

Future Spectrum Requirements

An Analysis of Transportation Spectrum Needs 2019 through 2033

U.S. Department of Transportation,
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Future Spectrum Requirements Report

1.0 Executive Summary

Radio frequency spectrum is critical to the safe and efficient use of the national transportation system by the traveling public, the freight community, other commercial and private entities, as well as other Federal agencies using the roads, rails, waterways, and airspace within the United States. The U.S. Department of Transportation (DOT) is one of the largest users of spectrum among Federal civilian agencies, and has a major stake in the development and implementation of a comprehensive spectrum policy for the 21st century.

The Presidential Memorandum on “Developing a Sustainable Spectrum Strategy for America’s Future,” issued October 25, 2018, requires executive branch departments and agencies, working through the National Telecommunication and Information Administration (NTIA), to identify anticipated future spectrum needs within 180 days. The DOT has gathered information from the Operating Administrations (OAs) and their stakeholders to develop a forward-looking examination of spectrum needs for the next 15 years (2019 through 2033), aligned with DOT’s strategic goals. The *U.S. Department of Transportation Strategic Plan for FY2018-FY2022* lays out four strategic goals: Safety, Infrastructure, Innovation, and Accountability. Spectrum availability and access play a key role in meeting these strategic goals.

Within DOT, the Federal Aviation Administration (FAA) is the largest direct user of spectrum and owns, operates, or regulates many spectrum-based systems that support the safe and efficient operation of the National Airspace System (NAS), including terrestrial and space-based navigation systems, communications systems, and surveillance (e.g., radar systems and Automatic Dependent Surveillance Broadcast). Other OAs within DOT also depend upon the availability and efficient use of spectrum for communications, navigation, and surveillance capabilities, but directly administer or manage a much smaller number of systems. Much of the spectrum use for non-aviation users is directly managed by State and local government agencies and the private sector.

Direct Federal use of spectrum for transportation applications is not expected to change significantly over the next 15 years and will be primarily focused on technology upgrades and evolution within existing applications. The most significant increases in spectrum utilization are expected to be in surface transportation, especially highway transportation, where the application of cooperative safety applications, automation, infrastructure monitoring, and in-vehicle sensors will have a significant impact on overall spectrum use. This spectrum will be used by State and local governments, industry, the freight community, and most significantly by the traveling public to improve safety and efficiency of the surface transportation network. The 5850-5925

MHz band is expected to be a cornerstone of this spectrum usage. The 5.9 GHz band has been allocated for DSRC Vehicle-to-Everything (V2X), a short-range communications service built on the IEEE 802.11 standard and needs to be preserved to support traffic safety and reduce the deaths from motor vehicle crashes (37,133 in 2017) and injuries that occur on our nation's roadways.

The National Highway Traffic Safety Administration (NHTSA) and FHWA expect that the 75 MHz of spectrum at 5.9 GHz for Intelligent Transportation Systems will be necessary to enable the deployment of safety and mobility applications for the surface transportation system. As described in *Preparing for the Future of Transportation: Automated Vehicles 3.0*, V2X services are currently deployed in over 26 states and 45 cities with plans to deploy in all 50 states by 2020. Further, multiple automotive original equipment manufacturers (OEMs) have announced plans for incorporating V2X technology in their production fleets in the early 2020s.

At this time, multiple radio access technologies, Dedicated Short Range Communications (DSRC) and Cellular Vehicle-to-Everything (C-V2X), are being tested and deployed. Furthermore, 3GPP has agreed to a study item that will identify the requirements for 5G "advanced" V2X communications to include new applications such as sensor sharing, platooning, remote driving, and automated driving systems.

It is critical that as spectrum-dependent applications develop, their technical requirements be incorporated into developing commercial services specifications. Current cellular deployments do not necessarily have the low latency and high availability required to support transportation safety applications. 3GPP, in Release 14, offers that through LTE-Direct communications, but only prototype equipment is available on a limited basis today so thorough testing to support surface transportation applications has just begun. Additional concerns have been raised over the future of the Release 14 equipment and its compatibility and interoperability with 5G New Radio "advanced" V2X. Incorporation of requirements is critical to ensuring sufficient spectrum is available to deploy these advanced technologies and applications.

Aviation is expected to see some level of decrease in spectrum use as it consolidates radar systems. However, spectrum needs for unmanned aircraft systems and the burgeoning commercial space transportation industry are expected to increase.

Access to spectrum to implement, operate, maintain and enable advanced technologies to assure safe, reliable, and efficient transportation will continue to be essential in enabling the DOT to meet its mission responsibility of ensuring that America's transportation network continues to be the safest and most technologically advanced.

2.0 Introduction

The National Telecommunications and Information Administration (NTIA) provided guidance to departments and agencies on determining future spectrum requirements in response to the Presidential Memorandum on “Developing a Sustainable Spectrum Strategy for America’s Future,” which included a task to define future spectrum requirements.

As stated in its request, “NTIA, on behalf of the Secretary, seeks to gather information from executive branch agencies on their anticipated future spectrum requirements for planned systems that are likely to become operational within the next fifteen (15) years (2019 through 2033). A primary benefit of understanding all of the Federal agencies’ future spectrum needs is that it enables the Federal and non-Federal spectrum user communities and their respective regulators to consider long-term collaboration opportunities along with, as the President’s Memorandum calls for the National Spectrum Strategy to include, “advanced technologies, innovative spectrum-utilization methods, and spectrum-sharing tools and techniques that increase spectrum access, efficiency, and effectiveness.”

All modes of transportation within the U.S. rely upon spectrum-based communications, navigation, and surveillance systems to support the safe operation of the nation’s aviation, rail, public transit, pipeline, highway, and maritime transportation networks. Spectrum must be protected from harmful interference and cyberattacks to ensure availability and reliability for the continued safe operation of these systems.

DOT gathered information from its Operating Administrations (OAs) and their stakeholders to develop a forward-looking examination of spectrum needs for the next 15 years (2019 through 2033), aligned with DOT’s strategic goals. The *U.S. Department of Transportation Strategic Plan for FY2018-FY2022* lays out four strategic goals: Safety, Infrastructure, Innovation, and Accountability.

In collecting information from the DOT OAs, two items are evident. The first is the uncertainty of future requirements over the 15-year timeframe, and the second is the expected reliance on commercial devices and services – dual use, unlicensed, 5G technologies; frequency-agile equipment; dynamic spectrum access methodologies; and other advanced technologies – and their implications on future spectrum demands.

3.0 Sources and Methodologies

The DOT Office of the Assistant Secretary for Research and Technology (OST-R) requested information on future spectrum use, based on NTIA's guidance, from subject matter experts in the various OAs within DOT, as well as from the Office of the Secretary of Transportation:

- Federal Aviation Administration (FAA)
- Federal Highway Administration (FHWA)
- Federal Motor Carrier Safety Administration (FMCSA)
- National Highway Traffic Safety Administration (NHTSA)
- Federal Transit Administration
- Federal Railroad Administration (FRA)
- Maritime Administration (MARAD)
- Pipeline and Hazardous Materials Safety Administration (PHMSA)
- Saint Lawrence Seaway Development Corporation (SLSDC)

Most of the DOT OAs are not significant direct users of spectrum, so many of the responses came from the research organizations of these agencies or from their State, local, or commercial partners. The DOT dependency on radiofrequency spectrum (Federal and non-Federal) communications, navigation, and surveillance systems across all modes of transportation is shown in Appendix B.

Longer-term perspectives are difficult to quantify due to the development stage of the applications. Many applications are evolving quickly, while others remain very much in a research phase. Additional information has been requested from various transportation associations. As this information becomes available, this document will be updated.

As previously mentioned, the *DOT Strategic Plan for FY 2018-FY 2022* has four goals: Safety, Infrastructure, Innovation, and Accountability. As a methodology, DOT has identified spectrum strategic goals in support of transportation safety, infrastructure, innovation, and accountability, as outlined below.

- **Safety: Reduce Transportation-Related Fatalities and Serious Injuries Across the Transportation System**
 - Spectrum Strategic Goal 1: Protect Spectrum from Harmful Interference
 - Spectrum Strategic Goal 2: Ensure Availability of Spectrum to Meet Current and Emerging Transportation Needs

- **Infrastructure: Invest in Infrastructure to Ensure Mobility and Accessibility and to Stimulate Economic Growth, Productivity, and Competitiveness for American Workers and Businesses**
 - Spectrum Strategic Goal 3: Encourage Increasing Use of Wireless Communications
 - Spectrum Strategic Goal 4: Enable Non-Federal Use of Spectrum for Transportation-Related Activities

- **Innovation: Lead in the Development and Deployment of Innovative Practices and Technologies that Improve the Safety and Performance of the Nation's Transportation System**
 - Spectrum Strategic Goal 5: Increase Spectrum Utility and Minimize Spectrum Footprint

- **Accountability: Serve the Nation with Reduced Regulatory Burden and Greater Efficiency, Effectiveness and Accountability**
 - Spectrum Strategic Goal 6: Reduce the Regulatory Burden of Individual Site Authorization for Testing by Maintaining Access to Experimental Authorization

DOT efforts related to these spectrum strategic goals are detailed in Section 4 of this document.

4.0 Anticipated Changes or Evolution in Use of Spectrum-Dependent Technologies

Spectrum use within DOT generally falls into surface, maritime, and aviation applications and can be further characterized by either direct Federal or non-Federal use of spectrum. This section describes planned or anticipated changes or evolution in use of spectrum-dependent technologies, including foreseen changes in missions or operations, in meeting DOT's six strategic spectrum goals. While there may be some overlap between these goals, the descriptions in this section will help in defining both the potential area of operations and the extent to which that operation may be supported by new and emerging commercial telecommunication systems.

Spectrum Strategic Goal 1: Protect Spectrum from Harmful Interference

With safety as DOT's top priority, looking to the future it is important to ensure radiofrequency spectrum is protected from harmful interference, and to ensure the availability of spectrum to meet current and emerging spectrum access and performance requirements.

Vehicle to Everything (V2X) Communications

In 2017, there were approximately 37,133 deaths on our nation's roadways, while rail, public transit, aviation, and waterway deaths were significantly lower, but no less important to the Department to reduce. Critical to the Department's safety improvements and efforts to reduce this number is the ability of vehicles to communicate with each other and everything around them including infrastructure and pedestrians. This connectivity creates a level of situational awareness such that properly equipped vehicles can warn drivers of impending crashes, pre-arm air bags, and offer other safety features when a crash is imminent. As these systems increase in density, research has shown that active vehicle control will reduce crashes even further. Critical to this is the low latency, short range, and immediate spectrum access offered by the 5850-5925 MHz band.

Positioning, Navigation, and Timing (PNT)

The Global Positioning System (GPS) and its related augmentation systems play a central, critical role in enabling the safe and efficient use of the national transportation system. Spectrum protection is necessary to ensure that GPS remains a robust, reliable, and secure space-based PNT system. As the civil lead for GPS, DOT is committed to ensuring that the GPS frequency spectrum is maintained free from harmful interference. DOT recently completed an adjacent band compatibility assessment to determine the maximum tolerable power levels in the adjacent radiofrequency bands. Given growing concerns over the need for a GPS backup or Complementary PNT capability, additional spectrum may be required to field those capabilities.

Spectrum Strategic Goal 2: Ensure Availability of Spectrum to Meet Current and Emerging Transportation Needs

Saint Lawrence Seaway Development Corporation Operations

The mission of the SLSDC is to serve the U.S. intermodal and international transportation system by improving the operation and maintenance of a safe, reliable, efficient, and environmentally responsible deep-draft waterway, in cooperation with its Canadian counterpart. The SLSDC also encourages the development of trade through the Great Lakes Seaway System (Seaway), which contributes to the comprehensive economic and environmental development of the entire Great Lakes region. Expected increases in spectrum use include the addition of virtual navigation buoys and automated lock ingress and egress operations.

Navigation buoys are important for marking channels and potential hazards to navigation. Winter temperatures may move or damage physical buoys, creating navigation hazards. With the use of electronic charts, virtual buoys may offer commercial shipping access to the Seaway earlier and later in the shipping season. Virtual Buoys may be incorporated into the Automated Identification System (AIS) in the VHF band.

Another potential increase in spectrum comes from automation of the Seaway's lock system. As Figure 1 illustrates, the size of a typical ship and the minimal clearance within the Lock leads to damage to both the Lock and the ship. To reduce damage, companies are developing automated ingress, station holding, and egress systems. None have been tested within the Seaway to date, but with the advances in sensor and automation technology, it is likely to occur soon. It is unclear if this commercial application would need Federal spectrum support, but does indicate an additional need for spectrum.



Figure 1. Ship in Saint Lawrence Seaway Lock. Source, SLSDC web site, 2/26/2019.

Maritime Administration Operations

The MARAD mission is to foster and promote the U.S. Merchant Marine and the American maritime industry to strengthen the maritime transportation system — including landside infrastructure, the shipbuilding and repair industry, and labor — to meet the economic and national security needs of our Nation. Programs of the Maritime Administration promote the development and maintenance of an adequate, well-balanced United States Merchant marine, sufficient to carry the Nation’s domestic waterborne commerce and a substantial portion of its waterborne foreign commerce, and capable of service as a naval and military auxiliary in time of war or national emergency. The Maritime Administration also seeks to ensure that the United States maintains adequate shipbuilding and repair services, efficient ports, effective inter-modal water and land transportation systems, and reserve shipping capacity for use in time of national emergency.

Through the U.S. Merchant Marine Academy (USMMA), MARAD provides top-level education and training to develop future merchant mariners. MARAD also plays a key role in the planning and development of port-related transportation infrastructure to address the challenge of growing U.S. transportation demands. The America’s Marine Highways and port infrastructure programs managed by MARAD provide funding, oversight, and technical assistance for port development and expansion projects. MARAD also works with State DOTs and its other modal partners to assist other transportation infrastructure related efforts such as Better Utilizing Investments to Leverage Development (BUILD) and Infrastructure for Rebuilding America (INFRA) Grant programs.

Spectrum use is limited to that required on seagoing vessels including S and X-Band radar, VHF and UHF ship to ship and local communications, INMARSAT terminals, and AIS, to highlight several. Ships for the USMMA at Kings Point New York are active users. For the Ready Reserve Fleet, this equipment is maintained until needed and the ship is made available for Department of Defense (DoD) use. MARAD does not foresee any expansion of spectrum use beyond routine updating and does not expect much use of commercial terrestrial systems given their current mission.

Spectrum Strategic Goal 3: Encourage Increasing Use of Wireless Communications

Rural Highway Construction

The mission of the Office of Federal Lands Highway, an office within the FHWA, is to improve transportation to and within Federal and Tribal Lands by providing technical services to the highway/transportation community, as well as building accessible and scenic roads that ensure the many national treasures within our Federal Lands can be enjoyed by all. This mission necessitates work in many rural and minimally developed areas including national parks, tribal lands, and similar areas that lack basic telecommunication resources available in more urban settings.

In the past, land mobile radio has been used to support communications in these areas. More recently, support for less complex (from the user perspective) equipment has been requested. Most notable is the use of communications equipment that works with cell phones when cellular connections are not available, to forward text messages between individuals. If commercial services become available in more of these areas, this communication link may be used less, depending on carriers' ability to deploy in these minimally populated areas.

Highway Operations

Highway Operations is a broad term that addresses everything from incident management and traffic flow to roadside infrastructure tracking and maintenance. The most significant change expected to impact spectrum use is the number and connectivity of sensors to monitor traffic flow, infrastructure sensing, and communications with roadside infrastructure.

Modern transportation systems are heavily loaded with sensors to determine traffic speed and to identify incidents. These sensors can be traffic radars in the 9-10 GHz range (similar to police radar), Bluetooth devices, noise sensors, loop detectors in the roadway, temperature sensors and a host of other sensors.

Critical infrastructure may have additional sensors to include strain gauges, anemometers, etc. The density of sensors is expected to increase as the level of traffic and vehicle automation increases, based on two assumptions: that all vehicles, including automated vehicles, will need greater situational awareness; and that system flow can be better managed to increase both speed and density of vehicles, safely utilizing the existing infrastructure much more efficiently than in the past. These are expected to form Wireless Sensor Networks (WSNs) that require communications from the sensor to a central point and then, potentially, back to a traffic management center. In other cases, edge computing may negate the need for this backhaul, but there may still be a requirement for some of the data to be centralized.

It is important to note that in-vehicle WSNs can be found today – consider tire pressure monitoring systems common in passenger vehicles. The use of WSNs is likely to increase over time, reducing the weight of vehicles and increasing the data intensity that supports efficient operation and control of safety systems.

Transit Services

Transit services will also see an increase in spectrum use. Applications that provide riders real time location, trip planning and incident information are becoming common as in highway transportation, but there is also the need to monitor fleet operations in real time to manage and maintain vehicles. High speed rail developers have expressed a requirement for two 6.25 kHz channels using LTE technology, but on a dedicated basis. It is expected this allocation will

provide safety services similar (or equal to) those provided by Positive Train Control (PTC) currently being deployed by rail users.

Underlying these increases in spectrum are a reliance on the commercial cellular infrastructure. In order to have that reliance, this infrastructure must meet the requirements of the applications being developed. In order to ensure that happens, there must be an effort to put those requirements in front of the standards communities and encourage support of those requirements. Longer-term perspectives are difficult to quantify due to the development stage of the applications. Many are evolving quickly while others remain in a research phase.

Rail Inspection

The Federal Railroad Administration (FRA) is currently using a combination of cell phones and laptop computers to meet its communications needs. This technology is reliant on the spectrum required by these devices. FRA inspectors are also provided with a radio used to monitor railroad communications. These technologies have proven to be adequate and reliable for FRA field personnel to perform their duties. It is not expected that FRA will change its reliance on these technologies, or on commercial spectrum.

Spectrum Strategic Goal 4: Enable Non-Federal Use of Spectrum for Transportation-Related Activities

Roads and Vehicles

For many years, the focus for surface transportation has been on improving the infrastructure (geometric design, lane width, super elevation, markings, guard rails, etc.) and, somewhat independently, improving vehicles (crumple zones, air bags, bumper height and impact resistance, etc.) to improve safety and efficiency. While this is an ongoing effort, incorporating communications and sensor technology in innovative ways into the infrastructure and vehicles is expected to yield additional safety, efficiency, and accountability benefits. This will lead to significant changes in highway transportation over the next 15 years. Figure 2 provides an artist's conception of the communication paths in a typical highway environment.



Figure 2. Artist's conception of Vehicle to Infrastructure Communication Paths. Source, ITSJPO Image Library.

Table 1 provides a high-level summary of the spectrum requirements and dependencies that might be expected in the next 15 years.

Many of these applications and implementations are multimodal, meaning they apply to roadways - personally owned vehicles, commercial vehicles (freight and others), transit - as well as railroads and, to some extent, ships. It is also clear that many applications and their implementation are in the early stages of development and defining specific spectrum needs is not possible today. Spectrum requirements will be further developed and described over the next five years as State and local governments and the transportation industry begin initial deployments and develop legal frameworks to support these approaches.

Table 1. Categories of vehicle transportation use dependent on spectrum.^{1,2,3}

System Name	Description/Purpose	Radio Service
Connected Automated Vehicles	Connectivity between automated systems, infrastructure, pedestrians, etc.	DSRC, Cellular, Wi-Fi, NextGen Comms
Dynamic Infrastructure Mapping	Roadway and peer to peer simultaneous mapping	DSRC, Cellular, Wi-Fi, NextGen Comms
Advanced Safety Systems (V2V and V2I)	Set of key applications that need low latency communication and reliability	DSRC, Cellular, Wi-Fi, NextGen Comms
Robotics and AI Transportation Systems	Collaborative and resource robots including AI for NextGen TSMO	DSRC, Cellular, Wi-Fi, NextGen Comms
Drone Transportation Systems	Innovative applications for transport of people and goods in rural and urban areas	Cellular, Wi-Fi, NextGen Comms
Transportation Payment Systems	Data collection and optimization	Cellular, Wi-Fi, NextGen Comms
Infrastructure Asset Management	Freight, roadway and infrastructure asset in automated and connected systems	Cellular, Wi-Fi, NextGen Comms
Wireless Sensor Networks	Data collection and optimization	Cellular, Wi-Fi, NextGen Comms

Further, DOT is conducting research to measure the efficiency and safety benefits of augmenting existing automated vehicle capabilities with V2X communication technologies to enable cooperative automated driving. The advanced cooperative automated driving applications being researched include vehicle platooning, freeway speed harmonization, cooperative lane change and merge, and sharing of advanced sensor data with nearby vehicles. Furthermore, 3GPP has agreed to a study item that will identify the requirements for 5G “advanced” V2X

¹ Many of these are referenced in the Annual Modal Research Plan produced by the Intelligent Transportation Systems Joint Program Office, https://www.its.dot.gov/about/ITS-JPO_AMRP.pdf Last accessed 3/18/2019

² Cellular in this chart is referring to traditional cellular (the uu interface) where infrastructure is required to support communications. A new approach sometimes referred to as Direct (or the PC5 interface), may have application in surface transportation, but is still in development and extensive testing will need to be completed prior to its use for safety applications.

³ NextGen Comms refers to next generation communications systems.

communications to include new applications such as sensor sharing, platooning, remote driving, and automated driving systems.

Research currently indicates that these traffic safety applications will benefit from utilizing the 5.9 GHz allocation for connected and automated vehicles and having this spectrum preserved for these applications.

For some of the near-term spectrum usage requirements in the 5.9 GHz band, the Car 2 Car Communication Consortium has documented spectrum needs.⁴ Their report addresses many of the near-term uses of spectrum as well as longer-term uses and documents paths from the current near-term warning systems into much more automated systems. Section 5.3 of their report provides a perspective on U.S. spectrum needs, concluding that at least the full 75 MHz of allocated spectrum is needed. Annex B of their report offers a detailed examination of the use of the 5850-5925 MHz spectrum. Figure 2 provides an artist's conception of the communication paths in a typical highway environment.

Spectrum Strategic Goal 5: Increasing Spectrum Utility and Minimizing Spectrum Footprint

Aviation

The FAA's mission is to provide the safest and most efficient aerospace system in the world. FAA is pursuing actions in order to meet its Strategic Spectrum management goal of increasing spectrum utility and minimizing its spectrum footprint. The output of this goal will provide benefits to the aviation industry, to Government and to commercial interests with an increasing availability of spectrum removed from the FAA mission. There also will be an increase in spectrum utilized by FAA cooperatively shared with like commercial use. Safe operation of the airspace is assured by this goal.

Spectrum Efficient National Surveillance Radar (SENSR)

A cross-agency program titled Spectrum Efficient National Surveillance Radar (SENSR) has been initiated and is seeking to make available a minimum of 30 MHz in the 1300 – 1350 MHz band for reallocation to shared Federal and non-Federal use through updated radar technology. In support of the SENSR program, a Spectrum Pipeline Plan has been developed to obtain funds from the Spectrum Relocation Fund (SRF) to conduct a two-phased approach, which will assess the feasibility of the proposed spectrum reallocation.

⁴ Car 2 Car Communication Consortium, Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Automation Applications (see: https://www.car-2-car.org/fileadmin/documents/General_Documents/C2CCC_TR_2050_Spectrum_Needs.pdf, last accessed 2/28/2019).

The systems currently in the 1300 – 1350 MHz band are DoD, Department of Homeland Security (DHS), and FAA systems. The plan emphasizes the spectrum assets associated with aeronautical surveillance requirements for aircraft navigation and national security as well as weather radar. To make available for auction a minimum of 30 MHz in the 1300 – 1350 MHz band, funding is needed to analyze the feasibility of moving the aeronautical long-range radar systems out of 1300 – 1350 MHz by potentially consolidating with the short-range radar systems and the weather radar systems into another spectrum band (possibly 2700 – 2900 MHz). This plan sets in motion actions to establish a Government Team to define requirements for long-range and short-range air surveillance, weather and terminal Doppler weather radar, the associated technologies that may meet those requirements, and proposed options for meeting those requirements.

Unmanned Aircraft Systems (UAS)

The emerging use of spectrum by UAS is not expected to result in a new allocation of spectrum as FAA is pursuing methods to accommodate UAS use on existing spectrum. Currently it is expected that commercial providers will provide and operate the infrastructure that will accommodate UAS functions. FAA is also moving many of its communication systems to terrestrial, commercial fiber optics. This is already releasing significant amounts of communications spectrum to non-FAA use. As part of a constant review FAA is looking to see if systems and missions may be combined or eliminated and what barriers exist to success. Details of these actions form the body of the FAA submission to NTIA.

Spectrum Strategic Goal 6: Reduce the Regulatory Burden of Individual Site Authorization for Testing by Maintaining Access to Experimental Authorization

Within the Federal Manual of Regulations and Procedures for Federal Radio Frequency Management, several facilities are designated as able to use any frequency for a short period of time without gaining a site authorization. This is often referred to as a 7.11 authorization based on Experimental use under Section 7.11 of the Federal Spectrum Manual. Two of DOT's facilities are covered under this rule, the Volpe National Transportation Systems Center and the FRA's test center in Pueblo, Colorado. Over the last 10 years, an effort has been made to reduce the size of these experimental authorization areas, as well as to restrict potential use due to a perceived interference threat.

Without this authorization, each new system would require a separate frequency authorization for testing, creating significant overhead and reducing the number of innovative systems that could be considered in a given time-frame. Removing the ability to use this authorization would add significant bureaucratic effort and delay testing of proposed systems at both facilities.

Specifically, maintaining FRA's capability to test new and innovative wireless concepts without the burden of separate frequency authorizations for each new device is critical to ensuring the

economic competitiveness of the railroad test facility in Pueblo, Colorado, as well as for the Volpe Center.

5.0 Conclusions and Findings

There are many challenges that lie ahead for DOT, including: the sharing of spectrum with licensed and unlicensed devices; obtaining sufficient shared bandwidth for systems to work together without causing harmful interference; understanding the costs for new systems; and ensuring availability of adequate resources, including spectrum to implement, operate, and maintain a safe, reliable, efficient, and technology-friendly transportation network.

Federal spectrum use for surface and maritime applications is expected to remain relatively constant over the next 15 years. Within the surface modes of DOT, spectrum use by Federal agencies is expected to remain relatively constant with only minor increases. Some of these increases will be in mobile communications equipment supporting field staff in rural areas where commercial (cellular or otherwise) are unavailable. Non-Federal spectrum use for improving safety and efficiency is expected to dramatically increase provided spectrum is available and requirements can be built into the standards as early as possible to ensure that whichever technology is adopted is a viable mechanism moving forward.

Aviation is expected to see some level of decrease in spectrum use as it consolidates radar systems. However, spectrum needs for the burgeoning commercial space transportation and UAS industries are expected to increase, although they are highly dependent on the number of commercial companies vying for access.

In conclusion, availability of and access to spectrum to implement, operate, and maintain safe, reliable, and efficient transportation will continue to be essential in enabling DOT to meet its mission responsibility of ensuring that America's transportation network continues to be the safest and most technologically advanced.

Appendix A

Acronyms

5G	Next generation of cellular communications
AI	Artificial Intelligence
AIS	Automated Identification Systems
BUILD	Better Utilizing Investments to Leverage Development
DoD	Department of Defense
DOT	U.S. Department of Transportation
DHS	Department of Homeland Security
DSRC	Dedicated Short Range Communications
FAA	Federal Aviation Administration
FASTLANE	Fostering Advancement in Shipping and Transportation for the Long-term Achievement of National Efficiencies
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GHz	Gigahertz
INFRA	Infrastructure For Rebuilding America
INMARSAT	International Marine/Maritime Satellite
ITS	Intelligent Transportation Systems
kHz	Kilohertz
LTE	Long Term Evolution
MARAD	Maritime Administration
MHz	Megahertz

NextGen	Next Generation
NHTSA	National Highway Traffic Safety Administration
NTIA	National Telecommunications and Information Administration
OEM	Original Equipment Manufacturer
OST DOT	Office of the Secretary of the Department of Transportation
PHMSA	Pipeline and Hazardous Material Safety Administration
PTC	Positive Train Control
SENSR	Spectrum Efficient National Surveillance Radar
SLSDC	Saint Lawrence Seaway Development Corporation
TIGER	Transportation Investment Generating Economic Recovery
UAS	Unmanned Aircraft Systems
UHF	Ultra High Frequency
USMMA	U.S. Merchant Marine Academy
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to Everything
VHF	Very High Frequency
Wi-Fi	A trade name for IEEE 802.11x devices
WSN	Wireless Sensor Network

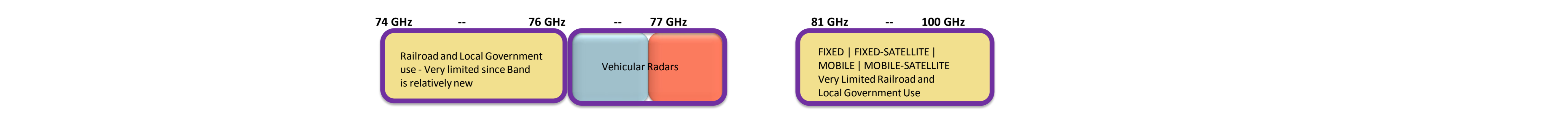
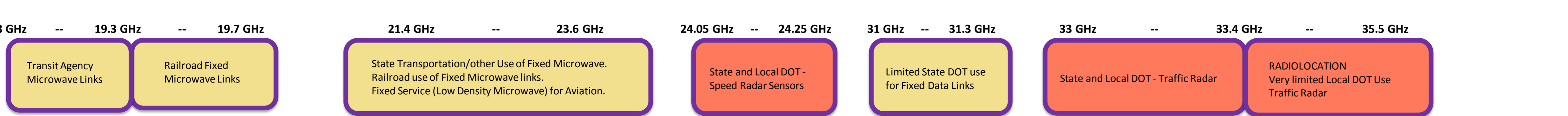
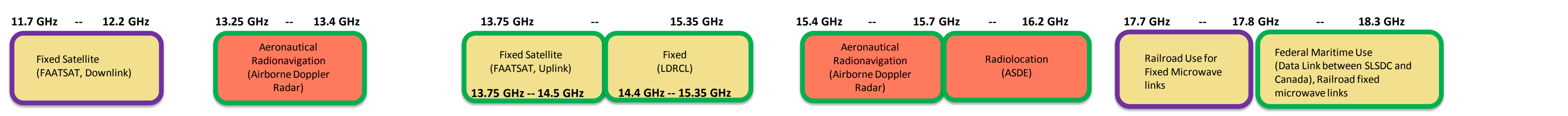
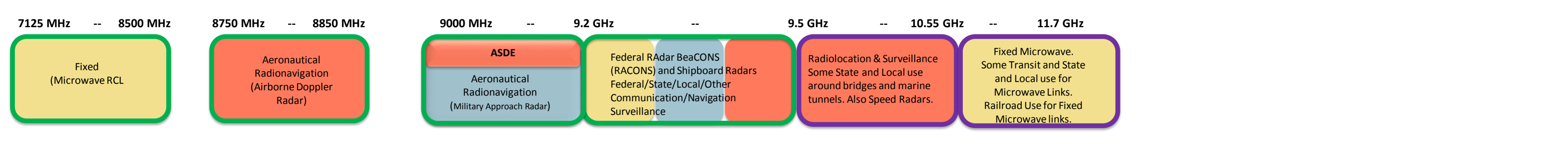
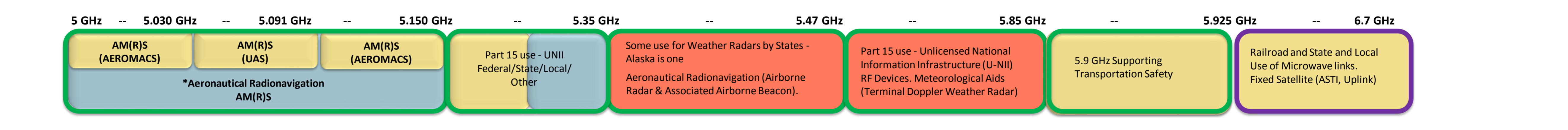
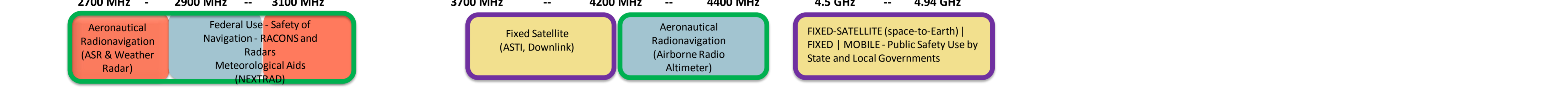
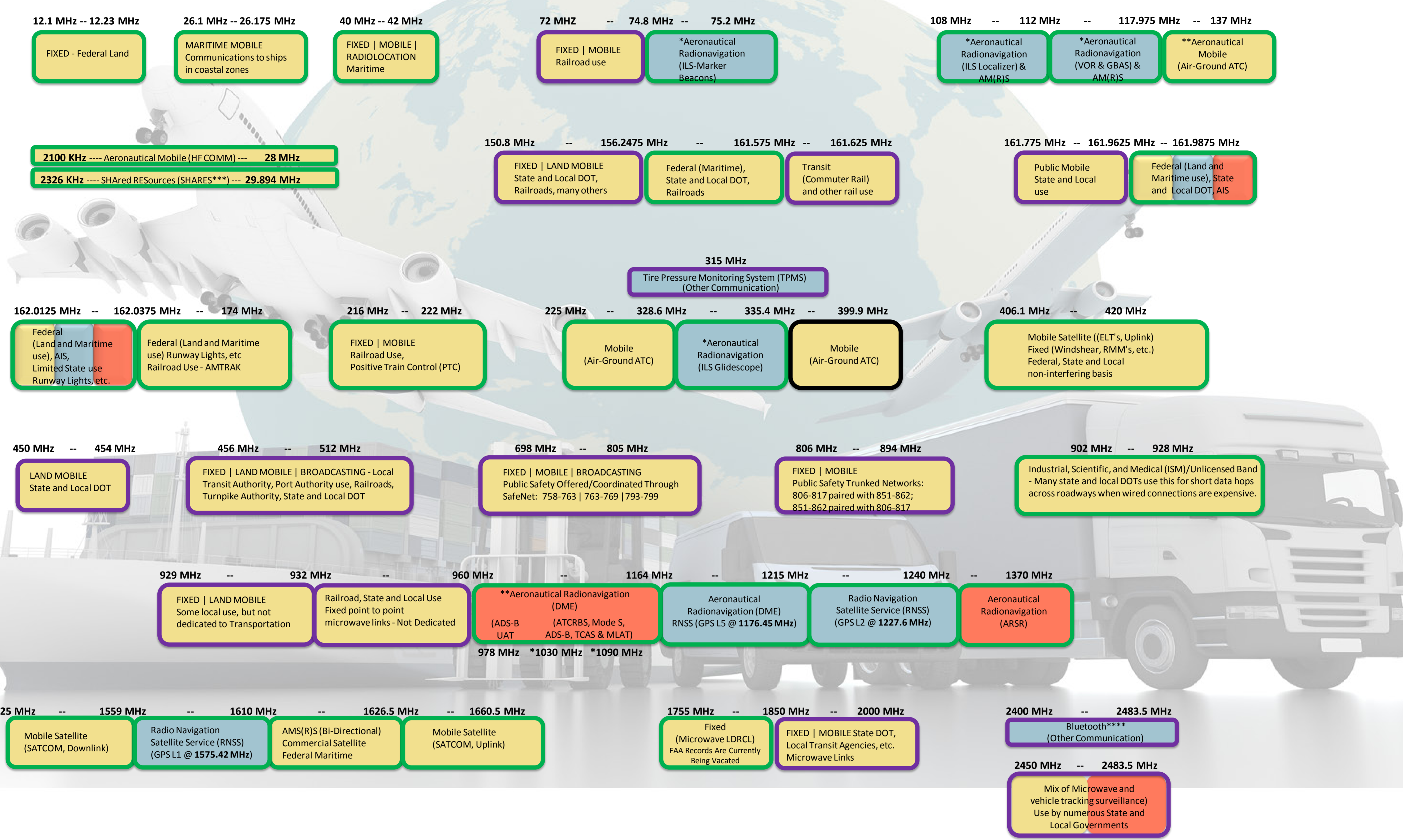
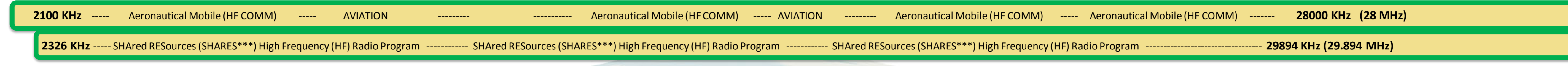
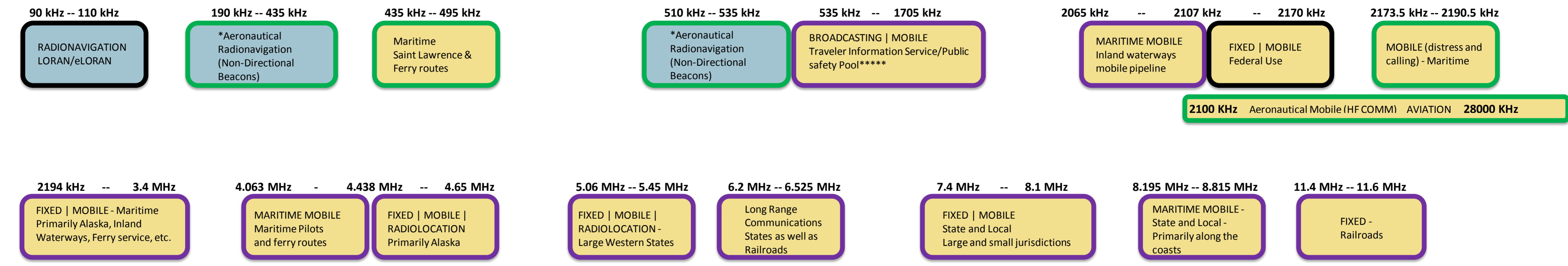
Appendix B

US Radio Frequency Bands Supporting Surface & Aviation Transportation



US Radio Frequency Bands Supporting Surface & Aviation Transportation

- COMMUNICATION
- NAVIGATION
- SURVEILLANCE
- FED EXCLUSIVE
- SHARED FED/NON-FED
- NON-FED EXCLUSIVE



***SHARED RESOURCES (SHARES) High Frequency (HF) Radio Program, used by state and local agencies to talk with DHS and other federal agencies, is a back-up communications network that is used in the event local communications have failed. While USDOT is not part of this network directly, DOT will receive information from it via other Federal agencies when there is a catastrophic event that prevents communication between USDOT field staff and local transportation communities. Frequencies are in the HF band from 4458 kHz through 29894 kHz.

**** 2400-2483.5 MHz is used for bluetooth. Bluetooth is being used to determine vehicle speed between two points by noting the MAC address of the bluetooth device and determining how long between successive readers has elapsed. 2450-2483.5 is used by State and local transportation agencies for vehicle tracking and point-to-point communication systems. Non-government use is for Television Pickup.

*****Public safety Pool is accessible by more than Public safety. If identified here, then a State or local transportation agency was accessing the available spectrum with a license. In this particulate case, they are accessing the spectrum for a Highway Advisory Radio station as part of a Traveler Information System delivery.

