Transportation.gov
U.S. Department of Transportation

Spectrum Engineering Services

USTTI Course 19-311
Radio Frequency Spectrum Management

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DOT/FAA Spectrum

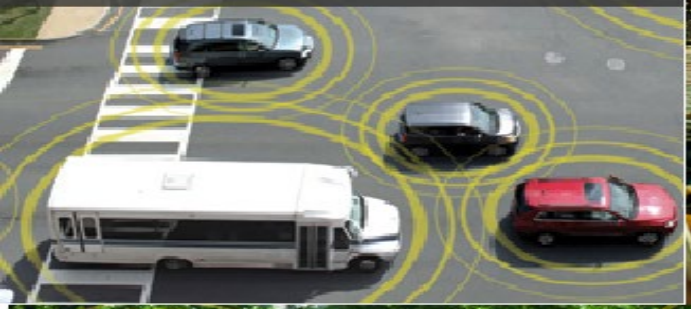
Presented at the USTTI Course 19-311

Radio Frequency Spectrum Management
September 19, 2019

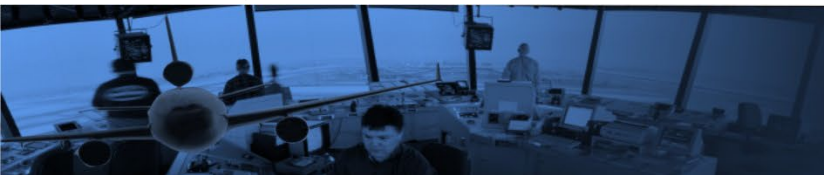
Federal Aviation Administration

PREPARING FOR THE FUTURE OF TRANSPORTATION

Connected Vehicle Basics



https://cms.dot.gov/pnt/future-spectrum-requirements-analysis-transportation-spectrum-needs-2019-through-2033-final



US Radio Frequency Bands Supporting Surface & Aviation Transportation

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

90 kHz -- 110 kHz
RADIONAVIGATION LORAN/eLORAN

190 kHz -- 435 kHz
*Aeronautical Radionavigation (Non-Directional Beacons)

435 kHz -- 495 kHz
Maritime Saint Lawrence & Ferry routes

510 kHz -- 535 kHz
*Aeronautical Radionavigation (Non-Directional Beacons)

535 kHz -- 1705 kHz
BROADCASTING | MOBILE Traveler Information Service/Public safety Pool*****

2065 kHz -- 2107 kHz -- 2170 kHz
MARITIME MOBILE Inland waterways mobile pipeline
FIXED | MOBILE Federal Use

2173.5 kHz -- 2190.5 kHz
MOBILE (distress and calling) - Maritime

2100 KHz Aeronautical Mobile (HF COMM) AVIATION **28000 KHz**

2194 kHz -- 3.4 MHz
FIXED | MOBILE - Maritime Primarily Alaska, Inland Waterways, Ferry service, etc.

4.063 MHz - 4.438 MHz -- 4.65 MHz
MARITIME MOBILE Maritime Pilots and ferry routes
FIXED | MOBILE | RADIOLOCATION Primarily Alaska

5.06 MHz -- 5.45 MHz
FIXED | MOBILE | RADIOLOCATION - Large Western States

6.2 MHz -- 6.525 MHz
Long Range Communications States as well as Railroads

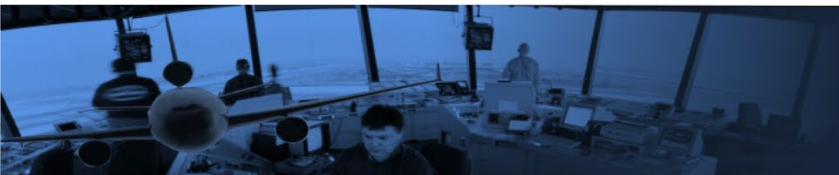
7.4 MHz -- 8.1 MHz
FIXED | MOBILE State and Local Large and small jurisdictions

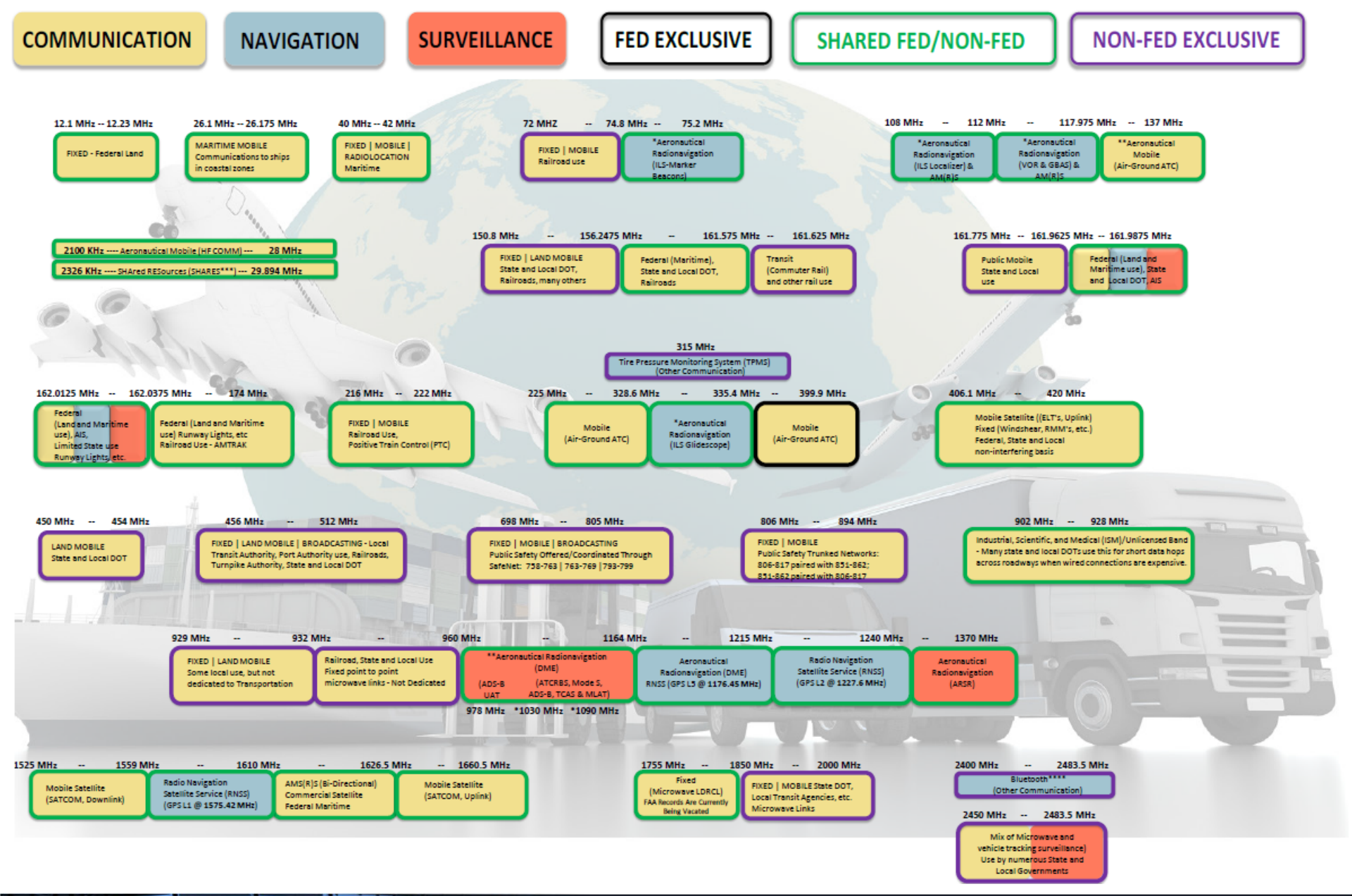
8.195 MHz -- 8.815 MHz
MARITIME MOBILE - State and Local - Primarily along the coasts

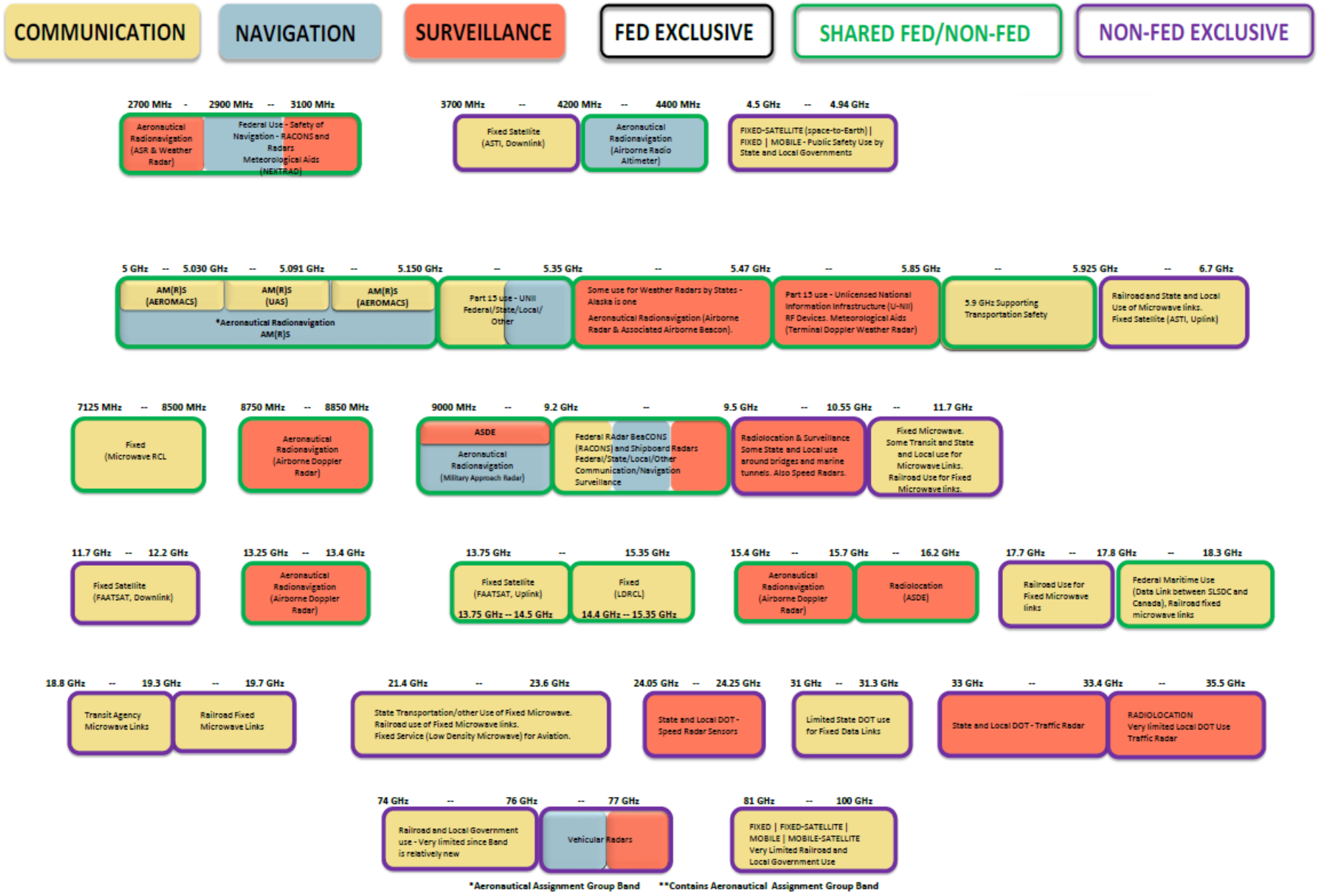
11.4 MHz -- 11.6 MHz
FIXED - Railroads

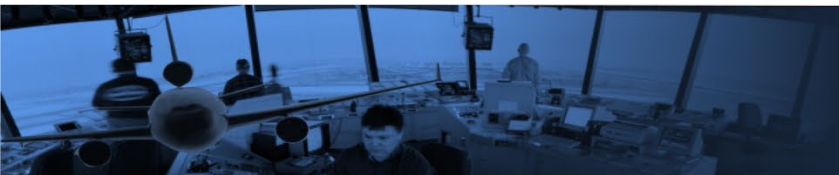
2100 KHz ----- Aeronautical Mobile (HF COMM) ----- AVIATION --------- ---------- Aeronautical Mobile (HF COMM) ----- AVIATION --------- Aeronautical Mobile (HF COMM) ----- Aeronautical Mobile (HF COMM) ------- **28000 KHz (28 MHz)**

2326 KHz ----- SHAred RESources (SHARES***) High Frequency (HF) Radio Program ---------- SHAred RESources (SHARES***) High Frequency (HF) Radio Program ---------- SHAred RESources (SHARES***) High Frequency (HF) Radio Program ---------- **29894 KHz (29.894 MHz)**

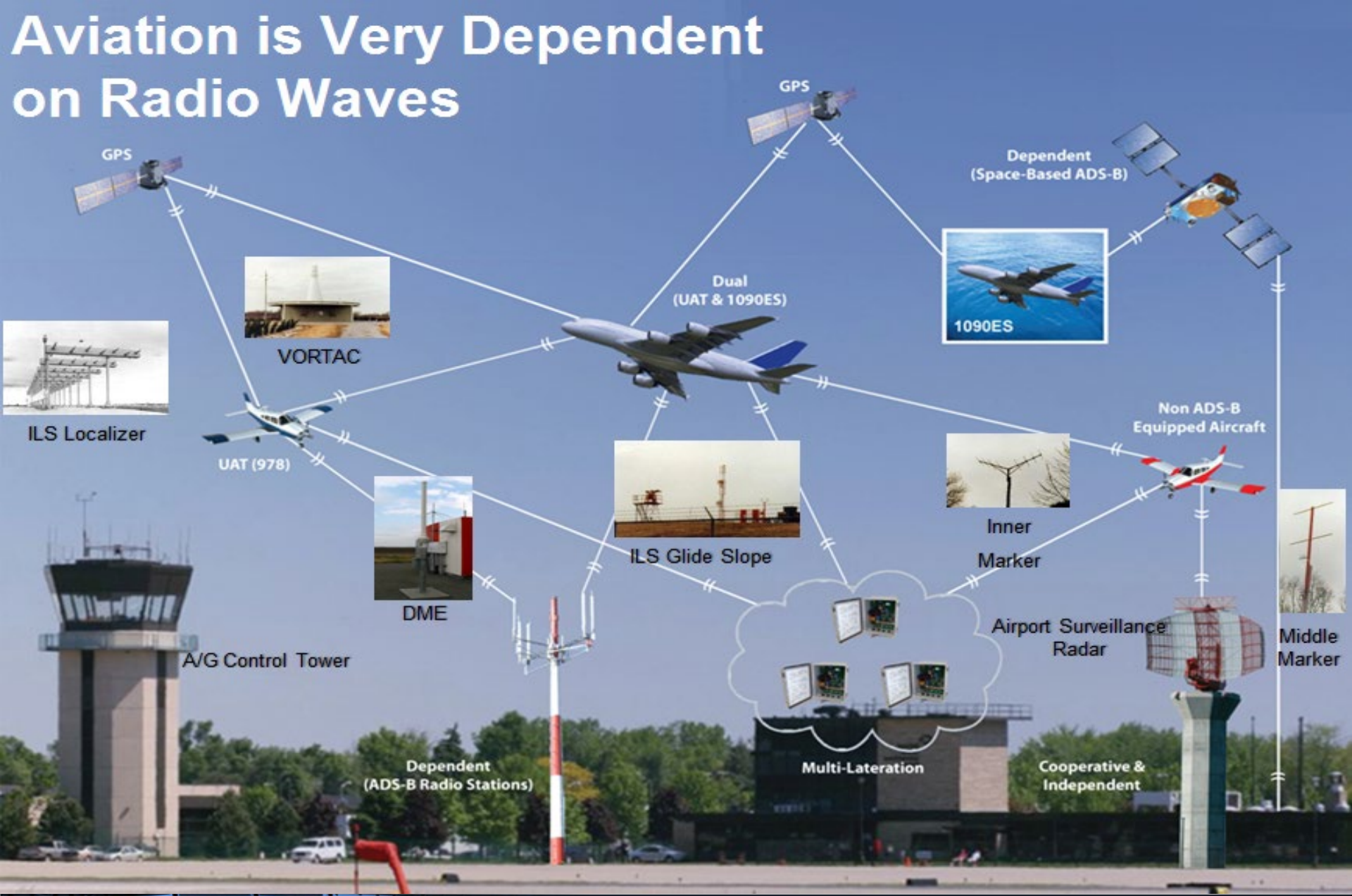



COMMUNICATION
NAVIGATION
SURVEILLANCE
FED EXCLUSIVE
SHARED FED/NON-FED
NON-FED EXCLUSIVE
12.1 MHz -- 12.23 MHz
FIXED - Federal Land
26.1 MHz -- 26.175 MHz
MARITIME MOBILE
Communications to ships in coastal zones
40 MHz -- 42 MHz
FIXED | MOBILE | RADIOLOCATION
Maritime
72 MHZ -- 74.8 MHz -- 75.2 MHz
FIXED | MOBILE
Railroad use
*Aeronautical Radionavigation (ILS-Marker Beacons)
108 MHz -- 112 MHz -- 117.975 MHz -- 137 MHz
*Aeronautical Radionavigation (ILS Localizer) & AM(R)S
*Aeronautical Radionavigation (VOR & GBAS) & AM(R)S
**Aeronautical Mobile (Air-Ground ATC)
2100 KHz ---- Aeronautical Mobile (HF COMM) ---- 28 MHz
2326 KHz ---- SHAred RESources (SHARES***) ---- 29.894 MHz
150.8 MHz -- 156.2475 MHz -- 161.575 MHz -- 161.625 MHz
FIXED | LAND MOBILE
State and Local DOT, Railroads, many others
Federal (Maritime), State and Local DOT, Railroads
Transit (Commuter Rail) and other rail use
161.775 MHz -- 161.9625 MHz -- 161.9875 MHz
Public Mobile
State and Local use
Federal (Land and Maritime use), State and Local DOT, AIS
315 MHz
Tire Pressure Monitoring System (TPMS)
(Other Communication)
162.0125 MHz -- 162.0375 MHz -- 174 MHz
Federal (Land and Maritime use), AIS, Limited State use Runway Lights, etc.
Federal (Land and Maritime use) Runway Lights, etc
Railroad Use - AMTRAK
216 MHz -- 222 MHz
FIXED | MOBILE
Railroad Use,
Positive Train Control (PTC)
225 MHz -- 328.6 MHz -- 335.4 MHz -- 399.9 MHz
Mobile (Air-Ground ATC)
*Aeronautical Radionavigation (ILS Glidescope)
Mobile (Air-Ground ATC)
406.1 MHz -- 420 MHz
Mobile Satellite ((ELT's, Uplink)
Fixed (Windshear, RMM's, etc.)
Federal, State and Local non-interfering basis
450 MHz -- 454 MHz
LAND MOBILE
State and Local DOT
456 MHz -- 512 MHz
FIXED | LAND MOBILE | BROADCASTING - Local Transit Authority, Port Authority use, Railroads, Turnpike Authority, State and Local DOT
698 MHz -- 805 MHz
FIXED | MOBILE | BROADCASTING
Public Safety Offered/Coordinated Through SafeNet: 758-763 | 763-769 | 793-799
806 MHz -- 894 MHz
FIXED | MOBILE
Public Safety Trunked Networks: 806-817 paired with 851-862; 851-862 paired with 806-817
902 MHz -- 928 MHz
Industrial, Scientific, and Medical (ISM)/Unlicensed Band - Many state and local DOTs use this for short data hops across roadways when wired connections are expensive.
929 MHz -- 932 MHz -- 960 MHz -- 1164 MHz -- 1215 MHz -- 1240 MHz -- 1370 MHz
FIXED | LAND MOBILE
Some local use, but not dedicated to Transportation
Railroad, State and Local Use
Fixed point to point microwave links - Not Dedicated
**Aeronautical Radionavigation (DME)
(ADS-B UAT)
(ATCRBS, Mode S, ADS-B, TCAS & MLAT)
978 MHz *1030 MHz *1090 MHz
Aeronautical Radionavigation (DME)
RNSS (GPS L5 @ 1176.45 MHz)
Radio Navigation Satellite Service (RNSS)
(GPS L2 @ 1227.6 MHz)
Aeronautical Radionavigation (ARSR)
1525 MHz -- 1559 MHz -- 1610 MHz -- 1626.5 MHz -- 1660.5 MHz
Mobile Satellite (SATCOM, Downlink)
Radio Navigation Satellite Service (RNSS)
(GPS L1 @ 1575.42 MHz)
AMS(R)S (Bi-Directional)
Commercial Satellite
Federal Maritime
Mobile Satellite (SATCOM, Uplink)
1755 MHz -- 1850 MHz -- 2000 MHz
Fixed
(Microwave LDRCL)
FAA Records Are Currently Being Vacated
FIXED | MOBILE State DOT, Local Transit Agencies, etc.
Microwave Links
2400 MHz -- 2483.5 MHz
Bluetooth****
(Other Communication)
2450 MHz -- 2483.5 MHz
Mix of Microwave and vehicle tracking surveillance)
Use by numerous State and Local Governments


COMMUNICATION
NAVIGATION
SURVEILLANCE
FED EXCLUSIVE
SHARED FED/NON-FED
NON-FED EXCLUSIVE
2700 MHz - 2900 MHz -- 3100 MHz
Aeronautical Radionavigation (ASR & Weather Radar)
Federal Use - Safety of Navigation - RACONS and Radars Meteorological Aids (NEXTRAD)
3700 MHz -- 4200 MHz -- 4400 MHz
Fixed Satellite (ASTI, Downlink)
Aeronautical Radionavigation (Airborne Radio Altimeter)
4.5 GHz -- 4.94 GHz
FIXED-SATELLITE (space-to-Earth) | FIXED | MOBILE - Public Safety Use by State and Local Governments
5 GHz -- 5.030 GHz -- 5.091 GHz -- 5.150 GHz -- 5.35 GHz -- 5.47 GHz -- 5.85 GHz -- 5.925 GHz -- 6.7 GHz
AM(R)S (AEROMACS)
AM(R)S (UAS)
AM(R)S (AEROMACS)
*Aeronautical Radionavigation AM(R)S
Part 15 use - UNII Federal/State/Local/ Other
Some use for Weather Radars by States - Alaska is one
Aeronautical Radionavigation (Airborne Radar & Associated Airborne Beacon).
Part 15 use - Unlicensed National Information Infrastructure (U-NII) RF Devices. Meteorological Aids (Terminal Doppler Weather Radar)
5.9 GHz Supporting Transportation Safety
Railroad and State and Local Use of Microwave links. Fixed Satellite (ASTI, Uplink)
7125 MHz -- 8500 MHz
Fixed (Microwave RCL
8750 MHz -- 8850 MHz
Aeronautical Radionavigation (Airborne Doppler Radar)
9000 MHz -- 9.2 GHz -- 9.5 GHz -- 10.55 GHz -- 11.7 GHz
ASDE
Aeronautical Radionavigation (Military Approach Radar)
Federal RAdar BeaCONS (RACONS) and Shipboard Radars Federal/State/Local/Other Communication/Navigation Surveillance
Radiolocation & Surveillance Some State and Local use around bridges and marine tunnels. Also Speed Radars.
Fixed Microwave. Some Transit and State and Local use for Microwave Links. Railroad Use for Fixed Microwave links.
11.7 GHz -- 12.2 GHz
Fixed Satellite (FAATSAT, Downlink)
13.25 GHz -- 13.4 GHz
Aeronautical Radionavigation (Airborne Doppler Radar)
13.75 GHz -- 15.35 GHz
Fixed Satellite (FAATSAT, Uplink)
13.75 GHz -- 14.5 GHz
Fixed (LDRCL)
14.4 GHz -- 15.35 GHz
15.4 GHz -- 15.7 GHz -- 16.2 GHz
Aeronautical Radionavigation (Airborne Doppler Radar)
Radiolocation (ASDE)
17.7 GHz -- 17.8 GHz -- 18.3 GHz
Railroad Use for Fixed Microwave links
Federal Maritime Use (Data Link between SLSDC and Canada), Railroad fixed microwave links
18.8 GHz -- 19.3 GHz -- 19.7 GHz
Transit Agency Microwave Links
Railroad Fixed Microwave Links
21.4 GHz -- 23.6 GHz
State Transportation/other Use of Fixed Microwave. Railroad use of Fixed Microwave links. Fixed Service (Low Density Microwave) for Aviation.
24.05 GHz -- 24.25 GHz
State and Local DOT - Speed Radar Sensors
31 GHz -- 31.3 GHz
Limited State DOT use for Fixed Data Links
33 GHz -- 33.4 GHz -- 35.5 GHz
State and Local DOT - Traffic Radar
RADIOLOCATION Very limited Local DOT Use Traffic Radar
74 GHz -- 76 GHz -- 77 GHz
Railroad and Local Government use - Very limited since Band is relatively new
Vehicular Radars
81 GHz -- 100 GHz
FIXED | FIXED-SATELLITE | MOBILE | MOBILE-SATELLITE Very Limited Railroad and Local Government Use
*Aeronautical Assignment Group Band
**Contains Aeronautical Assignment Group Band



Aviation is Very Dependent on Radio Waves

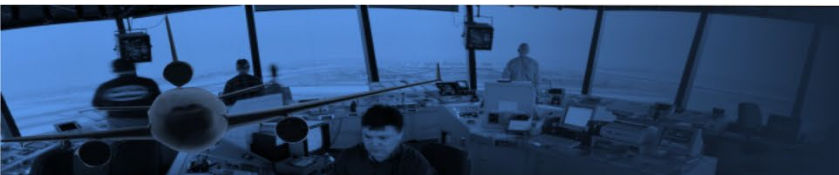


So 99.9% Rate – What Does it Mean

- **In Educational Terms – A Wonderful Grade in School, but ...**
- **99.9% Rate In Other Perspectives Equates To for Example:**
  - 16,000 lost pieces of postal mail **per hour.**
  - 22,000 checks deducted from the wrong account **each hour.**
  - 2 Unsafe Landings at O'Hare International Airport **each day**.

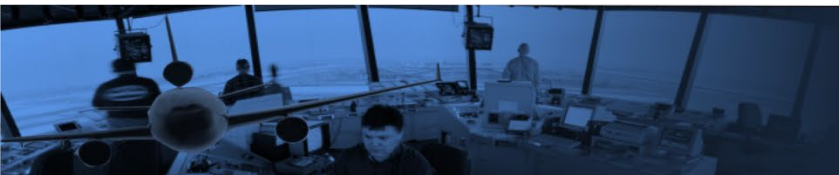
- **Requirements for Aeronautical Navigation Systems is in the Order of 99.99999%**
  - That is "Seven-9's" of Integrity.
  - In the US National Airspace System (NAS) selecting one scheduled flight at random each day a passenger can expect, on average, go for 21,000 years before the probability of being in a fatal crash.

- **How are these extraordinary levels achieved?**



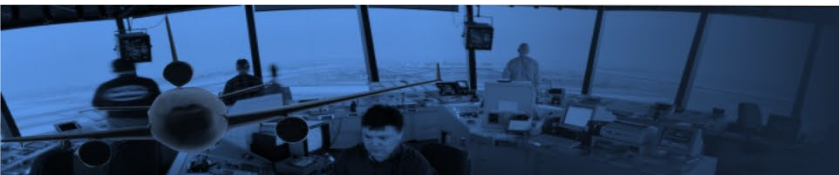
High Levels of Safety are Achieved by ...

- **Redundancy, Safety Margins**
- **Remove, or Mitigate, all Possible Sources of Risk**
- **Freedom from Radio Frequency Interference (RFI)**
  - from authorized users of the aeronautical bands.
  - from authorized users of any other bands.
  - from any unauthorized user of any bands.
- **ITU Article 4.10 recognizes the need for protection of Safety Services**
- **Exclusive allocation for Aeronautical Radionavigation Systems**
- **Exceptions to exclusive allocations:**
  - In band 960-1215 MHz ARNS shares spectrum with RNSS
  - In bands 1555-1559 MHz and 1656.5-1660.5 MHz, SATCOM shares spectrum with Mobile Satellite Service
    - ITU footnotes (e.g., 5.362A) provide priority and preemption for satellite safety communications over non-safety communications



Regulatory Authority

- **Communications Act of 1934 as Amended**
  - Established Radio Spectrum usage in the USA
- **Federal Aviation Act of 1953 as Amended**
  - Authority for FAA use of Radio Spectrum
- **Office of Management and Budget Circular A-11**
  - Spectrum Authorization Before Expenditure of Funds
- **ITU Radio Regulations**
  - Including International Civil Aviation Organization (ICAO)
- **NTIA Manual of Regulations and Procedures for Federal Radio Frequency**
- **FCC Rules and Regulations, Part 87**



National Airspace System (NAS) Facilities

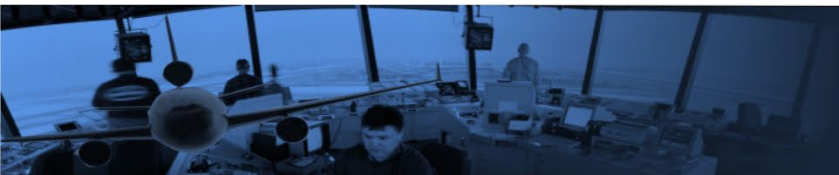
(numbers are approximate)

- **Communication** — 9000 VHF and 5000 UHF facilities
- **Navigation** — 1000 VOR, 1300 localizers, 1100 glideslopes, 1100 DME, 2500 other
- **Surveillance** — 700 SSR, 900 primary, 1600 other

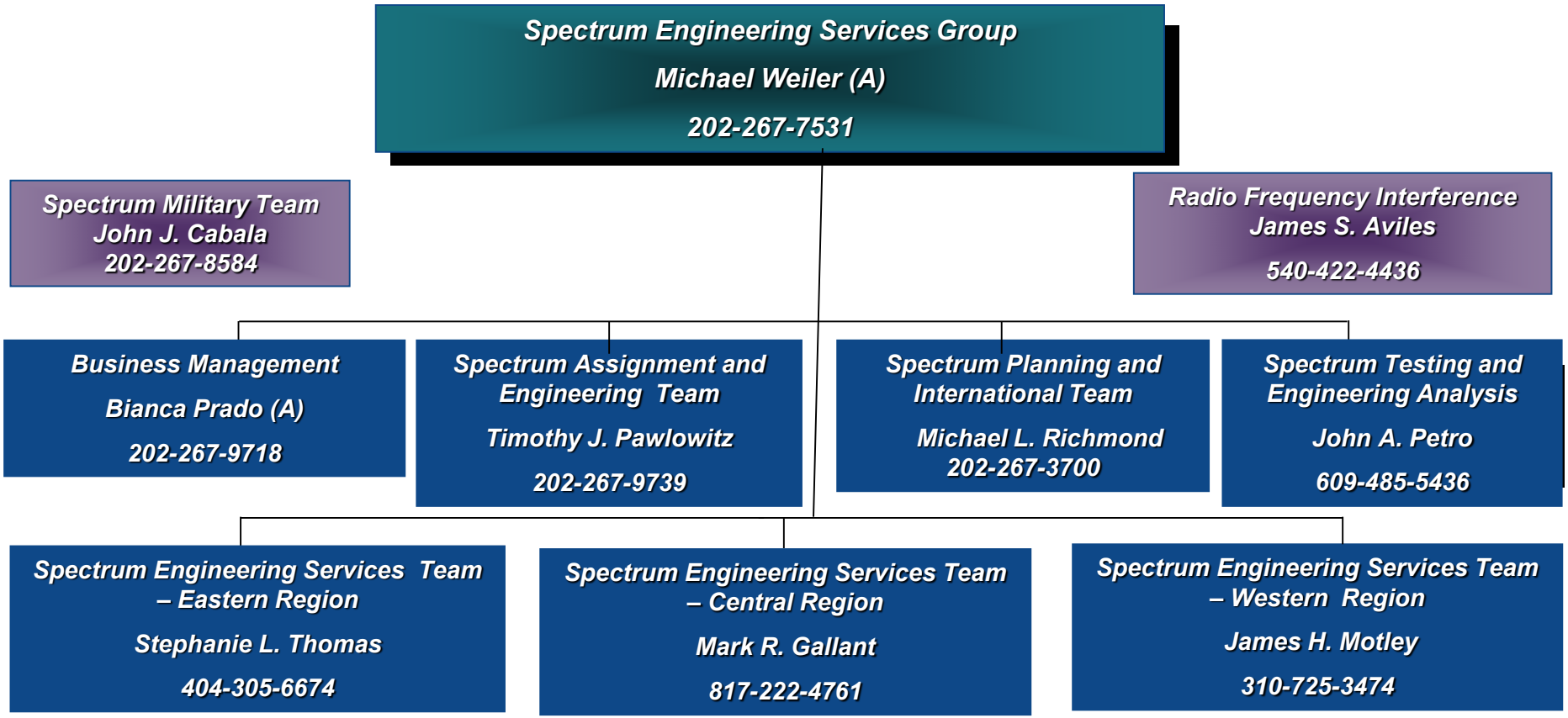
COMM **NAV** **SURV**

Frequency Assignments by Agency

Agency	Number of Assignments (Approximate)
Air Force	35000
FAA	32000
Army	30000
Navy	26000
Justice	21000
Homeland Security	19000
Agriculture	17000
Interior	14000
Coast Guard	13000
Other Agencies (combined)	37000

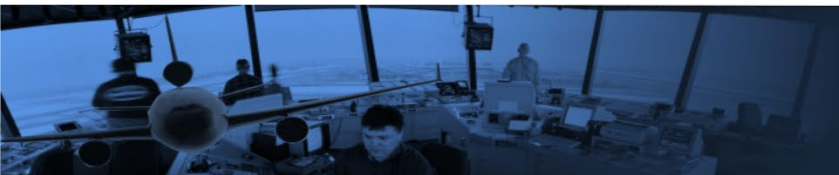


FAA Spectrum Organization



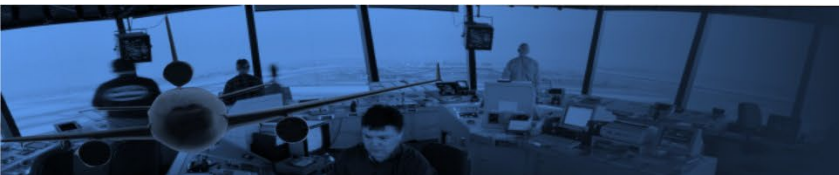
Spectrum Assignment and Engineering Team

- **Implement Spectrum Engineering Criteria and Policy for the FAA**
  - Support the operational radio frequency spectrum requirements of the National Airspace System (NAS)
  - Support the Research and Development of Technologies and Equipment that are intended to be implemented into the NAS
  - Engineer Frequencies that meet ICAO protection requirements to provide Interference Free Communications, Navigation, and Surveillance (CNS) services for every Air Traffic Control facility used through out the NAS
  - Acquire and maintain NTIA frequency authorizations for all NAS CNS facilities
  - Conduct Coverage Analysis studies to ensure that the minimum received signal power meets ICAO requirements through out the frequency protected service volume



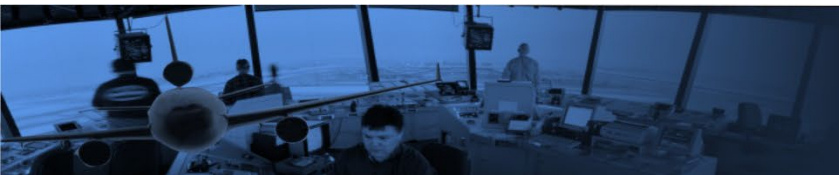
Spectrum Assignment and Engineering Team

- **Analyze the impact of and coordinate risk mitigations to support military operational/training/exercise requirements that might impact NAS operations**
  - This includes support for Interrogation Friend or Foe (IFF) exercises, Electronic Attack, Global Positioning System (GPS) jamming, Counter-Improvised Explosive Devices (C-IED's), Counter- Unmanned Aircraft System (C-UAS), and the Joint Tactical Distribution System (JTIDS)
- **Provide FAA representation on the Frequency Assignment Subcommittee (FAS) of the IRAC**
- **Chair the IRAC Aeronautical Assignment Group (AAG)**
- **Execute the FAA's Interference Resolution Program**
  - Maintain the Radio Frequency Interference Tracking (RFIT) System.
  - Assist Field Personnel in the resolution of RFI Events.
  - Provide Spectrum Services at the FAA's Operations Command Center



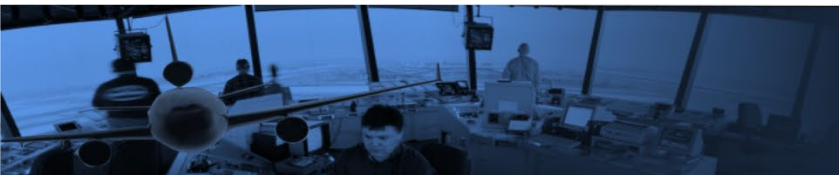
Spectrum Planning and International Team

- **Develops spectrum specifications for NAS**
  - Both technical and operational
- **Ensures FAA systems meet both domestic and International Spectrum Standards**
- **Conduct Studies necessary to help ensure RFI free spectrum**
- **Represent FAA at the IRAC and it's Subcommittees**
- **Engage in RTCA Inc. Special Committees**
- **Represent aviation needs on US delegations to international fora**
  - ICAO, ITU-R, CITEL, WRC
- **Chair ICAO Frequency Spectrum Management Panel**

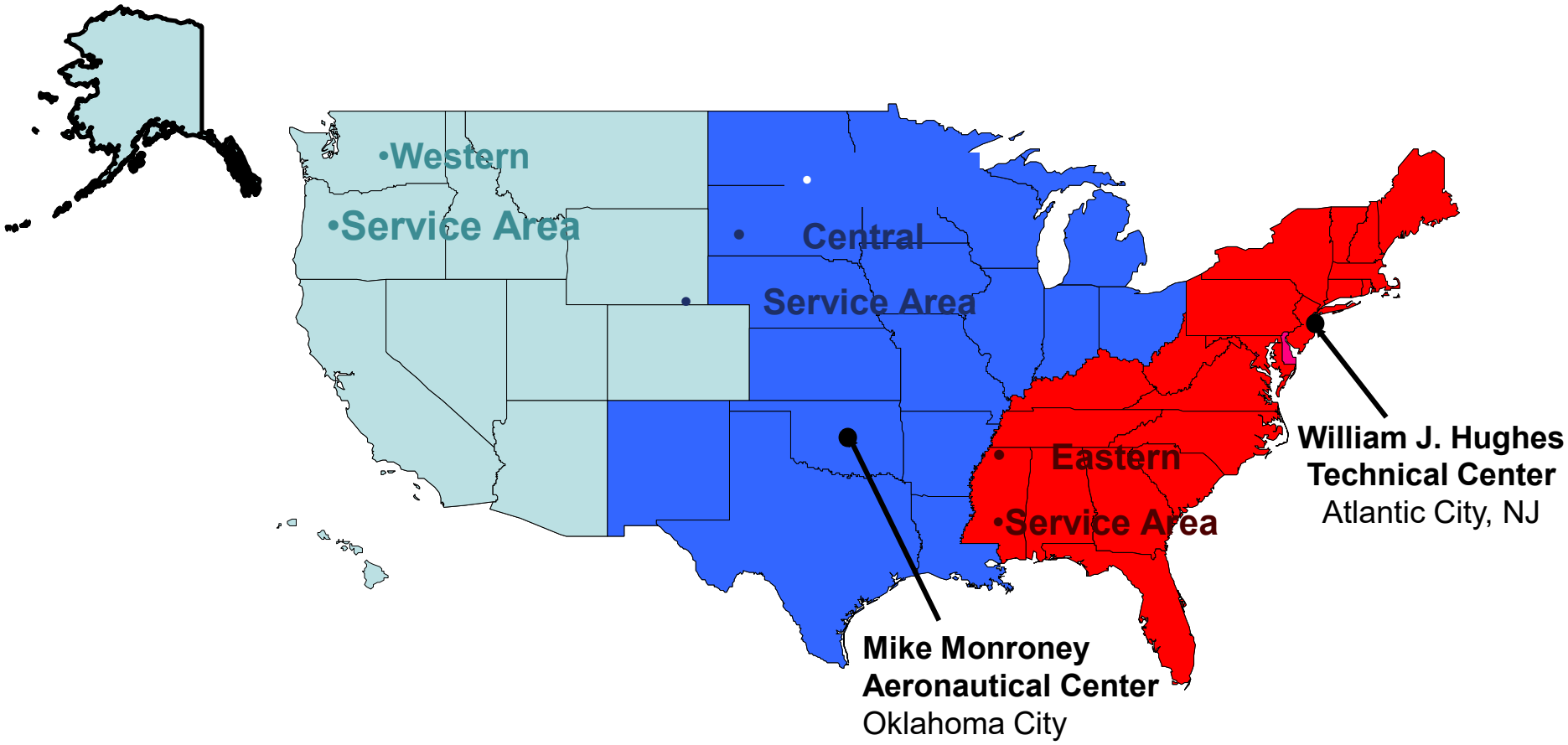


Spectrum Testing and Analysis Team

- **Located at William J. Hughes Technical Center, Atlantic City New Jersey**
  - Performs spectrum measurements on aeronautical communication and navigation equipment.
  - Validates technical characteristics of FAA and commercial equipment.
  - Tests vulnerabilities of communication, navigation, and surveillance equipment to various modulations and technologies.
  - Develops advanced software and electronics components for compatibility assessment measurements and for field RFI detection and location.

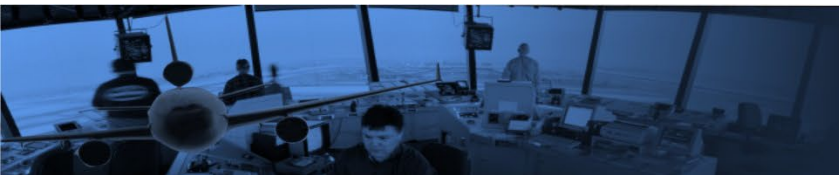


FAA Service Areas & Centers



Spectrum Service Area Teams

- **Eastern, Central, Western (including Alaska, Hawaii, Guam)**
  - Conduct Day-to-Day Frequency Assignments to meet ATC Requirements
  - Conduct Field Radio Frequency Interference (RFI) Investigations.
- **Resolve RFI Events Disrupting NAS CNS Services**
  - Coordinate with FCC, NTIA, DHS, DOD and Local State Government Agencies as needed
- **Coordinate Department of Defense Radio Frequency Tests**
  - Those which require use of NAS frequencies in the local areas
- **Engineer NAS frequency requirements**
  - New aeronautical frequencies,
  - Temporary Frequencies for air shows, Fire Fighting and Hurricanes
  - Conduct frequency coverage analysis
  - Perform Obstruction Evaluation Airspace Analysis
- **Coordinate Frequencies with Mexico and Canada**



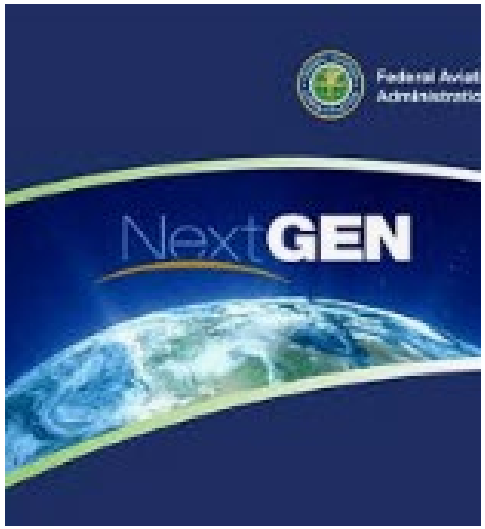
RTCA Incorporated

- **Employs a consensus-driven process on issues affecting air traffic management operations**
- **Generates minimum performance standards (MOPS) for CNS/ATM systems and equipment**
- **MOPS generally are the basis for FAA regulatory requirements**
- **The Spectrum Engineering Service participates in the Special Committees dealing with spectrum related issues:**
  - GPS (SC-159)
  - ADS-B (SC-186)
  - Unmanned aircraft systems (SC-228)
  - AMS(R)S (SC-222)
  - ATCRBS & Mode S (SC-209)

https://www.rtca.org/content/about-us-overview

NAS NextGen

- **NextGen is a wide ranging transformation of the entire national air transportation system to meet future demands both in the air and at airports**
- **Incorporates satellite based technologies to the mix of legacy ground based technologies**
- **Purpose is to reduce congestion, and improve the passenger experience**
- **New capabilities are based on RNSS**
  - Include GPS (L1 & L5), GALILEO, GLONASS
  - Additional planned global RNSS systems
  - Augmentations - GBAS, SBAS, Regional
  - Automatic Dependent Surveillance-Broadcast
  - VHF Data Link Mode 2

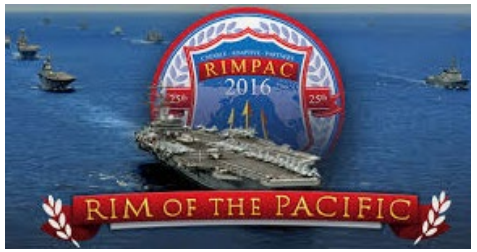


FCC

- **Title 47 CFR Part 87**
  - Rules under which civil aviation uses spectrum
- **FAA comments on draft FCC rule makings via the IRAC process**
  - Primarily those which have potential impacts to aviation
- **FAA works with FCC Enforcement Bureau**
  - Solve RFI to aviation services
- **Works with FCC on PPSG**
  - PPSG tasked to look at Federal spectrum for repurposing for civil wireless, etc.

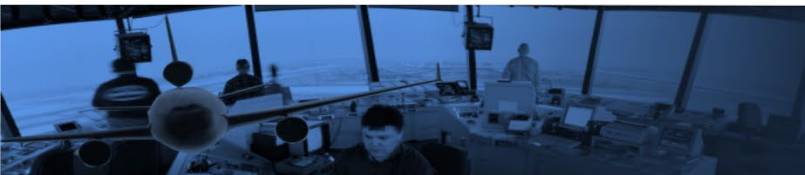
DoD Coordination

- **FAA has the responsibility to manage the spectrum associated with the National Airspace System (NAS) as per Section 8.3.16 of the NTIA Manual**
- **DoD Spectrum Management Office (SMO) sends frequency assignment request to FAA for pre-coordination.**
  - Issues, e.g., DoD use of civil frequencies (e.g. GPS) for testing, are worked out between FAA and DoD,
  - FAA coordinates with DoD over large scale exercises, e.g., RIMPAC, Bold Quest, Red Flag
- **DoD SMO submits frequency assignment to NTIA to be voted**
- **NTIA grants permission to radiate**
- **FAA works with AFTRCC to coordinate Joint use of spectrum by civil and military for aircraft flight testing**



DoD (continued)

- **DoD use of 1030/1090 MHz frequencies**
  - FAA and DoD share the 1030/1090 MHz band - Military Mode 1, 2, 3/A, C, 4 and 5 & Civil Modes 3/A, C and S
  - DoD primary IFF uses: Interrogators, Transponders, and Test Sets
  - DoD uses civilian equipment such as TCAS and Transponders with Civil Modes
  - FAA use 1030/1090 MHz to support surveillance and collision avoidance systems, such as ADS-B, SSR, TCAS, and MLAT
- **WG-8 Subcommittee of SPS for 1030/1090 MHz Systems**
  - Collaboration between FAA and DoD to develop certification language for DoD operational characteristics
    - locations, IFF modes, recommendations on operational parameters and conditions and any features/modes not being certified
    - Recommendations on discrepancies from AIMS letter that affects civil modes
    - NTIA is the final signature authority for SPS certification



DoD (continued)

- **International AIMS PO**
  - Conduct box, platform, interoperability and performance testing
  - FAA interest is to ensure conformance with agreed EMC standards necessary to protect civil systems
  - FAA participates in the DoD AIMS PO Configuration Control Board (CCB) held quarterly discussing AIMS Manual update
  - Technical discussion on change proposals (CPs) of 1030/1090 MHz system characteristics and requirements
  - FAA is also a voting member on those CP at CCB

International Civil Aviation Organization (ICAO)

- **A specialized agency of the United Nations with 190 Member States**
- **Created in 1944 to promote the safe and orderly development of international civil aviation throughout the world**
- **Sets standards and regulations necessary for aviation safety, security, efficiency and regularity, as well as for aviation environmental protection**
- **Panels on which the FAA participates**
  - Aeronautical Communications Panel
  - Navigation Systems Panel
  - Aeronautical Surveillance Panel
  - Frequency Spectrum Management Panel
    - Chaired by FAA/Spectrum Engineering Service engineer

International Telecommunications Union-Radiocommunication (ITU-R)

- **Produces Recommendations which address**
  - Spectrum sharing between systems
  - Cross-border electromagnetic compatibilities
  - Most countries adhere to Recommendations as if they were law
- **Produces Reports**
  - Provide technical and operational background on specific issues
  - Provide system characteristics and RFI susceptibilities
    - for use in radio frequency compatibility studies and
    - sometimes referenced in Recommendations
- **Drafts Conference Preparatory Meeting (CPM) Report**
  - ITU-R technical and operational guidance for WRC delegates

https://www.gsma.com/spectrum/wrc-series/

ITU-R Study Groups in which FAA Participates

- **Study Group 4 Satellite Services**
  - GPS, SATCOM and compatibility with non-aviation systems
- **Study Group 5 Terrestrial Services**
  - Aviation systems and services including radar and avionics
- **Study Group 7 Science Services**
  - Compatibility with earth-exploration-satellite service operating in spectrum allocated to aviation services

World Radiocommunication Conference (WRC)

- **Meets every three to four years, or so**
  - Establishes radio frequency allocations, globally
  - FAA participates on the U.S. delegation
  - Critical for civil aviation due to aviation's global nature
- **WRC-19 Agenda Items (AIs) of interest for FAA/aviation**
  - 1.7, protection of voice and data links
  - 1.10, implement GADSS
  - 9.1 issue 4, integrate suborbital vehicles into NAS

Any Questions?

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