AiRANACULUS®

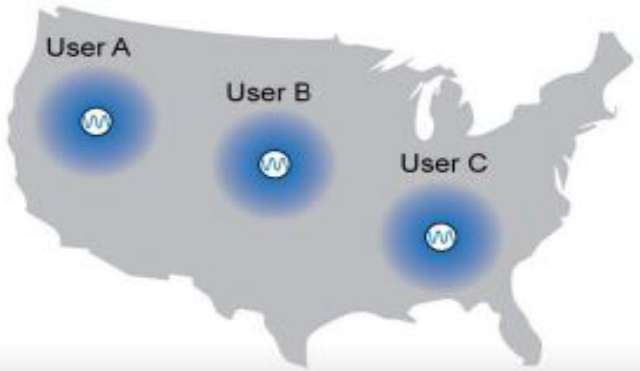
From Spectrum Agility to Network Agility

Dr. Apurva N. Mody, Fellow, IEEE
Founder, CEO, AiRANACULUS,
Executive Committee, National Spectrum Consortium
apurva.mody@AiRANACULUS.com
+1-404-819-0314

What is Bi-directional Spectrum Sharing

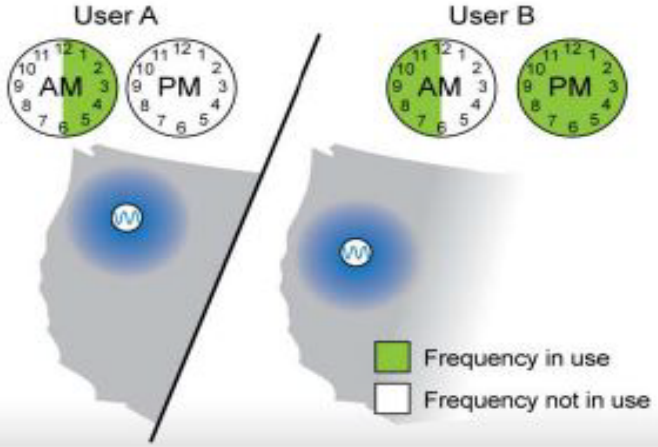
AiRANACULUS®

Geographic sharing occurs when multiple users access the same frequencies in different geographic areas which are sufficiently separated to avoid interference.



For example, if federal agency User A has a nationwide spectrum assignment for a particular frequency but only uses it at a pilot testing range in the Northwest for now, it can allow Users B and C to use that frequency in other locations as long as all the locations are far enough apart to avoid interference.

Sharing spectrum in time occurs when multiple users access the same frequencies at different times to avoid interference. When a primary spectrum user is not using its spectrum, it could allow access to a secondary user--even if users are in close proximity.



For example, if a federal agency transmits high-powered radar around the clock over a large area at certain frequencies, other users cannot use those frequencies in that space without interference. However, if the radar is used intermittently, in theory the agency can provide other users with the times when the frequency is available for sharing.

https://www.gao.gov/assets/650/648206.pdf

Sharing of the Same Spectrum based on Location or Time to avoid interference to a Primary User

Key FCC Spectrum Initiatives & Proceedings

AiRANACULUS®

- **Low Frequency Spectrum:**
  - TV Broadcast Incentive Auction (600 MHz band)
- **Mid Frequency Spectrum:**
  - 3.5 GHz (3450-3700 MHz) – Radar and 4G / 5G Spectrum Sharing
  - 3700 – 4200 MHz – Spectrum Sharing between Radar Altimeter, SATCOM Downlinks and 5G,
  - 5925 – 7125 MHz – Spectrum Sharing between Wi-Fi and Microwave Links
- **High Frequency Spectrum:**
  - Spectrum Frontiers (above 24 GHz)
  - Spectrum Horizons (above 95 GHz)

3.7 – 4.2 GHz – Proposed licensed access to C-band satellite DL spectrum

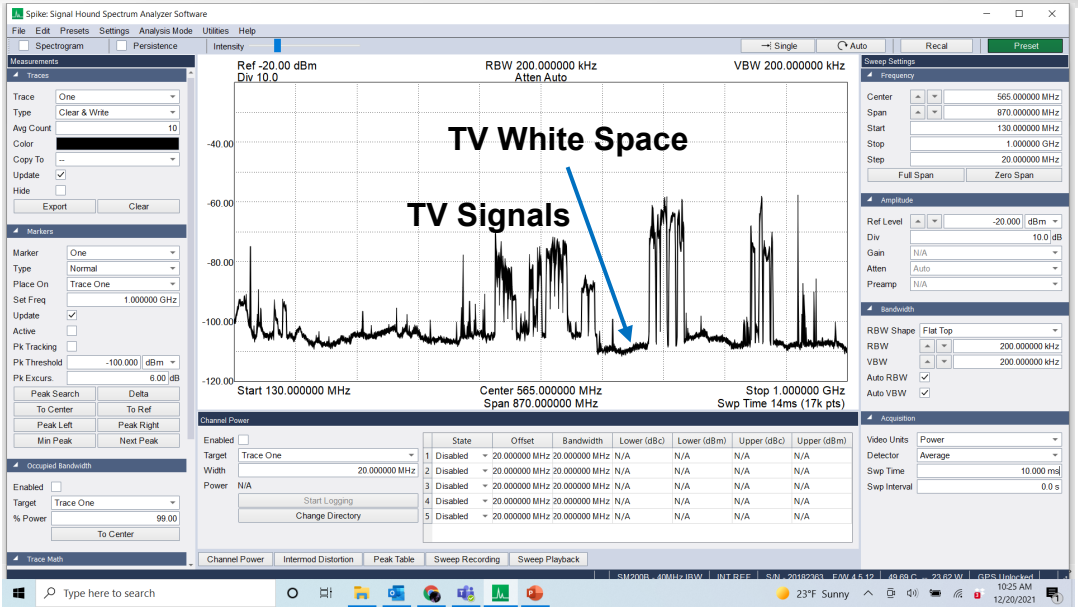
5.925 – 7.125 GHz – Proposed unlicensed sharing with Pt-2-Pt microwave & satellite uplinks

All these bands require mechanisms for spectrum sharing

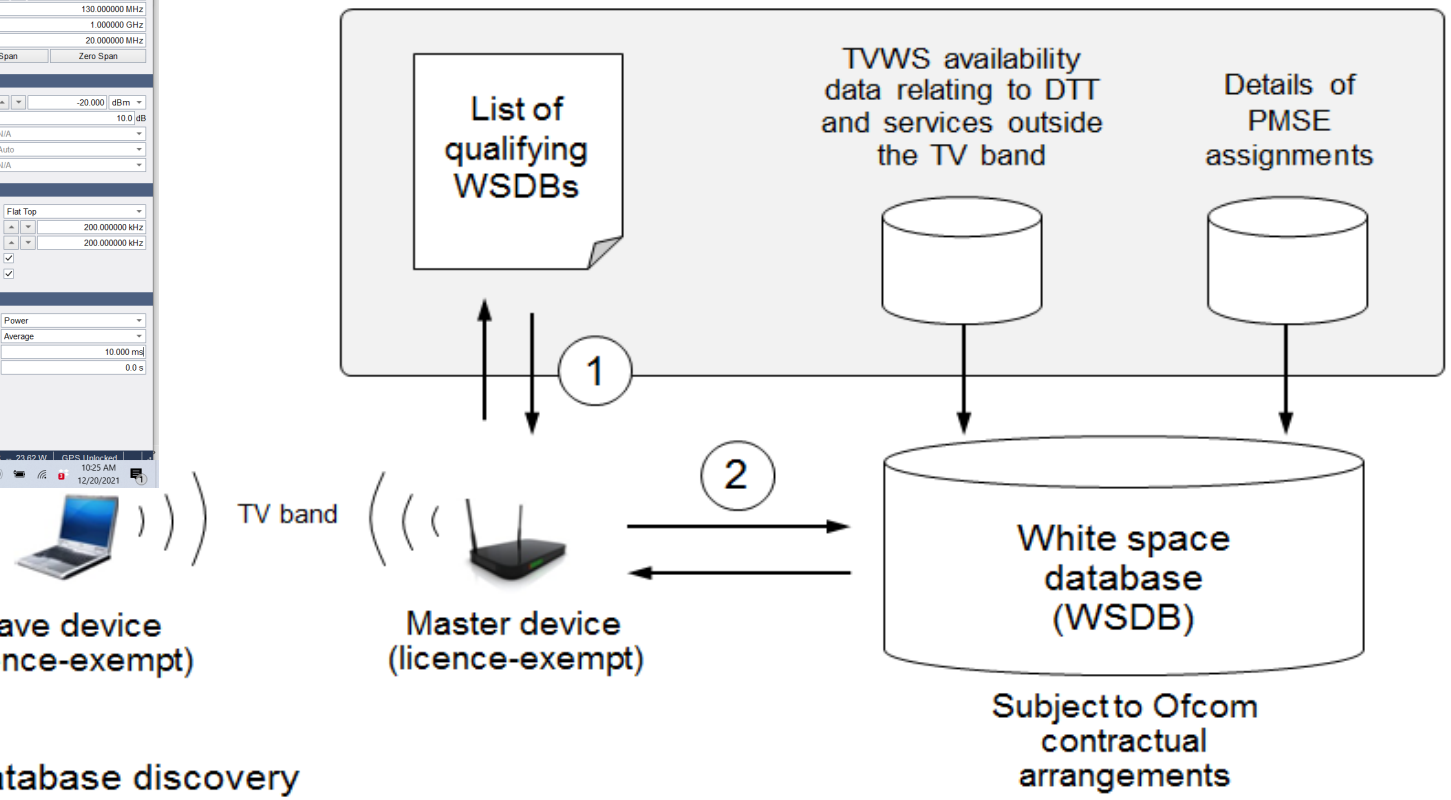
Television Band White Spaces – 55 – 88 MHz, 176 – 213 MHz, 470 – 598 MHz

Example of a Database and RF Sensing Driven Spectrum Sharing – Television White Spaces

AiRANACULUS®



TVWS example (Ofcom, UK)



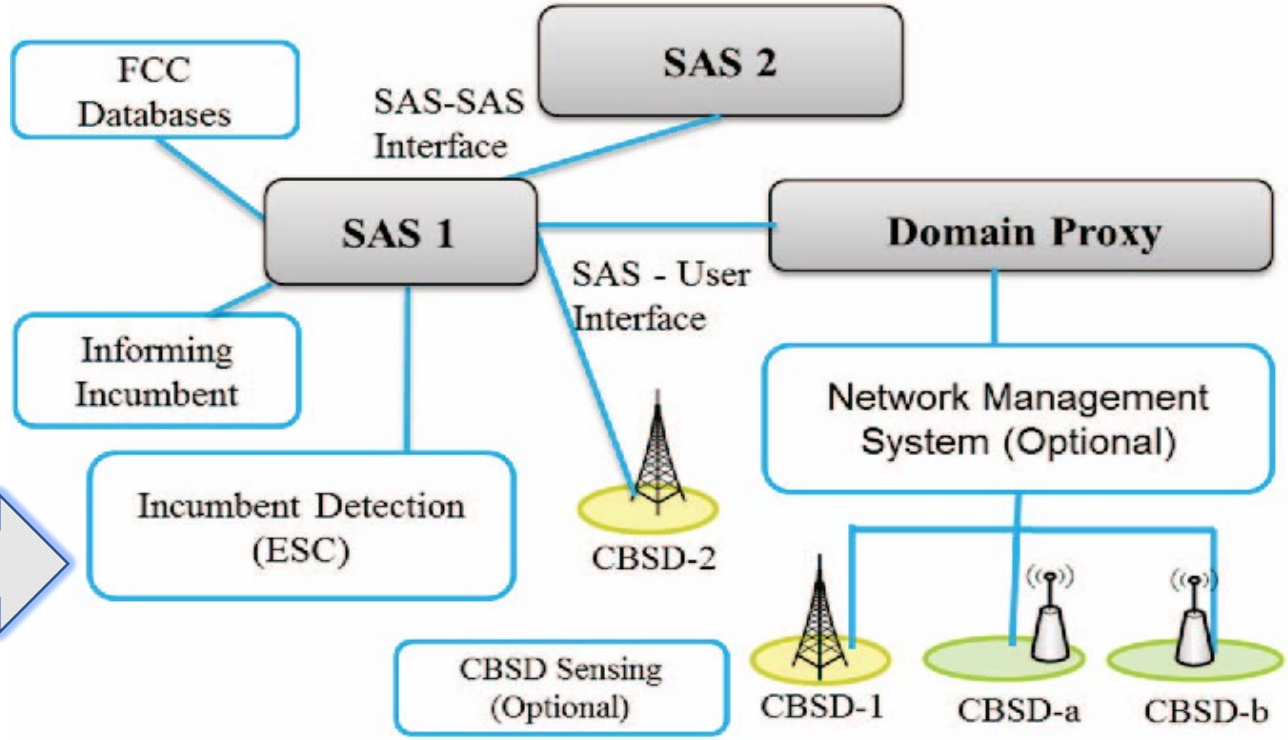
1) Database discovery
2) Device-database communications.

Two Tiers of Spectrum Users – Incumbents (TV Broadcasting / Broadcast Auxiliary Systems / Wireless Microphones) and Opportunity Users of Spectrum – TVWS Devices

S-Band – 3.1 GHz – 3.45 GHz, 3.45 GHz – 3.55 GHz and 3.55 GHz – 3.7 GHz

Example of a Database Driven Spectrum Sharing – 3.55 – 3.7 GHz Citizens Broadband Radio Service

AiRANACULUS®



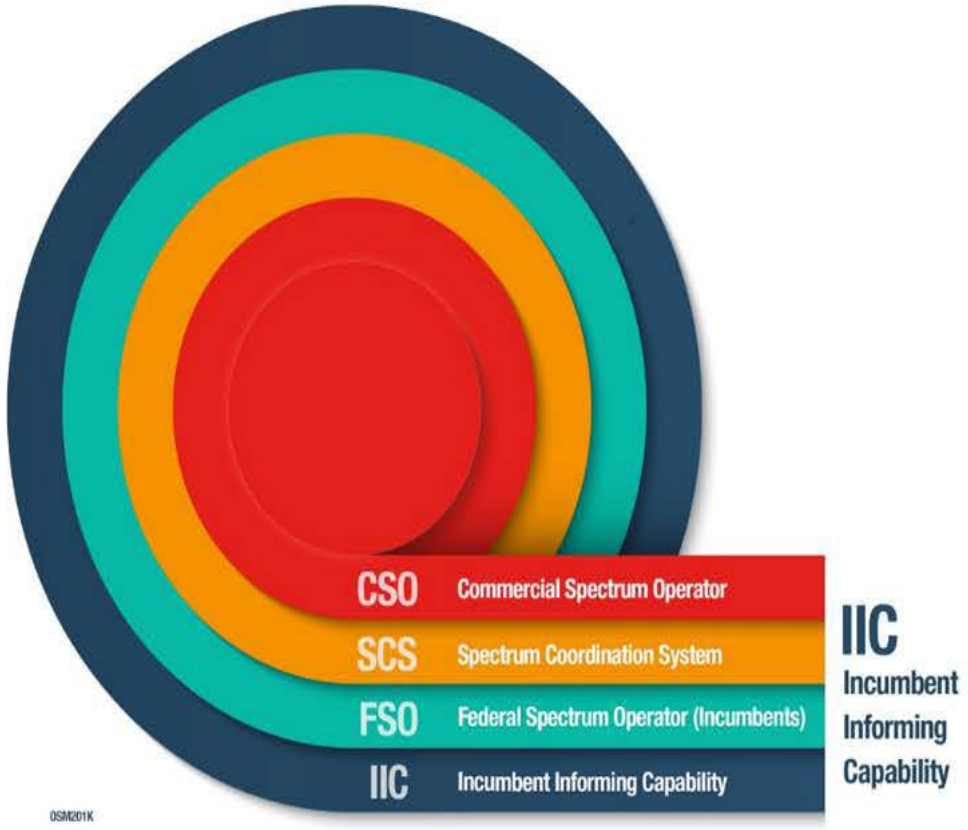
Incumbents – DoD Radars

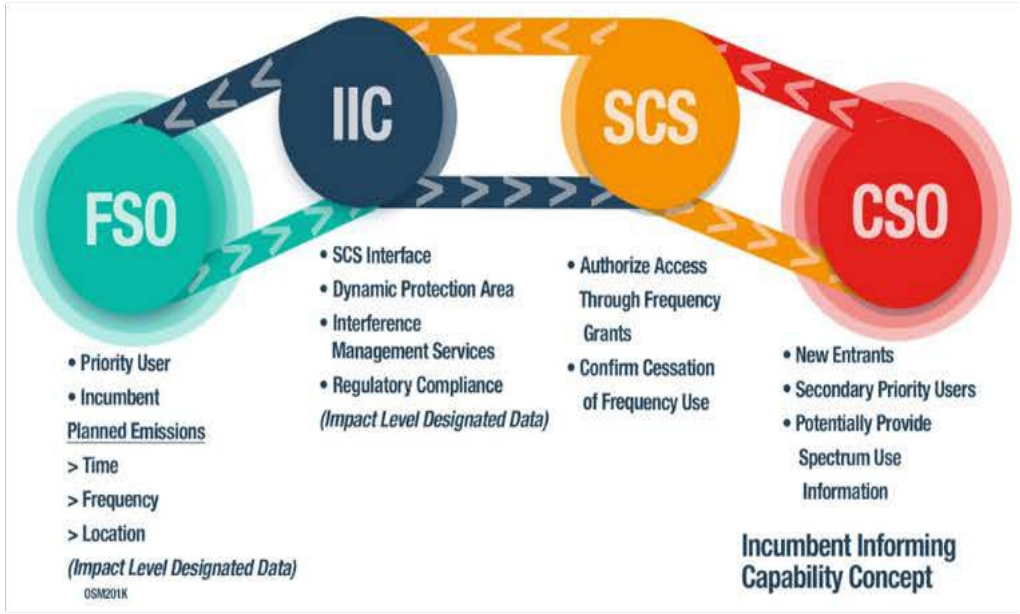
Primary (PAL) and Secondary Users (GAA) of Spectrum

Citizens Broadband Radio Service (CBRS) is also database (Spectrum Access System) driven

NTIA' s Proposed Incumbent Informing Capability (IIC)

AiRANACULUS®

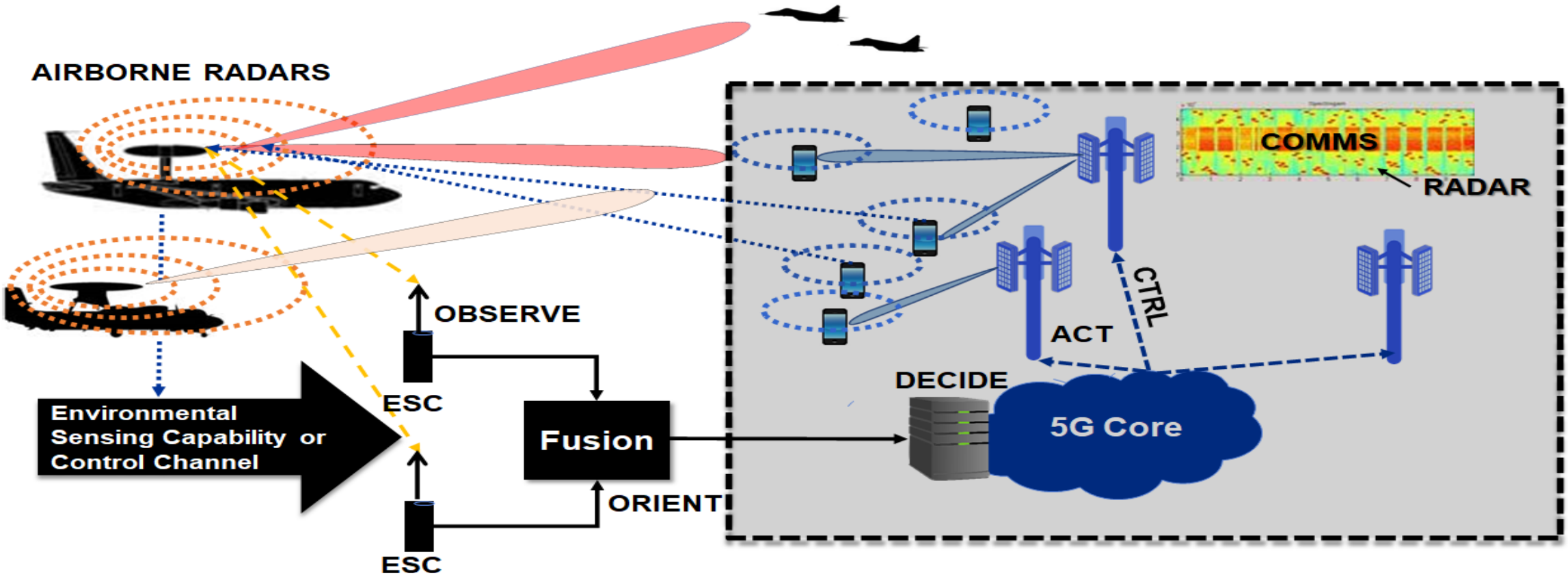




https://www.ntia.doc.gov/files/ntia/publications/iic_for_time-based_spectrum_sharing.pdf

Move towards Faster Machine to Machine Sharing of Spectrum – 3.1 – 3.55 GHz

AiRANACULUS®



Sharing is no longer about Spectrum Agility only. It needs to span ALL Layers of the Protocol Stack

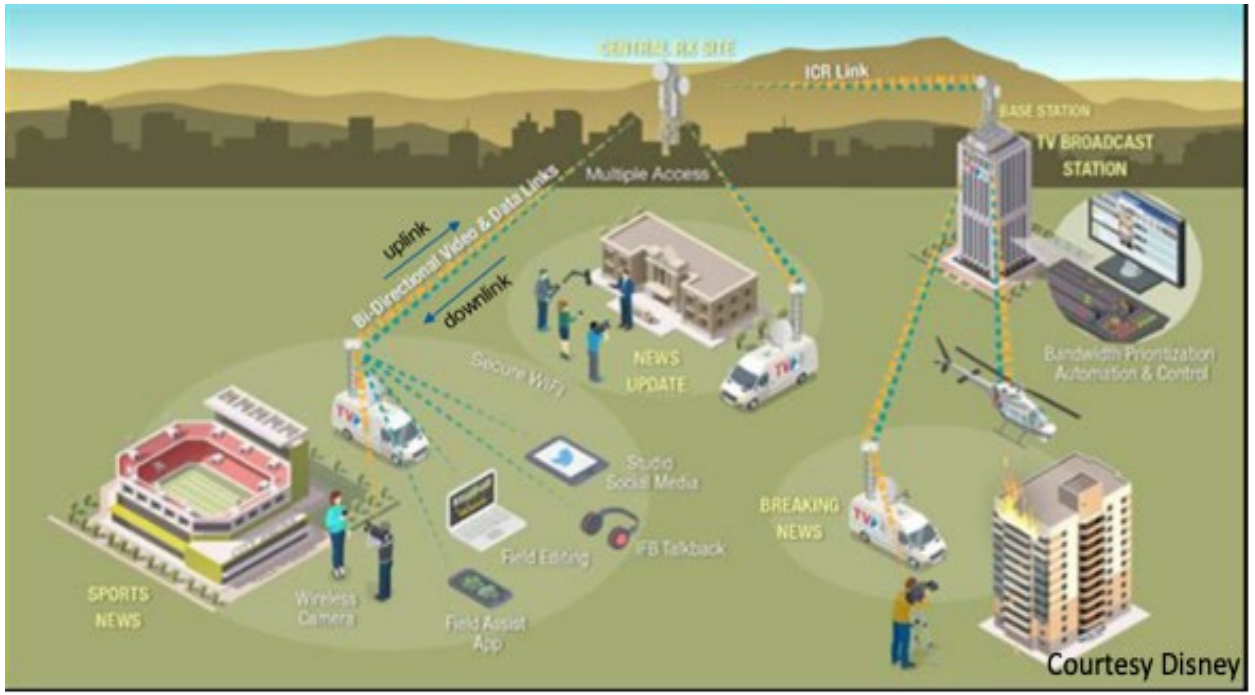
2025 – 2110 MHz Spectrum Sharing

2025 MHz – 2110 MHz Spectrum Users

AiRANACULUS®

	2025	DRL 1	2025.5	Channel 1	2037.5	Channel 2	2049.5	Channel 3	2061.5	Channel 4	2073.5	Channel 5	2085.5	Channel 6	2097.5	Channel 7	2109.5	DRL 2	2110
Width, MHz		0.5		12		12		12		12		12		12		12		0.5	
Center, MHz		2025.25		2031.5		2043.5		2055.5		2067.5		2079.5		2091.5		2103.5		2109.75	

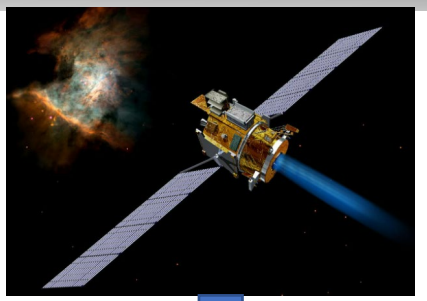
DRL - Data Return Link - Primarily used for helicopter TV pickup to steer antenna to receive site



Electronic News Gathering (ENG) Systems

TDL

Tactical Data Links (TDL), Tactical Radio Relay (TRR)



NASA Deep Space Missions

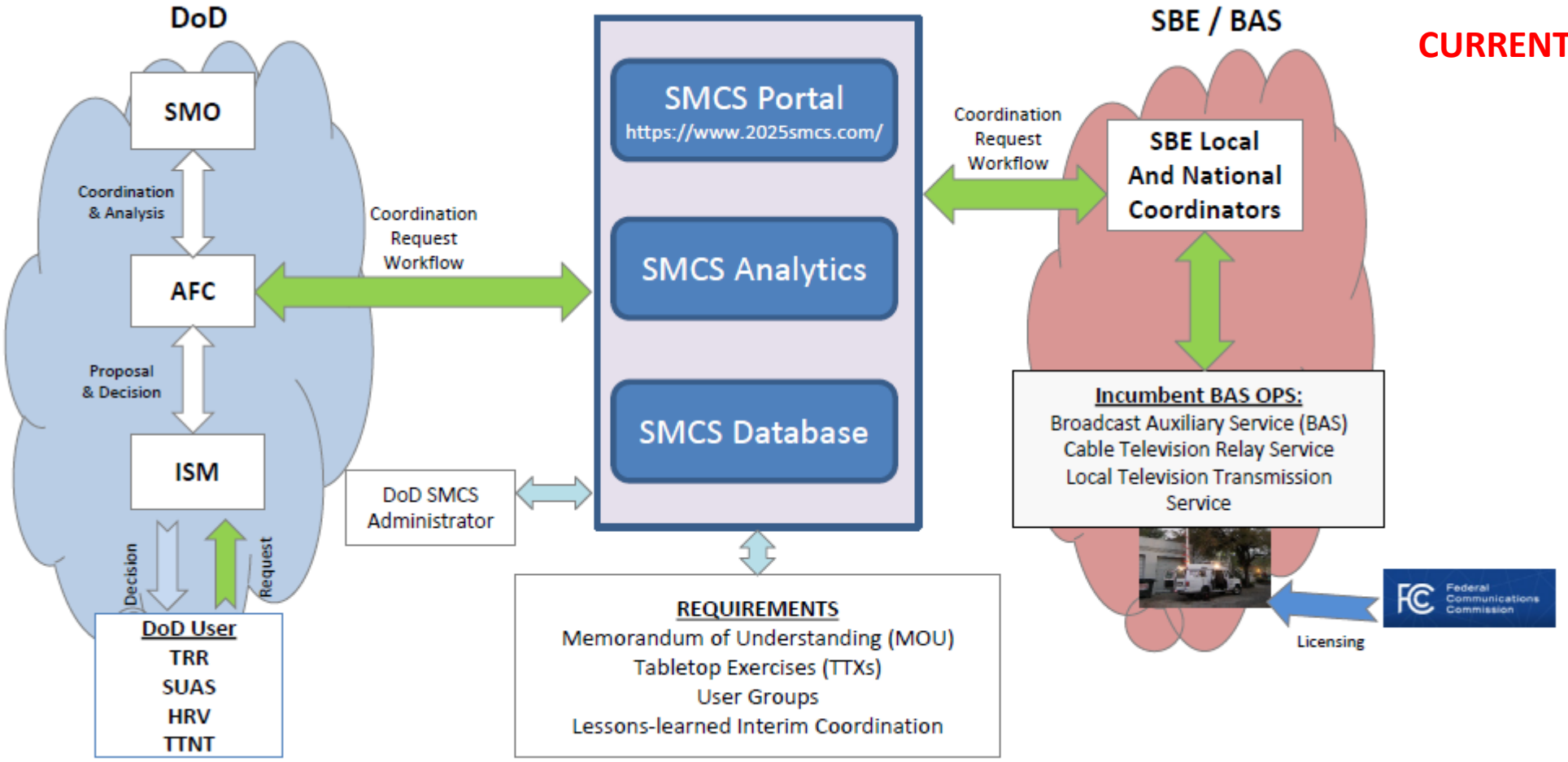
2025-2110 MHz will require sharing between Commercial Electronic News Gathering (ENG) Systems, Tactical Data Links (TDLs) as well as NASA' s Deep Space Missions

SMCS Operational Concept (OV-1)

- DoD requests access, SBE Coordinators approve or deny using established workflows

AiRANACULUS®

CURRENT

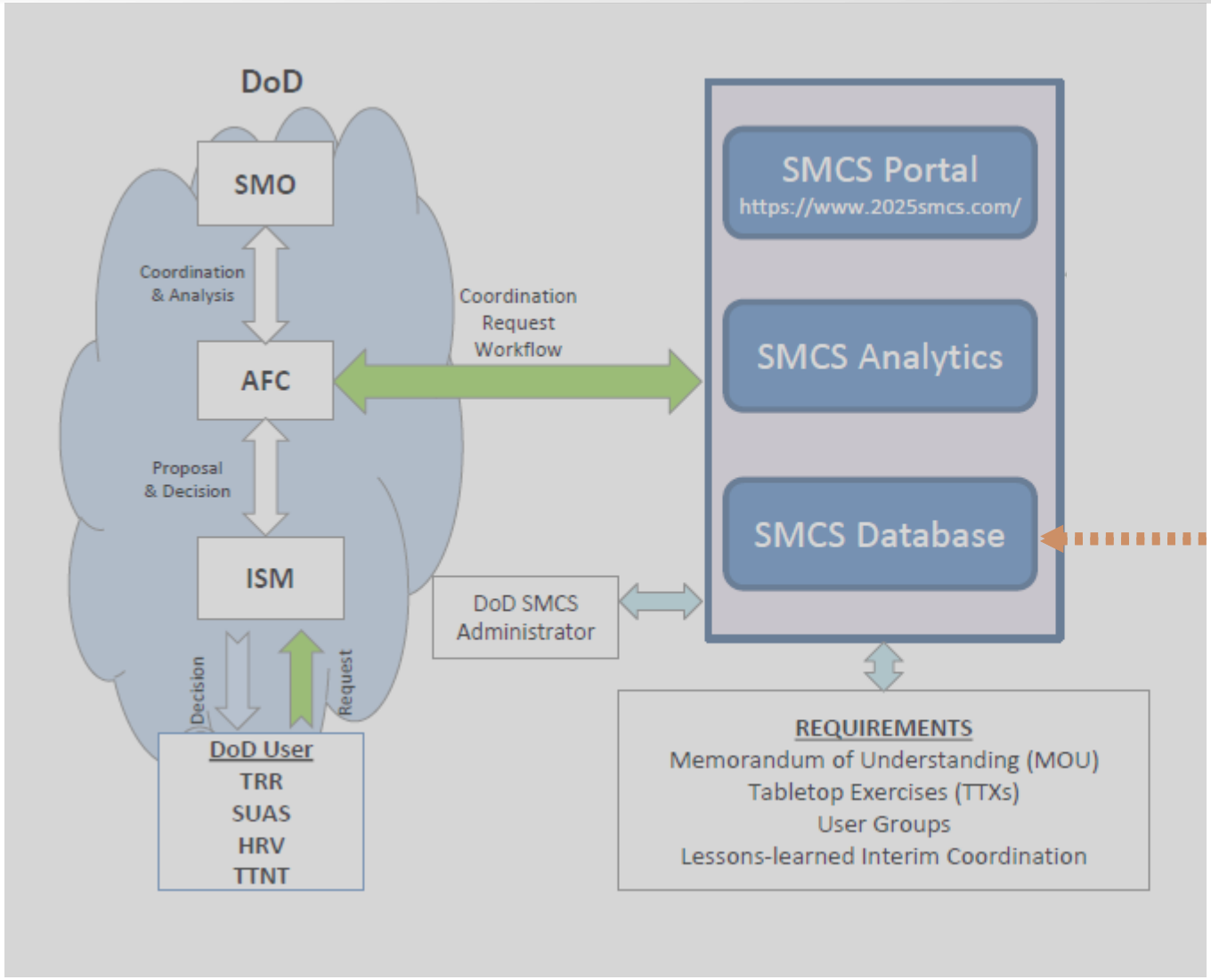


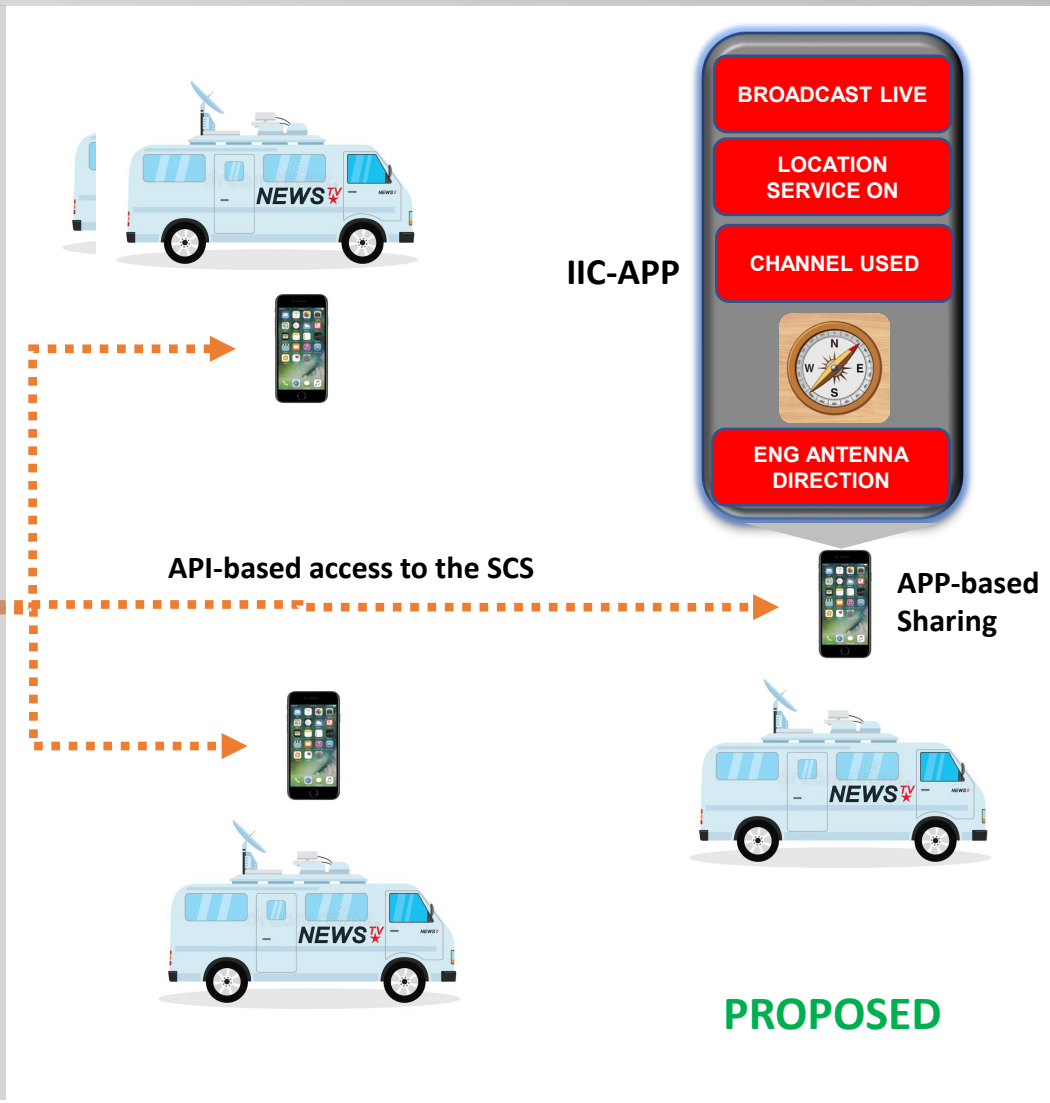
- Hosted on AWS (VPC) with a publicly accessible URL

2025-2110 MHz will require sharing between Commercial Electronic News Gathering (ENG) Systems, Tactical Data Links (TDLs) as well as NASA' s Deep Space Missions

APP-based Spectrum Sharing (Proposed)

AiRANACULUS®



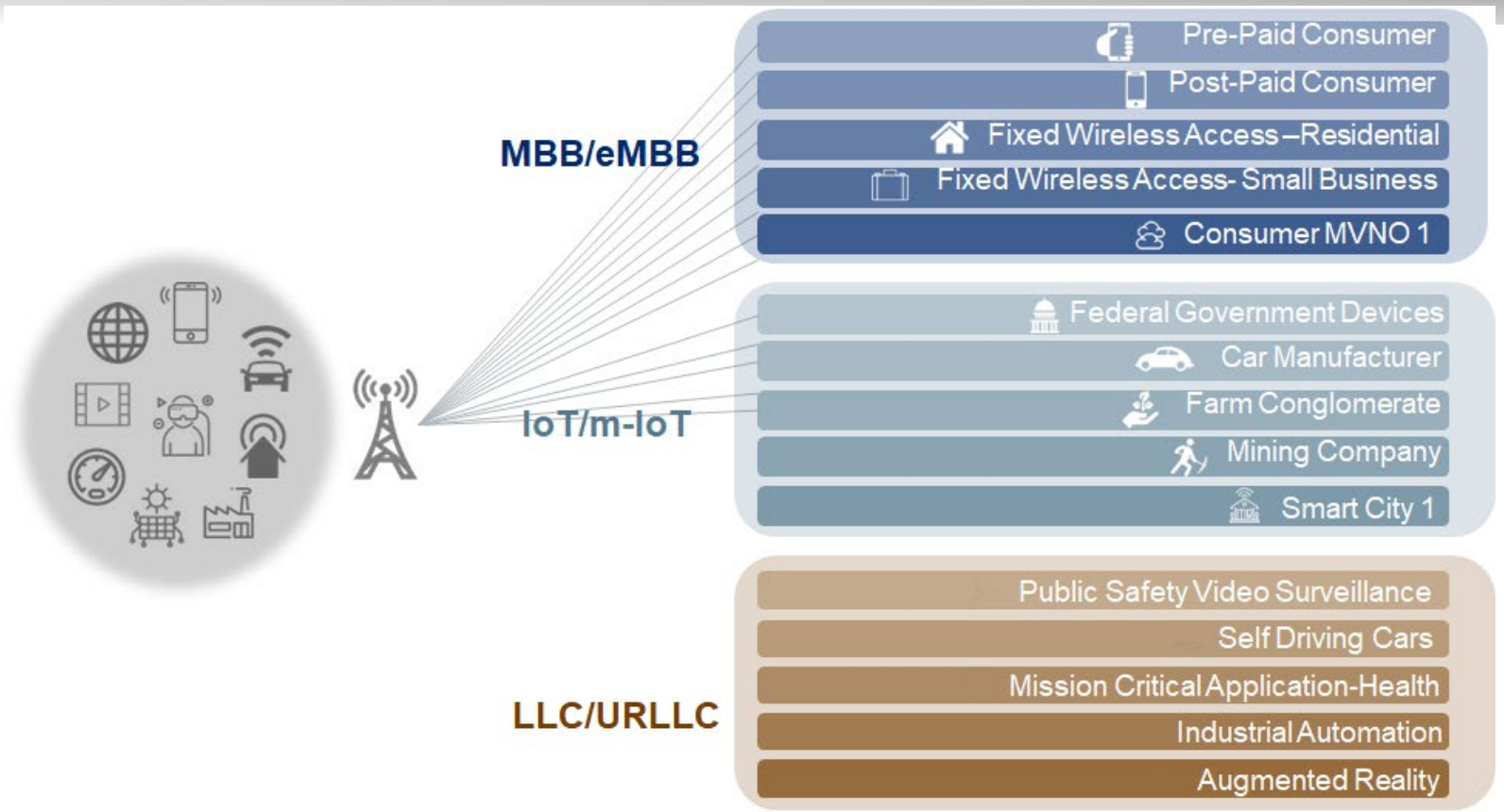


STATUS QUO

Spectrum Agility to Network Agility

Network Slicing – 5G

AiRANACULUS®

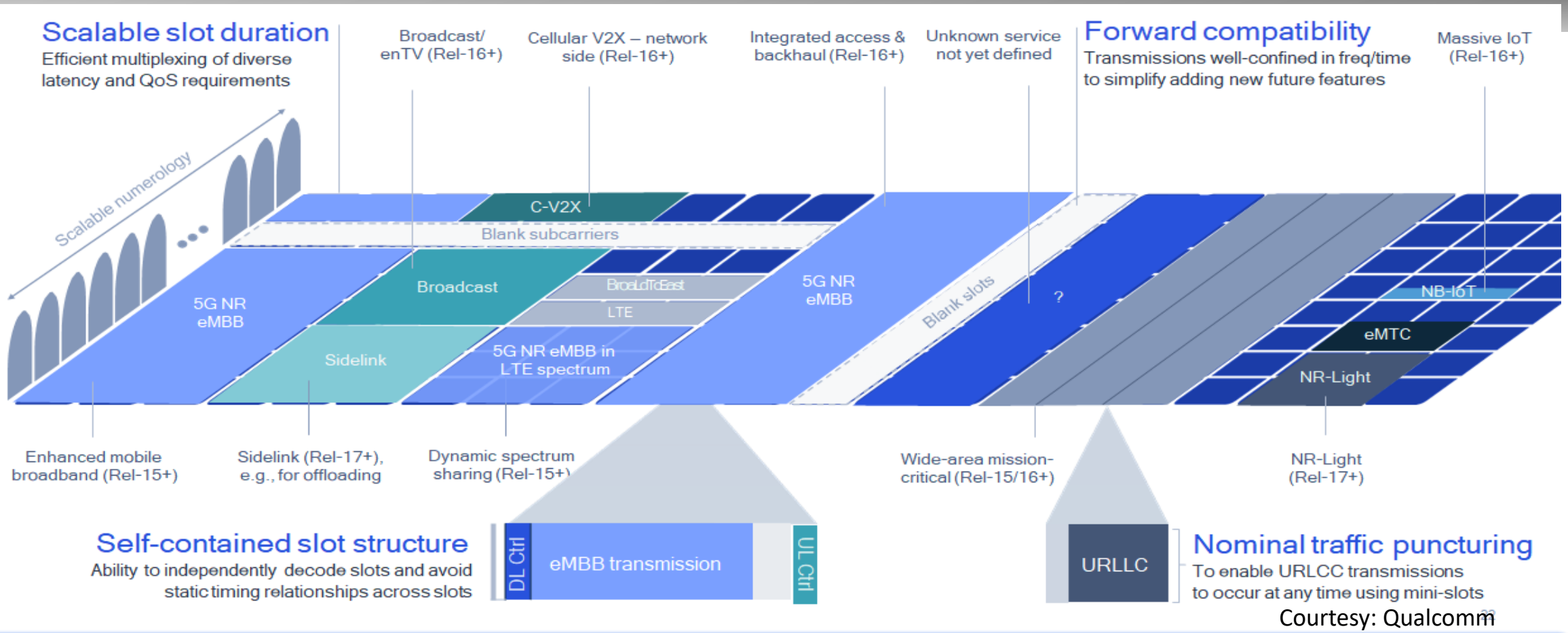


- Current 5G Network Slices generally belong to three categories:
  - eMBB: Enhanced Mobile Broadband Applications
  - IoT / mMTC: Massive Machine-type Communications
  - URLLC: Ultra-reliable Low Latency Communications
- These broad categories support numerous ***Missions and Applications***.

The ***Network Slicing*** paradigm within the 3gpp Rel. 17 (5g) spec defines three categories. These three categories (eMBB, URLLC and mMTC) may not be enough to meet the needs of Deep Space Networks

5G Network Slice Definition and Orchestration spans from Network Layer down to the Physical Layer

AiRANACULUS®



Courtesy: Qualcomm

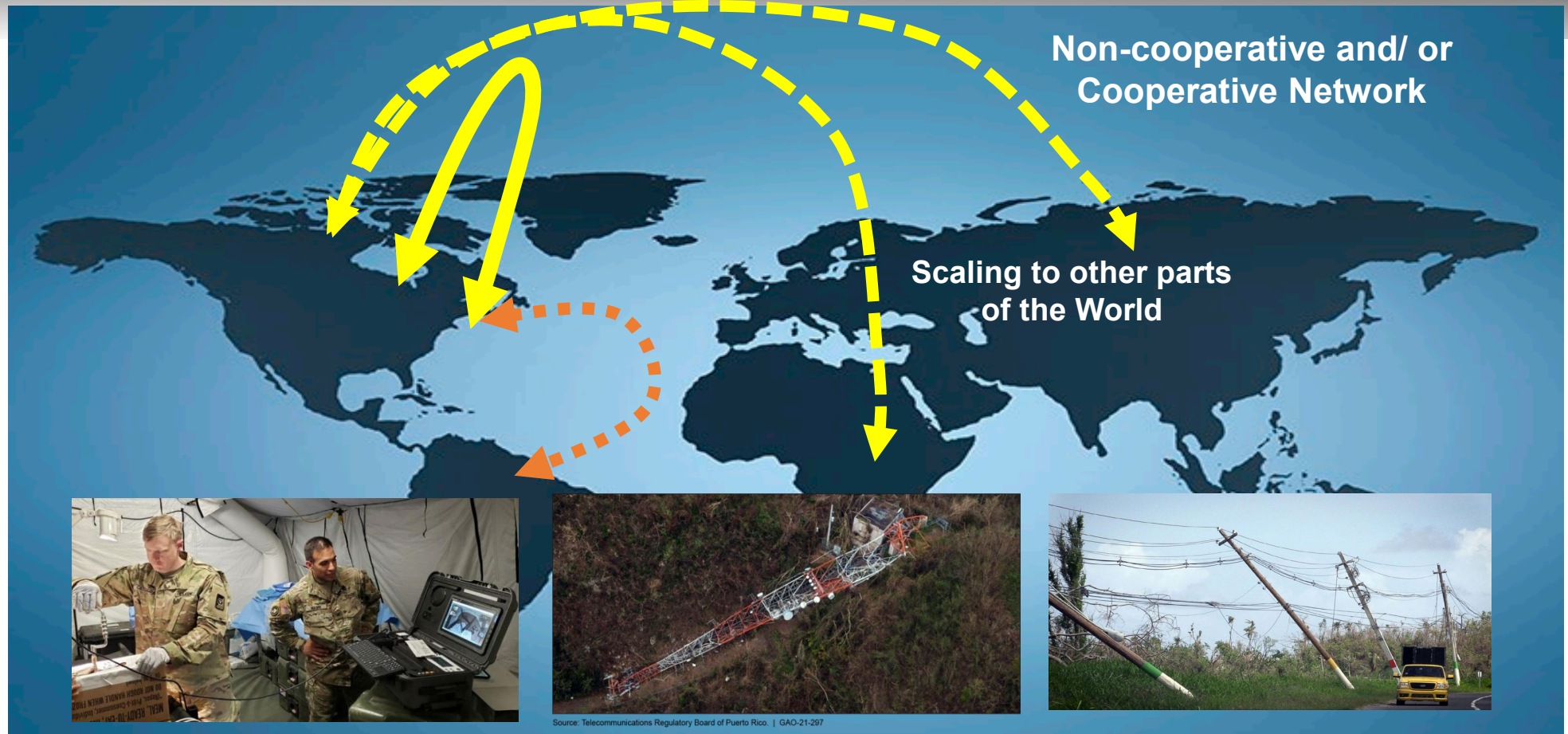
5G Network Slicing Spans Network Layer down to Physical Layer. E.g. eMBB Slice is provided more OFDMA Resource Blocks (RB). URLLC RBs are transmitted with higher Priority.

CHALLENGES

Scaling DoD Operations over large Geographical Areas, Heterogeneous ‘Un-trusted’ Non-cooperative Networks

Challenge – Scaling DoD Operation over Large Areas and Heterogeneous 'Untrusted' Networks

AiRANACULUS®



5G Network Slicing TODAY, does not scale across large geographic boundaries and over a heterogeneous network

WHAT IS NEW IN OUR APPROACH

CLAIRE AND INSPiRE ARCHITECTURE

New Way to Organize the Service Oriented Architecture: Mission / Applications / Organization / Performance Priorities

AiRANACULUS®

ORGANIZATION

NASA

esa

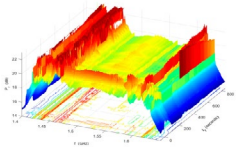
JAXA

इसरो · ISRO

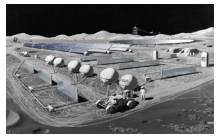
MISSION / APPLICATION

EVA – Human Life Support

Robotics

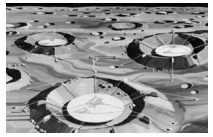


Interference and Weather Patterns (Solar Flares)



Moon Base Network

High-Res Deep Space Images and Videos



Radio Telescope

PERFORMANCE METRIC

- Throughput
- Latency
- Jitter
- Resilience

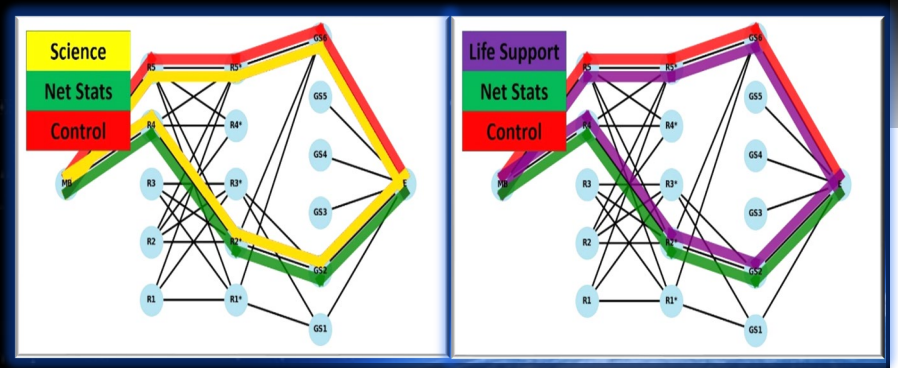
Quality of Experience = ***f*** (all of the above)

An Architecture for a Flexible Framework that allows Organization / Mission / Applications / Performance Priorities and Attributes to change Dynamically.

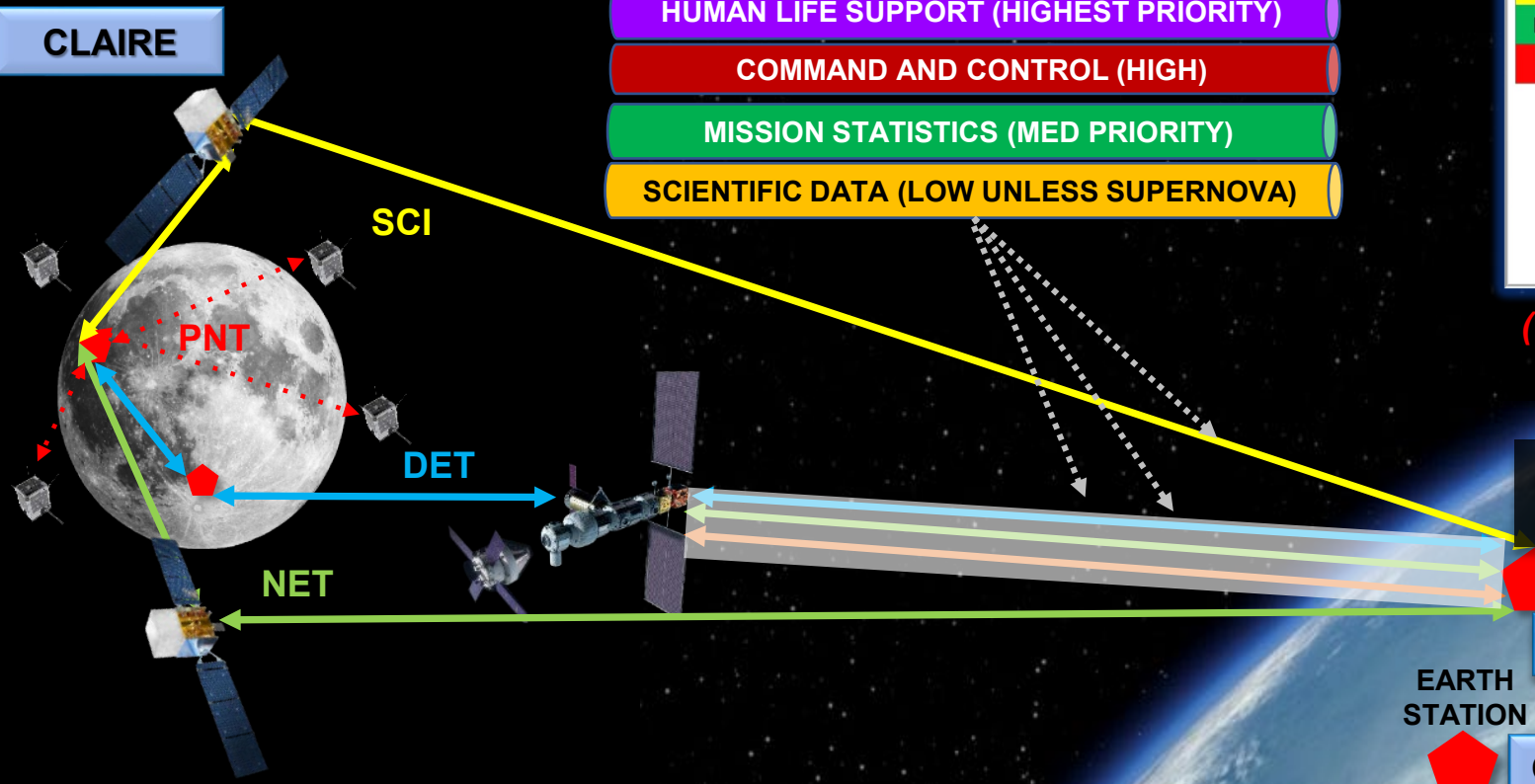
CLAIRE / INSPiRE

Network Slices

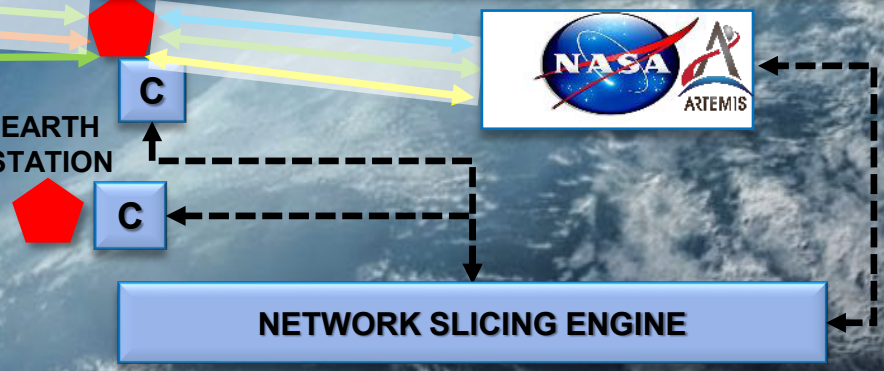
- HUMAN LIFE SUPPORT (HIGHEST PRIORITY)
- COMMAND AND CONTROL (HIGH)
- MISSION STATISTICS (MED PRIORITY)
- SCIENTIFIC DATA (LOW UNLESS SUPERNOVA)



(1) CLAIRE / INSPiRE provide Predictive Policy-based Network Slicing Orchestration



(2) Machine Learning Driven Network Optimization



(3) Dynamic Spectrum Access

(4) Cognitive Control Plane and Zero Trust Architecture

NASA INSPiRE and CLAIRE bring 5G Architectures to Deep Space.

Closing Thoughts

AiRANACULUS®

- ***DoD should continue to invest in R&D to develop Prototypes for 5G Use Cases such as Tele-Medicine and specifically 'Tele-Mentoring'.*** *This technology has applicability across the entire DoD and other Federal Agencies.*
- *Spectrum and Network Sharing*: Network Sharing using Network Slices which provide DoD Systems with wide variety of Quality of Experience (QoE) for Organizations, Missions, Applications and Services is extremely important.
  - Further research needed in making Network Slicing real for DoD use-cases. Large geographical areas, heterogeneous un-trusted, non-cooperative and cooperative networks.
- *Spectrum Efficiency is an outdated Metric*: Bits / Seconds / Hz is an outdated metric that does not take into account the utility of a particular communications technology.
  - A robust 100 kbps LPD Command and Control Link in Contested and Congested Spectrum has higher utility than 100 Mbps link that is continuously jammed.
  - Technology providing 5 Mbps in remote rural areas has high utility as compared to FCC mandate to provide 25 Mbps for technologies to get federal subsidies.
  - A NASA Robotic Mission in presence of Solar Flare interference. Would gladly accept tens of kbps connectivity rather than outage of a 250 Mbps X Band Link.

About AiRANACULUS

AiRANACULUS (www.airanaculus.com) is at the forefront in Intelligent RF solutions for applications ranging from Space communications to Smart Cities. The company has assembled the world's leading experts in signal processing, cross-layer analysis, cybersecurity and networking to create Intelligent RF solutions that are spectrum aware and capable of re-configuring radio systems for optimal performance even in highly contested environments.