

Spectrum for Precision Agriculture

Options in the Mid & Upper bands

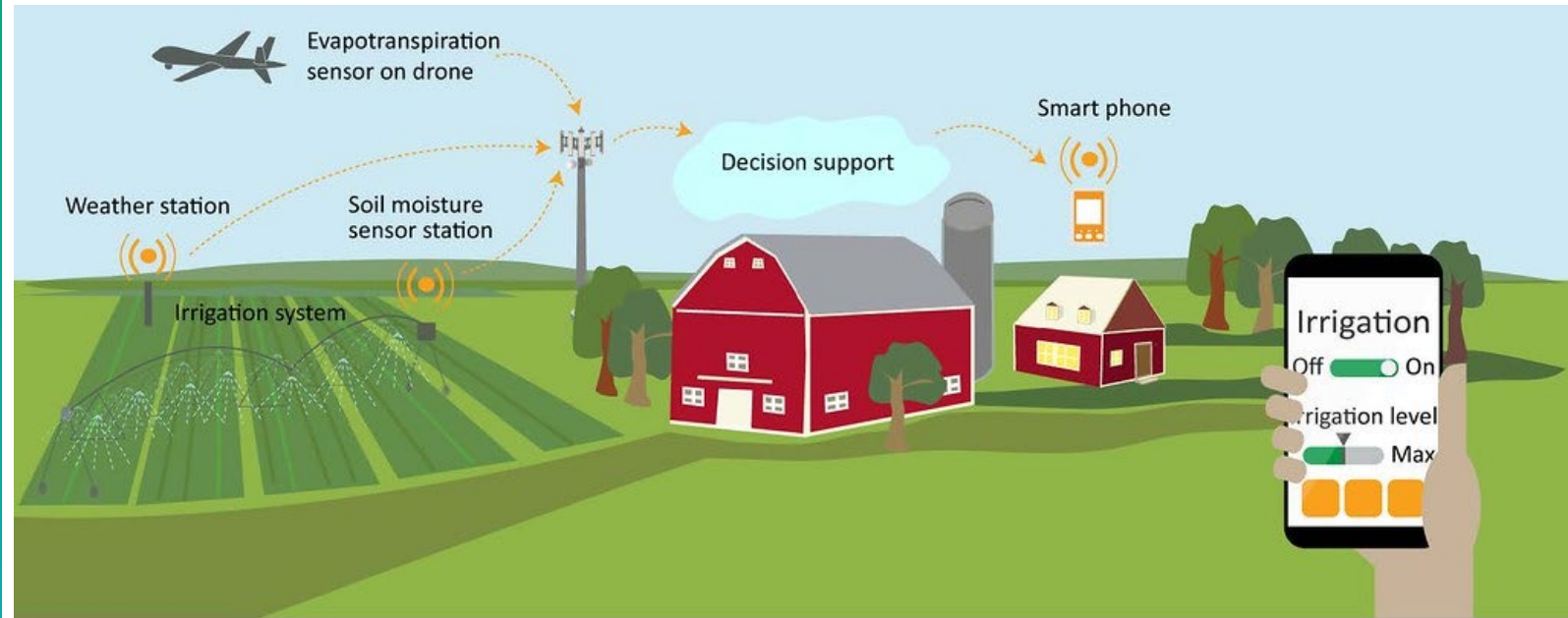
September 7, 2023

Mark Gibson

Sr. Director, Regulatory & Policy

Topics

- Review Precision Agriculture Task Force Spectrum-related Recommendations
- Review Precision Agriculture Connectivity Context
- Spectrum Pipeline



Source: GAO. | GAO-20-128SP

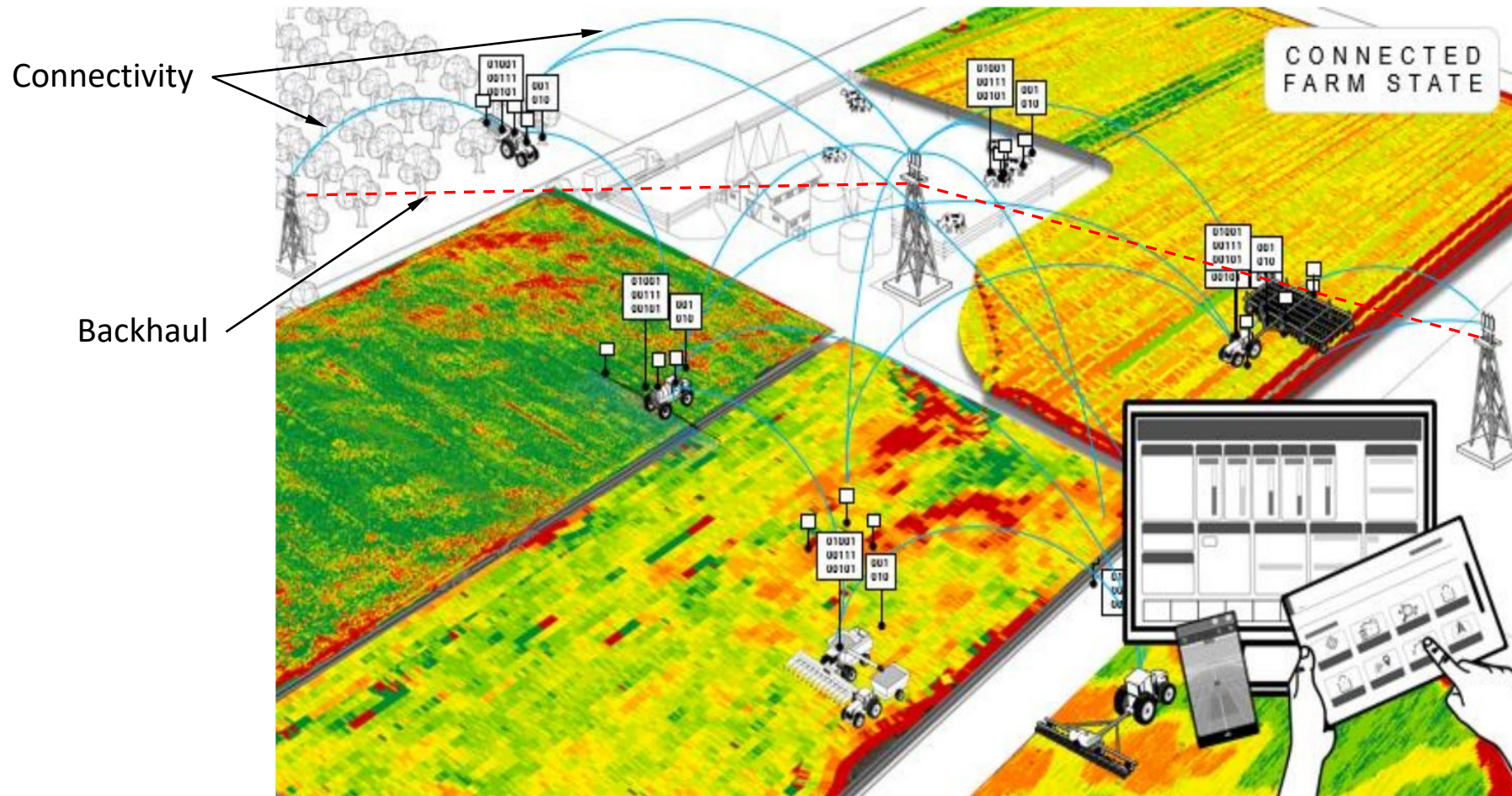
Accelerating Broadband Deployment on Unserved Agricultural Working Group

- The FCC should make available dedicated spectrum for PA at a low cost
- The FCC Should Implement Geographic Build-Out Requirements for spectrum-based licenses and the FCC, USDA and NTIA should use this metric for funding to ensure the coverage of unserved agricultural lands on a timely basis

Examining Current and Future Connectivity Demand for Precision Agriculture

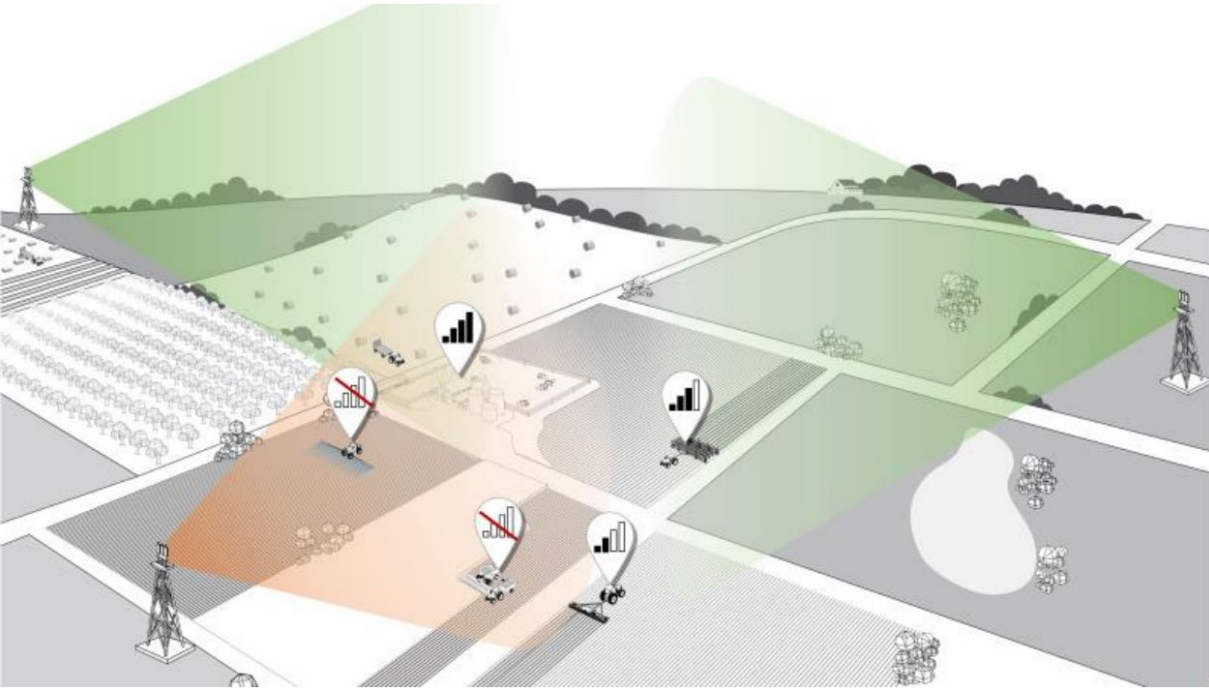
- Increase Spectrum Available for Precision Ag
 - FCC develop a strategy to provide a range of licensed and unlicensed spectrum to agriculture for fixed wireless access and mobile broadband, rather than the spectrum be auctioned [looking at new spectrum between 7-24 GHz and the sub-THz bands]
 - Develop comprehensive spectrum policy
 - Evaluate additional spectrum needed for 5G and 6G access to the farm decision headquarters and IoT device connectivity to the last sensor
 - FCC should consider opening up spectrum for space-to-earth communication for satellites via auction
 - Adopt policy in 3-5 years to accelerate 5G, 6G and like spectrum access, including shared spectrum, and deployment to farmlands in 2030 and beyond
 - Create incentives for service providers to mitigate coverage gaps created during decommissioning of older “G” technologies

PA Task Force Spectrum-Related Recommendations

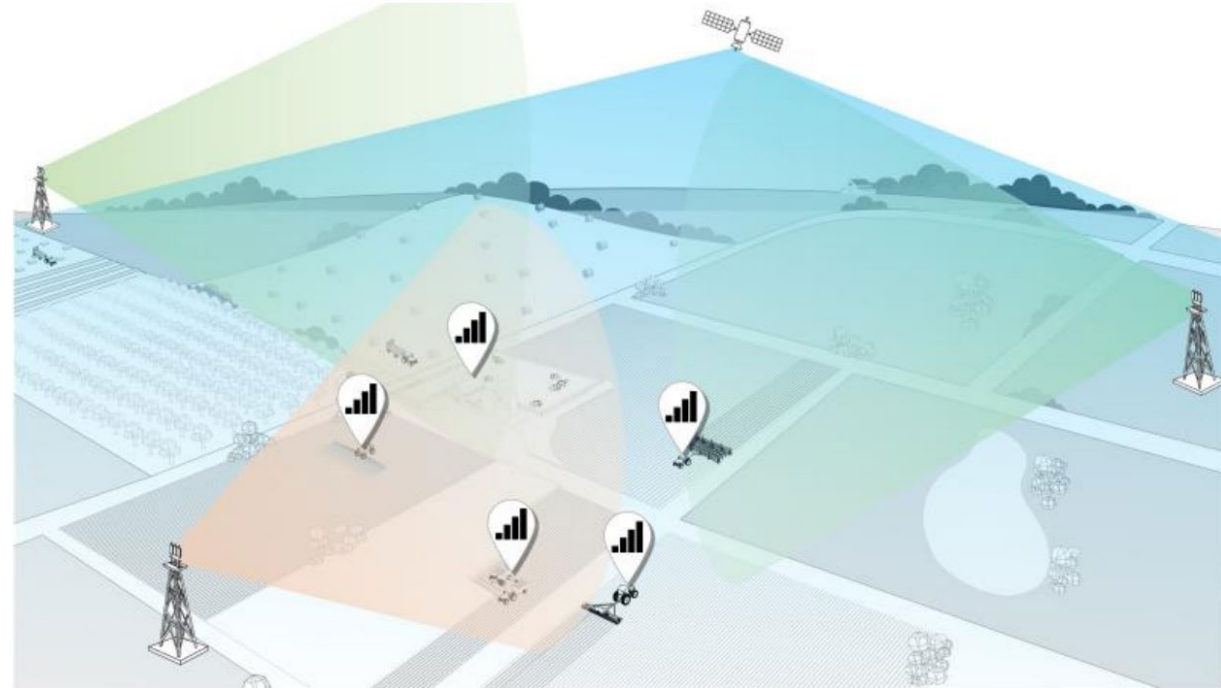


“Connectivity enables a grower to build and seamlessly execute a plan which matches the complexity of the environment in which their crop is grown.”

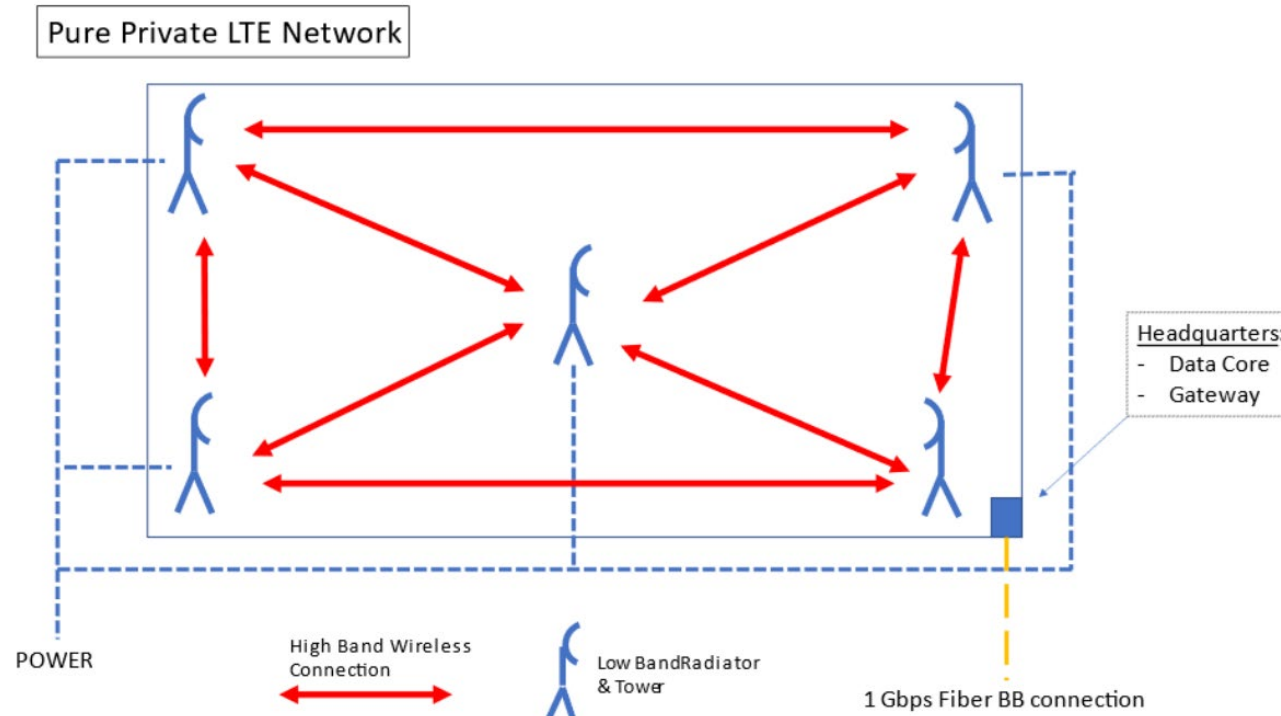
Two terrestrial service providers



Two terrestrial and a satellite service provider



Farmers face challenges connecting their equipment on every acre of their fields.



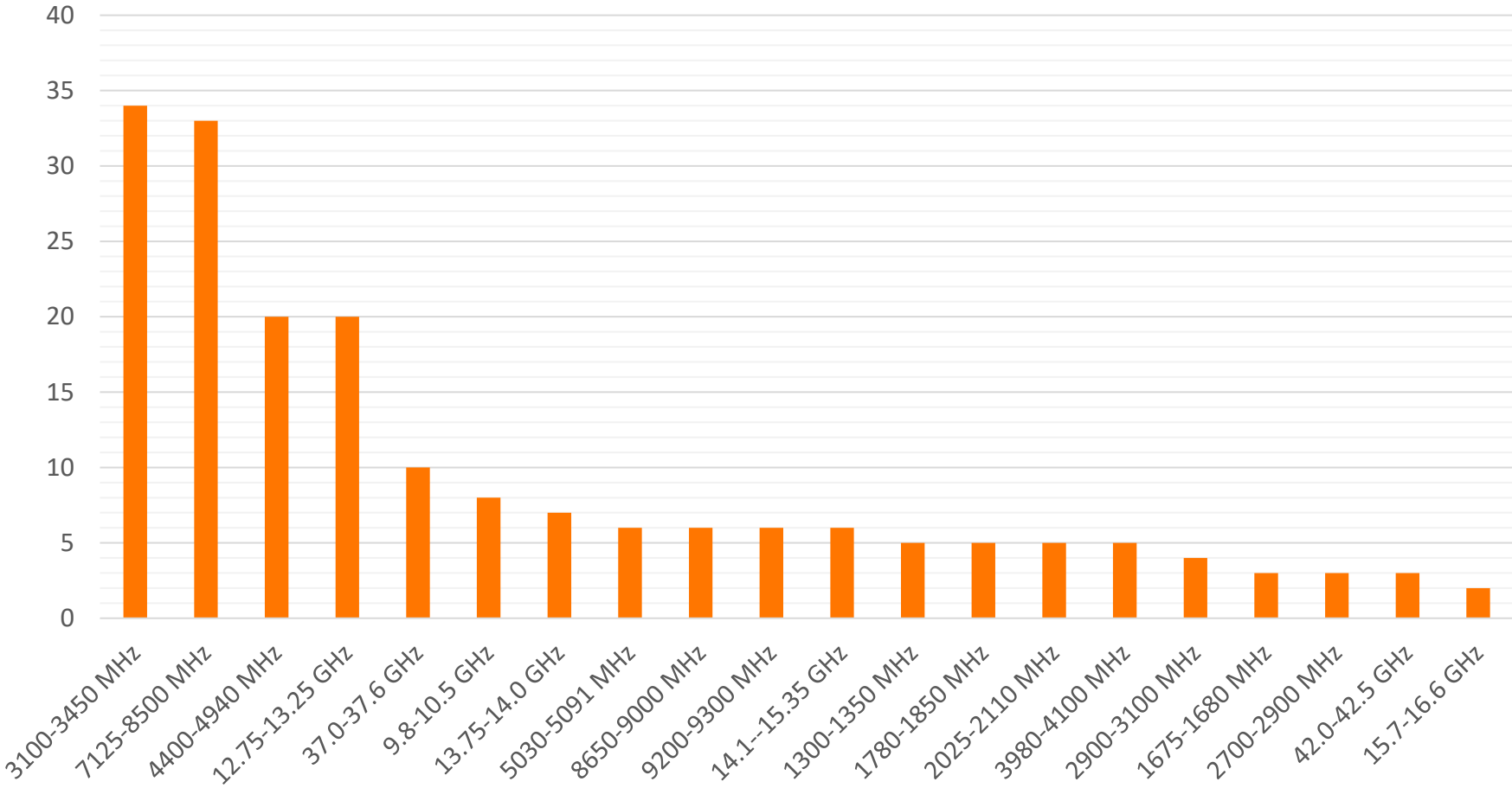
Precision Agriculture Connectivity Context

Spectrum Pipeline

NTIA National Spectrum Strategy

Comments per Band

Band
3100-3450 MHz
7125-8500 MHz
4400-4940 MHz
12.75-13.25 GHz
37.0-37.6 GHz
9.8-10.5 GHz
13.75-14.0 GHz
5030-5091 MHz
8650-9000 MHz
9200-9300 MHz
14.1--15.35 GHz
1300-1350 MHz
1780-1850 MHz
2025-2110 MHz
3980-4100 MHz
2900-3100 MHz
1675-1680 MHz
2700-2900 MHz
42.0-42.5 GHz
15.7-16.6 GHz



NTIA National Spectrum Strategy

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM



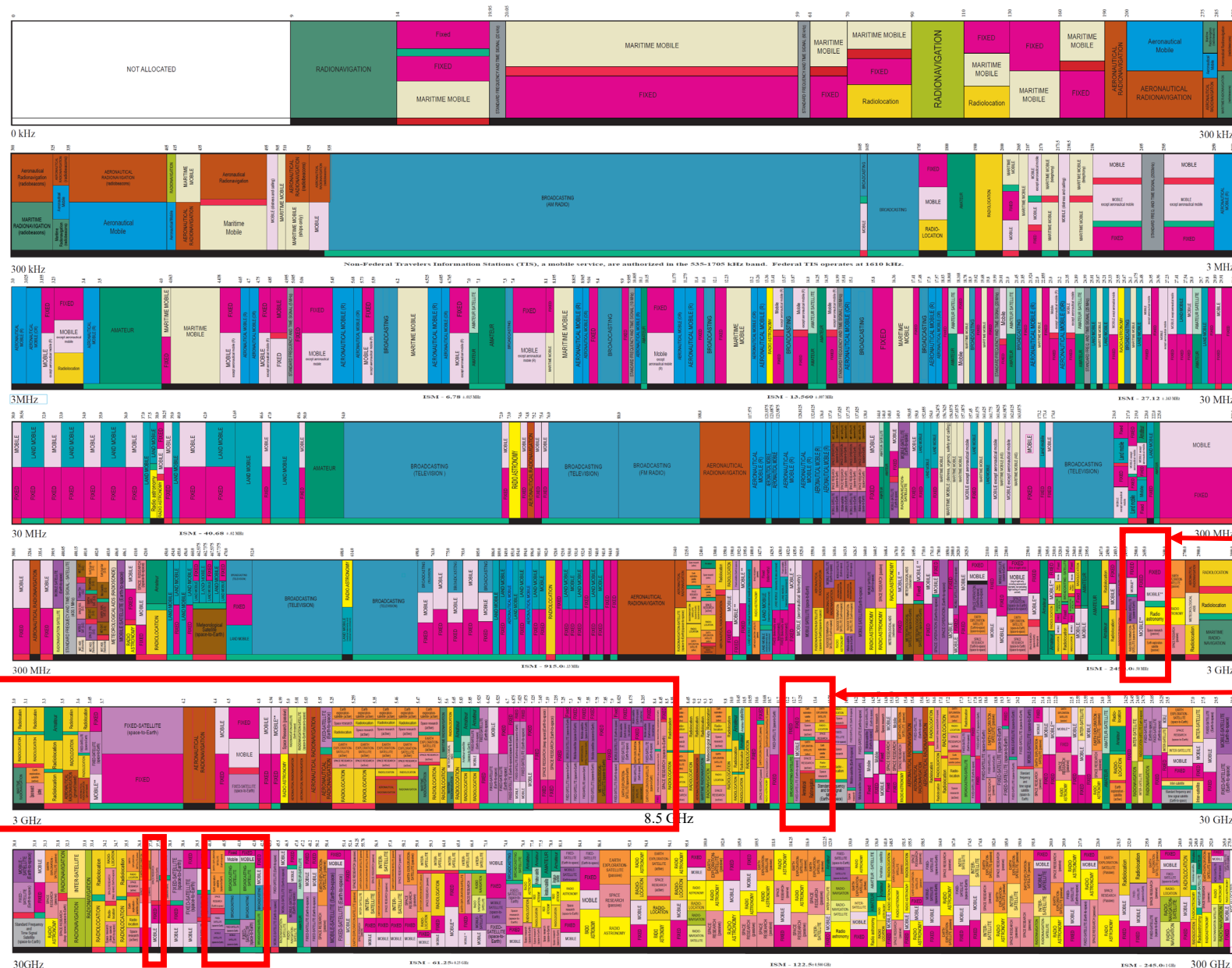
ACTIVITY CODE
 FEDERAL EXCLUSIVE
 FEDERAL/NON-FEDERAL SHARE

 NON-FEDERAL EXCLUSIVE

ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	Mobile	1st Capital with lower case letters

This chart is a graphic single-point-in-time portrayal of the Table of Frequency Allocations used by the FCC and NTIA. As such, it may not completely reflect all aspects, i.e. footnotes and recent changes made to the Table.



PLEASE NOTE: THE SPACING ALLOTTED THE SERVICES IN THE SPECTRUM SEGMENTS SHOWN IS NOT PROPORTIONAL TO THE ACTUAL AMOUNT OF SPECTRUM OCCUPIED.

Spectrum Pipeline

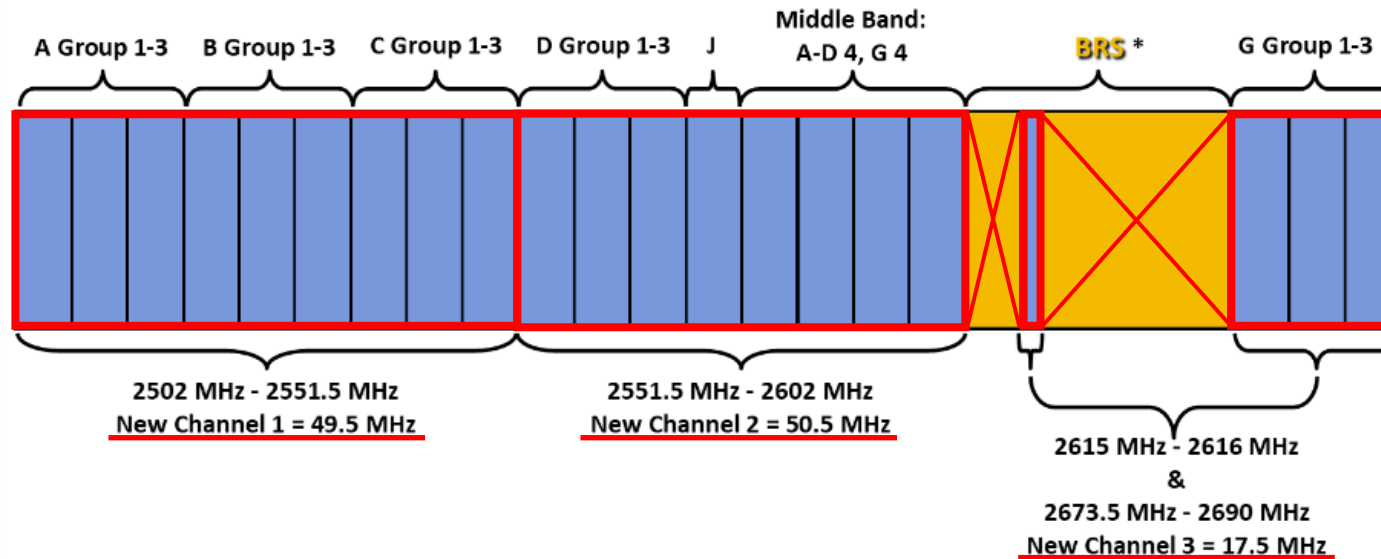
2.5 GHz
BRS

12 GHz

Mid-Bands

42 GHz

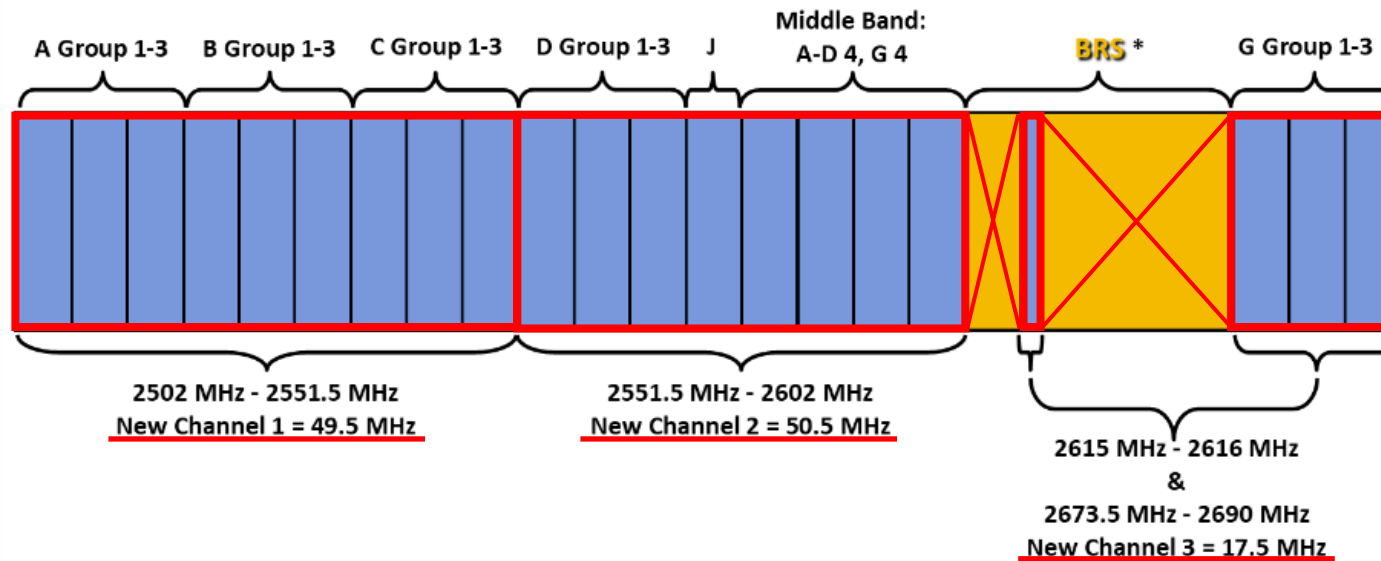
37 GHz



* BRS is the Broadband Radio Service; spectrum shown in yellow is not available as part of this window.

- Licensed on a per-county basis
- Previously licensed channels within a channel block/county (encumbrances) are not available
- Spectrum availability is primarily in “white space” rural areas – most metro areas are highly encumbered
- Licenses are for ten-year renewable terms subject to construction requirements
- Licensees may provide any services permitted under terrestrial fixed or mobile allocations

2.5 GHz BRS Band Plan & Licensing



* BRS is the Broadband Radio Service; spectrum shown in yellow is not available as part of this window.

- **Mobile/Point-to-Multipoint Service:**

- Demonstrate reliable signal coverage of 50% of the population of the geographic service area within 4 years of initial license grant, and 80% of the population of the geographic service area within 8 years of initial license grant.

- **Point-to-Point Service:**

- Demonstrate operation of one link for each 50,000 persons in the geographic service area within 4 years of initial license grant, and one link for each 25,000 persons in the geographic service area within 8 years of initial license grant.

- **Failure to Meet Performance Requirements:**

- Deadline for that authorization to meet its final performance requirement will be advanced by 2 years. If a licensee fails to meet its final performance requirement, its license shall automatically terminate without specific Commission action.

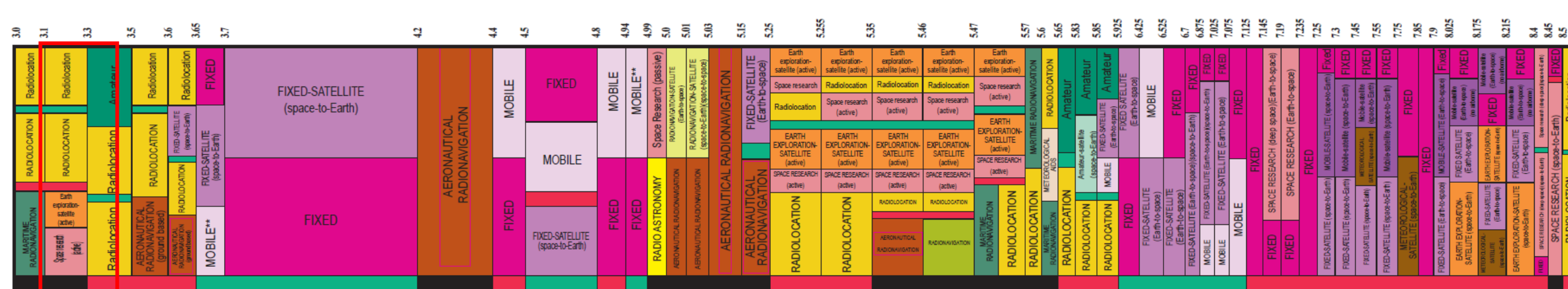
2.5 GHz BRS Band Plan & Buildout Requirements

Bidder	Licenses Won
5G Alliance Utah	4
8538 Green Street LLC	1
Aeronet Wireless Broadband LLC	13
Agri-Valley Communications, Inc.	1
American Samoa Telecommunications Authority	15
Arctic Slope Telephone Association Cooperative, In	6
BDCIH Wireless, LLC	14
Big Bend Telecom, LTD	2
Broadband One of the Midwest, Inc.	42
Carolina West Wireless, Inc.	7
Cass Cable TV, Inc.	1
Cellco Partnership	12
Cellular South Licenses, LLC	38
Central Louisiana License Co., LLC	22
Central Texas Communications, Inc.	2
City of Ketchikan d/b/a Ketchikan Public Utilities	3
Comcell, Inc.	3
Comelec Services, Inc.	1
Copper Valley Wireless, LLC	6
Cordova Telephone Cooperative, Inc.	3
DoCoMo Pacific, Inc.	3
East Kentucky Network, LLC	27
Evergy Kansas Central	54
Evolve 5G Consortium	30
Farmers Mutual Telephone Company, Inc.	2
Granite Wireless LLC	8
LICT Wireless Broadband Company, LLC	46
Mark Twain Communications Company	16
Mediapolis Telephone Company	4
Michigan Wireless, LLC	6
Miller, David L	33

Bidder	Licenses Won
Nex-Tech Wireless, L.L.C.	1
Nimbus Solutions	1
North American Catholic Educational Programming Fd	107
Northern Valley Communications, LLC	24
Northwest Open Access Network	2
Nsight Spectrum, LLC	10
OptimERA Holdings, Inc.	4
Paladin Wireless LLC	9
Panhandle Telecommunication Systems, Inc.	4
Pathfinder Wireless Corp.	1
Poka Lambro Telecommunications, Ltd.	3
PTI Pacifica Inc.	9
Rocky Mountain Broadband, LLC	2
RSA 1 Limited Partnership	6
SAL Spectrum, LLC	15
SkyPacket Networks	2
SKYRIDER COMMUNICATIONS LLC	2
Smith Bagley, Inc.	7
Southern Communications Services, Inc.	1
Swinehart, Kenneth D	1
TeleGuam Holdings, LLC	3
T-Mobile License LLC	7,156
Twin Lakes Telephone Cooperative Corporation	9
Uintah Basin Electronic Telecommunications, LLC	4
Union Telephone Company	9
United States Cellular Corporation	34
United Wireless Communications, Inc.	9
VTel Wireless, Inc.	1
WUE, Inc.	2
Xtreme Enterprises, LLC	2
ZIRKEL Wireless, LLC	3

License grants suspended pending renewal of FCC auction authority

2.5 GHz BRS Licensees



3 GHz

3100-3450 MHz

- Over 120 DoD systems
- Shipborne Radiolocation (3100-3500 MHz)
 - Navy AN/SPY-1 (Aegis)
- Land-Based Radiolocation (3100-3300 MHz)
 - Army transportable radars (information on artillery, rockets, missiles, mortars and other threats)
- Airborne Radiolocation (3100-3300 MHz)
 - Air Force (near-surface and high-altitude airborne objects, tracking of airborne objects)
 - U.S. Air Force Station Keeping Equipment



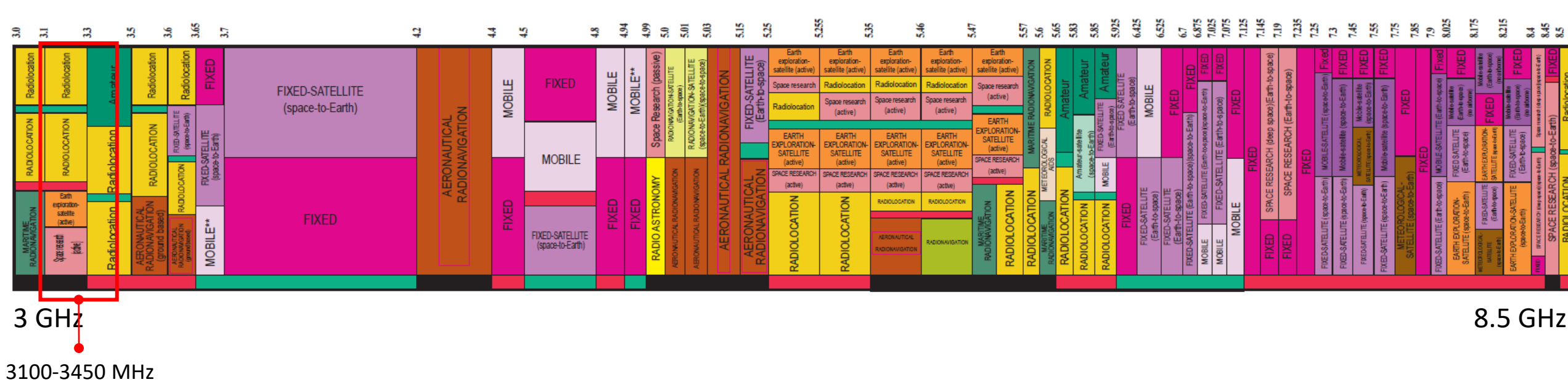
Aegis Radar



AWACS Radar

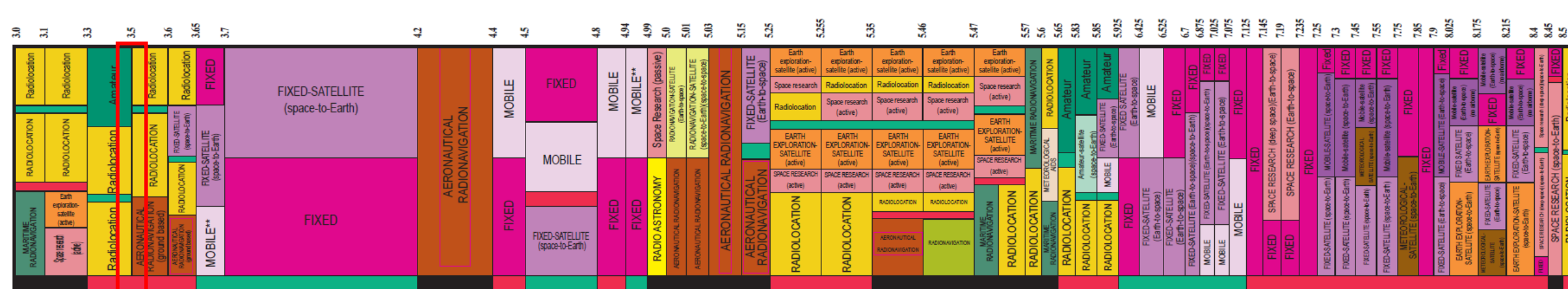
8.5 GHz

3100-3450 MHz Federal Use



- Infrastructure Investment and Jobs Act (IIJA) requires study of the feasibility of making the band available for commercial use
- DoD have stated that the costs to relocate would be in the \$100's of billions and take decades
- Partnering on Advancing Trusted and Holistic Spectrum Sharing (PATHSS) study created under National Spectrum Consortium
 - Report due at end of September
- Some sort of sharing may be necessary

3100-3450 MHz Status



3 GHz

8.5 GHz

3450-3550 MHz
(3.45 GHz Band)

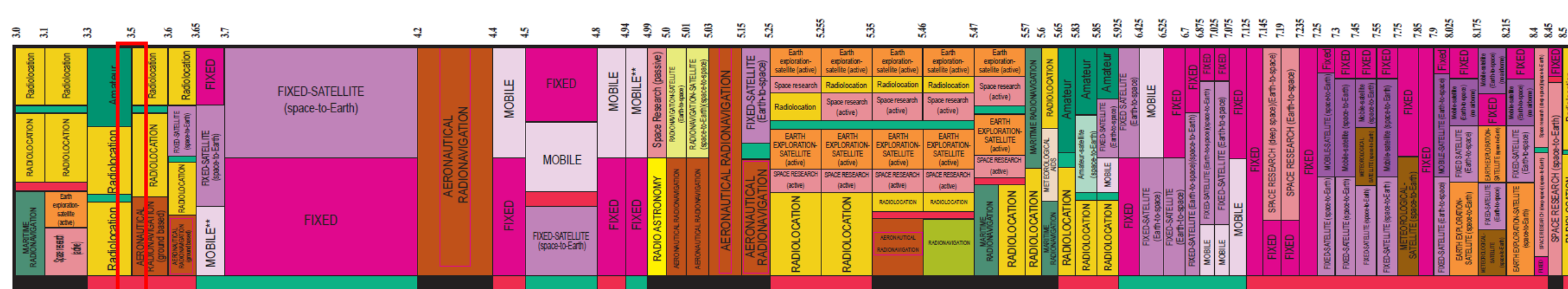
- Shipborne Radiolocation (3450-3650 MHz)
 - Navy AN/SPY-1 (Aegis)
 - Navy AN/SPN-43 ATC (3500-3700 MHz)
- Airborne & Ground-based Radiolocation (3450-3510 MHz)
 - U.S. Air Force Station Keeping Equipment (ground and airborne)



Antenna

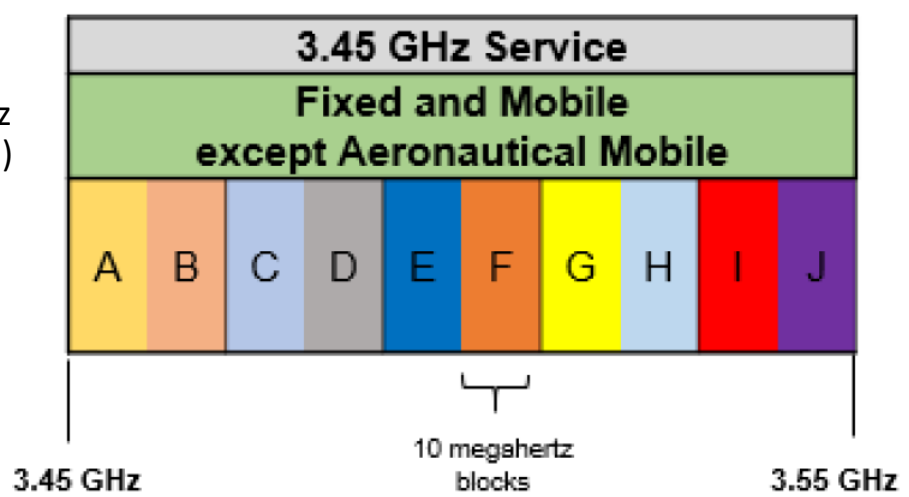
Aegis Radar

3.45 GHz (3450-3550 MHz) Federal Use

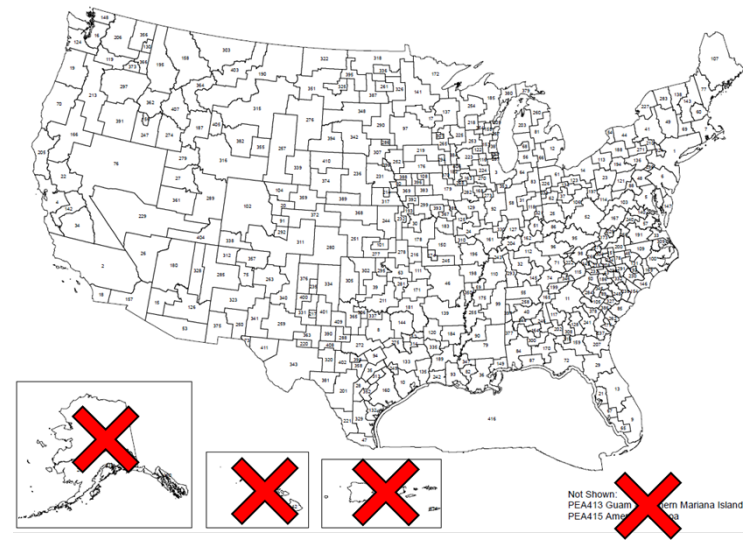


3 GHz

3450-3550 MHz
(3.45 GHz Band)



FCC Partial Economic Area (PEA) Boundaries



8.5 GHz

3.45 GHz (3450-3550 MHz) Band Plan & Licensing



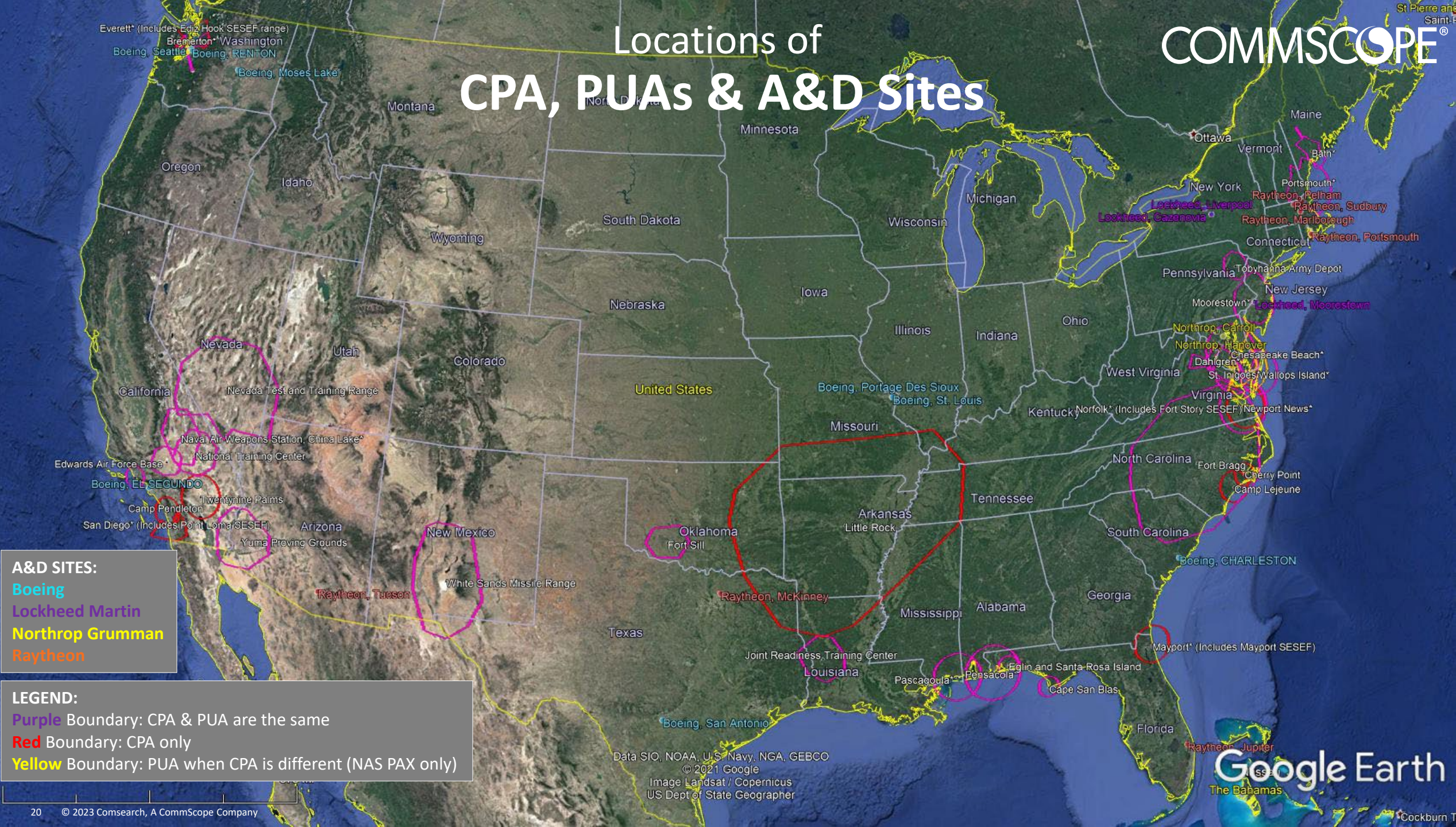
8.5 GHz

- ## 3.45 GHz (3450-3550 MHz)

Locations of CPA, PUAs & A&D Sites

A&D SITES:
Boeing
Lockheed Martin
Northrop Grumman
Raytheon

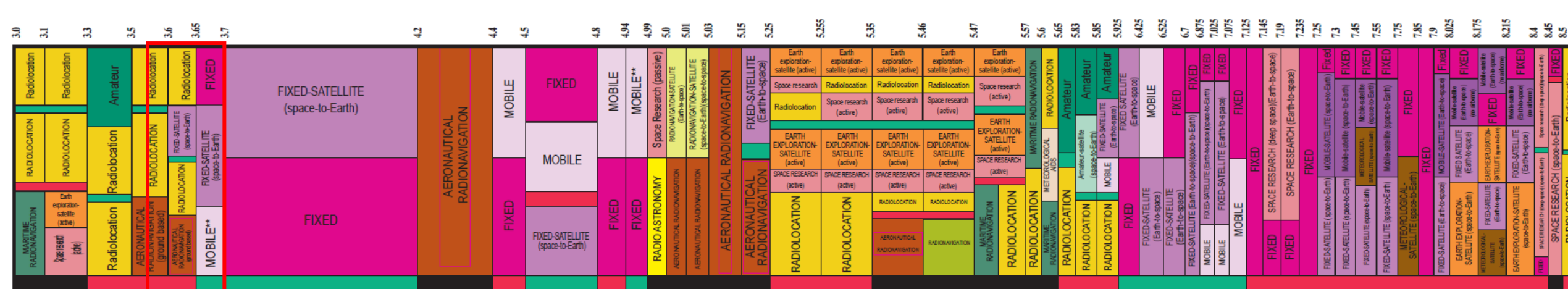
LEGEND:
Purple Boundary: CPA & PUA are the same
Red Boundary: CPA only
Yellow Boundary: PUA when CPA is different (NAS PAX only)



23 licensees

Licensee	# Licenses Won
Agri-Valley Communications, Inc.	7
AT&T Auction Holdings, LLC	1624
Blue Ridge Wireless LLC	39
Carolina West Wireless, Inc.	11
Cherry Wireless, LLC	319
East Kentucky Network, LLC	2
Horry Telephone Cooperative, Inc.	12
Jones, Anthony L	2
LICT Wireless Broadband Company, LLC	24
N Squared Wireless, LLC	55
NE Colorado Cellular, Inc	18
NewLevel III, L.P.	8
Nsight Spectrum, LLC	6
PocketiNet Communications, Inc.	1
PVT Networks, Inc.	6
Raptor Wireless LLC	6
RSA 1 Limited Partnership	1
Skylake Wireless II, LLC	57
Three Forty-Five Spectrum, LLC	18
T-Mobile License LLC	199
United States Cellular Corporation	380
Weminuche L.L.C. (Dish)	1232
Whitewater Wireless, II, L.P.	14

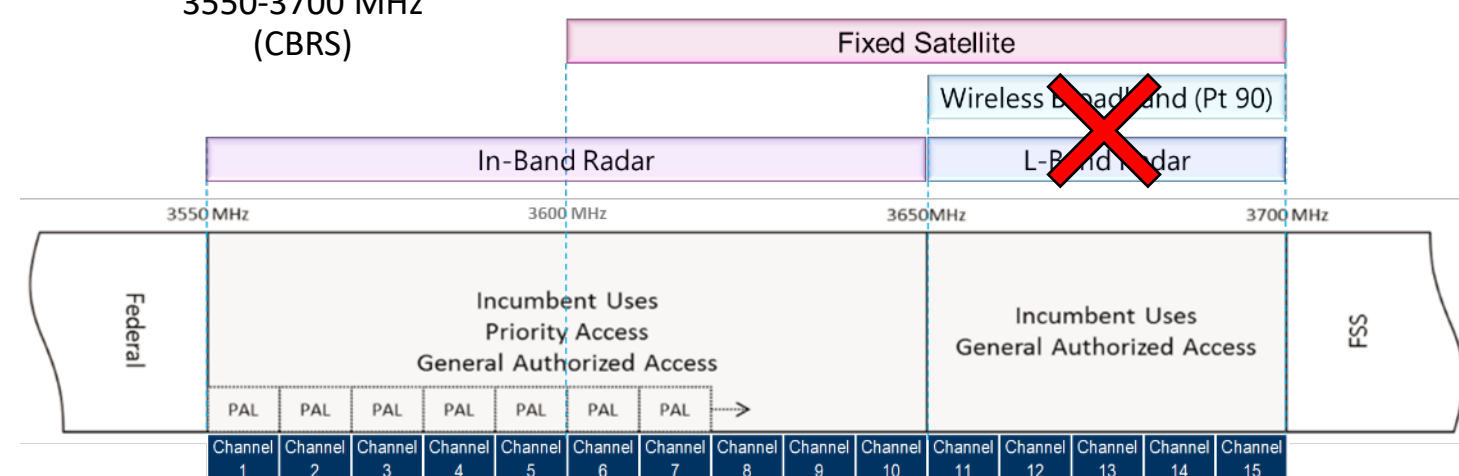
3.45 GHz Licensees



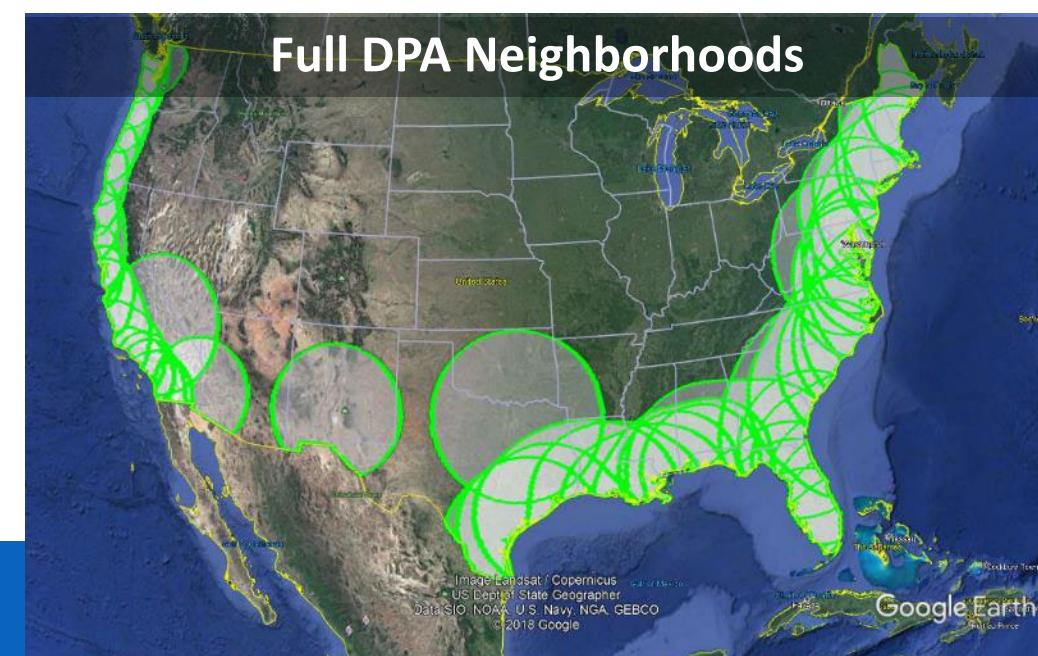
3 GHz

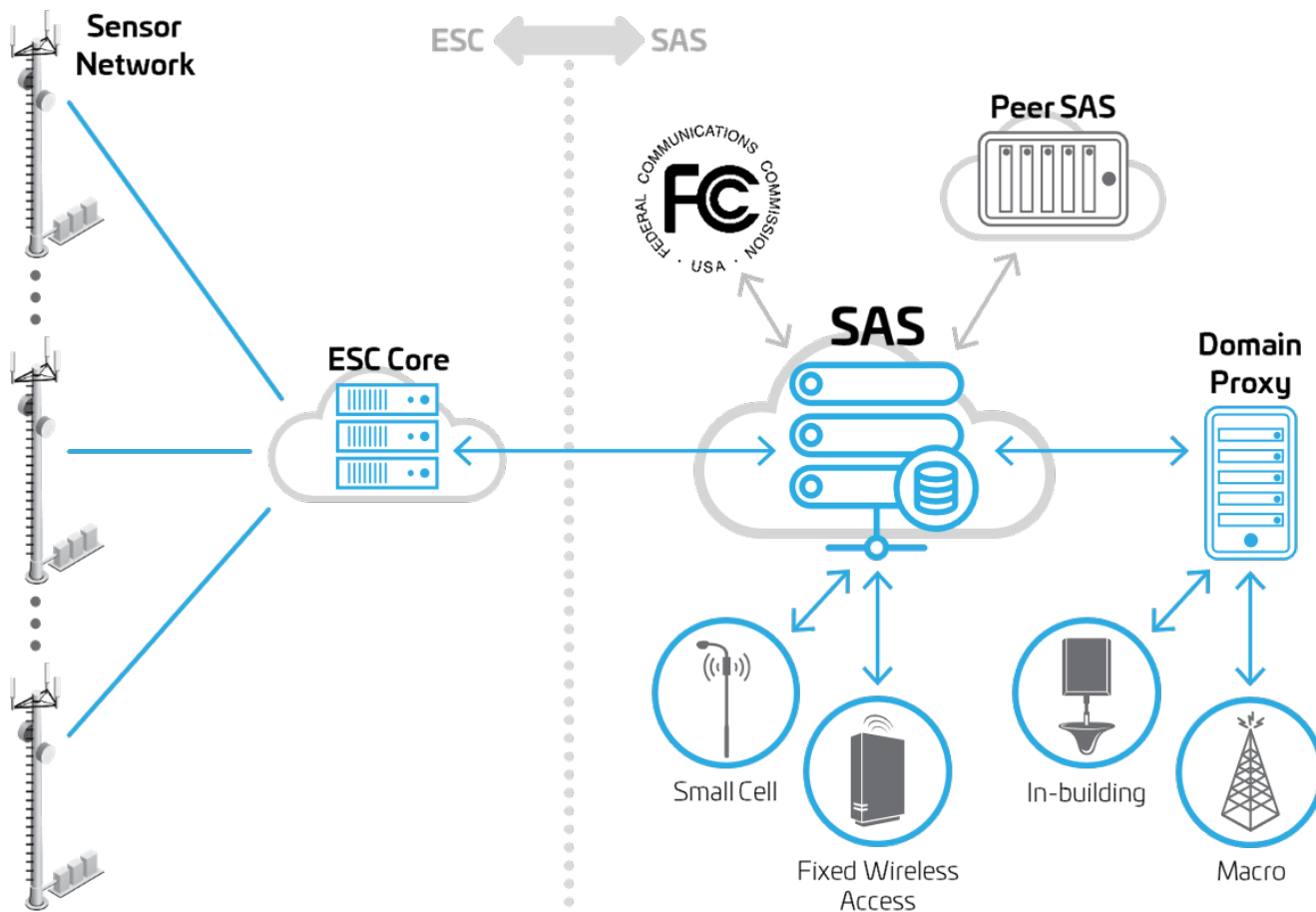
8.5 GHz

3550-3700 MHz
(CBRS)



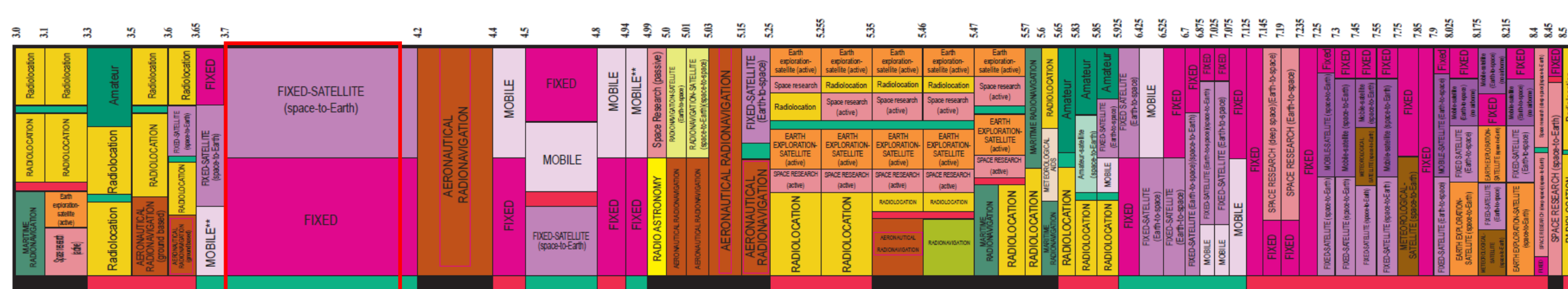
CBRS (3550-3700 MHz)





- Register and authenticate the identification information and process requests from CBSDs
- Determine the available frequencies and max powers at a given geographic location available to CBSDs
- Enforce protection of incumbent users
- Process information from ESCs to detect and protect federal radar operations
- Coordinate data and access with Peer SASs
- Protect Priority Access Licensees (PAL) from harmful interference and coexistence among General Authorized Access (GAA) Users
- High power (50W, Cat B) and low power (1W, Cat A) operation

CBRS (3550-3700 MHz): Spectrum Access System

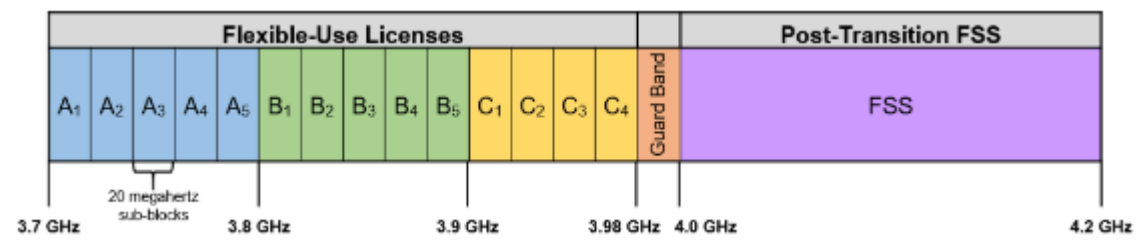


3 GHz

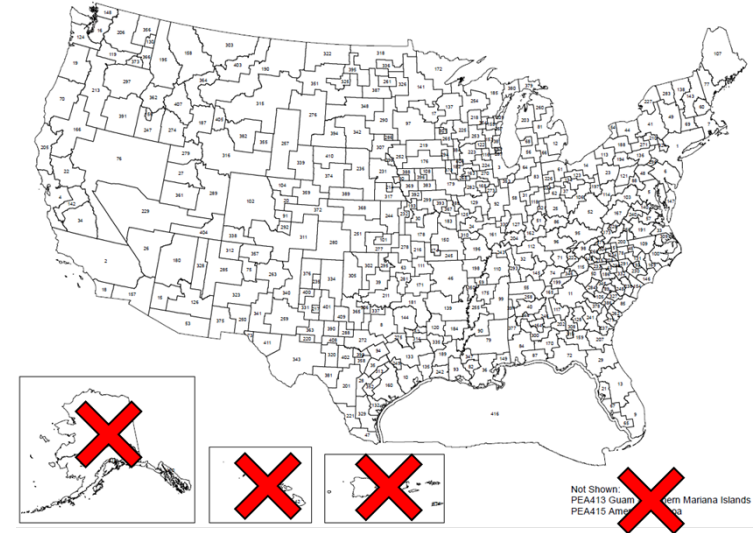
3700-3980 MHz
(3.7 GHz Band)

8.5 GHz

License Blocks



FCC Partial Economic Area (PEA) Boundaries



3.7 GHz Band (3700-3980 MHz)

21 licensees

Licensee	# Licenses
Agri-Valley Communications, Inc.	2
AT&T Spectrum Frontiers LLC	1,621
Canopy Spectrum, LLC	84
Carolina West Wireless, Inc.	7
Cellco Partnership	3,511
Cellular South Licenses, LLC	8
East Kentucky Network, LLC	1
Grand River Communications, Inc.	2
Granite Wireless LLC	1
Horry Telephone Cooperative, Inc.	3
LICT Wireless Broadband Company, LLC	5
Little Bear Wireless L.L.C.	1
NewLevel II, L.P.	10
Nex-Tech Wireless, L.L.C.	5
Nsight Spectrum, LLC	3
Pioneer Telephone Cooperative, Inc.	4
Smith Bagley, Inc.	4
T-Mobile License LLC	142
Union Telephone Company	2
United States Cellular Corporation	254
Widespread Wireless, LLC	14

3.7 GHz Band (3700-3980 MHz)

SERVICE OFFERING	1 st PERFORMANCE BENCHMARK 3.4 GHz: Within 4 Years of Initial License Date 3.7 GHz: Within 8 Years of Initial License Date	2 nd PERFORMANCE BENCHMARK 3.4 GHz: Within 8 Years of Initial License Date 3.7 GHz: Within 12 Years of Initial License Date
Mobile or Point-to-Point	Provide reliable signal coverage and offer service to at least 45 percent of the population in each of its license areas.	Provide reliable signal coverage and offer service to at least 80 percent of the population in each of its license areas.
Point-to-Multipoint	For population within the license area $\leq 268,000$, demonstrate 4 operating links servicing either customers or internal use. For population $> 268,000$, demonstrate at least 1 operating link servicing either customers or internal use per every 67,000 persons within a license area.	For population within the license area $\leq 268,000$, demonstrate 8 operating links servicing either customers or internal use. For population $> 268,000$, demonstrate at least 2 operating links servicing either customers or internal use per every 67,000 persons within a license area.
Internet of Things	Provide geographic area coverage to 35 percent of the license.	Provide geographic area coverage to 65 percent of the license.
Failure to Meet Performance Benchmark	2 nd Performance Benchmark and license term reduced by 1 year (2 years for 3.7 GHz).	License is terminated for the area.

3.45 & 3.7 GHz Buildout Requirements

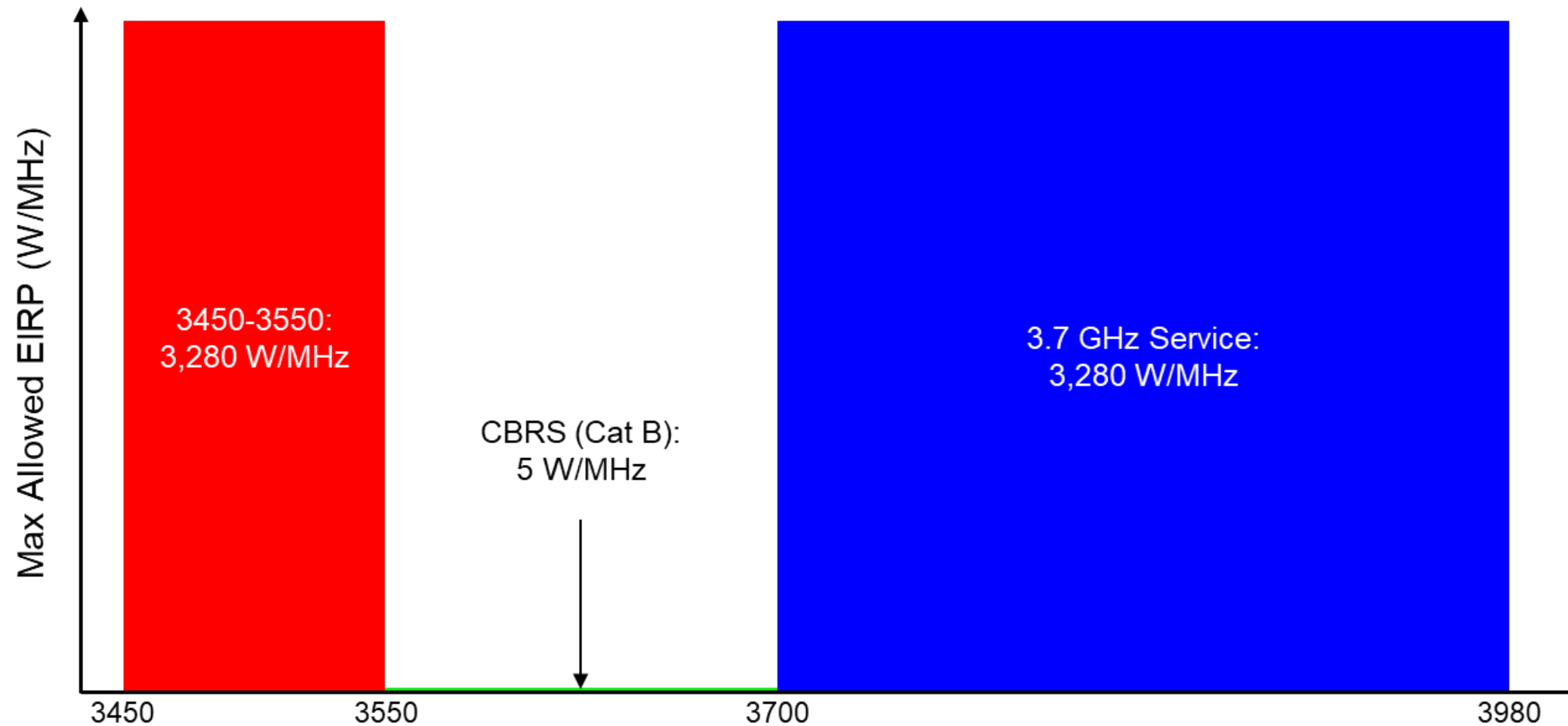
SERVICE OFFERING	CBRS
Mobile or Point-to-multipoint	Provides substantial service signal coverage and offer service, either to customers or for internal use, over at least 50 percent of the population in the license area.
Point-to-Point	<p>Provide substantial service by showing construction and operation at least four links, either to customers or for internal use, in license areas with 134,000 population or less and in license areas with greater population, a minimum number of links equal to the population of the license area divided by 33,500 and rounded up to the nearest whole number.</p> <p>To satisfy this provision, such links must operate using registered Category B CBSDs.</p>
Failure to Meet Performance Benchmark	Forfeiture of the license without further Commission action, and the licensee will be ineligible to regain it.

CBRS Buildout Requirements

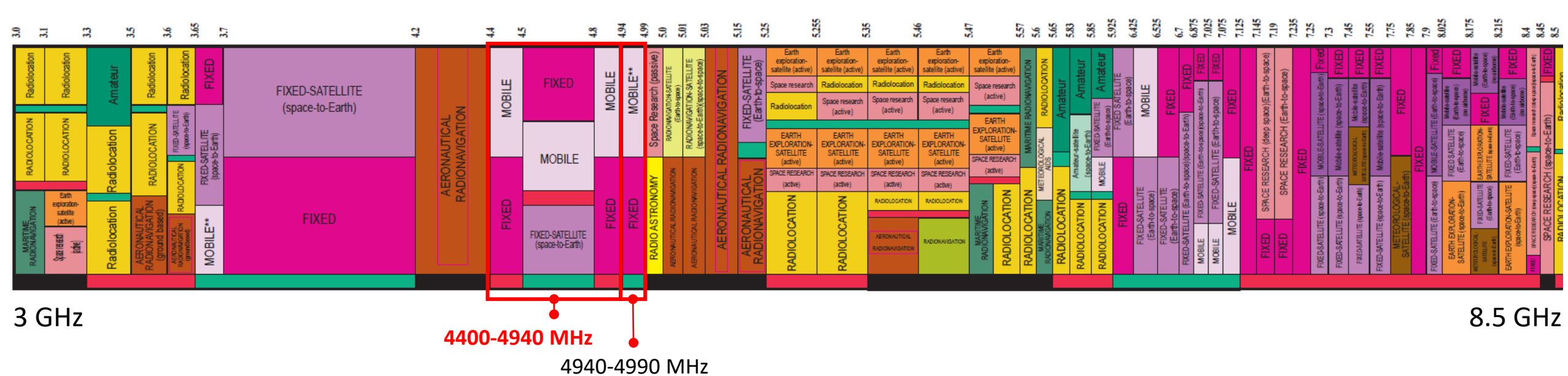
3.45 GHz Band	CBRS	3.7 GHz Band (C-Band)
1640 W/MHz non-rural (32.8 kW/20 MHz) 3280 W/MHz rural (65.6 kW/20 MHz) 1W mobiles 10 x 10 MHz Channels	.1 W/MHz Cat A (10 W/10 MHz) 5 W/MHz Cat B (50 W/10 MHz) 200 mW for "mobiles" 15 x 10 MHz Channels	1640 W/MHz non-rural (32.8 kW/20 MHz) 3280 W/MHz rural (65.6 kW/20 MHz) 1W for mobiles 9 x 20 MHz Channels
3450 MHz	3550 MHz	3700 MHz
		3980 MHz

Rural is defined as a county with a population density of less than or equal to 100 people/mi²

Max EIRP Comparisons

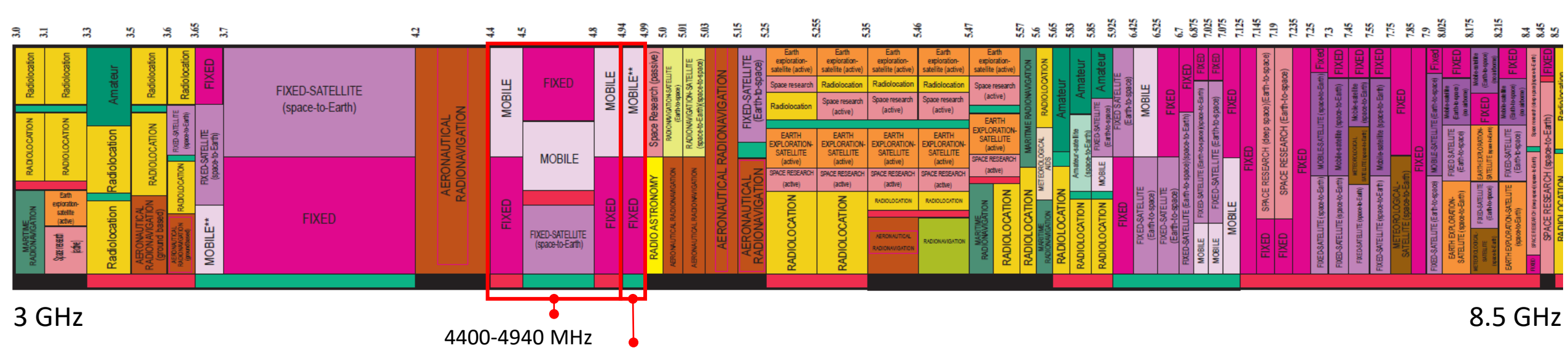


Max EIRP Comparisons



- Band is of interest to mobile providers
 - 5G designation as n79 (4400-5000 MHz)
- Part of the “spectrum pipeline”
- Federal exclusive for fixed Line of Sight (LOS) and transportable-fixed point-to-point microwave systems, drone vehicle control, and telemetry systems
- WRC23 agenda item for 4800-4990 indicates international interest
- Note 4200-4400 MHz band below is home for radar altimeters

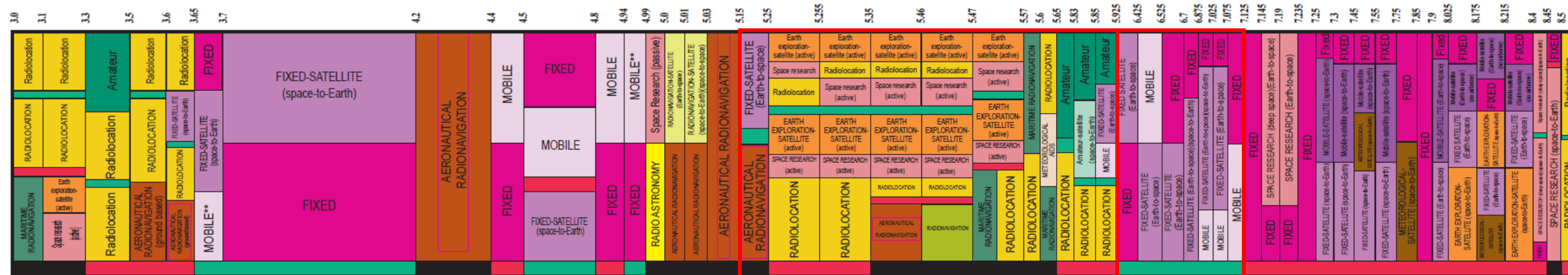
4400-4990 MHz



- 4940-4990 (4.9 GHz Service) is one of the most complex rulemakings the FCC has undertaken
 - 7th R&O and 9th FNPRM (over 20 years)
- Initially established to support Public Safety use: mobile, fixed, point-to-point and point to multi-point
- License areas are state and local jurisdictions
- Band had been underutilized until FCC considered making available for commercial use
- Awaiting FCC decision on band manager & details for leasing

- 1, 5, 10, 15, 20, 30, 40 & 50 MHz channels
- Up to 37 dBm max EIRP
- General use is for:
 - Video streaming
 - Backhaul
 - Data connections
- Over 3500 licenses currently in the band
 - Over 130 statewide
 - Almost 1150 countywide
 - Almost 2260 other (groups of counties, cities, etc.)

4400-4990 MHz




3 GHz

8.5 GHz

5150-5925 MHz

5925-7125 MHz

5 GHz & 6 GHz Unlicensed Nationwide Information Infrastructure (U-NII)

U-NII Designation & Bandwidth			U-NII-1 100 MHz				U-NII-2A 100 MHz				U-NII-2B 120 MHz				U-NII-2C 255 MHz										U-NII-3 125 MHz				U-NII-4 75 MHz												
Frequencies (MHz)		5150	5170		5250				5350				5470				5600				5650				5725				5735				5850				5895				5925
IEEE 802 Channel Designation & Bandwidths	20 MHz		36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	104	108	112	116	120	124	128	132	136	140	144	149	153	157	161	165	169	173	177	C-V2X		
	40 MHz		34		38																																				
	80 MHz		42				58				74				90				106				122				138				155				171						
	160 MHz		50								82								114																						
Incumbents		Aeronautical Radionavigation (microwave landing sys) FSS uplink				Earth Exploration Sat Space Research Radiolocation				Earth Exploration Sat Space Research Radiolocation Aeronautical Radionav Radionavigation				<div></div> <div>TDWR (5600-5650)</div> Maritime Radionavigation										Radiolocation																	
Rule Part		15.407(a)(1)				15.407(a)(2) 15.407(h)(1) & (2)				All Proposed: 15.407 (power limitation, max 250 mW)				250mW Indoor/Outdoor DFS										1W ³ Indoor/Outdoor DFS (NPRM)																	
Max EIRP & PSD Outdoor		30 dBm 17 dBm/MHz 21 dBm for ant elev > 30° above horiz				24 dBm or 11 dBm + 10log(emission BW) 11 dBm/MHz																																			
Max EIRP & PSD Indoor		30 dBm 17 dBm/MHz																																							
Max EIRP Client		24 dBm 11 dBm/MHz																																							
Max EIRP Fixed Point-to-point		30 dBm 17 dBm/MHz																																							
Other Limitations						Dynamic Frequency Selection Transmit Power Control																																			

Bands heavily used for unlicensed point-to-point and Wi-Fi access points

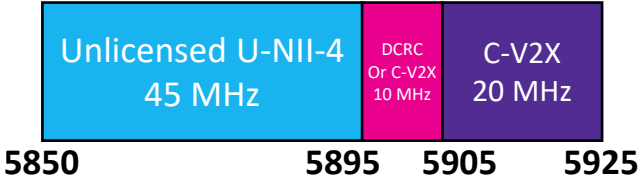
Dynamic Frequency Selection in TDWR

5150-5925 MHz (U-NII-1 to U-NII-4)

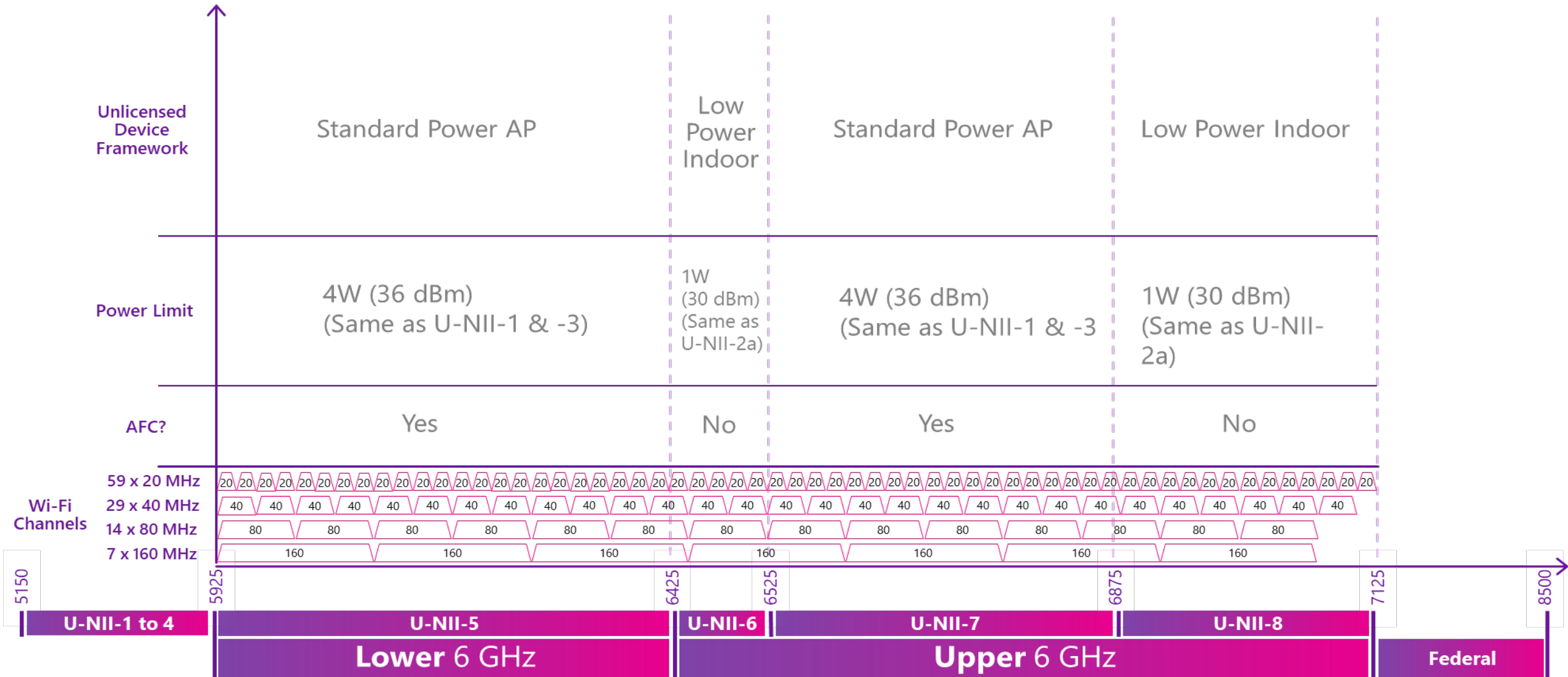
U-NII Designation & Bandwidth			U-NII-1 100 MHz					U-NII-2A 100 MHz					U-NII-2B 120 MHz					U-NII-2C 255 MHz										U-NII-3 125 MHz						U-NII-4 75 MHz																		
Frequencies (MHz)			5150		5170						5250						5350						5470						5600				5650				5725				5735				5850				5895		5925	
IEEE 802 Channel Designation & Bandwidths	20 MHz		36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100	104	108	112	116	120	124	128	132	136	140	144	149	153	157	161	165	169	173	177	C-V2X													
	40 MHz		34		38																																															
	80 MHz		42				58				74				90				106				122				138				155				171																	
	160 MHz		50								82								114																																	
Incumbents			Aeronautical Radionavigation (microwave landing sys) FSS uplink					Earth Exploration Sat Space Research Radiolocation					Earth Exploration Sat Space Research Radiolocation Aeronautical Radionav Radionavigation					Maritime Radionavigation										TDWR (5600-5650)		Radiolocation																						
Rule Part			15.407(a)(1)					15.407(a)(2) 15.407(h)(1) & (2)					All Proposed: 15.407 (power limitation, max 250 mW)					250mW Indoor/Outdoor DFS										1W ³ Indoor/Outdoor DFS (NPRM)																								
Max EIRP & PSD Outdoor			30 dBm 17 dBm/MHz 21 dBm for ant elev > 30° above horiz					24 dBm or 11 dBm + 10log(emission BW) 11 dBm/MHz																																												
Max EIRP & PSD Indoor			30 dBm 17 dBm/MHz																																																	
Max EIRP Client			24 dBm 11 dBm/MHz																																																	
Max EIRP Fixed Point-to-point			30 dBm 17 dBm/MHz																																																	
Other Limitations								Dynamic Frequency Selection Transmit Power Control																																												



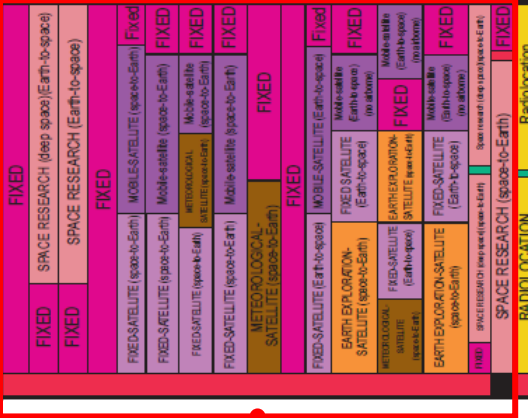
FCC 5.9 GHz NPRM 19-138



5150-5925 MHz (U-NII-1 to U-NII-4)

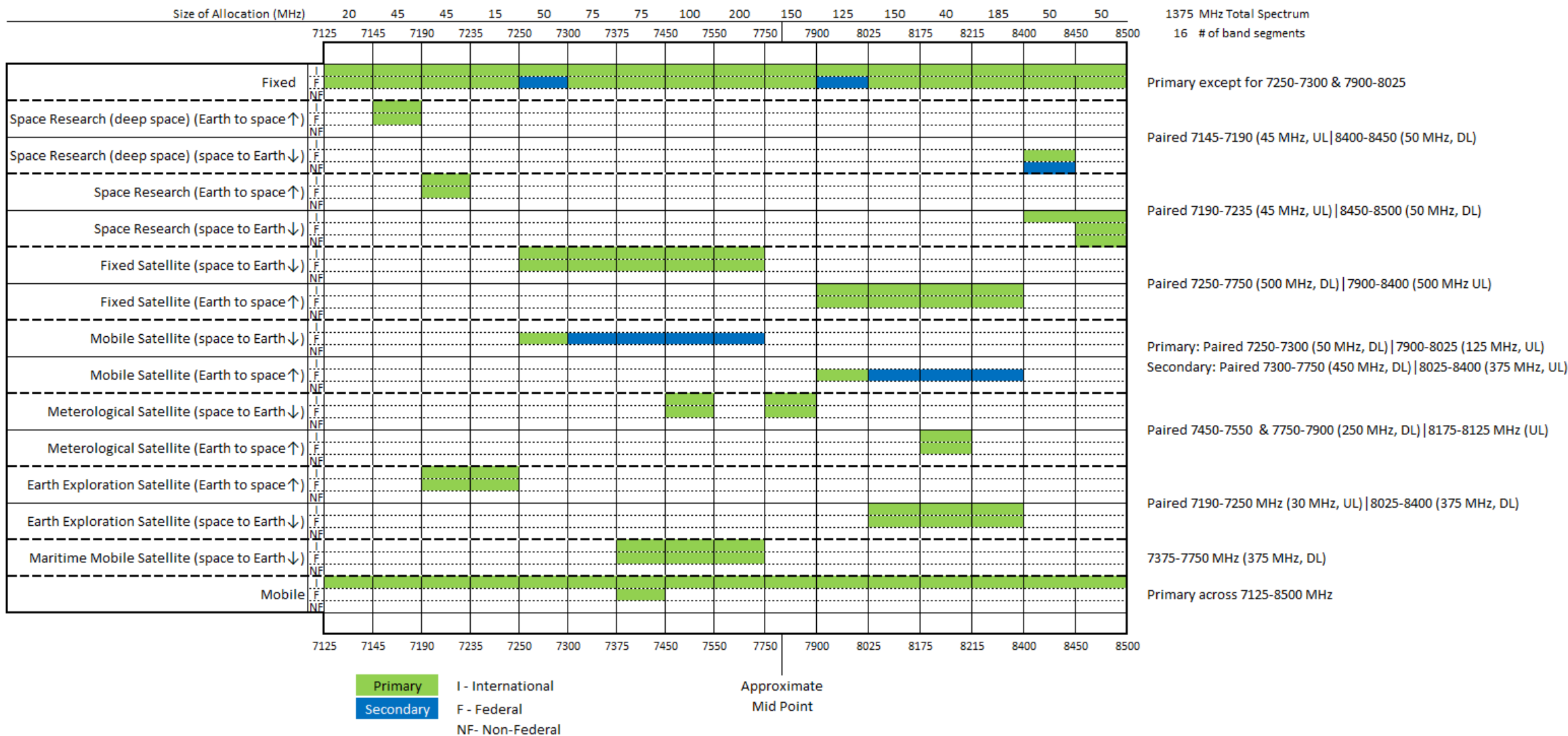


5925-7125 MHz (U-NII-5 to U-NII-8)

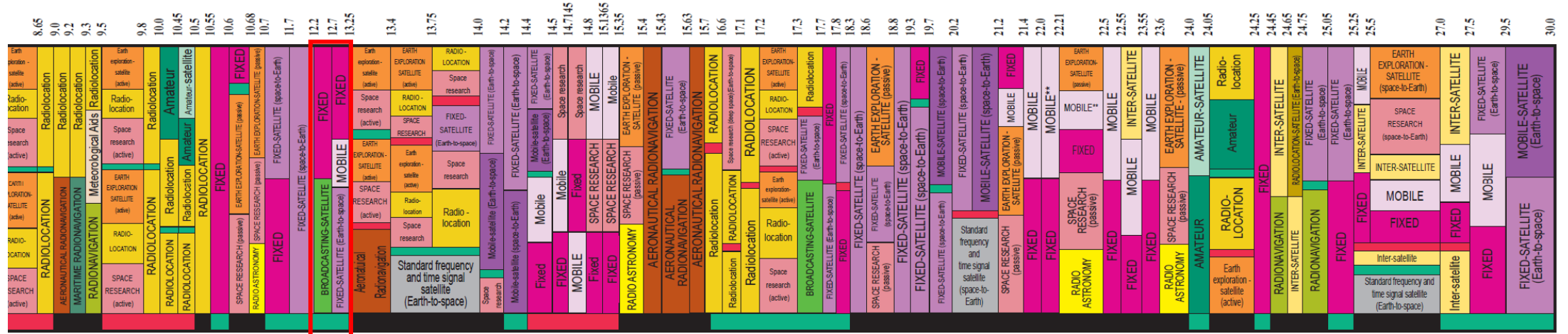


- 7125-8500 MHz

7/8 GHz Band (7125-8500 MHz)



7/8 GHz Band (7125-8500 MHz) Allocations



30 GHz

12.2-12.7 GHz
12.7-13.25 GHz

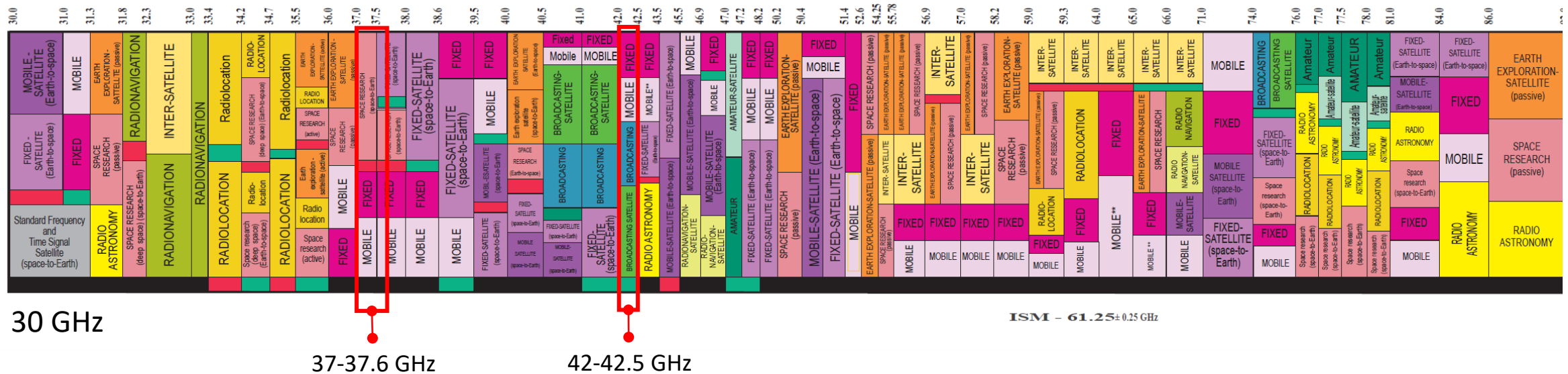
12 GHz (12.2-12.7 GHz)

- Subject of recent FCC rulemaking (WT 20-443)
- Currently used for Direct Broadcast Satellite (DBS) and the Multi-Channel Video and Data Distribution Service (MVDDS)
- NPRM seeking thoughts on making the band open for terrestrial fixed or unlicensed use
- 500 MHz available

13 GHz (12.7-13.25 GHz)

- Subject of recent FCC rulemaking (GN 22-352)
- Currently used mostly for fixed microwave, Cable Relay (CARS) and Broadcast Auxiliary (BAS)
- NPRM seeking thoughts on making the band open for mobile broadband or other expanded use
- 550 MHz available

12 GHz (12.2-12.7 GHz & 12.7-13.25 GHz)



37 GHz (37-37.6 GHz)

- Part of the Upper Microwave Flexible Use Service (UMFUS)
- Very limited incumbent federal use for NASA and some DoD
- NPRM seeking thoughts on making the band open for flexible use and how to coordinate
- 600 MHz available

42 GHz (42-42.5 GHz)

- Subject of recent FCC rulemaking (WT 23-158)
- No incumbent use
- NPRM seeking thoughts on making the band open for mobile broadband or other expanded use
- 500 MHz available

37 GHz (37-37.6 GHz) & 42 GHz (42-42.5 GHz)

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM

RADIO SERVICES COLOR LEGEND

ACTIVITY CODE

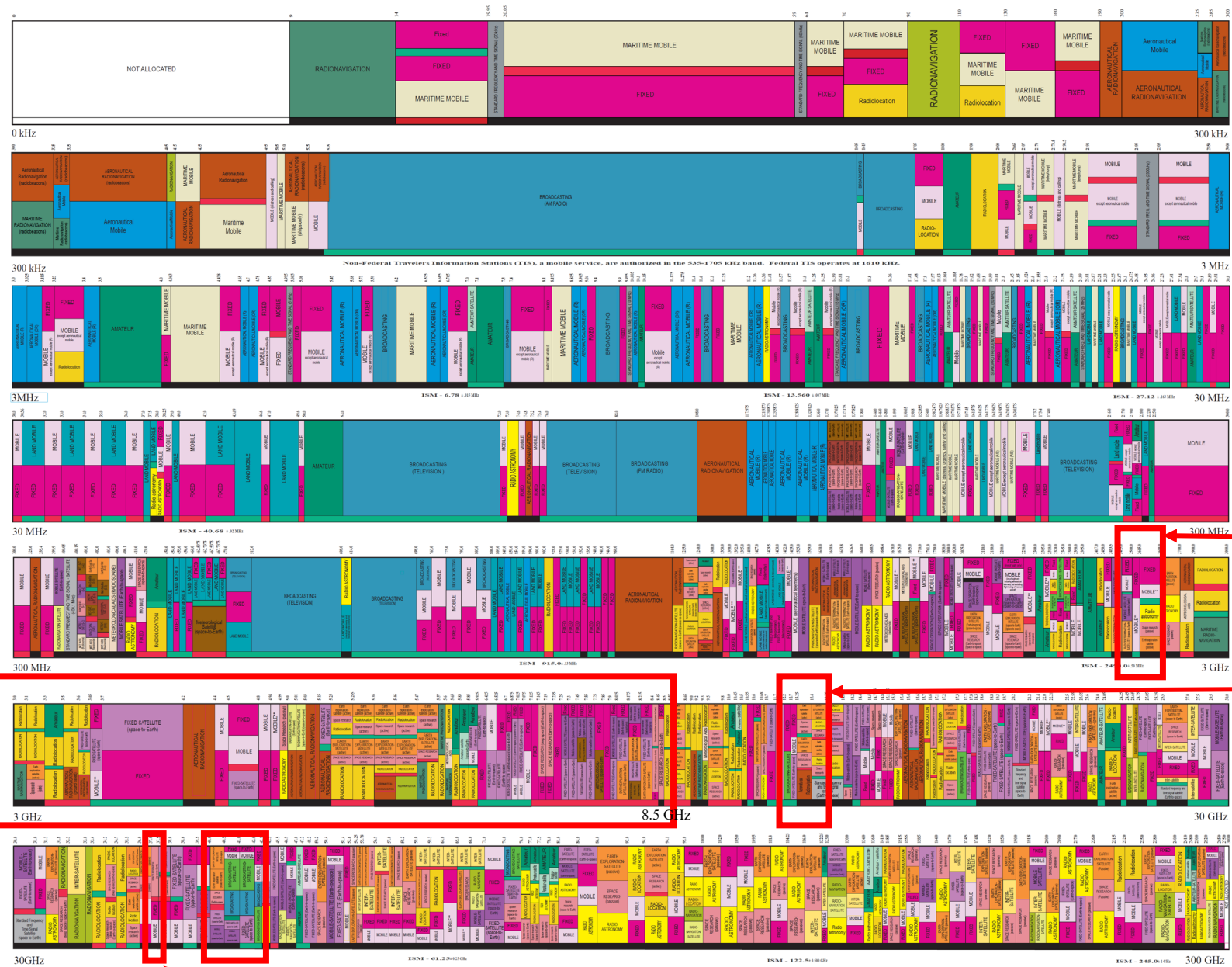
ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	Fixed	Capital Letter
Secondary	Mobile	1st Capital with lower case letters

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U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management

JANUARY 2016



Spectrum Pipeline

2.5 GHz
BRS

12 GHz

Mid-Bands

42 GHz

37 GHz

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