
WInnForum Presents:
Lower 3 GHz: The Next Frontier in Spectrum Sharing between Federal Systems and Commercial Telecom
Thursday, 30 January
8:30 - 10 am PT/
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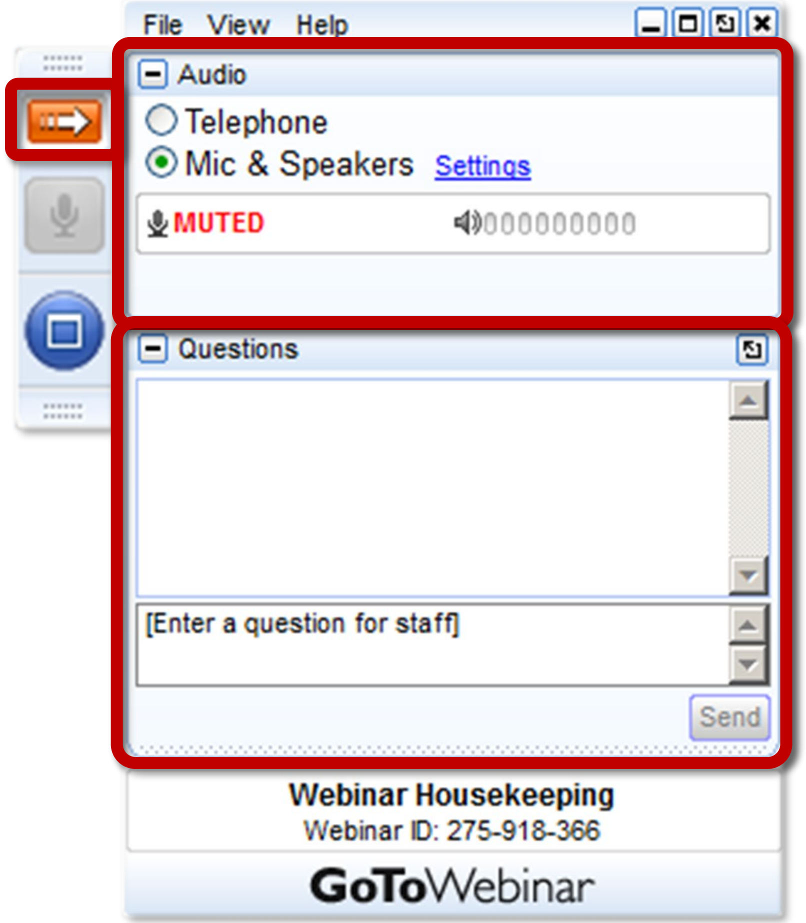

Presenters

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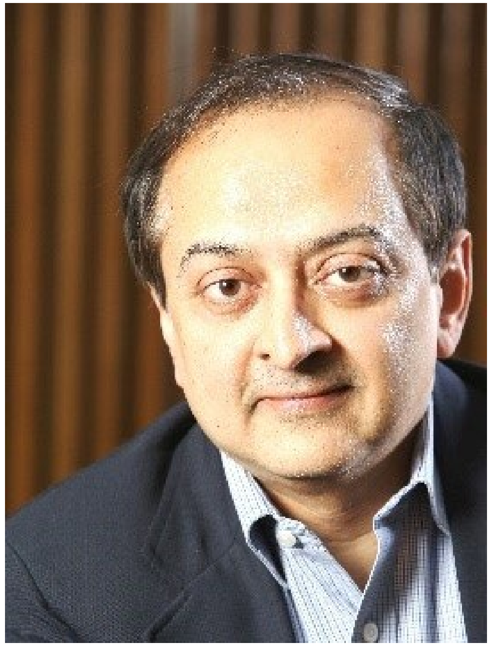

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Topics

1. The current domestic U.S. 3 GHz spectrum history & landscape (Andy)
2. Today's dynamic spectrum sharing mechanisms in CBRS and coexistence in AMBIT (Andy)
3. The need for temporal and spatial sharing between DoD and commercial systems (Amit)
4. Sharing enhancements to support lower 3 GHz: Spotlight on WInnForum's Highly Dynamic Spectrum Sharing efforts (Amit)
5. WInnForum's action plan (Andy)

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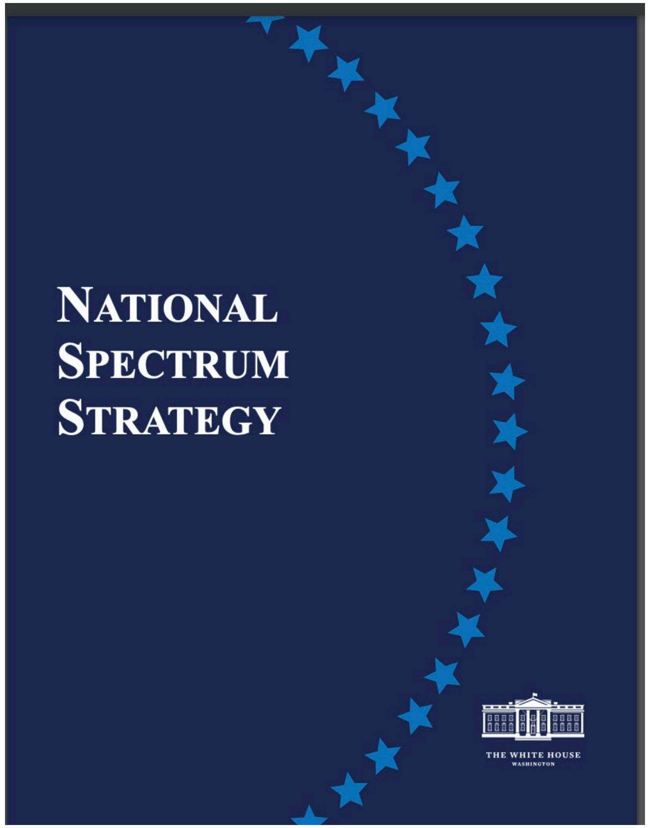
The Need for Ever More Spectrum Resources

- "U.S. leadership in next-generation technologies and services requires greater spectrum access for both the private and public sectors."
- "To continue our Nation's economic growth, to maintain and improve our global competitiveness, and to support critical public services and missions, we must make spectrum available for innovative new uses and to meet growing demand."



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Spectrum Flavors

Low, mid, and high band spectrum are the three frequency bands that make up 5G networks. Each band has different capabilities, such as coverage, speed, and capacity.

- **Low band**
  - Frequency range: Below 1 GHz, typically 600 MHz to 1 GHz
  - Capabilities: Good for covering large areas, including rural or hard-to-reach locations
  - Speed: Slower speeds than mid-band and high-band
- **Mid band**
  - Frequency range: 2 GHz–10 GHz, including C-band
  - Capabilities: Good for balancing speed, capacity, coverage, and penetration
  - Speed: Faster speeds than low-band, but slower than high-band
- **High band**
  - Frequency range: 24 GHz–53 GHz, including mm Wave
  - Capabilities: Good for high-density situations, such as video communications and virtual reality
  - Speed: Faster speeds than low-band and mid-band, but less coverage

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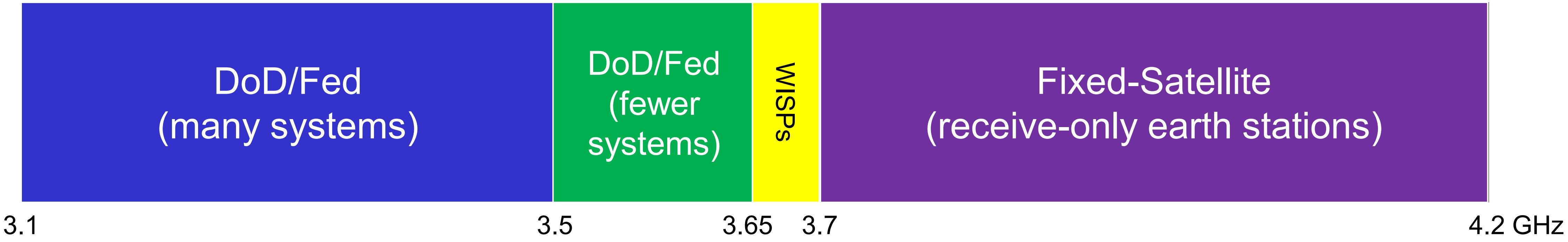
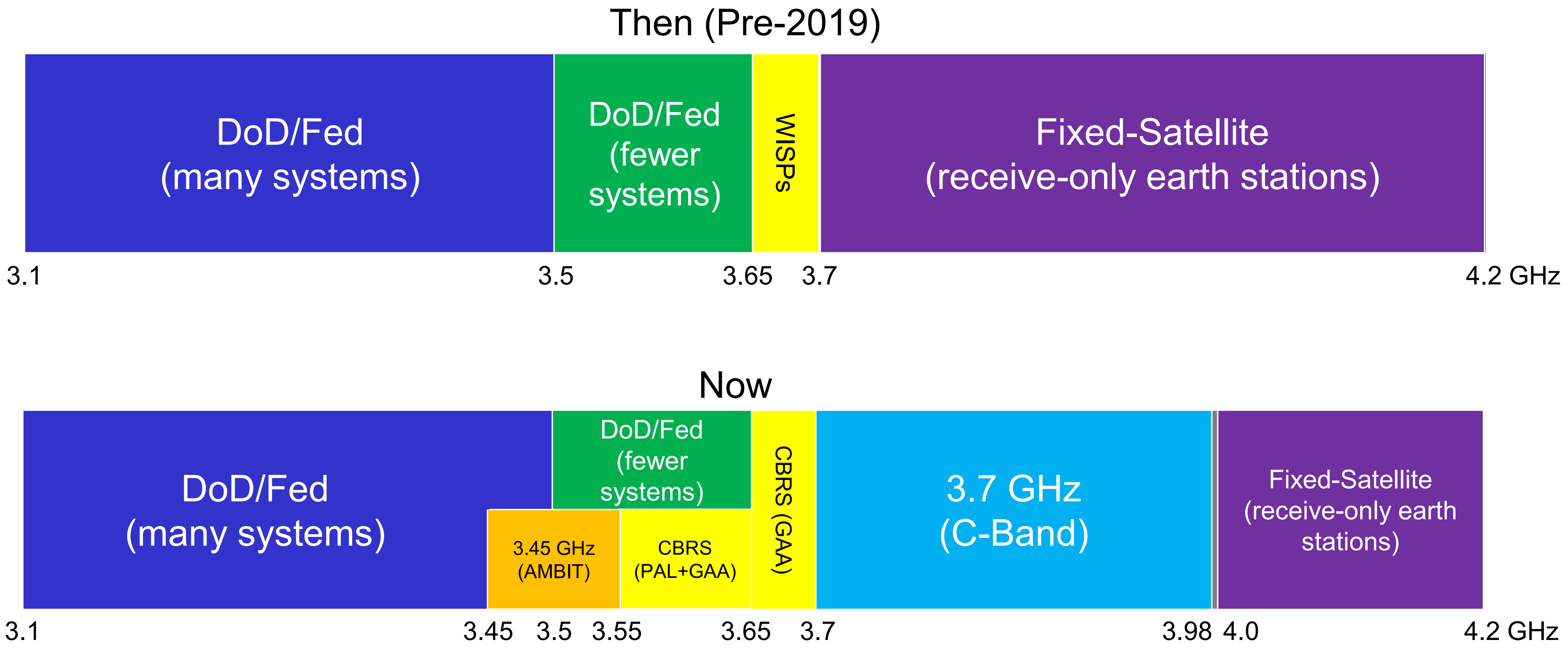
U.S. 3 GHz Band Principal Uses – Then

Then (Pre-2019)



- Some minor/legacy uses not shown: Extended C-band FSS, amateur radio, EESS, non-fed radars

U.S. 3 GHz Band Principal Uses – Then and Now



- Some minor/legacy uses not shown: Extended C-band FSS, amateur radio, EESS, non-fed radars
- 3.45 GHz and 3.7 GHz services apply in the contiguous U.S. only; CBRS is US&P

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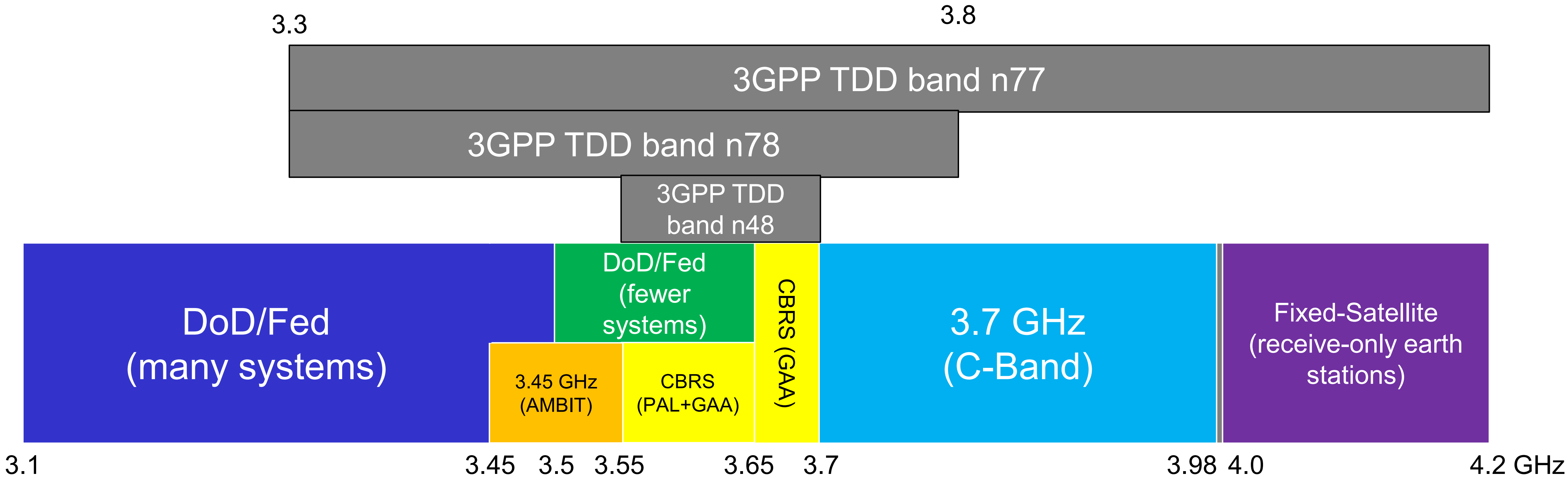
U.S. 3 GHz Band vs. 3GPP 5G Bands



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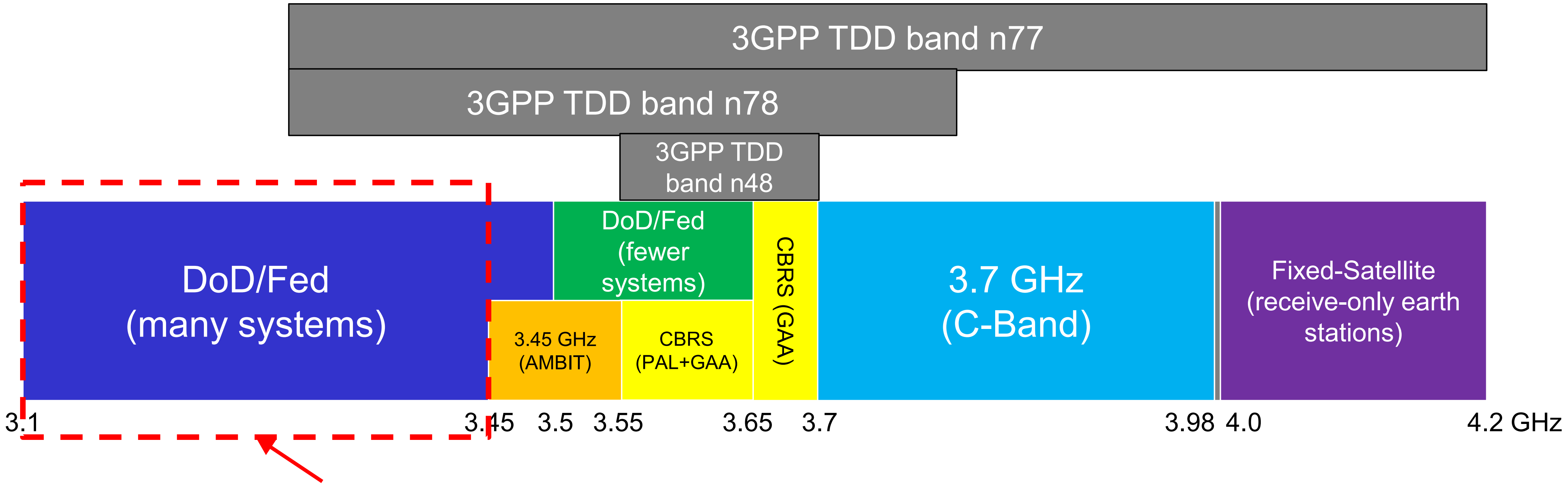

3.1 – 3.45 GHz ("Lower 3 GHz"):
The principal topic of this webinar

Lower 3 GHz Regulatory and Legislative Background

- **2010 March** FCC National Broadband Plan recommends government make 500 MHz available for broadband
- **2010 June** Presidential Memorandum calls for agencies to coordinate with FCC to make 500 MHz available
- **2010 October** NTIA ten-year plan identifies multiple bands; 3.1 – 3.5 GHz is one of the largest
- **2018 March** MOBILE NOW Act directs NTIA, in consultation with FCC, to evaluate the feasibility of allowing commercial wireless in 3.1– 3.55 GHz
- **2020 July** NTIA reports out on feasibility study
  - 3.45 – 3.55 GHz is suitable for potential spectrum sharing
  - Some sharing below 3.45 GHz possible but needs more study
- **2020 August** President announces availability of 3.45-3.55 GHz band for 5G (AMBIT)
- **2020 December** Congress requires auction of 3.45-3.55 GHz
- **2021 March** 3.45-3.55 GHz auctioned (Auction 110, nets $22.4B)
- **2021 November** IIJA provides funds for DoD to study shared use of 3.1-3.45 GHz
  - **2021 October** National Spectrum Consortium stands up the Partnership for Advanced Trusted and Holistic Spectrum Solutions (PATHSS)
  - **2023 September** PATHSS Report (aka the Emerging Mid-band Spectrum Sharing (EMBRSS) Feasibility Assessment) concludes that sharing 3.1-3.45 GHz is feasible under certain conditions

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Lower 3 GHz Regulatory and Legislative Background (cont'd)

- **2023 November** NTIA's National Spectrum Strategy identifies 3.1-3.45 GHz band (among others) for in-depth study
  - Funding for agency studies is through the Spectrum Relocation Fund
- **2024 March** NTIA Releases the NSS Implementation Plan ("I-plan")
  - See specifically Annex A, pp. A-6 & A-7 for lower 3 GHz schedule, milestones, and deliverables
    - Seek and receive approval for funding for agencies' related R&D under SRF (completed 2024 December)
    - Establish intragovernmental and government/industry study/exchange groups (work underway; for example, NSC multistakeholder group)
    - Develop a Dynamic Spectrum Sharing (DSS) demo (2025 September)
    - Coordinate DSS demo findings with all stakeholders (2026 July)
    - Complete study and issue final report (2026 October)
- **2024 April** PATHSS follow-on study ("PATHSS 2") initiated
- **2024 December** National Spectrum Consortium & DoD release Request for Prototype Proposal (RPP) for Advanced Dynamic Spectrum Sharing Demonstration (ADSSD) (aka the September 2025 DSS demo)

EMBRSS Report Findings Regarding Dynamic Sharing of 3.1 – 3.45 GHz Band

FINDINGS

- **Developing a capability for large-scale dynamic spectrum sharing (DSS)**, including a dynamic spectrum management system (DSMS) operated by and within the DoD, that evolves the implementation of Citizens Broadband Radio Service (CBRS) in the 3550-3700 MHz band, presents a potential spectrum sharing framework between the Federal and commercial systems in the covered band, but must be proven through rigorous, in-depth, real-world full scope operational testing with Joint Force assets.
- Sharing of the 3100-3450 MHz band between Federal and commercial systems is not feasible unless certain regulatory, technological, and resourcing conditions are proven and implemented. A coordination framework must facilitate spectrum sharing in the time, frequency, and geography domains as well as **stringent adherence to <u>all</u>** the following conditions:
  - DoD retains regulatory primacy
  - Maintain national emergency preemption policy
  - Expand and improve existing CBRS sharing framework policy and technology **(DSS capability)**
  - Government is not liable for damages to commercial systems
  - Address information/operational/cyber security
  - The Defense Industrial Base retains band access for testing and experimentation
  - Current and future Federal systems accommodated equally
  - Establish interference safeguards
  - Address resource requirements
- Even with the above framework and conditions, spectrum sharing between Federal and non-Federal users in the 3100-3450 MHz band will remain challenging. DoD is concerned about the high possibility that non-Federal users will not adhere to the established coordination conditions at all times; the impacts related to airborne systems, due to their range and speed; and required upgrades to multiple classes of ships. **Developing a DSS capability presents a massive engineering challenge.**

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Protecting Dynamic Incumbents in the CBRS Band

CBRS Incumbents

- **The CBRS band has two principal "Tier 1" incumbents**
  - Federal (DoD) radars
  - Non-federal fixed-satellite service (FSS) receive-only service earth stations
- **FSS earth stations are essentially static and don't require dynamic protection**
- **DoD radars are protected on a dynamic basis**
- **The radars come in three general varieties:**
  - Shipborne Navy radars (principal radar incumbent)
  - Ground-based radars operated by various DoD entities and contractors, used for training, testing, and R&D
  - One site in which airborne operations are protected
- **WInnForum published a detailed analysis of CBRS encumbrances prior to the CBRS auction (WINNF-TR-5003)**

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How CBRS Dynamically Protects Incumbent DoD Radars

- **A SAS becomes aware of DoD radar activity on specific 10-MHz CBRS channel(s) at a specific time in a general area (“Dynamic Protection Area” or DPA)**
- **The night before, the SAS has pre-calculated – channel by channel – the CBSDs within a certain distance (“DPA neighborhood”) of the radar operational area whose aggregate interference would cause the radar’s interference criterion to be exceeded**
- **After the SAS becomes aware of radar activity, in response to the next heartbeat between the CBSD and the SAS, the SAS instructs the CBSD to cease operation on the frequency grants that overlap the affected channels**
    - In DPA neighborhoods, heartbeats occur approximately every 2-4 minutes
    - By rule, CBSDs must be reconfigured within 5 minutes of the SAS becoming aware of radar activity

Example DPA and DPA Neighborhood

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How SASs Become Aware of DoD Radar Activity

- **There are four methods by which SASs are aware of DoD radar activity**
  - **ESC (E-DPAs)**: 95 DPAs must be monitored by a network of radar sensors called Environmental Sensing Capability for CBSDs to be allowed to operate in the neighborhood of these sites
    - This technique is predominantly used in coastal areas for monitoring shipborne radar operations in the ocean and in some ports
    - This technique is only used for monitoring radars that operate in the 3550 – 3650 MHz segment of the CBRS band
  - **Portal (P-DPAs)**: Radar operations in 15 DoD DPAs are informed to the SAS by way of a web-based portal system
    - The original portal system was based on reservations in a calendar-like utility
    - Since replaced by a DoD-built portal-based system, the Telecommunications Advanced Research and Dynamic Spectrum Sharing System (TARDyS3)
    - SASs connect to TARDyS3 on a regular basis to download the current schedule of sites and frequencies that require protection
      - Information about upcoming radar activity is informed no earlier than 72 hours prior to radar operation (i.e., the maximum forewarning of upcoming activity is 72 hours, but by design SASs can support forewarning of as little as a few minutes)
      - Data are transmitted by way of a JSON data file with schedule, location, and frequency information, accessible only by white-listed IP addresses (SASs)
    - Portal-managed sites operate impact the 3550-3650 MHz band
    - Most of these sites are ground-based, but one site is defined to protect airborne operations (China Lake air)
  - **Always-on (GB-DPAs)**: 10 ground-based (GB) sites operating below 3550 MHz are always protected from out-of-band emissions. These protections impact CBRS operations in the 3550-3650 MHz band in the vicinity of these sites
  - **Exclusion zones (EXZ)**: Four areas in which CBRS operations are prohibited in certain frequency ranges.

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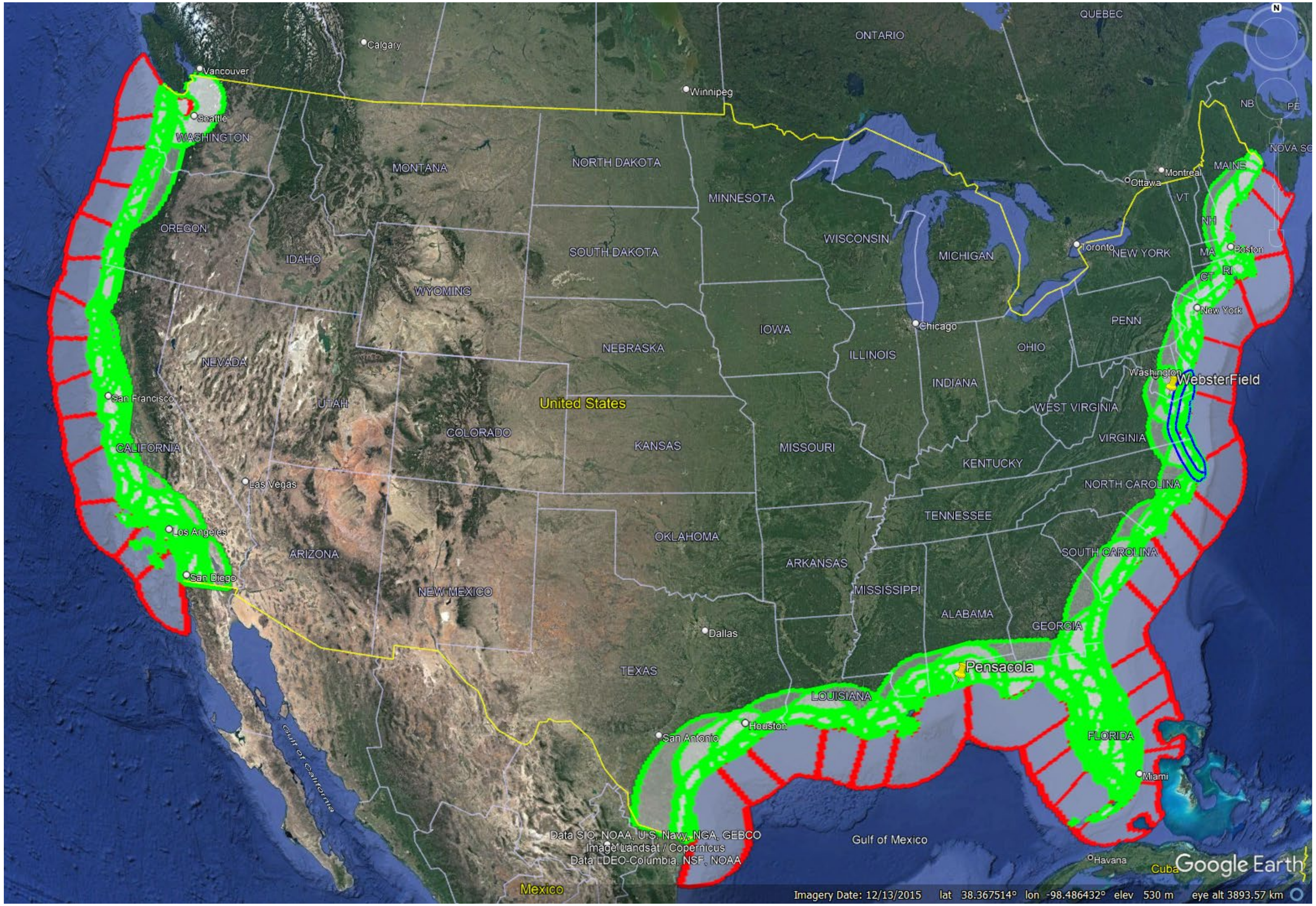
DoD Radar Geographic Areas of Operation Protected from CBRS Interference

Informing method	Dynamic	Number of DPAs	CBRS Frequency Range Impacted	Range of DPA neighborhood size
ESC (E-DPAs)	Yes Monitored by ESC	95 (57 excluding Alaska)	3550 – 3650 MHz	Indoor Cat A <= 6 m: 1 – 150 km Indoor Cat A > 6 m: 36 – 150 km Cat A <= 6 m: 36 – 200 km Cat A > 6 m: 72 – 248 km Cat B <= 6 m: 36 – 200 km Cat B > 6 m: 72 – 248 km
Portal (P-DPAs)	Yes Informed by TARDyS3 portal	15	3550 – 3650 MHz	Indoor Cat A <= 6 m: 2 – 6 km Indoor Cat A > 6 m: 12 – 150 km Cat A <= 6 m: 10 – 200 km Cat A > 6 m: 32 – 200 km Cat B <= 6 m: 10 – 200 km Cat B > 6 m: 32 – 200 km
Always-on (GB-DPAs)	No Always protected from CBRS OOBE	10	3550 – 3650 MHz	2 km, all categories/heights
Exclusion Zones (EXZ)	No Always in force	4	Three sites: 3650 – 3700 MHz One site: 3550 – 3650 MHz	N/A

KML files of E-, P-, and GB-DPAs (with neighborhood distances included as metadata) are available at
https://www.ntia.gov/spectrum-frequency-bands/3550-3650-mhz

E-DPAs and Neighborhoods (3550-3650 MHz)



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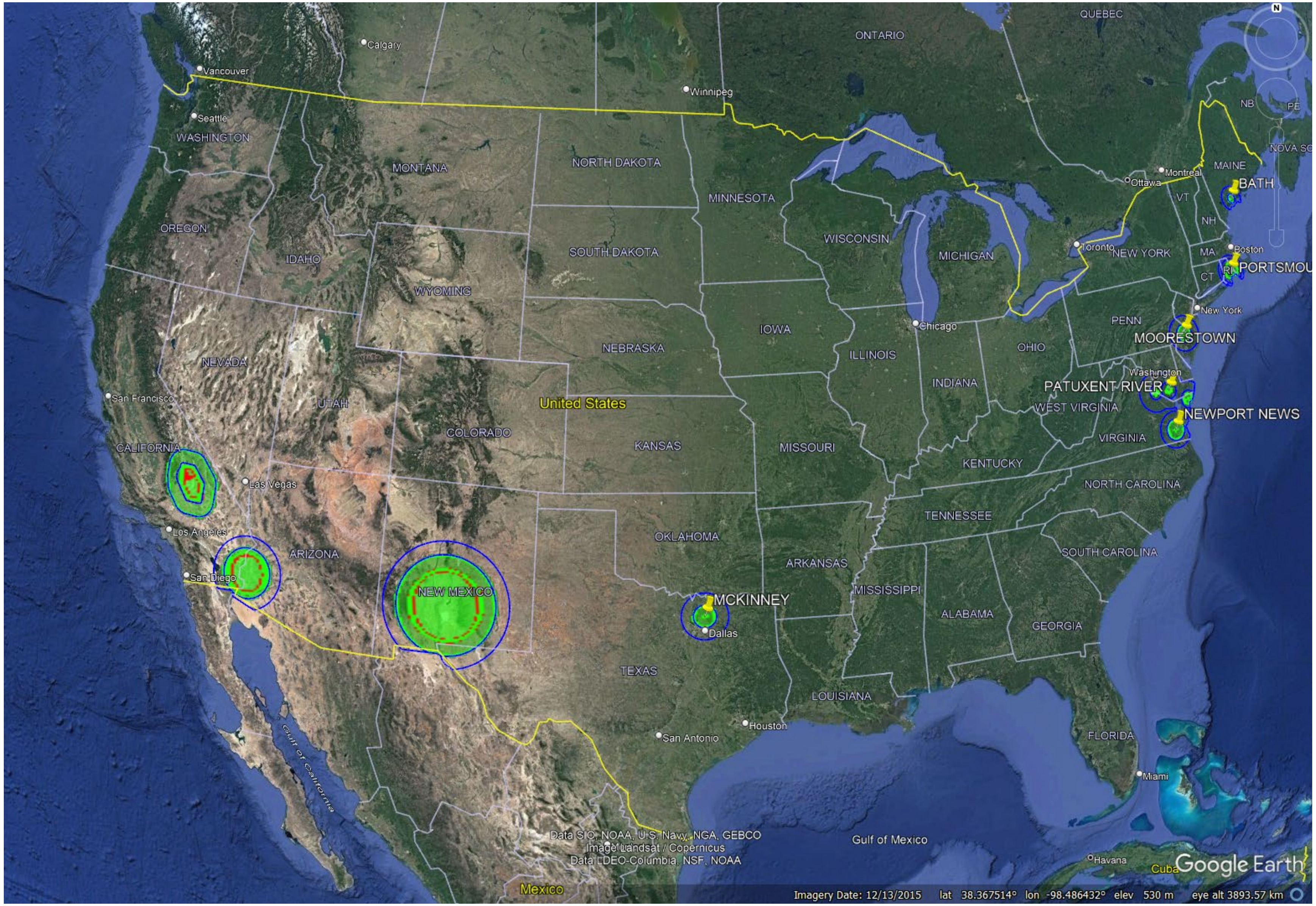
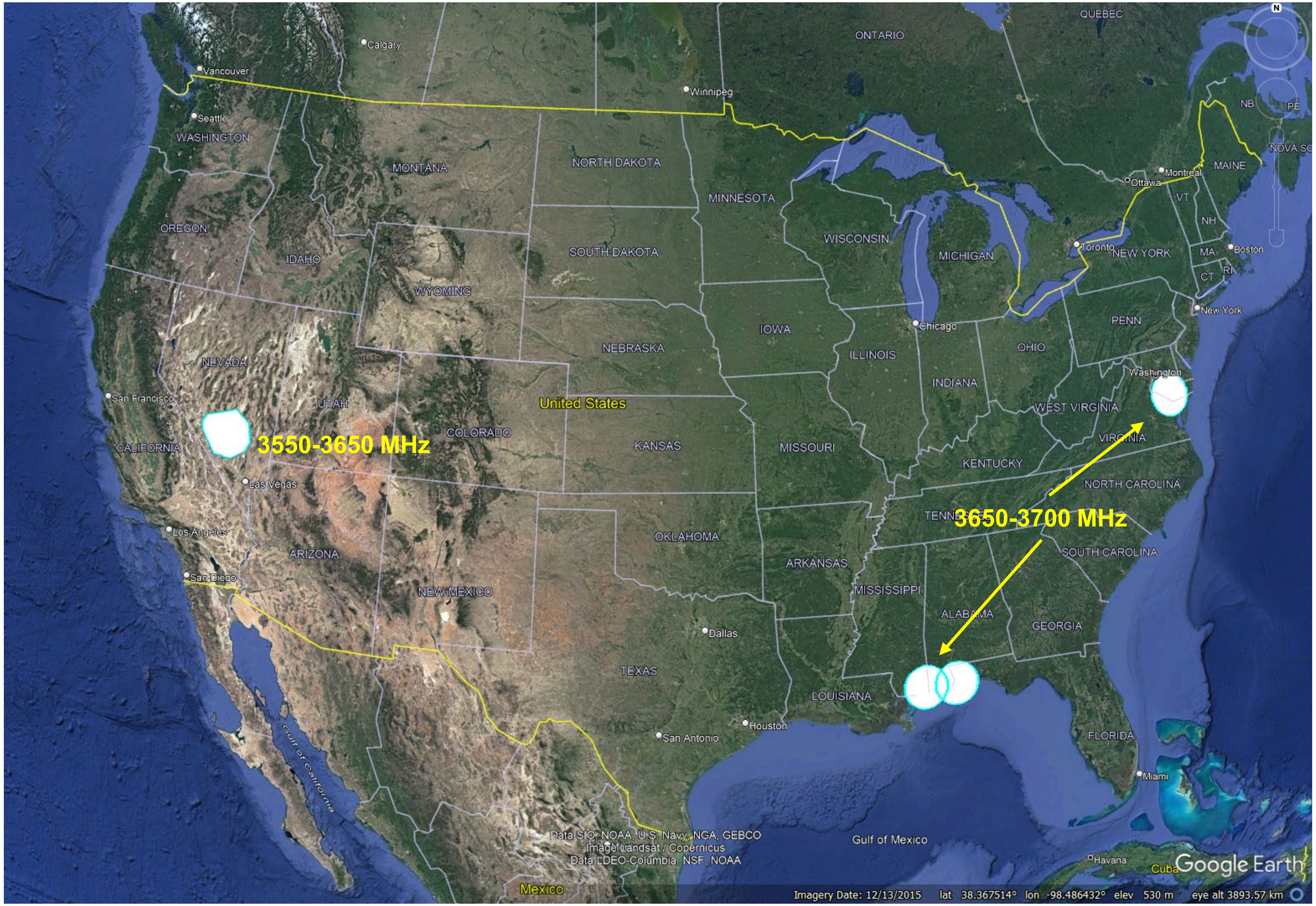
P-DPAs and Neighborhoods (3550-3650 MHz)



GB-DPAs (Always-on OOBE protections) (3550-3650 MHz)

Exclusion Zones (Always Active) (Frequency ranges as noted)



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China Lake Air Portal DPA and Cat A/B Neighborhoods

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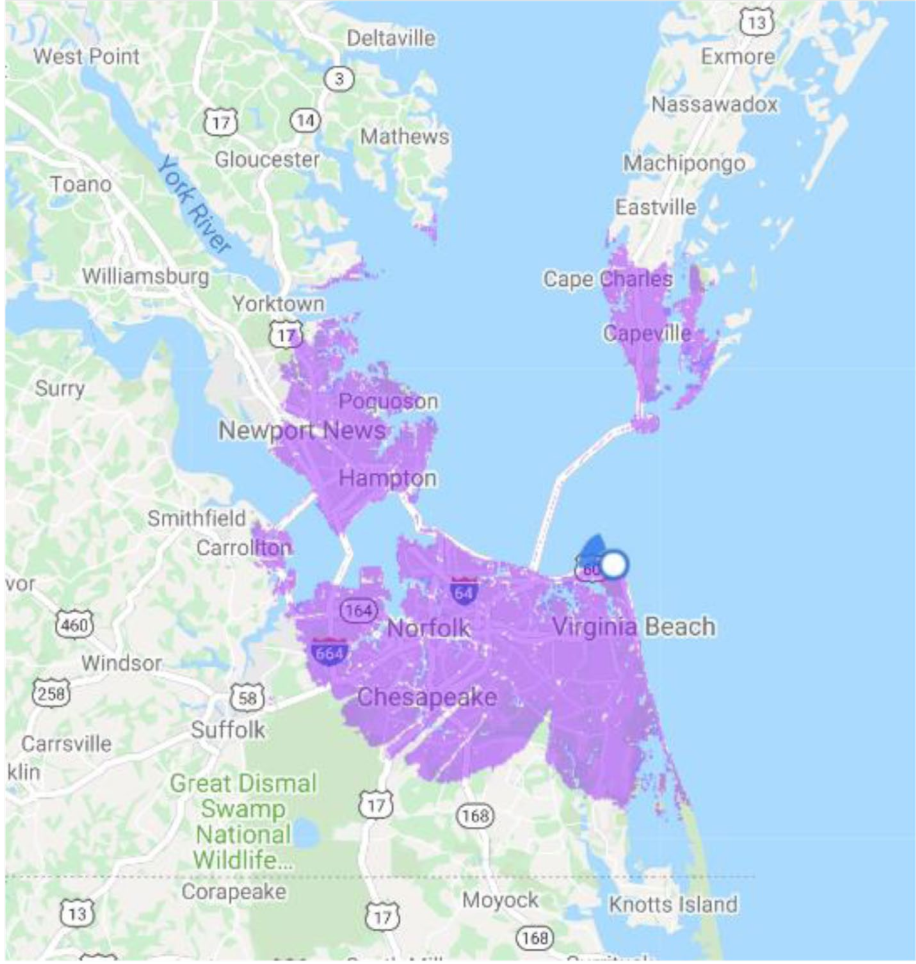
ESC Operation

- **ESC sensors are trained on five different radar waveforms, each with a range of pulse width, pulse repetition rate, and (for chirp waveforms) chirp width**
  - For ESC certification testing, min and max pulses per test burst were specified
- **Waveforms are defined in NTIA Technical Memorandum 18-527, *Procedures for Laboratory Testing of Environmental Sensing Capability Sensor Devices***

Pulse Modulation	Pulse Width (μs)	Chirp Width (MHz)	PRR (pulses per second)	Pulses per Burst (Min to Max)	Comments
P0N #1	0.5 to 2.5 Δ = 0.1	N/A	900-1100 Δ = 10.0	15 to 40 Min Δ = 5	Similar to currently deployed Radar 1
P0N #2	13-52 Δ = 13	N/A	300-3000 Δ = 10.0	5 to 20 Δ = 5	Simulates possible phase-coded waveforms that could be used in future radar modulations
Q3N #1	3-5 Δ = 1.0	50-100 Δ = 10	300-3000 Δ = 30	8 to 24 Δ = 2	Simulates possible future multi-function Q3N-type radar • Short τ • Wide Bc
Q3N #2	10-30 Δ = 1.0	1-10 Δ = 1	300-3000 Δ = 50	2 to 8 Δ = 2	Simulates possible future multi-function Q3N-type radar • Intermediate τ • Intermediate Bc
Q3N #3	50-100 Δ = 5.0	50-100 Δ = 10	300-3000 Δ = 100	8 to 24 Δ = 2	Simulates possible future multi-function Q3N-type radar • Wide τ • Wide Bc

ESC Challenges

- **Principal challenge is that ESC sensors must themselves be protected from CBRS interference so they can hear potentially distant radar signals**
  - Radar detection threshold: -89 dBm/MHz peak power at input of ESC
  - ESC protection criterion: -109 dBm/MHz RMS
- **ESC protection creates "whisper zones" around ESC sensors impacting CBRS deployments in 3550-3650 MHz**
  - Adjacent channel protections affect Cat A CBSDs up to 3660 MHz and Cat B CBSDs up to 3680 MHz (TS-0112 R2-SGN-25)
- **For whisper zone analysis, see WINNF-TR-1015, *Potential Metrics for Assessing the Impact of ESC Sensors and Networks on CBRS Deployments***



Simulated whisper zone impact for Cat B CBSD for a hypothetical ESC sensor in Va Beach, VA, from WINNF-TR-1015

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ESC Challenges

Additional challenges:

- **Out-of-operation ESC sensors can cause entire 3550-3650 MHz range to be declared active by that sensor**
- **ESC siting must be approved by DoD, NTIA, and FCC in advance, which can take weeks**
- **ESCs are likely to be negatively impacted by upcoming deployments of > 32,000 W 3.45 GHz service base stations in the immediately adjacent band (i.e., no guard band)**
- **Major storms can (and have) taken out ESC sensors. SAS Admins must then file emergency waiver requests with the FCC, which must then be considered by DoD/NTIA and approved by FCC, otherwise entire 3550-3650 MHz range must be declared active for that sensor, potentially disabling broadband service over CBRS in storm-damaged areas, at the time of greatest need**
- **ESC sensors can occasionally be impacted by false detections caused by a variety of electromagnetic interference**
  - Required detection capabilities (i.e., NTIA test requirements) have ESCs operating on a hair trigger

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Propagation Model and Aggregate Interference Calculation for DPA Protections

- **Defined in WInnForum TS-0112 (CBRS Release 1) and Post-Certification (Release 1+) TS-1020**
- **DPA protection prop model**
  - ITM median loss + P.2108 median clutter loss for CBSD AGL <= 6 m
  - ITM for CBSD AGL > 6 m, no clutter loss
  - For indoor (Cat A), use additional 15 dB building entry loss
  - Use ITM reliability and confidence factors to 0.5 (median loss)
- **ITM is a terrain-based propagation model**
- **P.2108 is a distance-based clutter loss model**
- **DPA activity and TDD factors for all CBSDs**
  - Reduces effective CBSD EIRP by 8 dB
- **Area protection standard**
  - Required to meet protection incumbent criterion at all points in a nominal 2 arc sec grid
- **Consideration for incumbent beam pattern**
  - DPA Move List analysis is performed using increments of half of beamwidth (beamwidth/2), where beamwidth is defined in the appropriate KML file, over the azimuth range of the given DPA, where the azimuth range is defined in the appropriate KML file
- **Nightly move list determination process requires terrain-based calculations over dimensions of CBSD, CBRS channel, incumbent protection point, and incumbent beam direction**
  - Each SAS must share its CBSD data with all other SASs each night for the purpose of aggregate interference and move list calculations

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3.45 GHz Service

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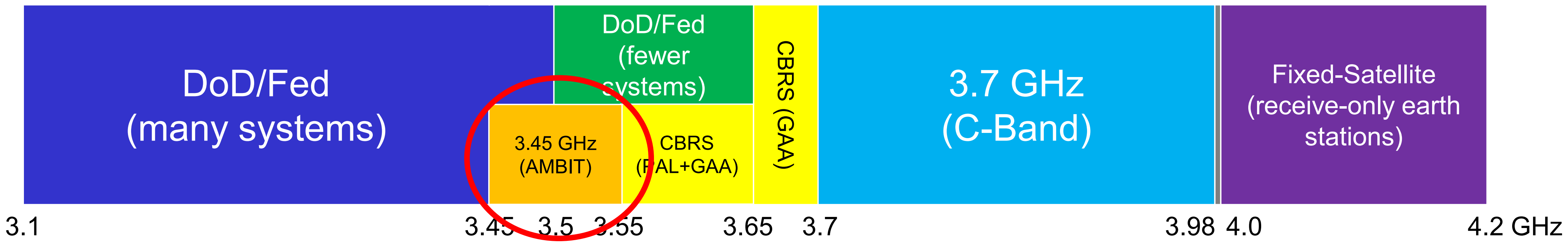
3.45 GHz Service



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3.45 GHz Service

- **Shared DoD/commercial spectrum use**
- **DoD use**
  - High-powered shipborne radars, lower power airborne radars, lower power ground-based radars, testing infrastructure, and training operations
- **Combination of static/dynamic sharing**
  - Cooperative Planning Areas (CPAs): Geographic locations in which non-Federal operations shall coordinate with Federal systems in the band to deploy non-Federal operations in a manner that shall not cause harmful interference to Federal systems operating in the band.
  - Periodic Use Areas (PUAs): Geographic locations in which non-Federal operations in the band shall not cause harmful interference to Federal systems operating in the band for episodic periods. During these times and in these areas, Federal users will require interference protection from non-Federal operations.
    - Operators of non-Federal stations may be required to temporarily modify their operations (e.g.,reduce power, filtering, adjust antenna pointing angles, shielding, etc.) to protect Federal operations from harmful interference, which may include restrictions on non-Federal stations' ability to radiate at certain locations during specific periods of time.
    - During such episodic use, non-Federal users in PUAs must alter their operations to avoid harmful interference to Federal systems' temporary use of the band, and during such times, non-Federal operations may not claim interference protection from Federal systems.
- **Not managed by a centralized spectrum access system**
- **Negotiations are directly between operators and DoD**
  - Coordination procedures are established by NTIA and DoD

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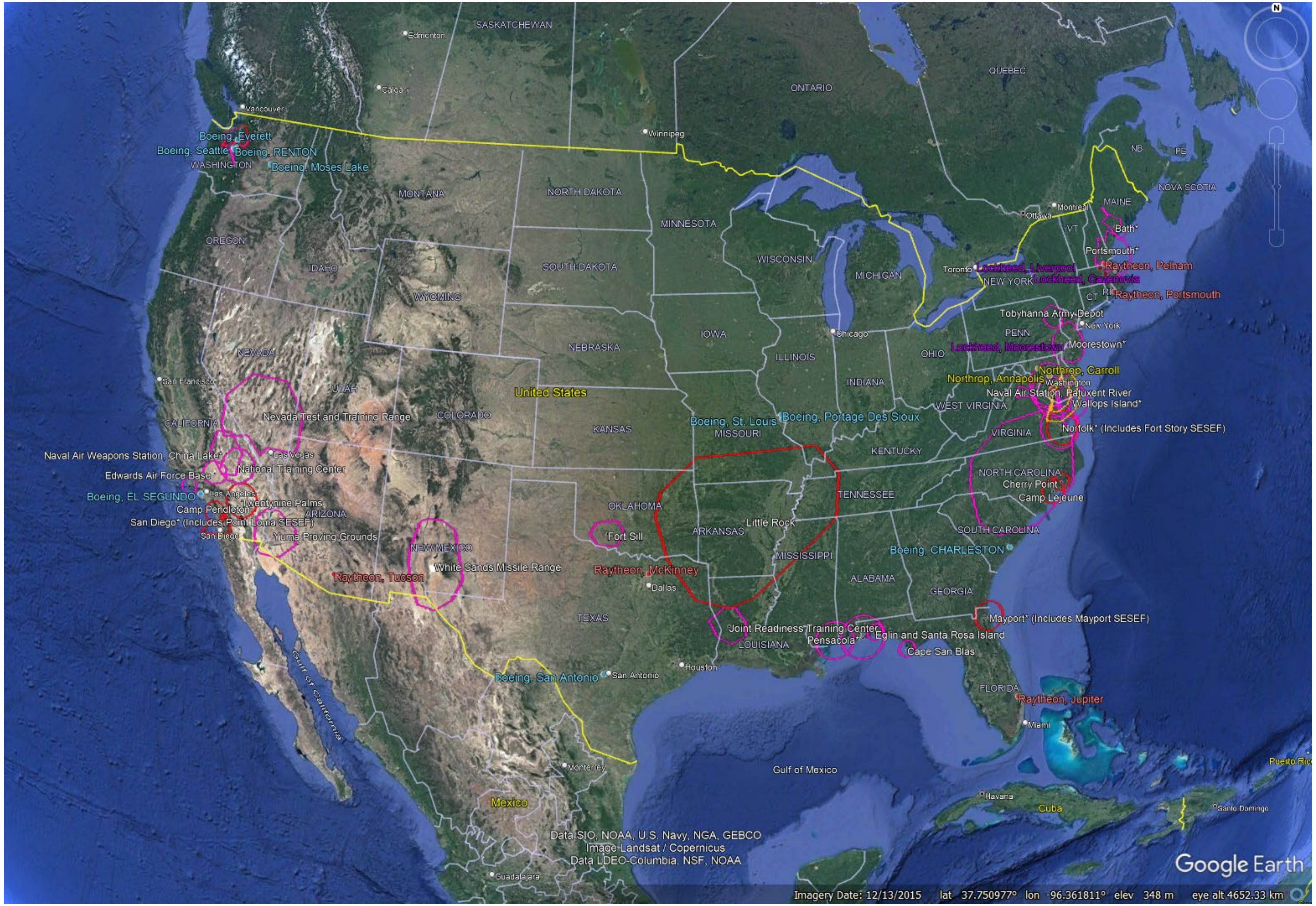
3.45 – 3.55 GHz CPAs & PUAs

Red: CPA only
Pink: CPA & PUA



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Need for Temporal and Spatial Sharing

NTIA initiatives: Spectrum sharing in lower 3 GHz (3.1-3.45 GHz) spectrum

National Spectrum Strategy (November 13, 2023)

"…the Department of Defense (DoD) has studied the possibility of **sharing** this 350 megahertz of spectrum with the private sector. DoD's studies helped to determine whether this band should be reallocated for **shared** Federal and non-Federal use and licensed through auction. DoD determined that **sharing is feasible** if certain advanced interference mitigation features and a coordination framework to facilitate spectrum sharing are put in place. …..Additional studies will explore **dynamic spectrum sharing** and other opportunities for private-sector access in the band, while ensuring DoD and other Federal mission capabilities are preserved, with any necessary changes."

National Spectrum Research& Development Plan (October, 2024)

"There are many definitions of **Dynamic Spectrum Sharing (DSS)**. In this National Spectrum R&D Plan, the term "**dynamic spectrum sharing**" means adaptive **coexistence** using techniques that enable multiple electromagnetic spectrum users to **operate on the same frequencies in the same geographic area** without causing harmful interference to other users ….by using capabilities that can adjust and optimize electromagnetic spectrum usage in **real time or near-real time**, consistent with defined regulations and policies for a particular spectrum band."

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A few spectrum sharing examples for reference

CBRS (3.55-3.7 GHz):

Releasing spectrum when federal incumbent user is active in same geography (**temporal sharing** over pre-defined geography, i.e., DPA Neighborhood, time scale to respond "~5 minutes")

AMBIT (3.45-3.55 GHz):

Coordinating in geographical areas (CPAs) where incumbent may be active (**coexistence**), and actively managing in certain areas (PUAs) at times of radar activity (manual **semi-static sharing** for now, may change in the future)

US 6 GHz (5.9-7.125 GHz)

Spectrum use by unlicensed spectrum users in higher power outdoor environment only to make sure it does not cause interference towards licensed 6 GHz Fixed Service users. Automatic checks are carried out once a day for any adjustments to unlicensed usage (geographical **semi-static sharing**)

WRC-27 Agenda Item 1.7:

"to consider studies on **sharing and compatibility** and develop technical conditions for the use of International Mobile Telecommunications (IMT) in the frequency bands 4 400-4 800 MHz, 7 125-8 400 MHz (or parts thereof), and 14.8-15.35 GHz taking into account existing primary services operating in these, and adjacent, frequency bands, in accordance with Resolution 256 (WRC-23);"

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Example DoD radar types deployed in 3.1-3.45 GHz spectrum range

Ground-based Stationary Radars	Ground-based Mobile Radars	Maritime Radars	Aeronautical Radars
			
Long range missile and air defense systems	Medium to short range tactical counterfire systems	Medium to long range air and missile defense systems	Long range detection of threats and providing command and control

Several dozens of radar systems deployed all over the country

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Increasing order of difficulty to manage interference with different radar types

Fully contained in military bases

Fixed radar systems
- Active 24/7
- Active intermittently

- Static spatial sharing
- Temporal sharing, only reacting to system activation

Mostly contained in military bases

Terrestrial mobile or maritime systems
- Fixed mobility area
- Arbitrary mobility area

- Static spatial sharing
- Temporal sharing, low response time to react to mobility

Mostly contained in training areas

Airborne radar systems
- Fixed mobility area
- Arbitrary mobility area

- Static spatial sharing
- Temporal sharing, very low response time to react to mobility

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Diverse set of requirements from the DoD and the commercial mobile industry

It is critical that DoD continues to have access to the spectrum to protect national interests (EMBRSS report):

- National emergency preemption policy is maintained
- Interference safeguards are established
- Information, operational, and cyber security concerns are addressed
- Current and future Federal systems are accommodated equally

Commercial interest in the spectrum band is directly related to the technical conditions for sharing:

- **Geography**: Minimize protection areas/coordination zones
- **Time**: Maximize the time of spectrum availability
- **Power**: Maximize re-use of existing infrastructure
- **Frequency**: Maximize available amount of spectrum

Coexistence and sharing: Common interpretation of terminologies and historical responsibilities

Coexistence (static)

- Operating conditions are static in nature. Incumbents do not change their use of spectrum in temporal, geographical, or frequency dimensions
- Incumbents continue service unencumbered. New entrants operate in a way that does not interfere with incumbents.
- New entrant expected to avoid interference towards incumbent
  - Maintain separation distance
  - Avoid radiating in certain directions
- Historically no expectation from incumbents to improve Tx/Rx capabilities that may benefit new entrants

Sharing (semi-static, dynamic, Highly Dynamic)

- Operating conditions are dynamic in nature. Incumbents and new entrants share the spectrum in the time dimension
- Incumbents continue to get protection from new entrants (at least in the short term). New entrants take all the responsibility to avoid interference towards incumbents
- Interference mitigation may be achieved through key levers:
  - Time (and also possibly, frequency, power, geography)
- New entrant expected to live with some interference resulting in certain degree of performance degradation

Different radar operating characteristics may require different interference management approaches

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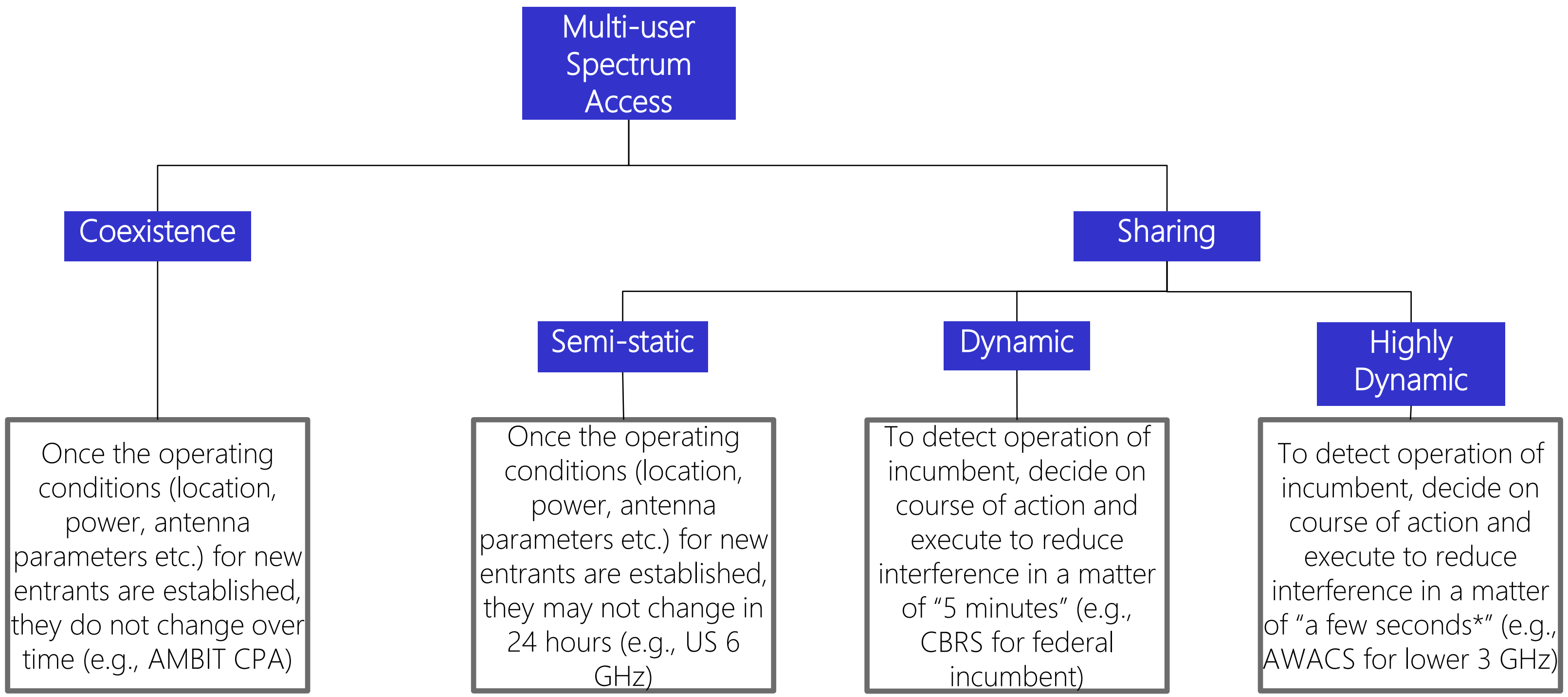
Dynamicity of sharing is driven by timescale

DoD/NTIA implication of "dynamic" is analogous to "highly dynamic" as described below



*Could be even milliseconds, depending upon the use cases

Enhancements to Sharing Frameworks to Support 3 GHz; and HDSS

Differences in approaches between lower 3 GHz compared to CBRS spectrum

CBRS

- Radars are mostly coastal and some inland; only one airborne radar coverage area
- Limited number of types of radars with a handful of operating characteristics
- Most radars are either stationary or relatively slow-moving
- All radars are at ground or sea level, impacting base stations are relatively closer
- Interference mitigation techniques may be applied and removed relatively slowly
- ESC sensors and portals are used to trigger base station interference mitigation

Lower 3 GHz

- Radars are located all over the country; they can be fixed, mobile or airborne
- Dozens of radars with different operating characteristics
- Radars can be stationary, relatively slow moving or very fast moving
- Airborne radars are at high altitudes, thus susceptible to base stations farther away
- Interference mitigation techniques may have to be implemented and removed quite fast
- Opportunity to overcome shortcomings of ESC sensors and improve portal-based notification

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Overview of functionalities required for spectrum sharing

Three key logical components (physical implementation may vary)

New commercial user

Tx: Minimize interference towards incumbent

- Nulling
- Beam muting
- EIRP monitoring & Control
- Layer management
- …

Rx: Accept interference from incumbent

- Optimize performance in spite of constraints
- Harmful interference detection and reporting?

Spectrum Manager

- Receive information about all users (incumbent and new entrant) about location, use time, frequencies etc.
- Store system operating characteristics and protection criteria
- Perform interference estimates
- Decide on spectrum allocation (including frequency, time, geography, power)
- Arbitrate harmful interference

Incumbent federal user

Rx

- Accept a predetermined level of interference and maintain performance
- Harmful interference detection and reporting

Tx

- Manage own harmful radiation (longer term)

Spectrum sharing is a two-way street – both commercial and federal systems need to evolve

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Possible implementation schemes

Independent sensors

RAN-as-a sensor

Sensor-based system

Notification-based system

DoD-managed system

Commercial system

Pro: No manual effort
Con: Error possibility

Pro: Incumbent responsibility
Con: Overprotection possibility

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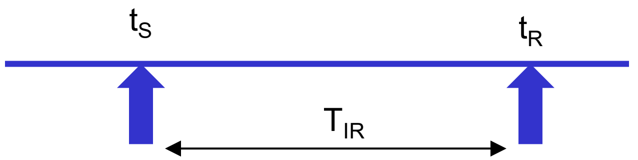
Incumbent system perspective:

t_S: Instant when incumbent becomes active

t_R: Instant when incumbent experiences relief from commercial interference

T_{IR}: Time interval for incumbent requirement of relief from commercial interference = $t_R – t_S$



Commercial system perspective:

t_A: Instant when commercial system senses incumbent activity

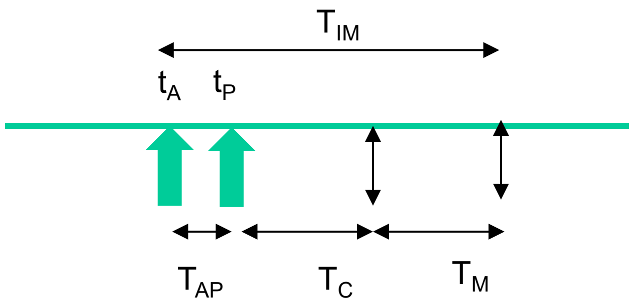
t_P: Instant when the sensing system positively detects incumbent activity

T_{AP}: Time interval for positive identification of incumbent activity = $t_P – t_A$

T_c: Time interval to determine course of action for the spectrum management system

T_M: Time interval to implement interference mitigation (e.g., beam muting, channel shifting etc.)

T_{IM}: Time interval for commercial system to implement interference mitigation = $T_{AP} + T_C + T_M$



$$T_{IM} \leq T_{IR}$$

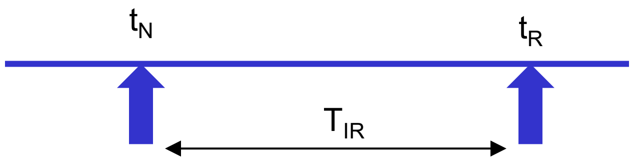
Example: Notification-based system

Incumbent system perspective:

t_N: Instant when incumbent sends out notification of becoming active

t_R: Instant when incumbent experiences relief from commercial interference

T_{IR}: Time interval for incumbent requirement of relief from commercial interference = $t_R - t_N$



Commercial system perspective:

t_N: Instant when incumbent sends out notification of becoming active

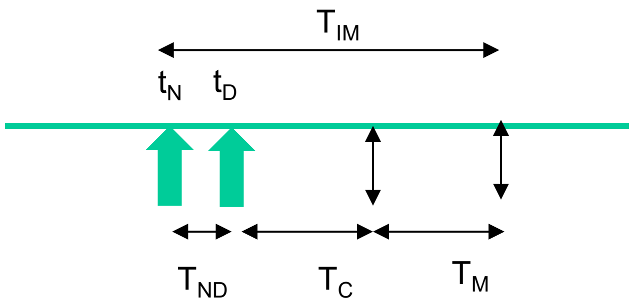
t_D: Instant when the notification is delivered to mitigation system for action

T_{ND}: Time interval reception of notification of incumbent activity = $t_D - t_N$

T_c: Time interval to determine course of action for the spectrum management system

T_M: Time interval to implement interference mitigation (e.g., beam muting, channel shifting etc.)

T_{IM}: Time interval for commercial system to implement interference mitigation = $T_{ND} + T_C + T_M$

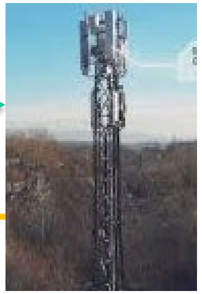


$$T_{IM} \leq T_{IR}$$

Possible enhancement for spectrum sharing: Closed loop control

A closed loop system with a feedback mechanism between federal incumbent and non-federal systems can further improve spectrum sharing in a highly dynamic way.

Sensing/ notification and mitigation system



Federal system starts → Notification/ sensing system gets updated → Non-federal system adjusts parameters → Federal OK?

Federal OK? — No → Non-federal system adjusts parameters

Federal OK? — Yes → Non-federal Continues → Federal still active?

Federal still active? — Yes → Non-federal Continues

Federal still active? — No → Non-federal resumes normal operation

Resumption of non-federal system quickly after federal system stops operating is essential for efficient sharing

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WInnForum Action Plan

Highly Dynamic Spectrum Sharing (HDSS) Working Group

Why?

- Call to action from the National Spectrum Strategy spectrum sharing “moonshot” effort
- NSS schedule calls for demo ~September 2025
- Focus is on 3.1 GHz band -- extremely congested with dozens of federal systems, mostly radars -- land, sea, and air

WInnForum can leverage expertise from CBRS and 6 GHz AFC sharing standards, deployments, and operations

- 3 GHz situation much more complex though and will require significant evolution from existing standards and operations

Question being tackled by HDSS WG: How can we make spectrum sharing more robust and dynamic to support sharing in increasingly complex bands?

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HDSS WG Objectives

1. Analyze the problem
    a. Includes looking at, but not limited to, the 3.1 GHz band (3.1-3.45 GHz)
    b. Highly dynamic sharing in time, space (including geography), and spectrum compared to existing solutions, with “highly dynamic” to be defined
    c. Includes further understanding of the incumbents that need to be protected, such as protection of airborne assets and their protection criteria.
    d. Need to also assess requirements for robustness, reliability, and security
2. Look at frameworks to support the identified requirements, to include:
    a. simplification or adaption of existing frameworks (e.g., CBRS/SAS and AFC), to include associated radio equipment and devices
    b. other, more real-time frameworks for decentralized spectrum management

Topics that will be evaluated during this project include:

1. Incumbent informing versus sensing
    i. What would be "informed" to the sharing framework
    ii. Would there be feedback from the incumbent to the informing system
    iii. What would be the end-to-end requirements and potential architecture solutions for interference reduction response time when incumbent conditions or needs change.
2. Propagation Models

First deliverable: February 2025 (currently a Technical Report)

Note: Opining on whether the U.S. 3.1 GHz or other bands should be shared is NOT in scope. This is only looking at IF a highly dynamic band is shared what parts of the sharing frameworks could be used.

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Topics Currently Under Discussion

Defining "highly dynamic"

- Lots of opinions here
- Fundamentally driven by incumbent protection requirements
- Airborne incumbents are particularly challenging -- fast moving, large impact radius ("neighborhood"), sudden appearance from over the horizon, lower path loss, etc.
- Timescales could vary from air interface intrinsic (i.e., 5G/6G frame rates/physical resource blocks, fractions of ms) to "macroscopic" driven by incumbent detection realities (i.e., tens of seconds)

Closed loop interference reporting

- Incumbent system provides feedback on interference level
- Can help optimize secondary spectrum use
- Obviates the use of propagation models!

The role of informing incumbent (portals) vs. sensors

Use of full 2D antenna patterns (azimuth and elevation; including downtilt)

Multilayer airborne Dynamic Protection Areas

Wrap-Up

For more information contact …

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… or visit www.wirelessinnovation.org

Thank You!!!

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