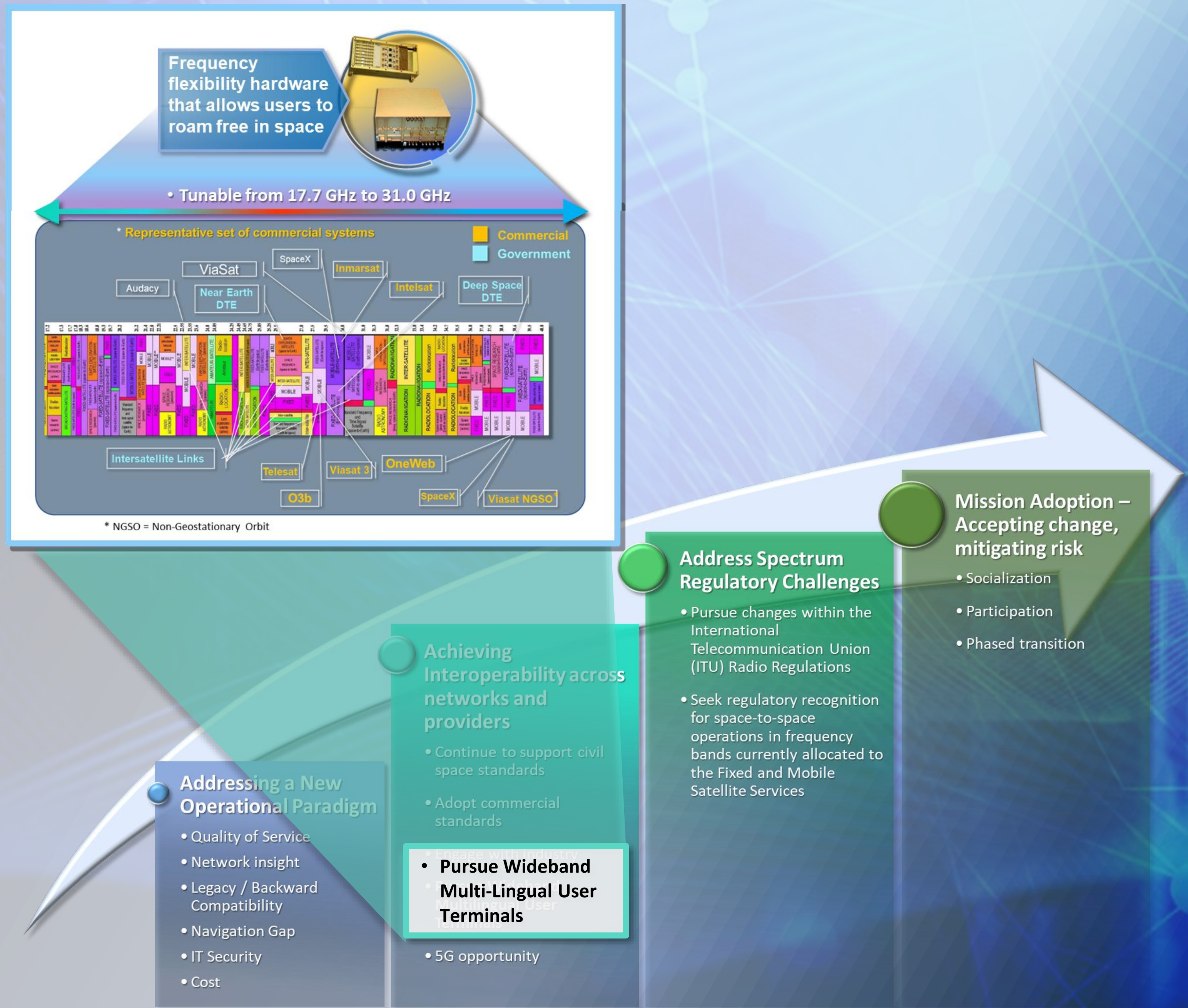
> Long-term desire is to have interoperability challenge addressed through standards – coordinated with industry and OGAs – but a "breakthrough" on that front is likely not feasible in the near term

> 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



Wideband Multilingual Terminal Overview & Approach

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

Drivers / Timeline:

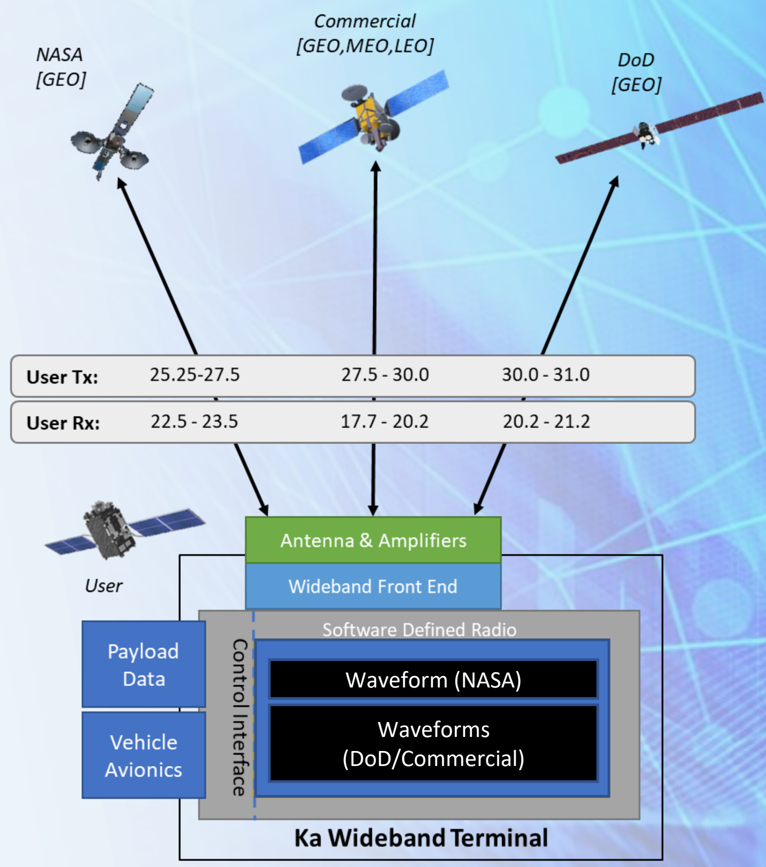
> **NASA decision to cut off new TDRSS commitments represents a major transition point for the agency. Commercial capability needs to be established prior to cut-off date**

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**

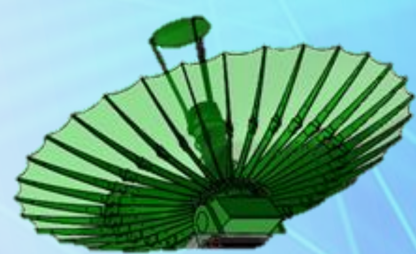
> **Conduct combination of early ground-based and space-based experiments to demonstrate proof-of-concept wideband terminal operations**
>
> > Invest in parallel development paths; Glenn Research Center (GRC) and Johns Hopkins Applied Physics Lab (APL)

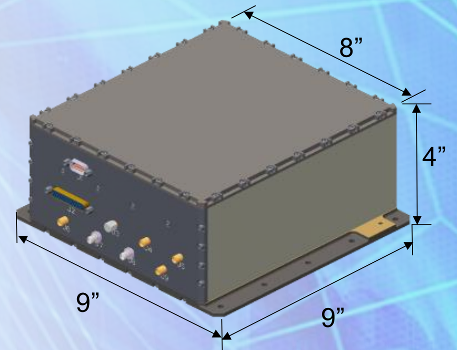


"Wideband 1.0" Terminal Specifications

Requirement	Comment
The Wideband Terminal shall interface and be interoperable with multiple Ka-Band space assets (commercial, government, and military)	RF Interface
The Wideband Terminal shall operate over the following frequency assignments: 25.25 GHz – 31 GHz (RTN), 17.7 GHz – 23.55 (FWD)	Spectrum
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.	RF Interface to Government and Commercial systems
The Wideband Terminal shall be able to track commercial, government, and military satellites operating in LEO, MEO or GEO	Service Provider Architecture
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.	Link Management
The Wideband Terminal shall support autonomous network management of multiple space assets, such as seamless handover	Network Management
The Wideband Terminal and its components shall be packaged in a form-factor that is compatible with the specified spacecraft and mission class.	Host Packaging
The Wideband Terminal shall be designed for spacecraft and missions with a dry mass >100kg	Host Packaging
The Wideband Terminal shall be capable of reconfiguration in flight to support communication with future space data networks	Re-programmability
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)	Security
The Wideband Terminal shall receive navigation information from the ground or host to perform pointing	Pointing
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.	Interface

Terminal Performance	
Frequency Bands	17.7 – 23.55 GHz Receive 25.25 – 31.0 GHz Transmit
Bandwidth	>500 MHz/200MHz (Tx/Rx)
Antenna	<1.0 m
Axial Ratio	1 dB Axial Ratio (Tx) 1.5 dB Axial Radio (Rx)
Polarization	Selectable RHCP and LHCP
EIRP	>50 dBW
G/T	>12 dB/K
Power	<150 W (active)
Mass	<15 kg
Temperature	-25C to +55C baseplate operational -35C to +60C baseplate survival -40C to +85C baseplate storage -35C cold start
Life, Radiation, EMC	Life >= 15 year Radiation =100 krad, no destructive SEE EMI/EMC = MIL-STD-461F





NASA Sponsored Wideband Demonstrations – FY21

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

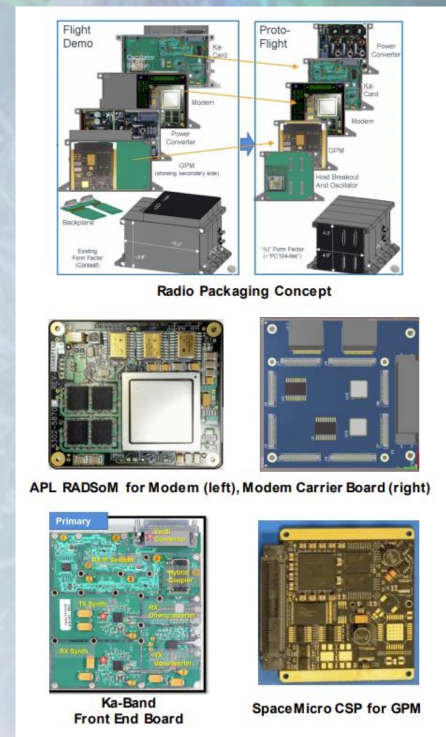
- TDRSS: Demonstrated peak data rates of ~540 Mbps with 8-PSK LDPC 9/10.
- Global Xpress: Demonstrated >100 Mbps bidirectional data using DVB-S2
- Successfully demonstrated service roaming from TDRSS to Global Xpress with <30 sec transition time
- Demonstrated CCSDS and IP-compatible data flow
- Emulated 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

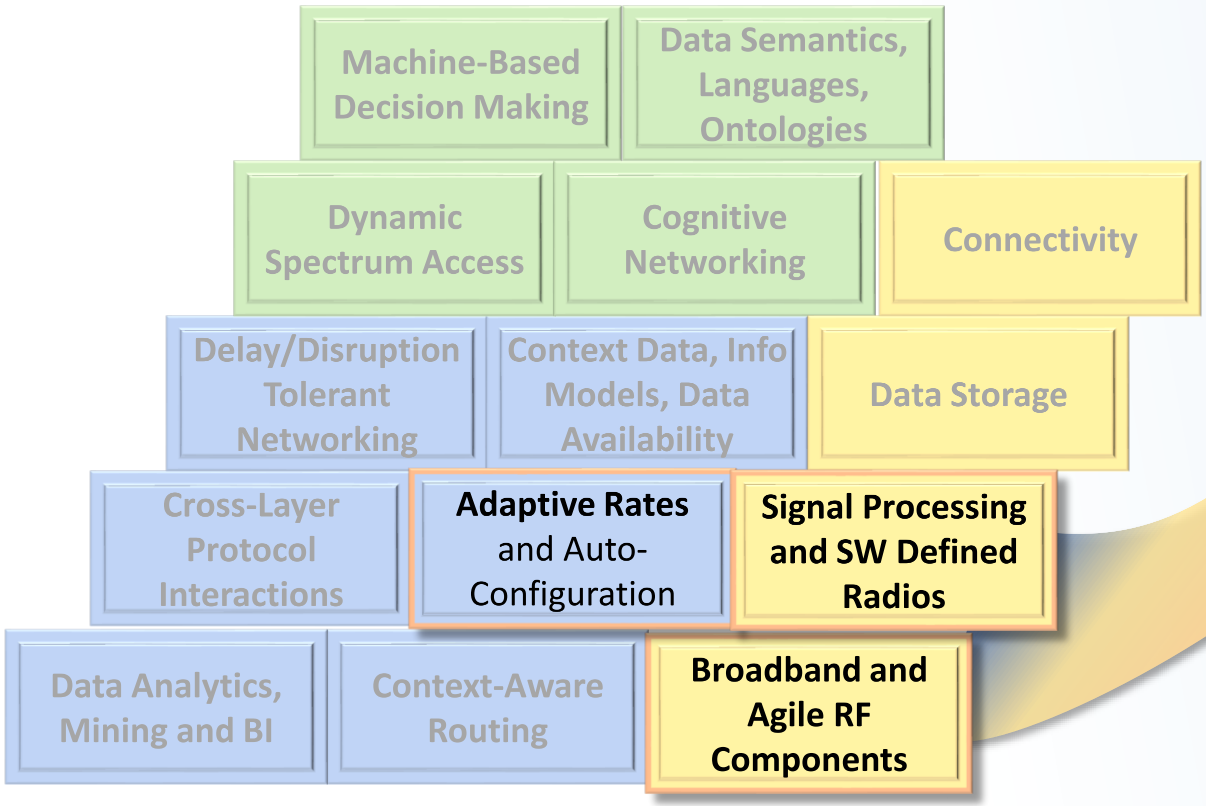
GRC Team and Terminal

Preparing for testing with O3b – APL Rooftop



Wideband Progress In the Cognitive Framework Context

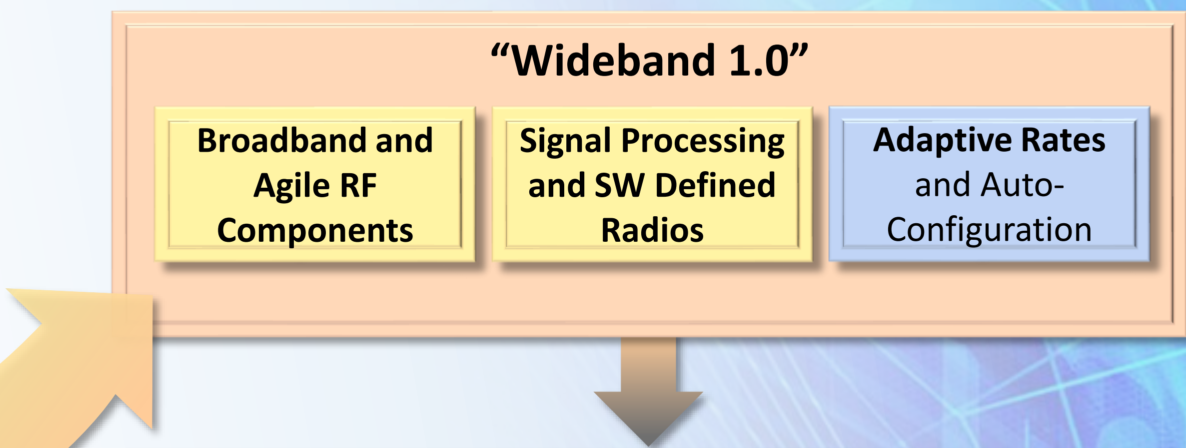
Cognitive Communications Framework



Cognitive Communication Framework: Reference – "Developing the Building Blocks for Cognitive Communications: Adaptive Rates and Intelligent Networking"
William D. Horne; Therese Suaris; Raymond T. Gilstrap; Ryan Rogalin

- Base Building Block
- Supporting Building Block
- Advanced Building Block

Development to Date



Wideband 1.0 Capability

> Roaming between networks
> Requires "manual" / operator intervention and direction

Looking Ahead to "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

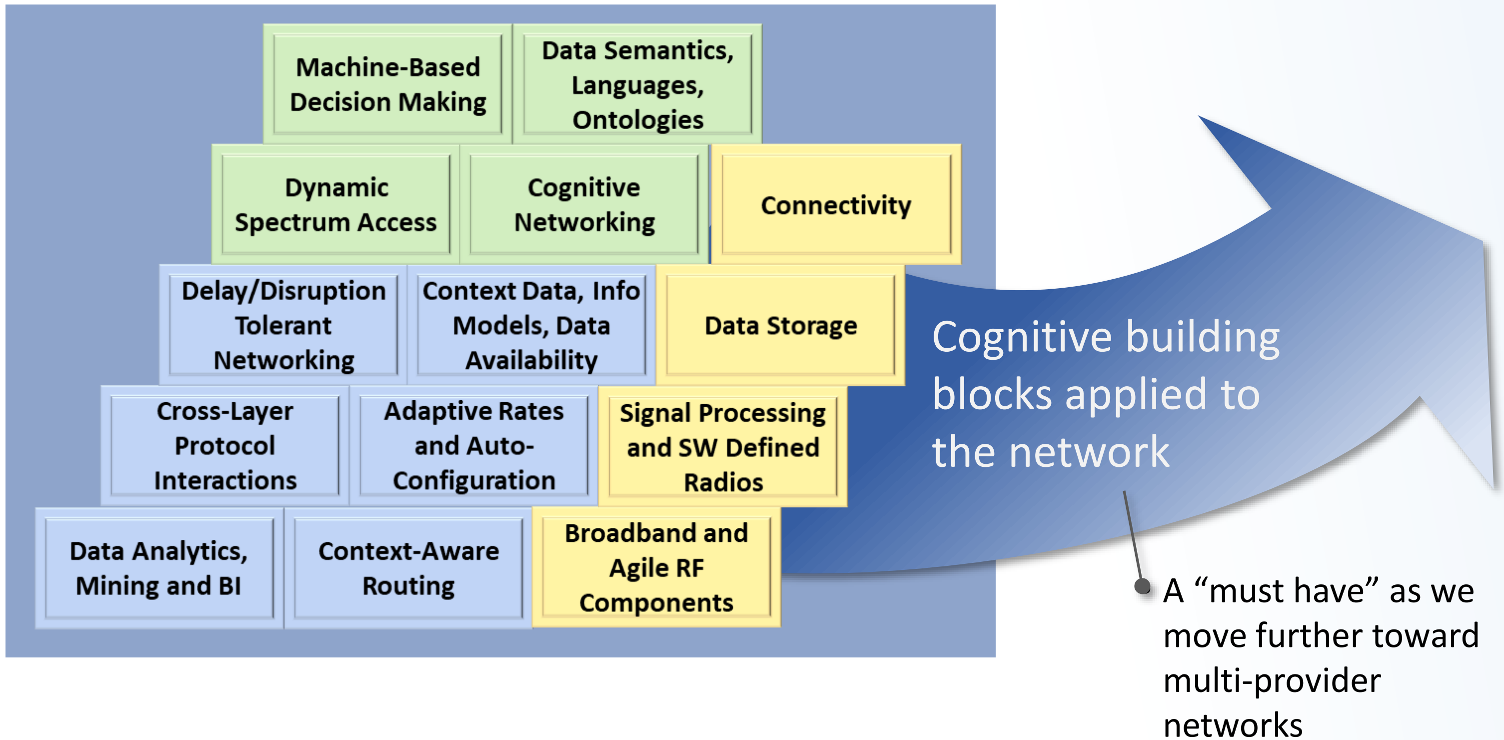
Wideband 2.0 Could Provide Seamless Roaming:

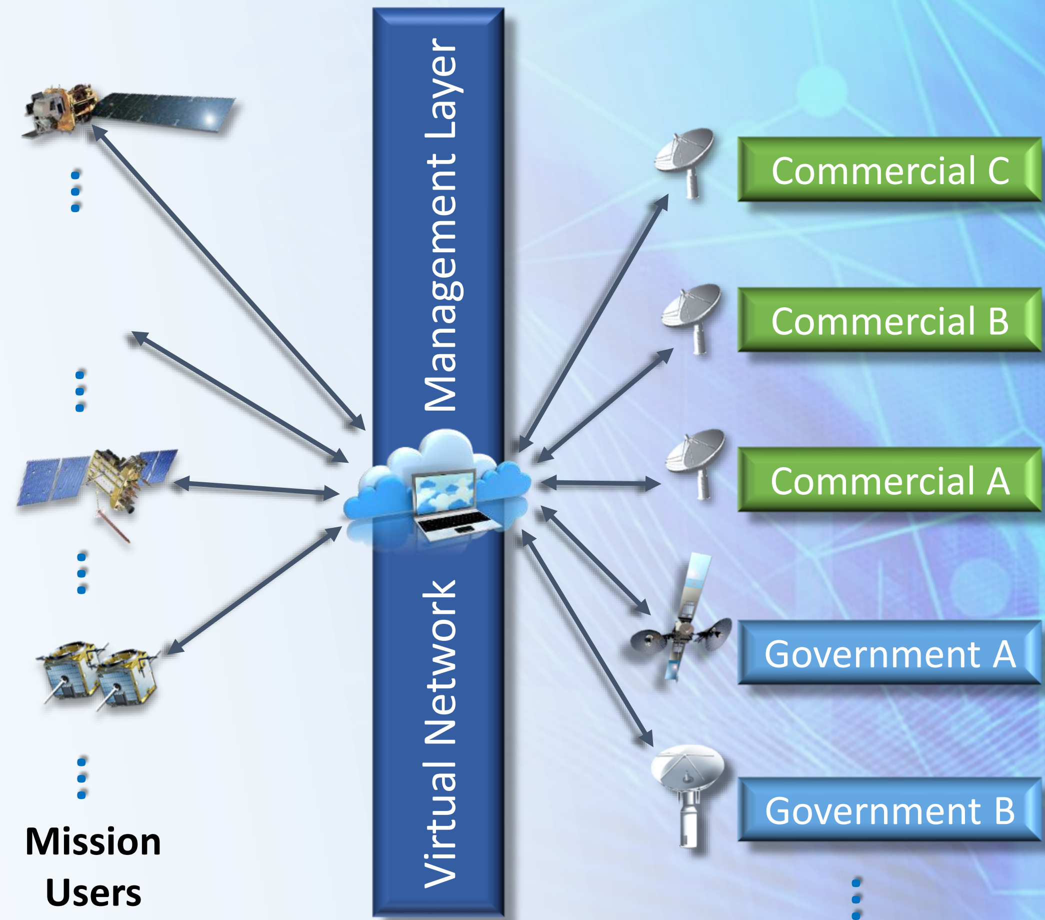
Eliminates user interaction by adding the "intelligence" of state prediction, spectrum sensing, and automated decision making about network connections

Mission users benefit from overall ease of operation – but impact is difficult to quantify and may challenge mission adoption

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 by applied in this new era?**





Virtual Network Management Concept

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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