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GSAW 2023

Viability of Edge and Public Cloud Computing for DoD/IC Ground System Architectures

Current Implementations and Future Use Cases

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Outline

- Who We Are
- Cloud-Based Digital Signal Processing
- Public and Private Clouds
- Engineering Tradeoffs/Recommendations
- Performance Characteristics
- Backwards Compatibility and Special Handling
- Notional Architectures for DoD/IC
- Conclusion/Questions

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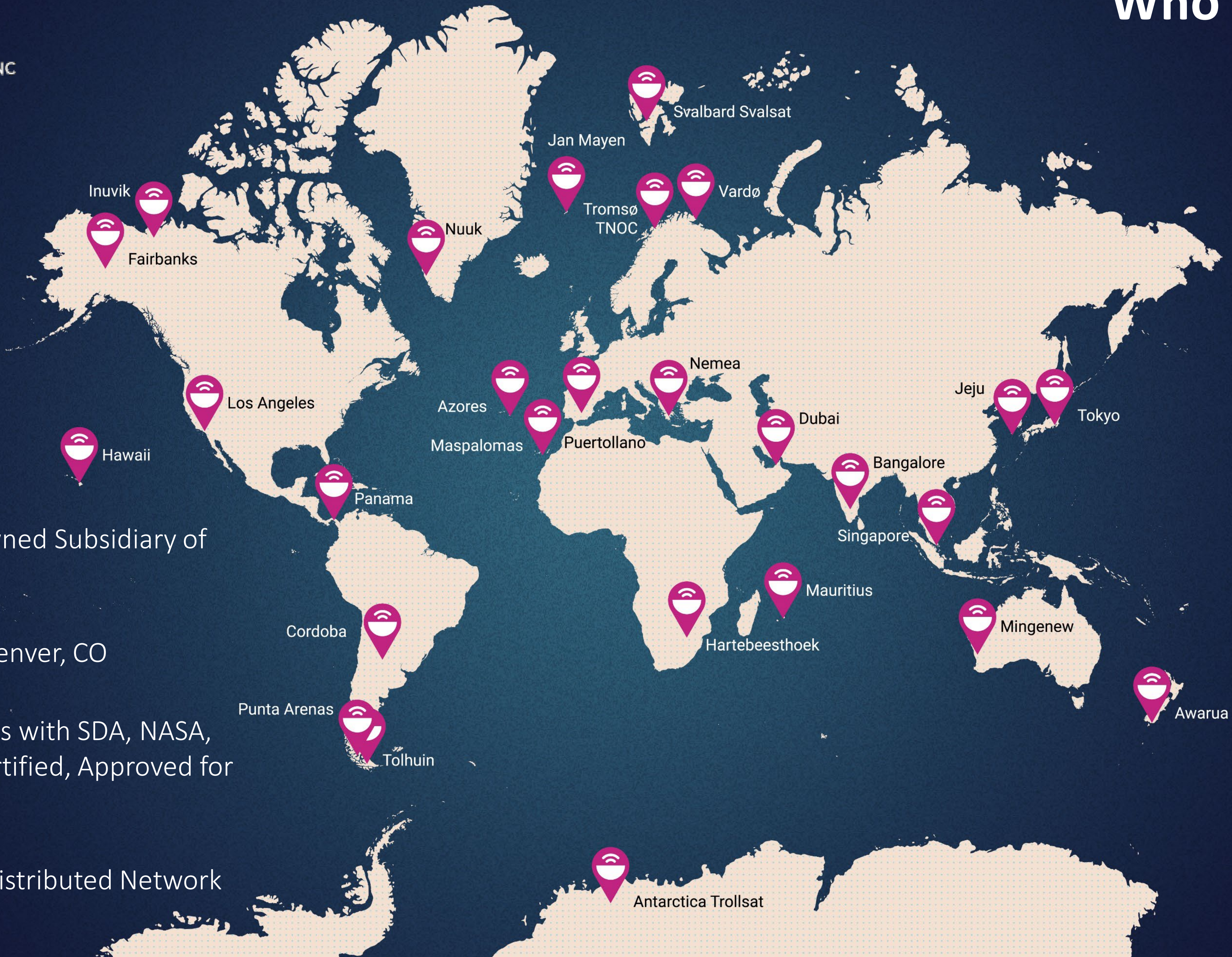
Who We Are



- KSAT Inc. Wholly Owned Subsidiary of KSAT AS, Norway
- Headquartered in Denver, CO
- Current Subcontracts with SDA, NASA, NOAA (NIST-800 Certified, Approved for CUI)
- Access to Globally Distributed Network with 200+ Antennas

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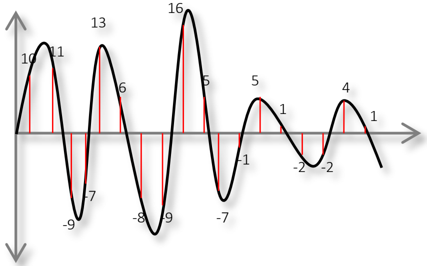
Cloud-Based Digital Signal Processing

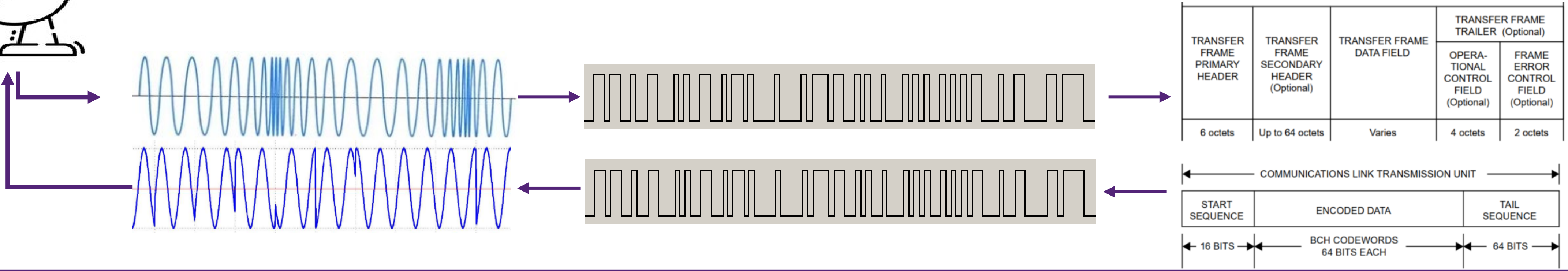
Digital Signal Processing of Spacecraft Data

- DSP encompasses
  - Modulation/demodulation
  - Encoding/decoding
  - Packetization/depacketization
  - Additional processing including filtering, measuring, compressing



Sampled IF waveform I/Q data to/from antenna/downconverter

- Deterministic spectrum transport over IP key to cloud-based DSP
  - Enables site diversity, centralization, disaster recovery and even rain fade mitigation



Digitization is a critical step in moving space data through the ground segment, to the end customer or user, and enables transport of digital IF to the cloud over IP.

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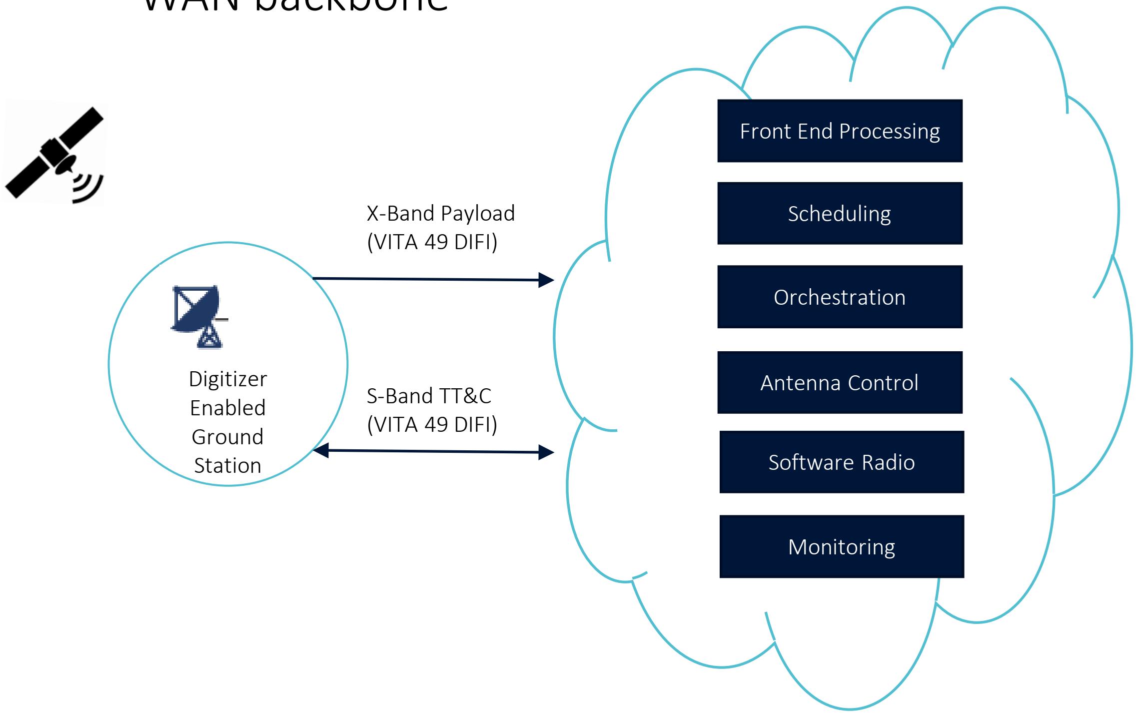
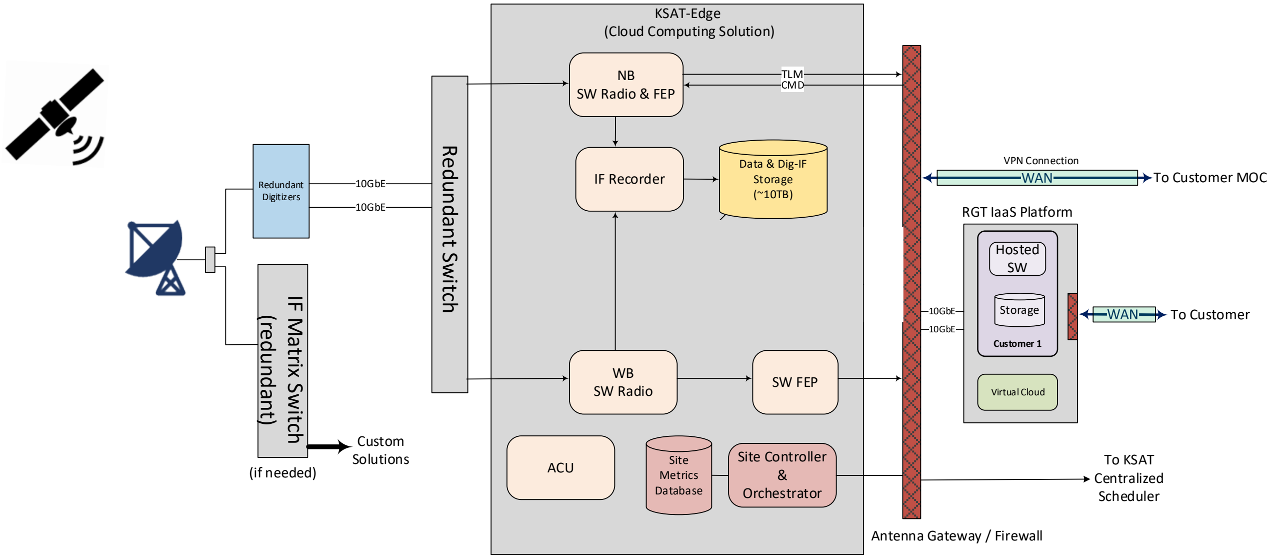
DSP in Public and Private Clouds

- Public Clouds
  - Pay-as-you-go offloaded datacenter management
  - Enterprise security
  - WAN backbone
- Private Clouds
  - Direct oversight of infrastructure design
  - Local security controls
  - Onsite processing when bandwidth is limited





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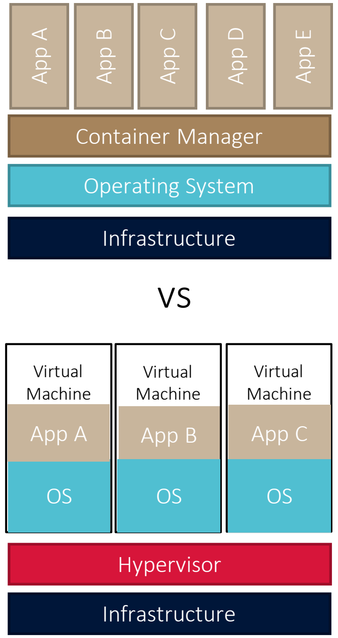
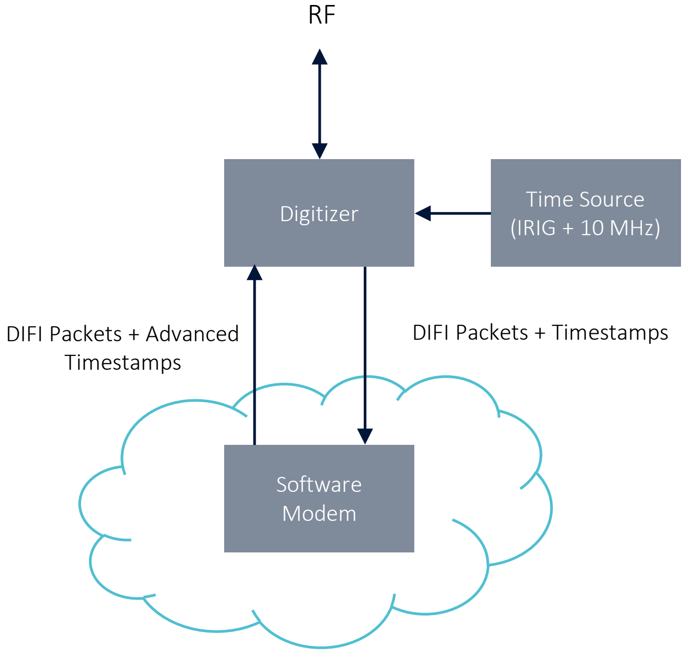
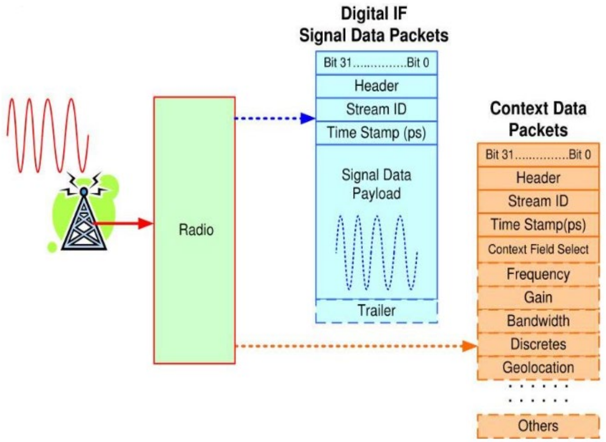
Engineering Tradeoffs/Recommendations



- General Purpose Processors: Slowest, but greatest flexibility and can take advantage of special instruction sets
- Graphics Processing Units: Faster, but supply issues and memory bandwidth hinders use
- Fully Programmable Gate Arrays: Fastest and lowest SWAP, but expensive and cannot be virtualized





https://dificonsortium.org

VIRTUAL MACHINES/CONTAINERS

Recommend containerization of DSP software modems automatically initialized and configured during pre-pass

HARDWARE CONSIDERATIONS

Recommend General Purpose Processors for narrowband/wideband and FPGAs for ultrawideband applications

TIMING/RANGING

Recommend timestamping digital IF at the antenna (edge) for Rx and advancing timestamps on Tx to be greater than network latency and transmitted at correct time

OPEN STANDARDS

Recommend use of:

- Digital IF Consortium Standards (VITA-49 & ISTO Std. 4900 2021)
- CCSDS
- DVB-S2

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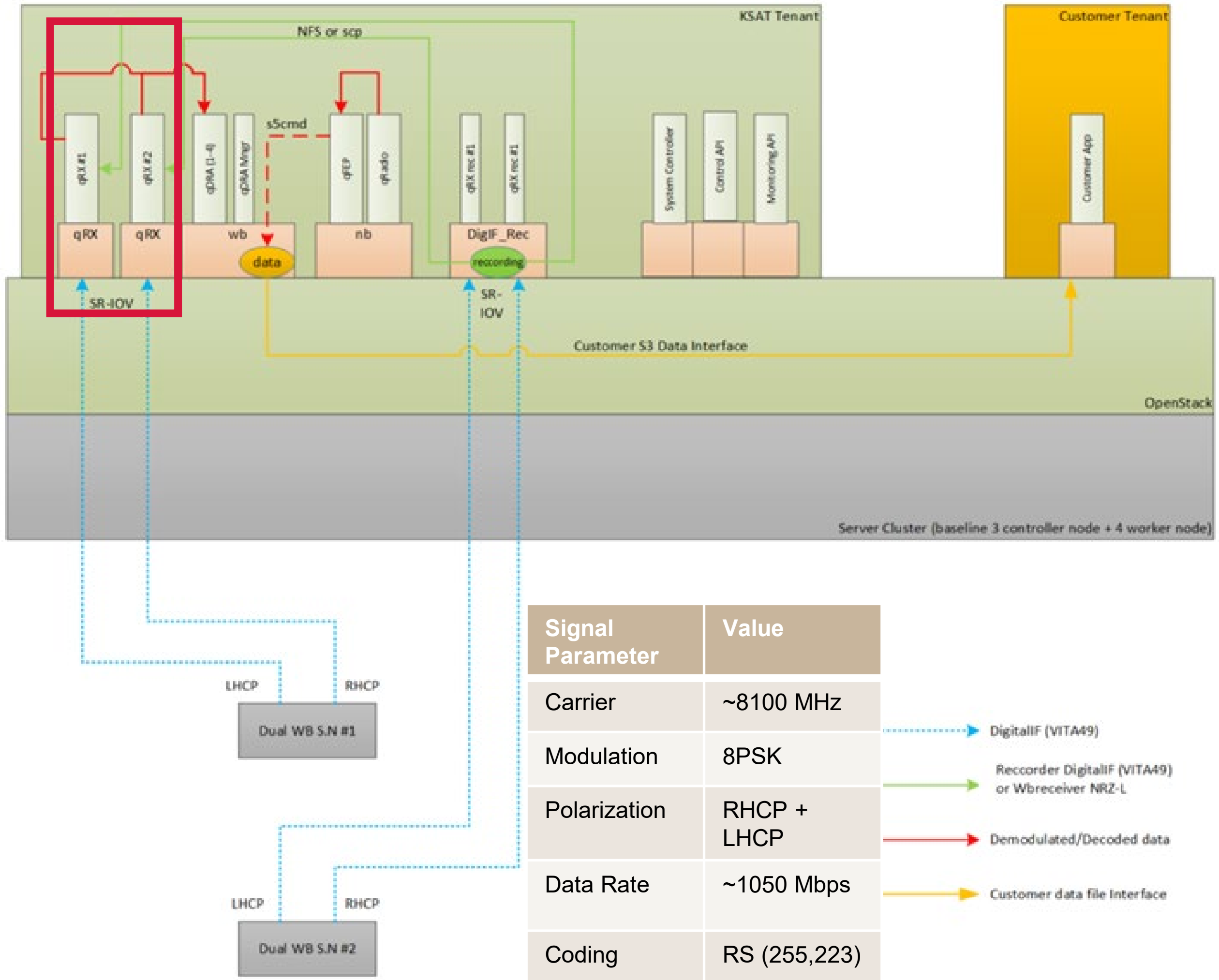
Performance Characteristics

- KSAT finalizing Kratos qRX wideband modem integration into a private cloud
- Current OpenStack platform at Tromsø processes wideband using both bare metal and OpenStack qRX
- Enables collection of performance metrics between full OpenStack implementation and qRX residing on separate bare metal servers



Signal Parameter	Value
Carrier	~8100 MHz
Modulation	8PSK
Polarization	RHCP + LHCP
Data Rate	~1050 Mbps
Coding	RS (255,223)

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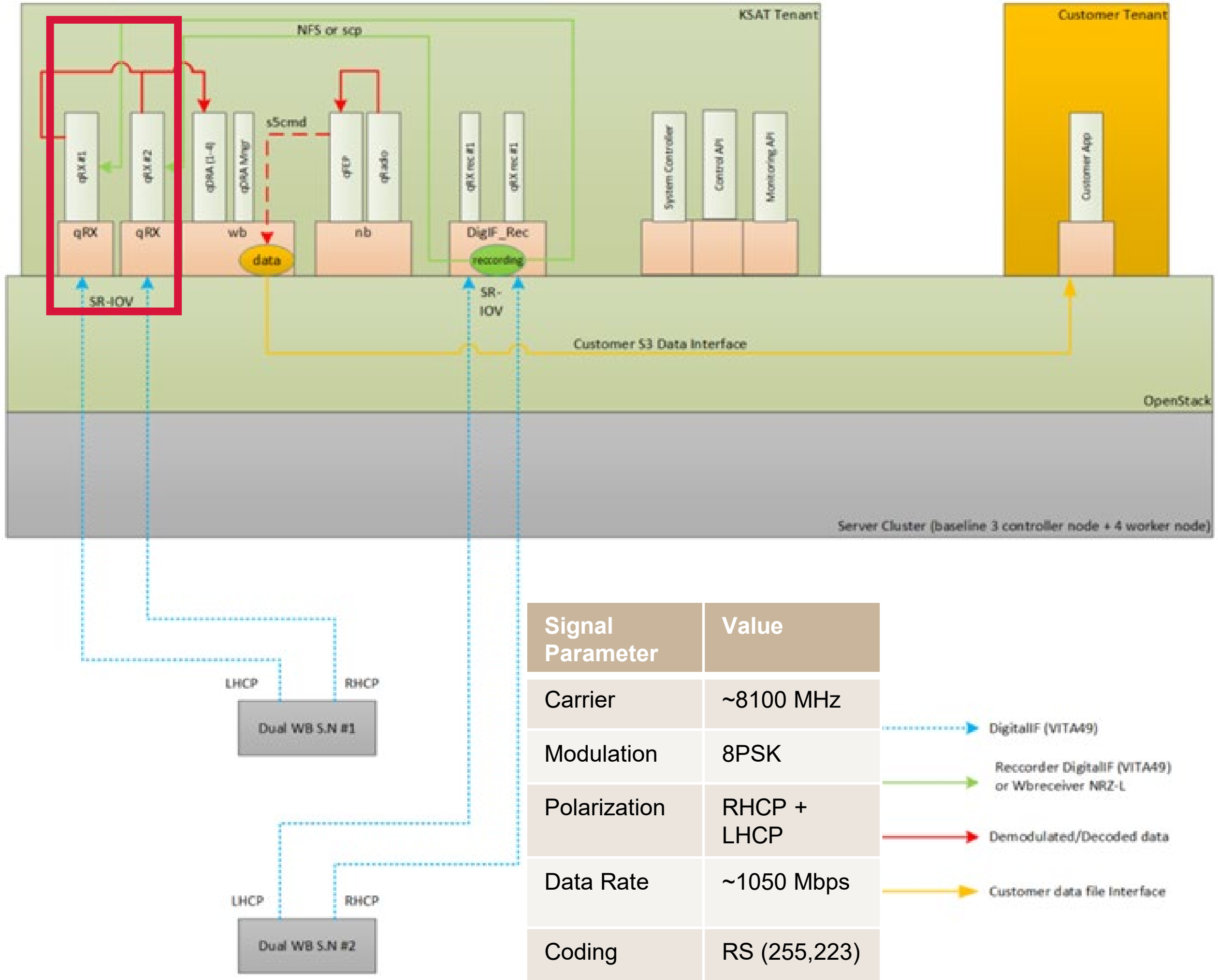
Performance Characteristics

- No performance limitations when migrating to OpenStack qRX implementation
- Some efficiencies seen in OpenStack implementation based on available resources (80 bare metal cores v 32 OpenStack cores)
- Ultrawideband applications will likely more strongly benefit from scalability of public cloud-based implementations



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Backwards Compatibility/Special Handling

- Single Root Input/Output Virtualization (SR-IOV)
  - Normal traffic transiting PCIe interface can be easily interrupted by resource request within the cloud stack
  - Allows pinning of PCIe interface to VM enabling uninterrupted dataflow to digital IF source
  - Critical for continuous packet transmission and correct ordering

- Non-Uniform Memory Access (NUMA) Pinning
  - Pins NUMA node, CPUs, and NIC to ensure nothing crosses the Ultra Path Interconnect (UPI) link
  - Prevents latency/dropped packets that are processed with non-local resources

- Advanced Vector Extensions 512-bit (AVX-512) Instruction Sets
  - Greatly improves vector processing on CPUs, allowing for performance closer to FPGA solutions
  - Not necessarily virtualization dependent, requires high-end Intel CPUs

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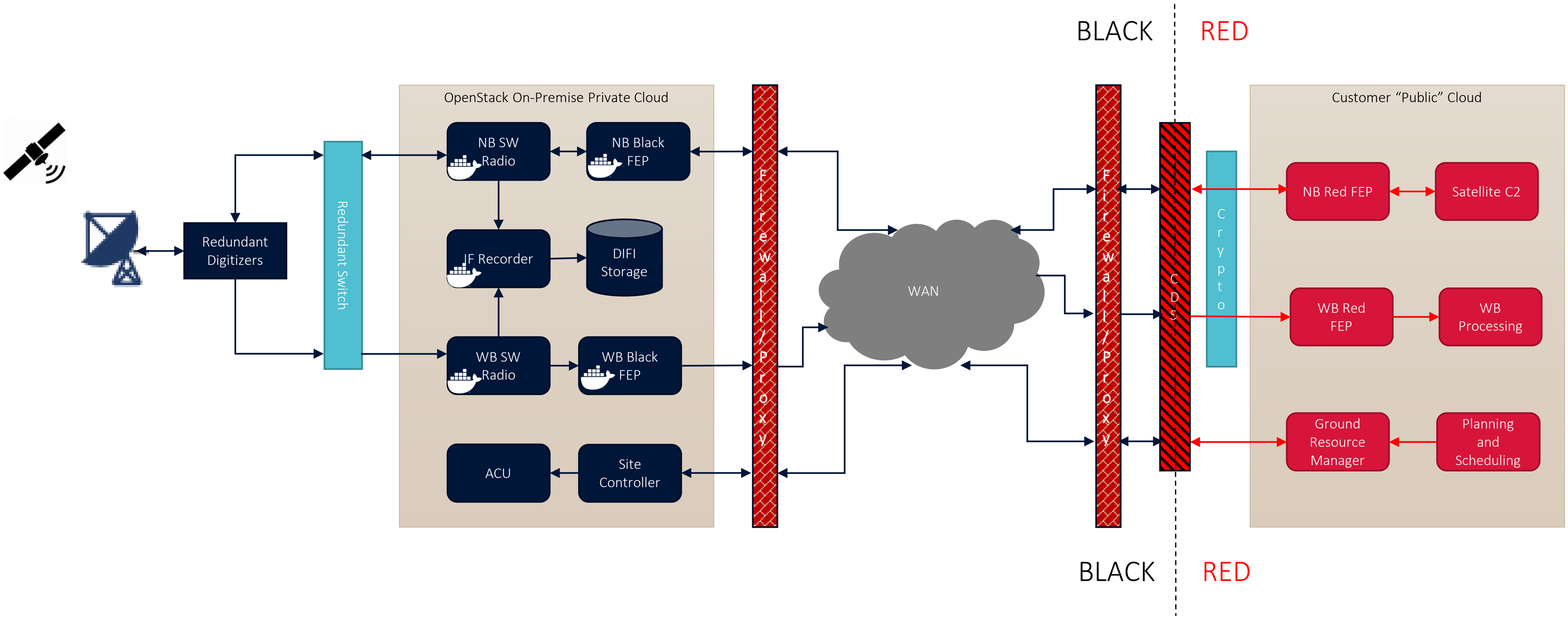
Notional On-Premise Architecture for DoD/IC 1



WE CONNECT SPACE AND EARTH

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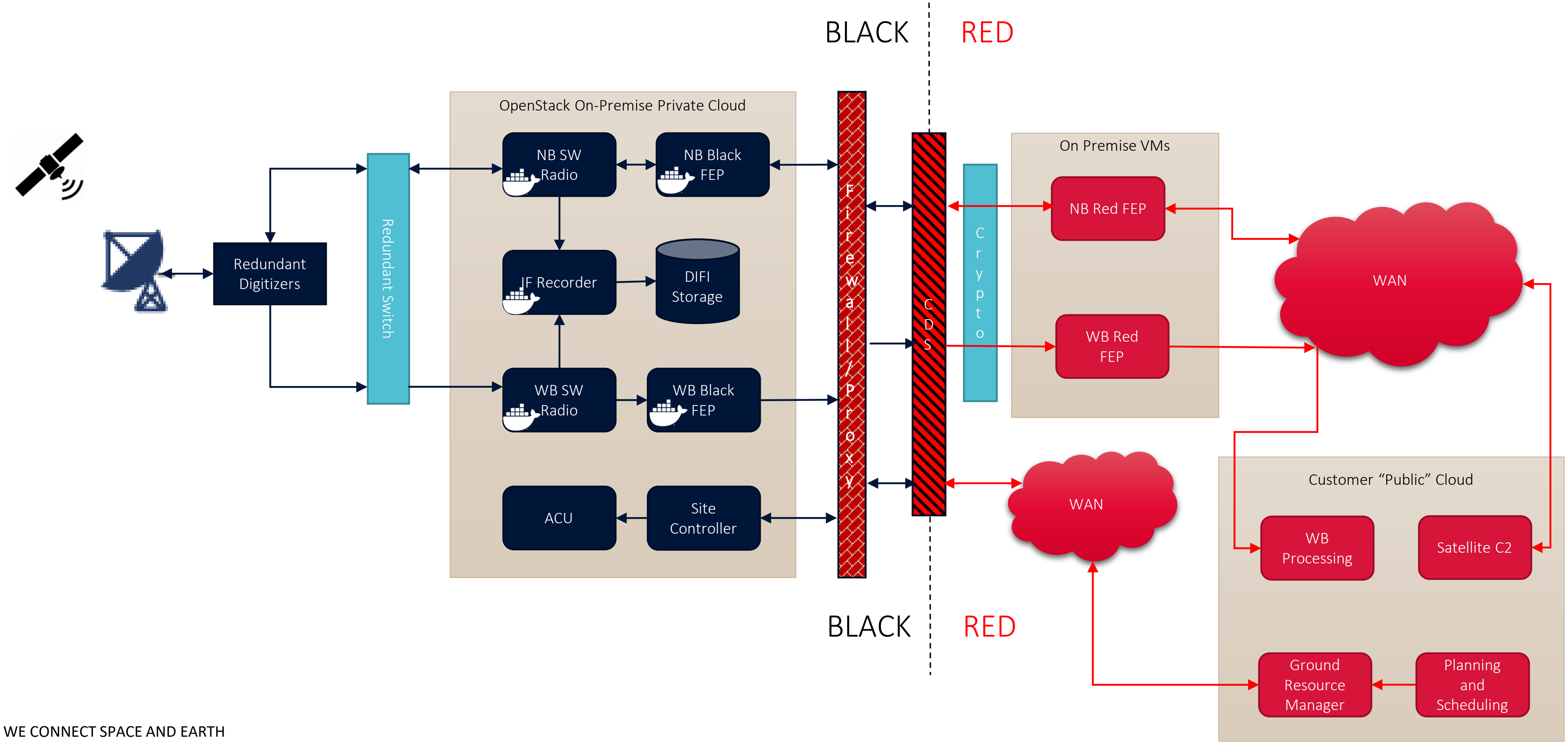
Notional On-Premise Architecture for DoD/IC 2



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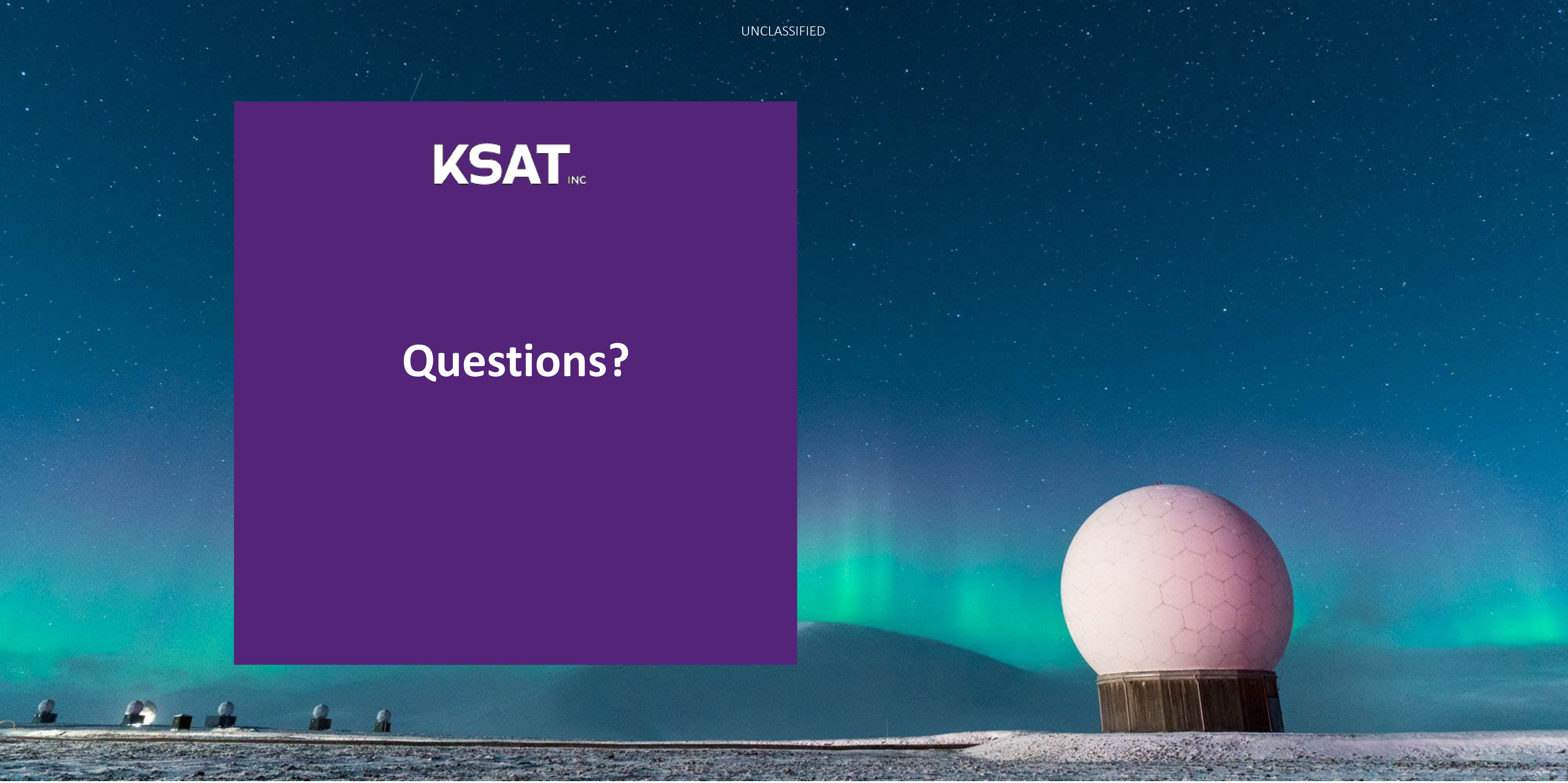
Conclusion

- Cloud-based DSP using digital IF offers many advantages over analog modems – viable for both narrowband and wideband applications
- Engineering tradeoffs must be considered when designing cloud architectures
- With specialized handling, performance characteristics are not limited, even in a private cloud
- Commercially available solutions are suitable and available for DoD/IC space-to-ground communication needs – extendable to higher classification level environments
- Future missions require globally distributed networks and wideband applications – cloud architectures ensure DSP is available, flexible, and cost-effective for cislunar missions and beyond.



Questions?