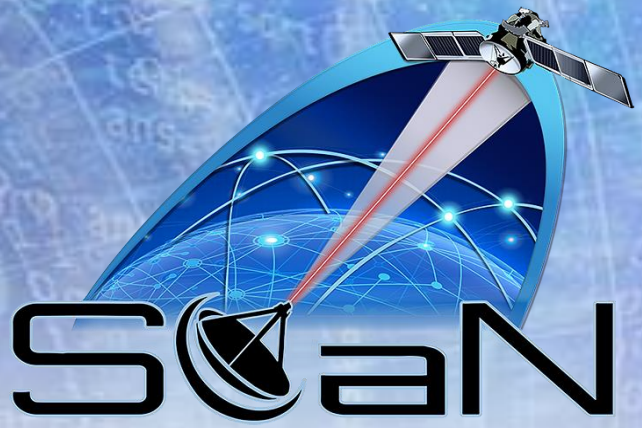
National Aeronautics and Space Administration



Space Communication and Navigation

Development and Demonstration of a Wideband RF User Terminal for Roaming between Ka-band Relay Satellite Networks

26th Ka and Broadband Communications Conference

38th International Communications Satellite Systems Conference (ICSSC)

Marie Piasecki

NASA Glenn Research Center

SCaN's Vision, Goal & Strategy

VISION: Interoperable and resilient space and ground communications and navigation infrastructure

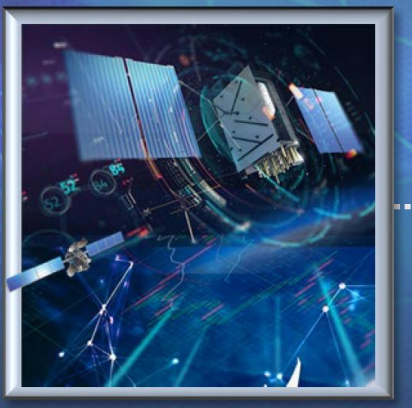
GOAL: Enable high speed, robust, secure, and cost-effective space communications and navigation services to future science and exploration missions

Foster an Affordable and Growing U.S. Space Industry

Leverage Commercial Capabilities to Increase Efficiency and Robustness of NASA Space Networks

Infuse Transformational Technologies to Enhance Services Near the Moon and Beyond

Ensure Efficient Use of Spectrum through Regulatory Oversight and Streamlined Processes

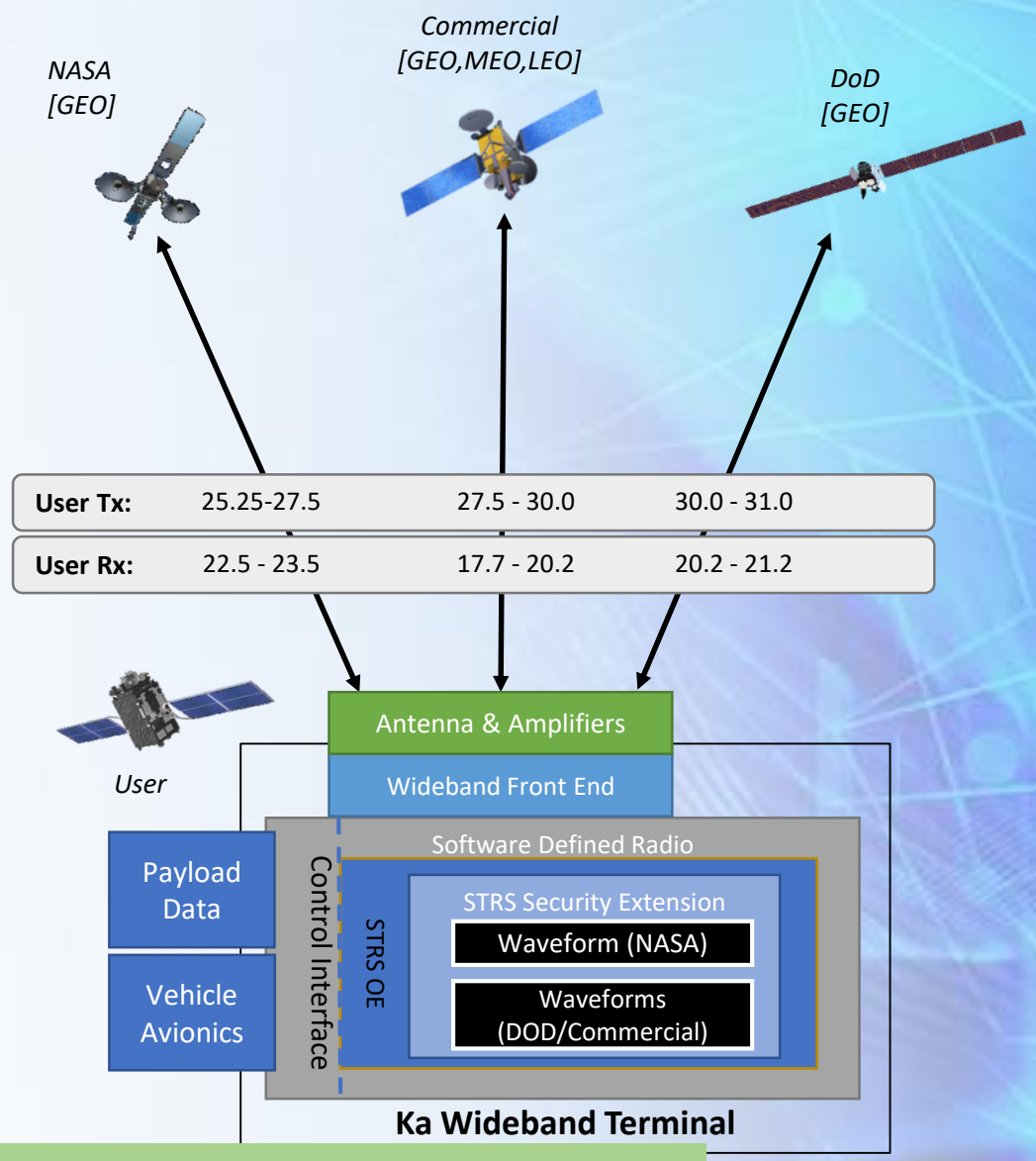


Provide Technical Leadership in Pursuing and Implementing PNT Policies and Technology

Wideband RF User Terminal Purpose and Approach

Demonstrate a Wideband Terminal with a path to flight to support NASA's transition to commercial SATCOM services

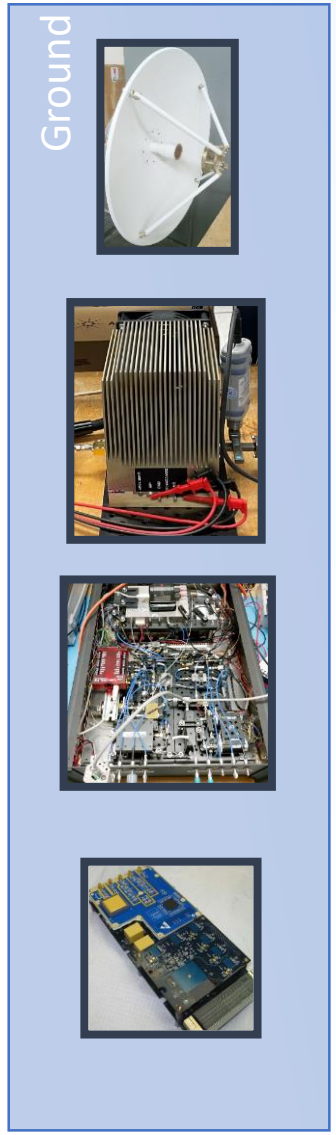
- **Demonstrate connectivity with a variety of services**
  - > NASA/Military/Commercial Relays
  - > LEO/MEO/GEO Orbits
- **Seamlessly Roam between different providers**
- **Develop and integrate commercially available products into a complete terminal**
- **Provide a flexible, resilient solution for future missions**

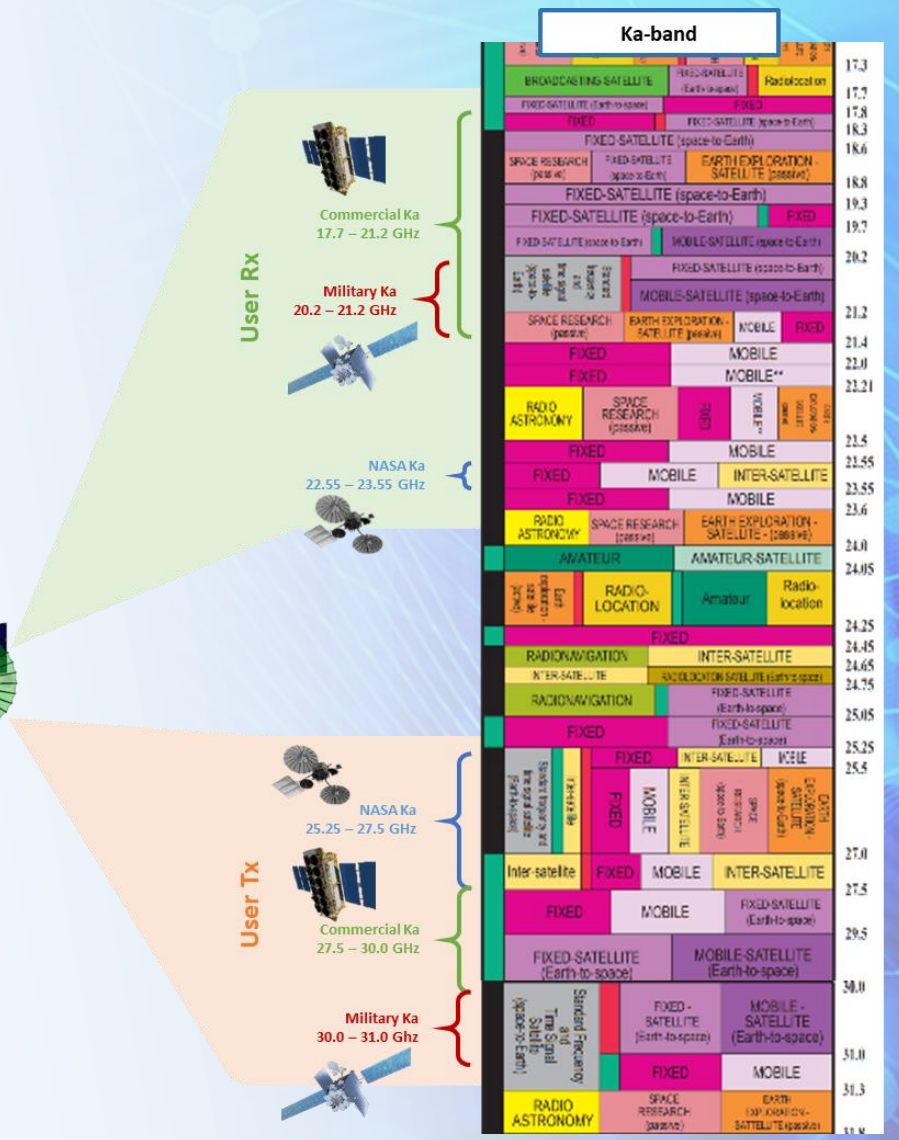


Provide future NASA near-Earth missions capability to roam and also utilize potential commercial relay services

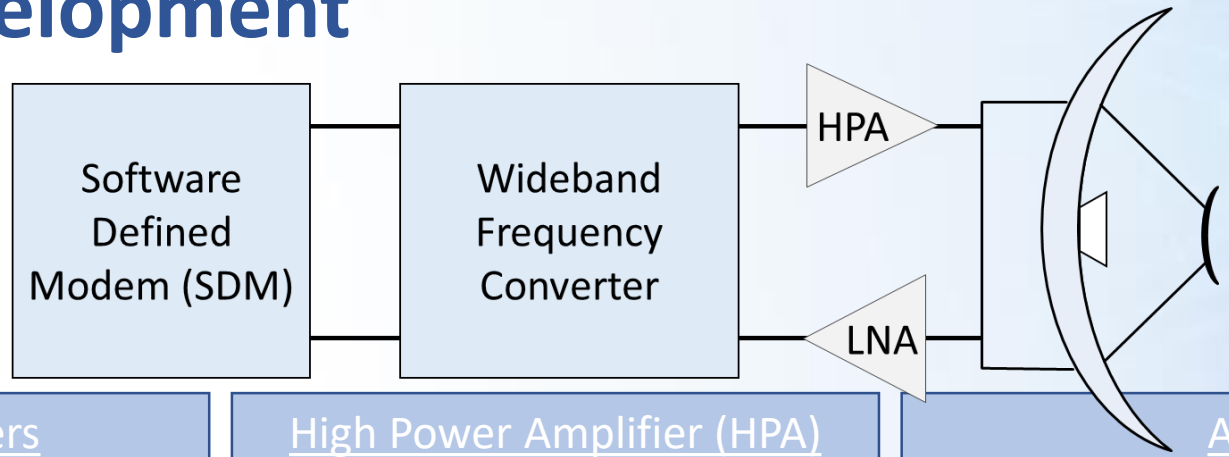
Wideband Terminal Specifications

Terminal Specs	
Frequency Bands	17.7 – 23.55 GHz Receive 25.25 – 31.0 GHz Transmit
Bandwidth	>500 MHz (Tx and Rx)
Antenna	<1m class
Axial Ratio	1 dB Axial Ratio (Tx) 1.5 dB Axial Radio (Rx)
Polarization	LHCP / RHCP
PA Output Power	10-20 W (SSPA)
EIRP	>50 dBW
G/T	>12 dB/K
Power	<200 W (Active)
Mass	< 15 kg
Temperature	-25 C to +55 C operational
Life	15 year
Radiation	100 kRad
EMC	MIL-STD-461F



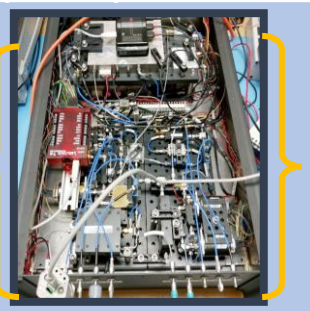


Terminal Development

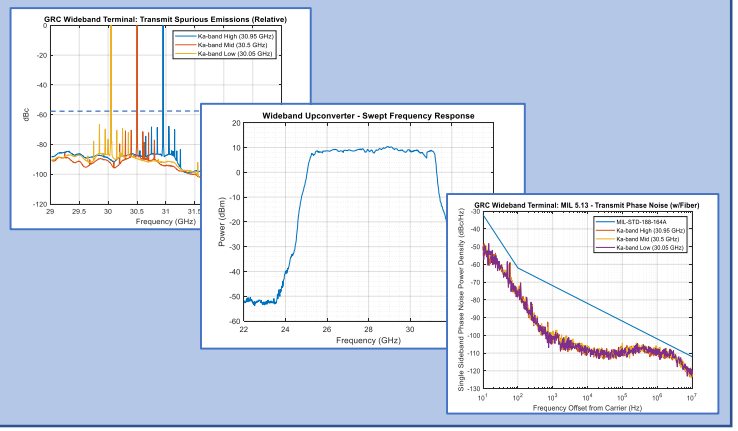


Frequency Converters

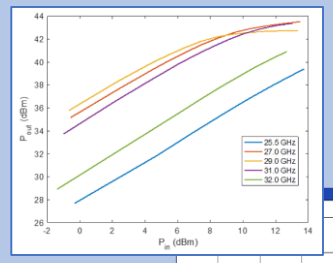
Up Converter

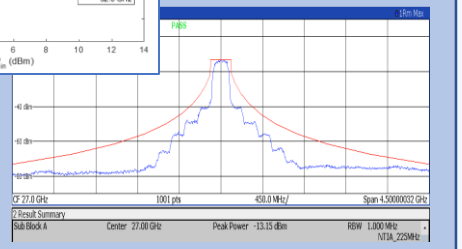


Down Converter

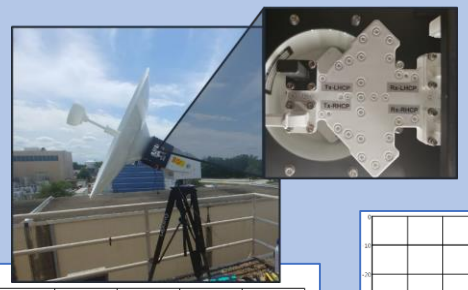


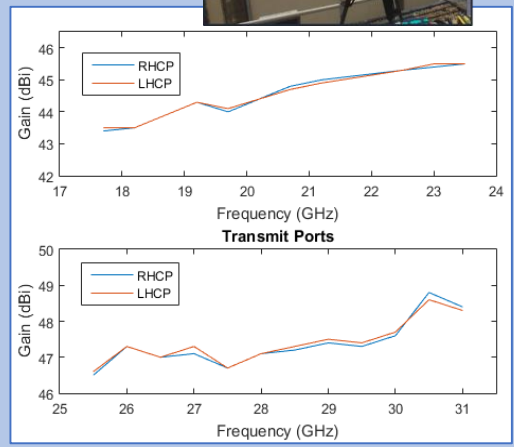
High Power Amplifier (HPA)

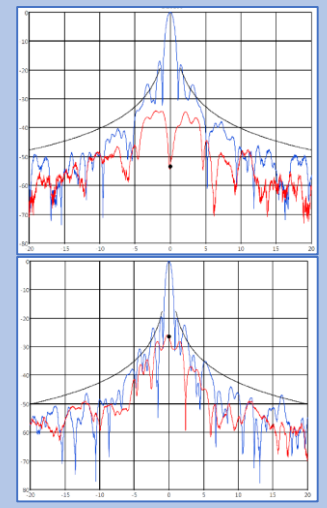




Antenna & Feed







Waveform Application Summary

High-Rate Bandwidth-Efficient Transmit Waveform

Modulation: GMSK, BPSK, OQPSK, 4/8/16-PSK, 16-QAM, 16/32-APSK

Data Rate: Tunable up-to 1.67 Gbps (un-coded), 333.33 Mbaud

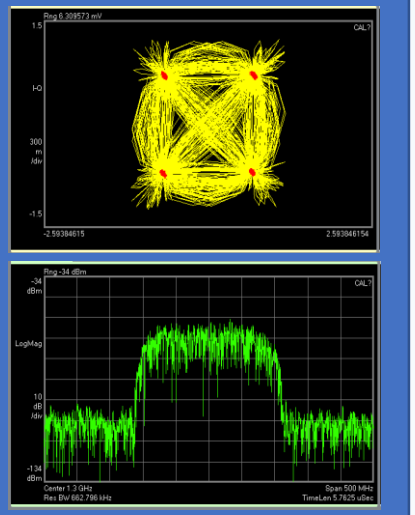
Pulse-shape Filtering: SRRC, RC

Forward Error Correction: LDPC 1/2, 2/3, 4/5, 7/8, Rate ½ Conv

Digital Pre-distortion: Memory-less, Symbol Pre-distortion

Channel Pre-compensation:

32-tap FIR



DVB-S2 Transmitter

Modulation: 4/8-PSK, 16/32-APSK

Data Rate: Tunable up-to 16 Mbaud (66.5 Mbps)

Pulse-shape Filtering: SRRC 0.2, 0.35

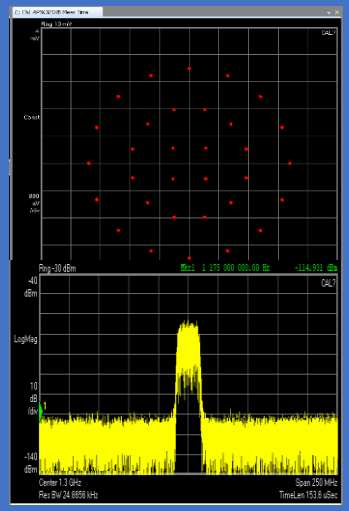
Forward Error Correction: LDPC ¼ to 8/9, Short Frames

Pilots: On or Off

Encapsulation: ~Generic Stream Encapsulation (GSE)-Lite

Digital Pre-distortion: Memory-less, Symbol Pre-distortion

Channel Pre-compensation: 32-tap FIR



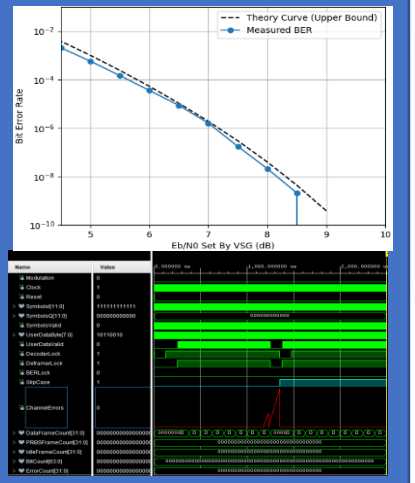
PSK Receiver

Modulation: BPSK / QPSK

Data Rate: Tunable up-to 7.5 Mbps, extensible to 62.5 Mbps

Forward Error Correction: Viterbi, Rate ½ convolutional code

Framing: CCSDS AOS



DVB-S2/S2X Receiver

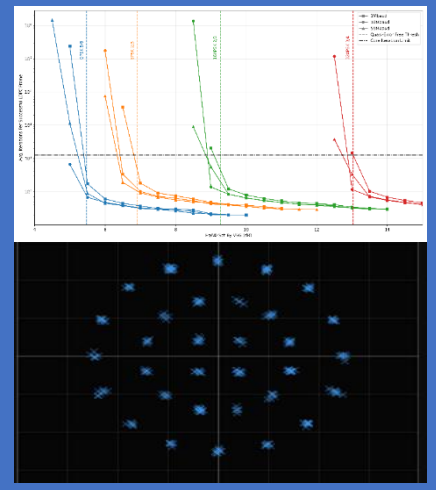
Modulation: 4/8-PSK, 16/32/64/128/256-APSK

Data Rate: Tunable up-to 62 Mbaud (~250 Mbps)

Pulse-shape Filtering: SRRC 0.05 ->, 0.35

Forward Error Correction: LDPC ¼ to 9/10, Short or Normal Frames

Pilots: On or Off



GRC Wideband Combined Commercial Service CONOPS

Service Provisioning

Commercial Services

- Schedule Service & move beam to location

TDRSS

- Scheduled TUT time

RF Path

Commercial Services

- Establish bi-directional over the air path with each provider using DVB-S2

TDRSS

- Standard SNUG Services or DVB-S2

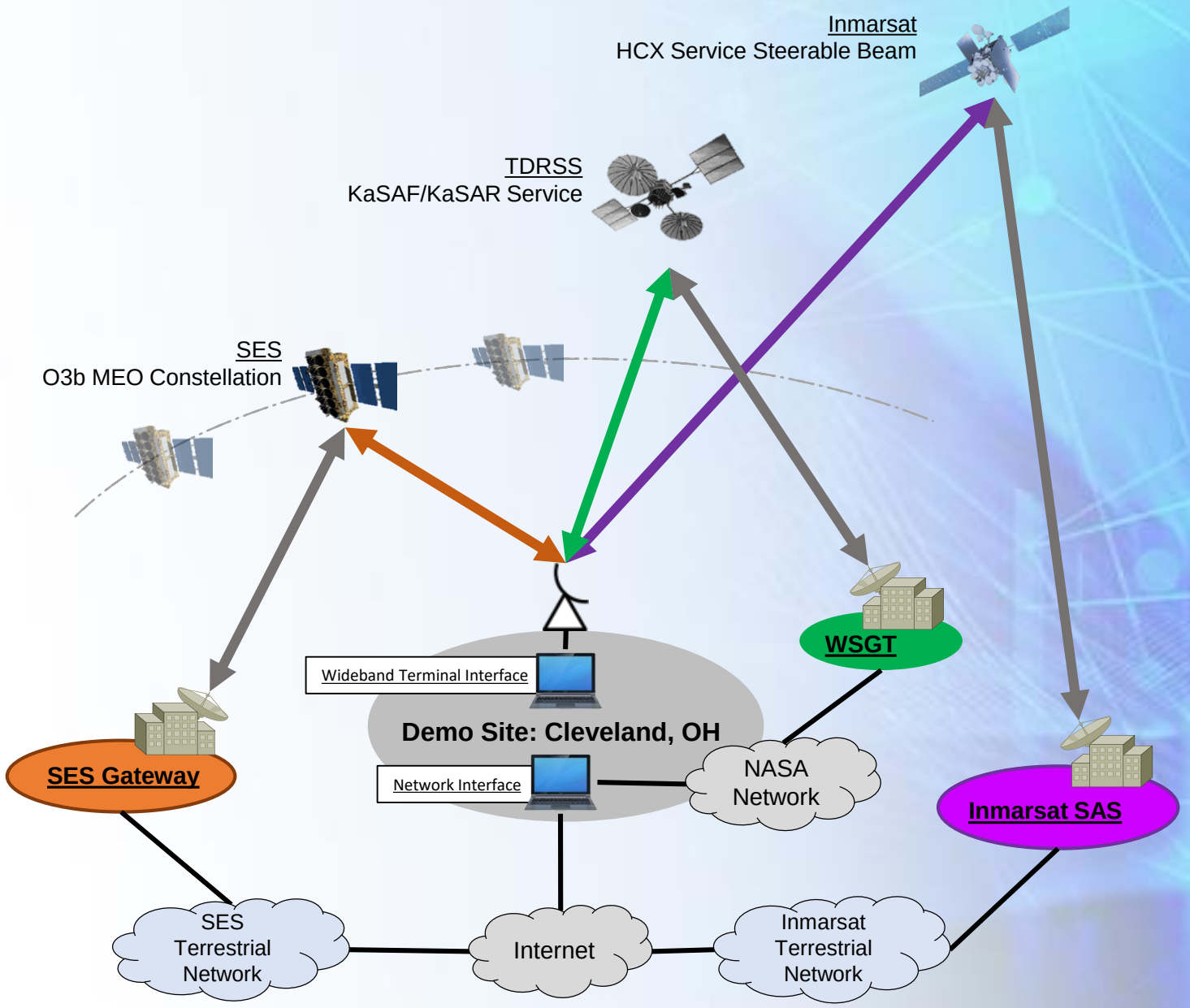
Network Interface

Commercial Services

- Establish bi-directional terrestrial data path with each provider over the internet

TDRSS

- Bi directional data path through closed NISN IO Network



Link Performance

Return Link Performance

	Modulation	FEC	Symbol Rate	Information Rate (Mbps)	RX Es/No (dB)
TDRSS	OQPSK	Rate 1/2	150M	150	N/A
TDRSS w/DVB-S2	8-PSK	LDPC 9/10	200M	535.8	12.8
Inmarsat	8-PSK	LDPC 3/5	70M	124.6	6.1
Inmarsat	16-APSK	LDPC 3/4	15M	41.42	12.3
O3b	8-PSK	LDPC 3/4	70M	145.45	9.5
O3b	32-APSK	LDPC 8/9	20M	83.2	16.3

Forward Link Performance

	Modulation	FEC	Symbol Rate	Information Rate (Mbps)	RX Es/No (dB)
Inmarsat	8-PSK	LDPC 5/6	59M	146	6.4
O3b	16-APSK	LDPC 2/3	80M	200.4	16.3

Additional Demonstration Results

Network Connectivity

- Internet Control Message Protocol (ICMP) Ping Tests
- UDP Data Tests

Variable Coding and Modulation

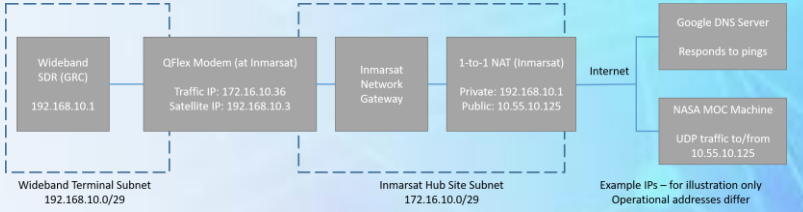
- All DVB-S2 MODCODs demonstrated
- Tests included +/-700 kHz Doppler at 1.1 kHz/sec

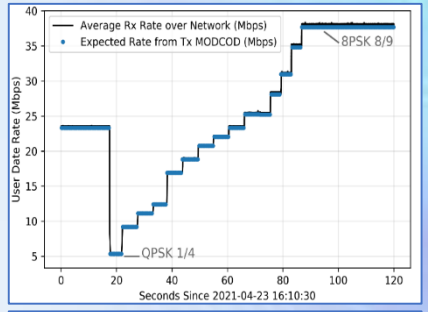
Doppler Emulation

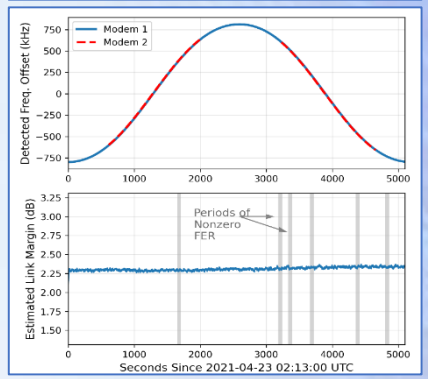
- Doppler tests run at 15 MBaud with 16-APSK LDPC 3/4 modulation

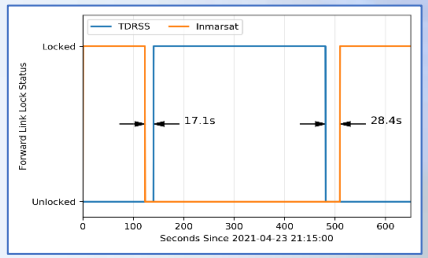
Roaming

- Successfully demonstrated service roaming between TDRSS and commercial vendors with <30 sec downtime









Lessons Learned & Future Work

- Interoperability on multiple services is viable using a single terminal
- Difference between Service providers even when using standards
- Wideband functionality (mostly) achievable with COTS hardware

Future Work:

- Enhancing terminal functionality
- Potential flight demonstration