# DOT Update

## Civil Agency Lead and Extended Pos/Nav Perspective

Space-Based PNT Advisory Board

May 16, 2018

# Safety Is Job #1

**The mission of the U.S. Department of Transportation (DOT) is to ensure our Nation has the safest, most efficient and modern transportation system in the world, which improves the quality of life for all American people and communities, from rural to urban, and increases the productivity and competitiveness of American workers and businesses.**

# Get There Fast, Get There Safe

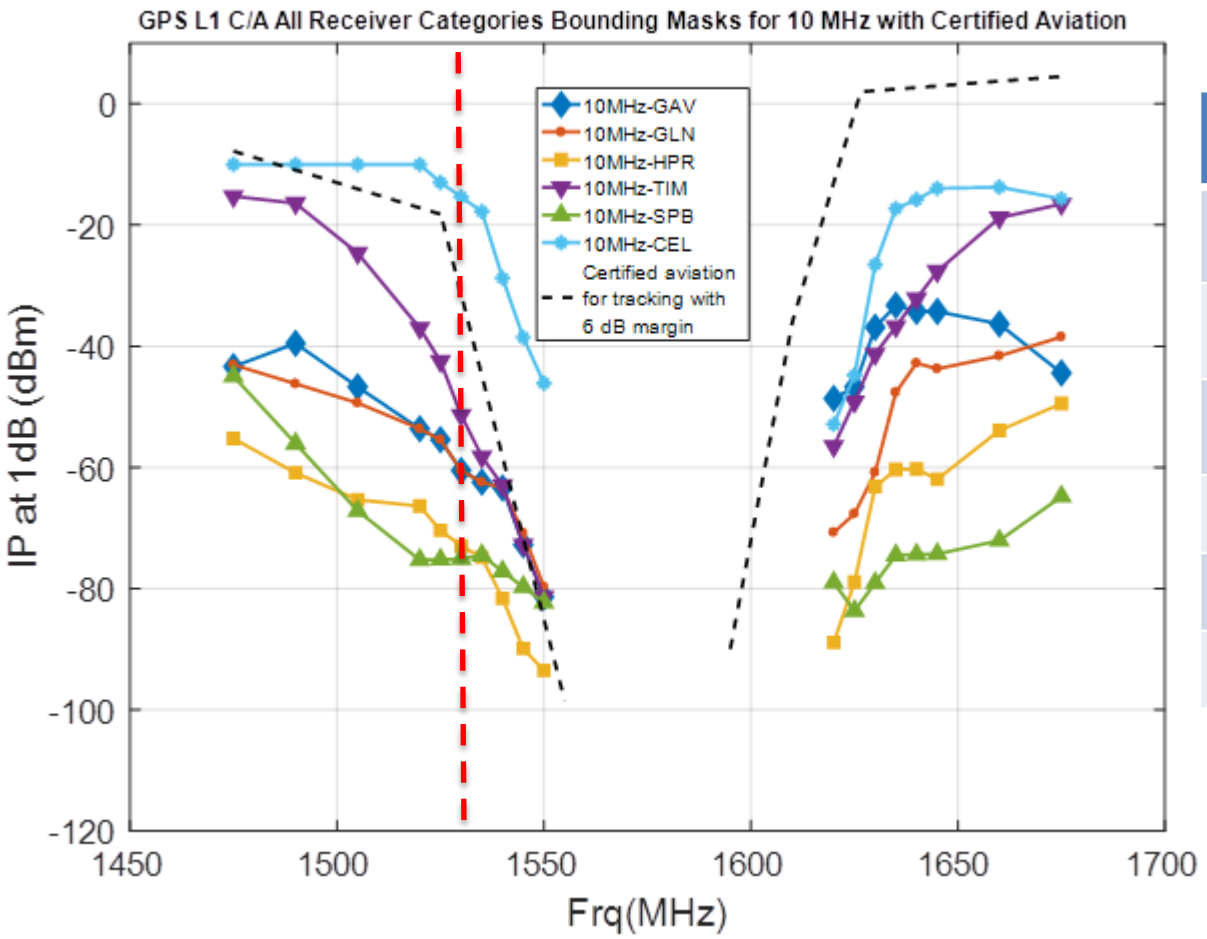
# DOT GPS Adjacent Band Compatibility Assessment

- Study is the culmination of DOT's GPS Adjacent Band Compatibility (ABC) Assessment to evaluate the maximum transmitted power levels of adjacent band radiofrequency (RF) systems that can be tolerated by GPS and Global Navigation Satellite System (GNSS) receivers.

# Space-Based PNT Advisory Board View: Minimum Criteria for Testing/Evaluation of GPS Adjacent Band Interference

1. **Accept and strictly apply the 1 dB degradation** Interference Protection Criterion (IPC) for worst case conditions (This is the accepted, world-wide standard for PNT and many other radiocommunication applications)
2. Verify interference for **all classes of GPS receivers** is below criteria, especially precision (Real Time Kinematic - requires both user and reference station to be interference-free) and timing receivers (economically these two classes are the highest payoff applications – many $B/year)
3. Test and **verify interference for receivers** in **all operating modes** is below criteria, particularly **acquisition** and **reacquisition** of GNSS signals under difficult conditions (see attachment of representative interference cases)
4. **Focus analysis on worst cases**: use ***maximum*** **authorized transmitted interference** powers and ***smallest-attenuation*** **propagation models** (antennas and space losses) that do not underrepresent the maximum power of the interfering signal (including multiple transmitters)
5. Ensure **interference to emerging Global Navigation Satellite System (GNSS) signals** (particularly wider bandwidth GPS L1C – Galileo, GLONASS), is below criteria
6. All **testing must include GNSS expertise** and be **open to public comment** and scrutiny.

# Summary of 10 MHz Bounding Masks GPS L1 C/A




| Category | ITM at 1530 MHz (dBm) |
|---|---|
| GAV - General Aviation (non certified) | -61.0 |
| GLN - General Location/Navigation | -60.5 |
| HPR - High Precision & Networks | -73.0 |
| TIM - Timing | -51.4 |
| SPB - Space Based | -73.5 |
| CEL - Cellular | -15.3 |

# Maximum Tolerable Power Level for GPS/GNSS Receivers at 1530 MHz

| Deployment | Stand off distance (m) | Max Tolerable EIRP (dBW) | | | |
|---|---|---|---|---|---|
| | | GLN | HPR | TIM | CEL |
| Macro Urban | 10 | -31.0 | -41.9 | -20.6 | 10.9 |
| | 100 | -11.0 | -21.9 | -0.6 | 31 |
| Micro Urban | 10 | -29.8 | -41.2 | -20.1 | 10.7 |
| | 100 | -9.8 | -21.1 | -0.1 | 30.8 |

| Deployment | Stand off distance (m) | Max Tolerable EIRP | | | |
|---|---|---|---|---|---|
| | | GLN | HPR | TIM | CEL |
| Macro Urban | 10 | 0.8 mW | 64 $\mu W$ | 8.7 mW | 12.3 W |
| | 100 | 79.4 mW | 6.5 mW | 0.9 W | 1.26 kW |
| Micro Urban | 10 | 1 mW | 76 $\mu W$ | 9.8 mW | 11.7 W |
| | 100 | 104 mW | 7.8 mW | 1 W | 1.2 kW |

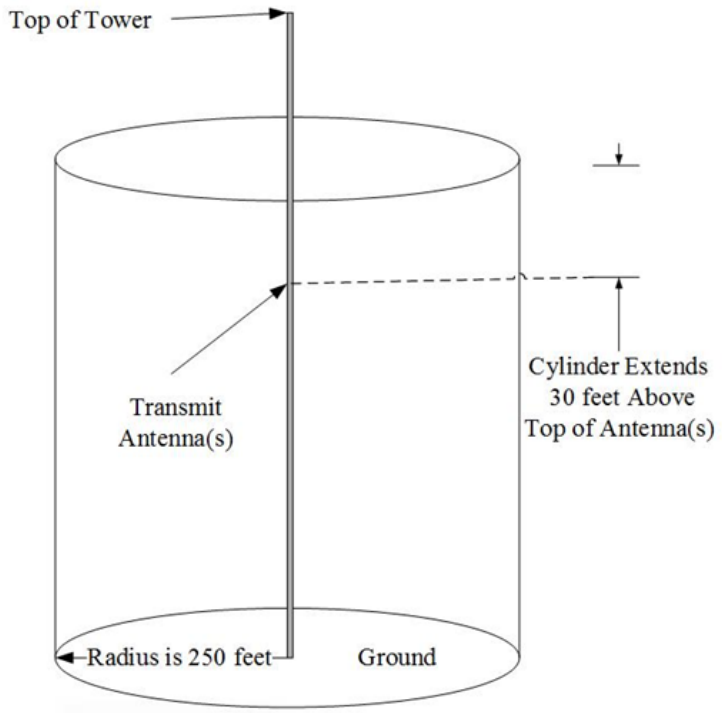
**Maximum EIRP to protect all GPS/GNSS receivers is in the Micro Watt to Milli Watt range depending on distance to transmitter**

# Maximum Tolerable Power Level for Space-Based Receivers at 1530 MHz

| Deployment Scenario | Number of Base Stations | Max Tolerable Power | |
|---|---|---|---|
| | | dBW | EIRP |
| Macro Cell | 184,500 | 11 | 12.6 W |
| Macro Cell | 67,240 | 16 | 39.8 W |
| Macro Cell | 44,850 | 17 | 50.1 W |
| Macro Cell | 24,140 | 21 | 125.9 W |
| Macro + Micro Cell | 282,186 | 8 | 6.3 W |
| Macro + Micro Cell | 102,841 | 12 | 15.8 W |
| Macro + Micro Cell | 69,477 | 14 | 25.1 W |
| Macro + Micro Cell | 39,695 | 16 | 39.8 W |

# Certified Avionics Analysis

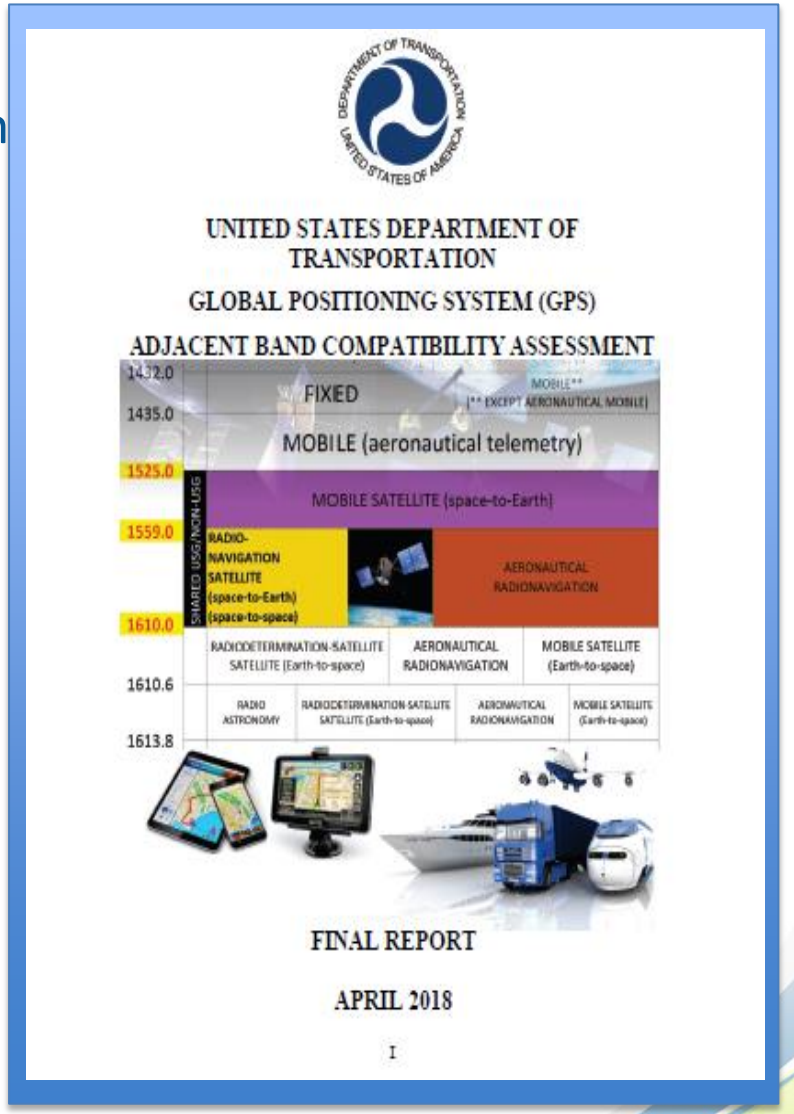
- Assessed base station and handset power using:
  - Internationally standardized avionics interference masks
  - Candidate assessment zone (cylinder) proposed by Ligado
  - Aviation handset scenarios
- Assessment Results:
  - Base station emissions above 9.8 dBW (~ 10 Watts) exceed certified avionics safety requirements
  - Ligado-proposed handset levels should not impact certified avionics
  - General aviation receiver use is not protected (reference DOT test results)



# Summary and Final Report

- Based on the results of the DOT testing and analysis, the transmitter power level that can be tolerated by certified aviation may cause interference with, or degradation to, most other categories of GPS/GNSS receivers
  - Including those used for General Aviation and Drones
- DOT GPS Adjacent Band Compatibility Assessment Final Report Coordinated within U.S. Government
  - Report consists of Main Body and 11 Appendices
  - Report includes certified avionics and non certified receivers
- Final Public Report issued April 2018

https://www.transportation.gov/sites/dot.gov/files/docs/subdoc/186/dot-gps-adjacent-band-final-reportapril2018.pdf



# DOT GPS Adjacent Band Participants

- DOT/Volpe Center
- FAA
- MITRE
- Zeta Associates
- Air Force / GPS Directorate
- Aerospace Corporation
- NASA
- U.S. Coast Guard
- U.S. Geological Survey
- NOAA
- Trimble
- Deere & Company
- Novatel
- uBlox
- General Motors
- UNAVCO
- Space-Based PNT Advisory Board
- NTIA
- FCC
- Workshop Participants

## Thank You!!

# 2019 Federal Radionavigation Plan

## Items Considered in Update

- GPS Adjacent Band Compatibility Results
- Termination of Nationwide Differential GPS (NDGPS)
- Update to the Standard Positioning Service Performance Standard
  - Incorporation of L2C and L5
- Civil GPS Signal Roadmap: IOC and FOC
- PNT Resiliency
  - Mitigation of Disruptions to GPS
  - Backup/Complementary PNT Technologies
  - Interference Detection
  - DHS Best Practices

# Positive Train Control and GPS

- Positive Train Control (PTC) is mandated under the Rail Safety Improvement Act (RSIA) for certain Freight and Passenger railroads;
  - All regularly scheduled intercity rail passenger transportation or commuter rail
  - Poison or toxic-by-inhalation hazardous materials on mainline freight tracks with more than 5MGT of traffic per year
  - Other tracks as the Secretary may prescribe by regulation

- Approx. 20,000 locomotives and 60,000 miles of the 140,000 miles of track on the national rail network need to be equipped in order for PTC to operate

# What does PTC do?

- Advanced system designed to automatically stop a train in order to prevent specific accidents
  - Train to train collisions
  - Derailments due to over speeding
  - Incursions of trains into roadway work zones
  - Movement through misaligned switches

- Prior to departure train downloads the following:
  - Geomap of railroad (grade, curvature, switches, signals and grade crossings)
  - Speed restrictions, work orders or construction zones

# What Type of PTC systems are Being Deployed?


## Interoperable Electronic Train Management System (I-ETMS)

- GPS and radio based, non-vital overlay (vital version under development)
- Used by Class I's, Amtrak (off NEC), and most commuters and shortlines

## Advanced Civil Speed Enforcement System (ACSES)

- Transponder based with ATC/Cab Signal, vital overlay
- Used by most NEC railroads

## Enhanced Automatic Train Control (E-ATC)

- ATC based, non-vital overlay
- Used by several passenger roads with limited interoperability needs

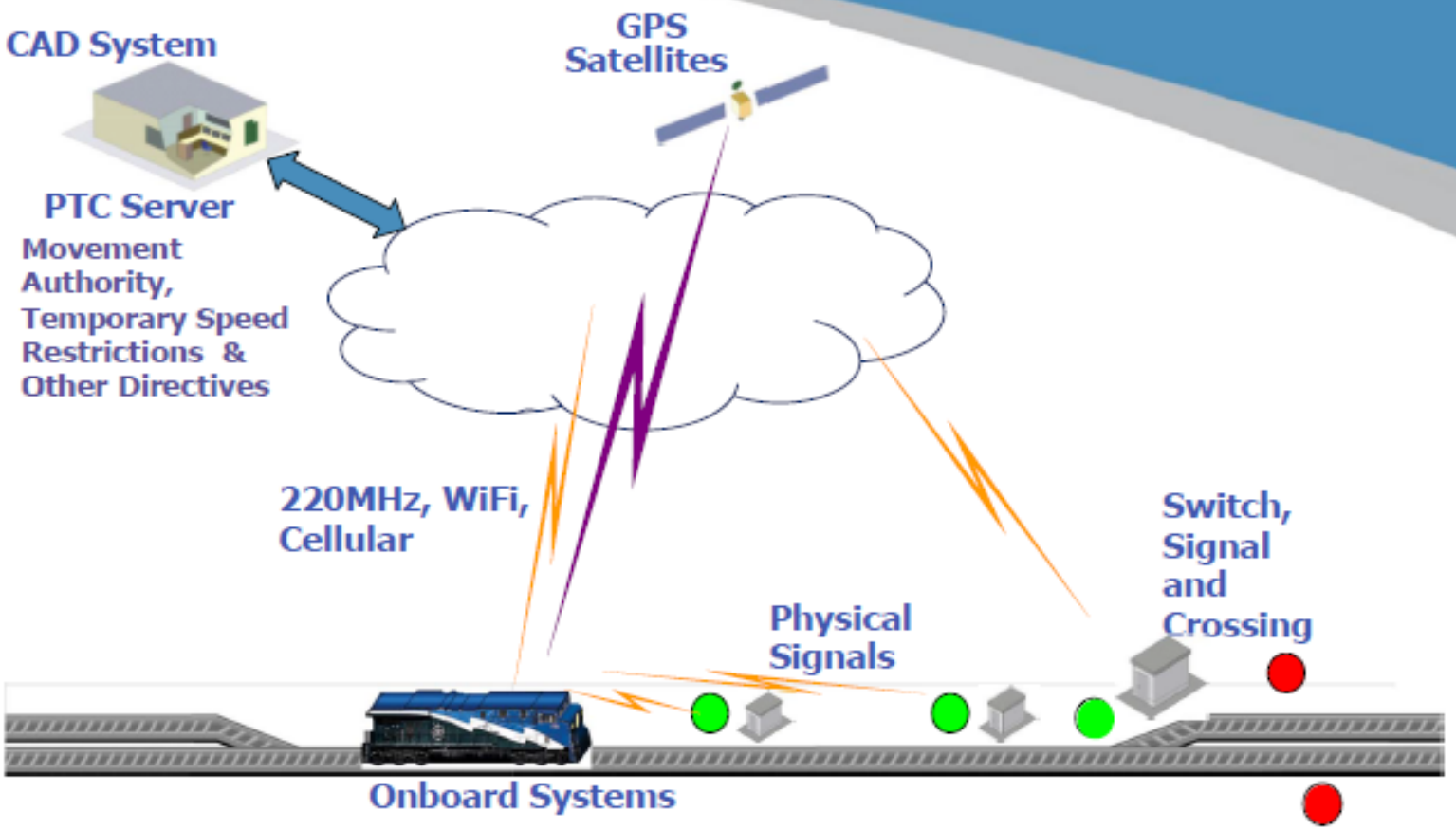

## Incremental Train Control System (ITCS)

- GPS, radio and transponder based, vital overlay
- Used by Amtrak on Michigan Corridor operations


## Other

- I-ITCS (formerly CBOSS) – combined I-ETMS and ITCS system used by Caltrain
- Communications Based Train Control (CBTC) – currently in testing with PATH

# I-ETMS System Architecture



# Looking to the Future of Navigation for Autonomous Systems

*"The vital need for efficient methods of navigation is as universal and ancient as the requirement to travel. Each era of navigation history has necessarily been marked by the particular situation of mankind at the time, including use of the available tools."*

*"At issue on a continuing basis are questions of geographic coverage, the particular types of radionavigation systems which are needed and who must bear the responsibility and expense of providing the signals."*

- DOT National Plan for Navigation, November 1977

# Thank You