Strategy for Spectrum Sharing

NAS Committee on Radio Frequencies

Washington, D.C.

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Dr. Keith Gremban, Director

Institute for Telecommunication Sciences (ITS)

National Telecommunications and Information Administration (NTIA)

Outline

- Introduction (NTIA and ITS)
- Spectrum Sharing
- State-of-the-Art – Examples
- Summary
- Questions

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- **Introduction (NTIA and ITS)**
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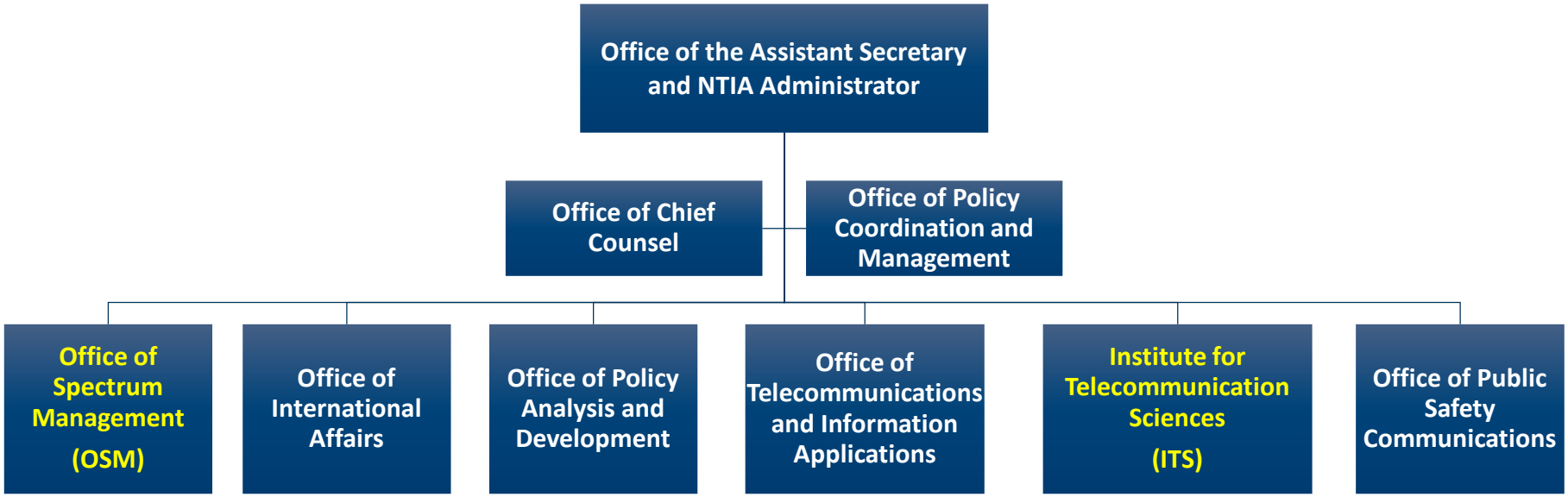
National Telecommunications and Information Administration (NTIA)

- The National Telecommunications and Information Administration (NTIA) is principally responsible for advising the President on telecommunications and information policy issues.
- NTIA is a branch of the Department of Commerce (DOC)
- NTIA offices include:
  - Office of Spectrum Management (OSM)
  - Institute for Telecommunication Sciences (ITS)
- NTIA is responsible for:
  - Managing Federal use of spectrum (OSM)
  - Identifying additional spectrum for commercial use (OSM)
  - Performing cutting-edge telecommunications research and engineering to inform policy (ITS)
  - Solve telecommunications problems of other Federal agencies (ITS)

NTIA's Organization

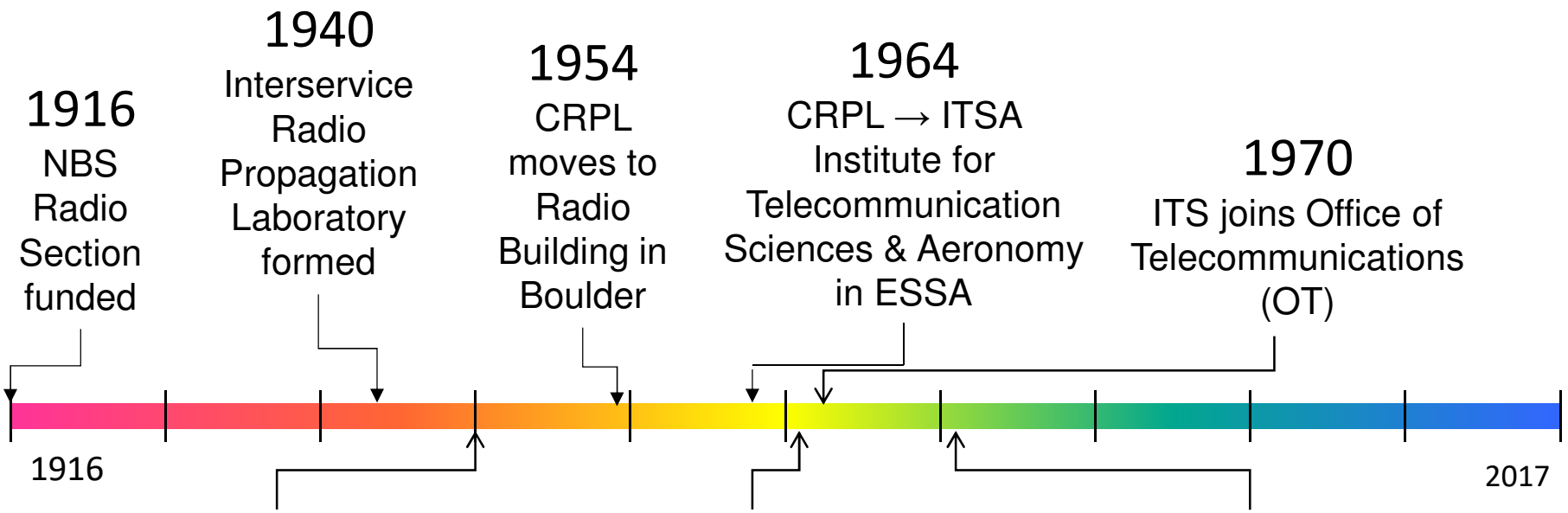


- OSM carries out NTIA's mission and role as the chief Executive Branch agency for federal spectrum policy and management
- ITS is the research and engineering branch of the NTIA and also solves the telecommunications problems of other agencies

Office of Spectrum Management (OSM)

- Manages the Federal government's use of the radio frequency spectrum
  - Establishing and issuing policy regarding allocations and regulations governing the Federal spectrum use
  - Developing plans for the peacetime and wartime use of the spectrum;
  - Assigning frequencies
  - Maintaining spectrum use databases
  - Reviewing Federal agencies' new telecommunications systems and certifying that spectrum will be available
  - Providing the technical engineering expertise needed to perform specific spectrum resources assessments and automated computer capabilities needed to carry out these investigations
- Paige Atkins - OSM Associate Administrator

ITS History: >100 Years of Research



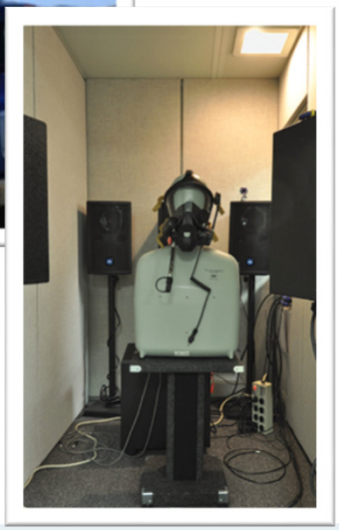
Radio Section → IRPL → CRPL → ITSA → ITS

Institute for Telecommunication Sciences (ITS)

- The Institute for Telecommunication Sciences (ITS) is the U.S. government's premier telecommunications laboratory
  - Located in Boulder, CO
  - ~60 scientists and engineers
- ITS mission:
  - Perform the research and engineering required to inform policy
  - Solve the telecommunications concerns of other Federal agencies
    - ITS receives over 50% of funding from other government agencies
- ITS core capabilities
  - RF propagation modeling (e.g., IF-77, ITM)
  - RF propagation measurement
  - Electromagnetic compatibility (EMC) analysis
  - User experience evaluation

ITS Assets

- **Table Mountain**
  - 1800 acre mesa in Boulder County
    - Radio quiet zone
    - One of 2 in the United States
  - Facilities include laboratory buildings, turntable, antennas
- **RSMS Vehicles and Portable Systems**
  - Mobile RF shielded laboratories
  - Precision measurement equipment
- **Laboratories**
  - Faraday cages, waveform generators
  - Controlled test, sound isolation chambers



Boulder, CO

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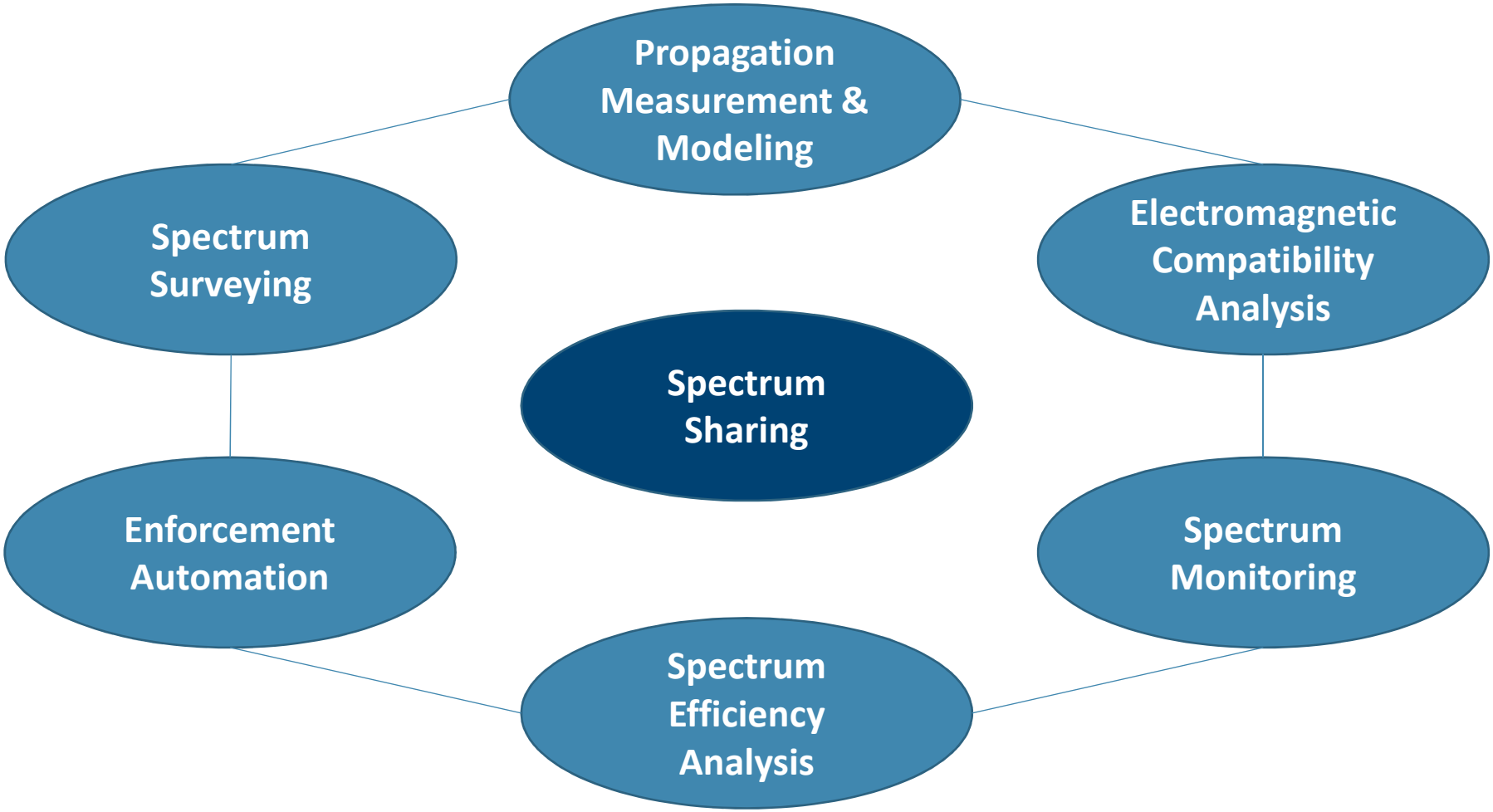
Spectrum Demand

- Demand for radio frequency spectrum is exploding
  - Proliferation of wireless devices
  - Increasing demand for bandwidth hungry data such as video
- But, spectrum is a finite resource
  - Exclusive rights to spectrum is not sustainable
  - Spectrum sharing is the new reality
- Goal to improve spectrum utilization
  - Make Federal/non-federal spectrum available for commercial operation
  - Ensure no loss of critical existing and planned government capabilities
- Sharing is a *strategic and economic imperative*
  - Exclusive use of spectrum will be the exception in the future

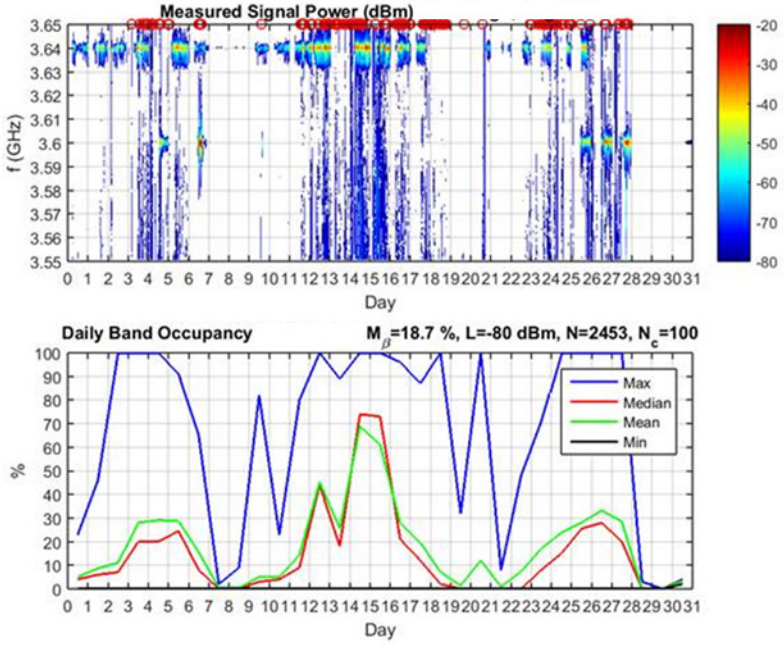
Technology Enablers for Spectrum Sharing



Spectrum Surveying

- Spectrum management requires data:
  - Characterize baseline noise
  - Measure occupancy over time and space
- Spectrum surveys are required to:
  - Validate occupancy/usage models
  - Field test coordination technology
  - Inform planners and policy makers

Measured spectrum occupancy data is required for evaluation of spectrum sharing opportunities.

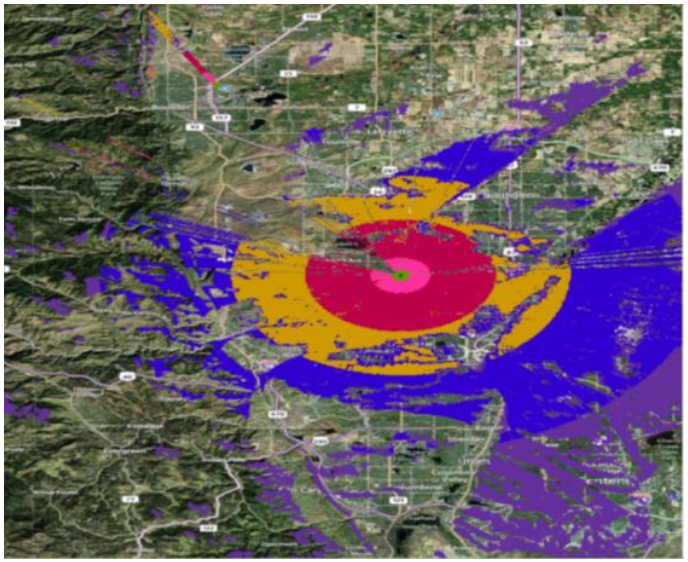


Challenge: Develop spectrum surveying technology that is interoperable, low-cost, high-resolution, and privacy-preserving.

RF Propagation Measurement and Modeling

- Understand and quantify real-world propagation effects
  - E.g., measure transmission loss due to clutter: terrain, structures, foliage, …
- Robust measurements inform enhanced propagation models
  - E.g., clutter distributions enable more accurate predictions of path loss
- Propagation models predict
  - Regions of acceptable reception
  - Areas of potential interference

Propagation models provide insight into operations and effects prior to deployment.

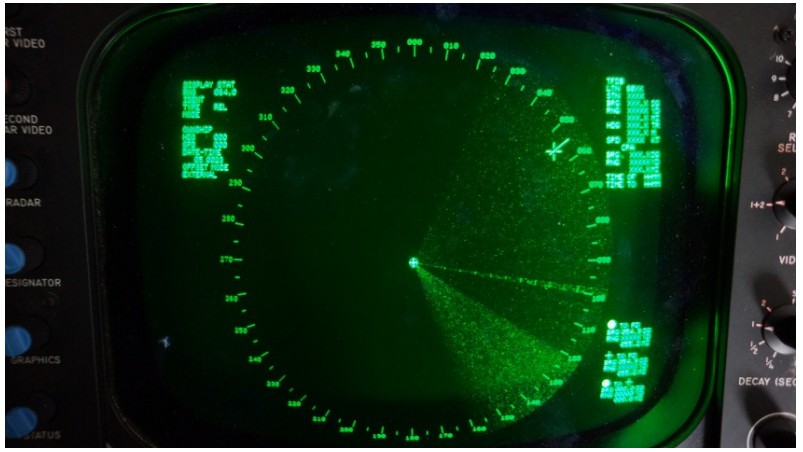


Challenge: Develop propagation models to accurately account for clutter and other effects (foliage, weather, …) and use high-resolution terrain/feature data.

Electromagnetic Compatibility (EMC) Analysis

- Sharing between Federal and non-federal systems must preserve mission-critical functions
  - Need quantitative determination of interference protection criteria (IPC)
  - Receiver IPC are needed to determine minimum separation distances between systems

Coupled with measurement and modeling, EMC analysis is required to protect systems from harmful effects.

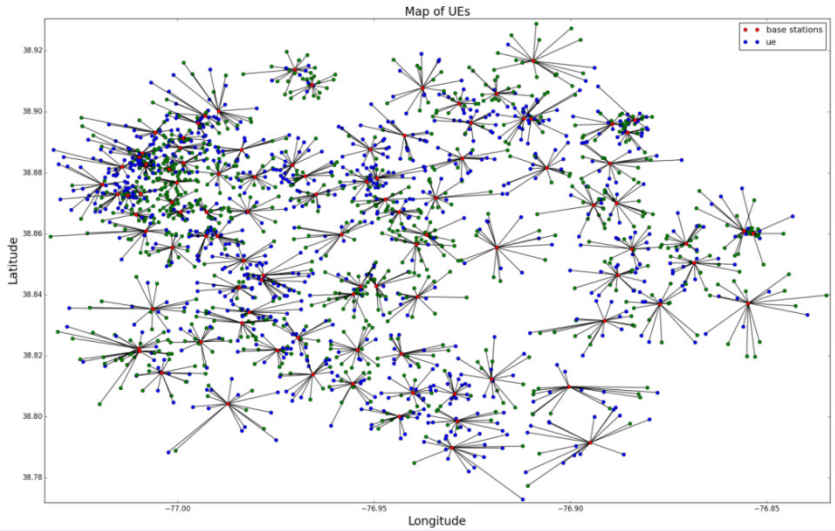


Strobe created by -6 dB INR LTE interference

Challenge: Develop tools to rapidly determine electromagnetic compatibility between legacy systems and new/evolving systems.

EMC Analysis - Aggregate Modeling

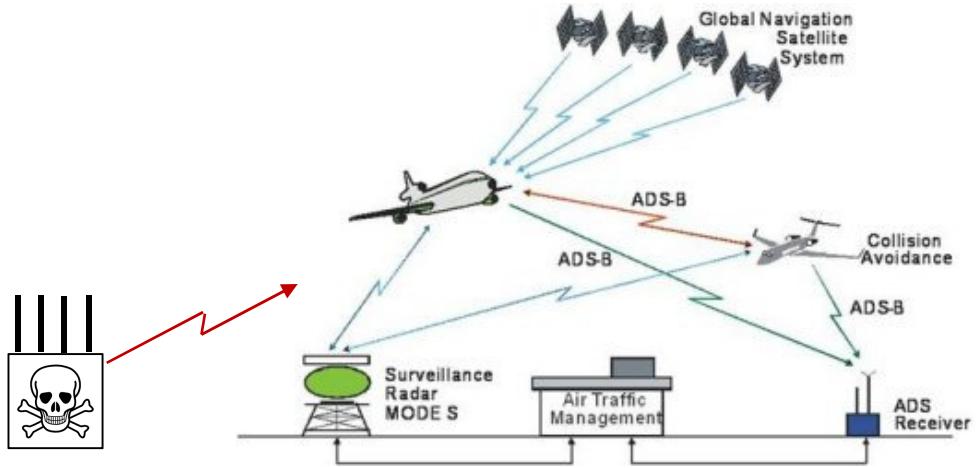
- Determine accurate predictions of probable aggregate interference from a collection of transmitters
  - e.g., overall effects of large numbers of cellphones in operation
- Critical tool for spectrum sharing
  - Risk assessment for geographic proximity of systems
  - Evaluation of proposed exclusion zones



Challenge: Understand and quantify the effects that result from collections of transmitters all operating within range of target systems.

Spectrum Monitoring

- Protect mission/life critical systems
  - e.g., radars, public safety comms, military training and telemetry, satellite comms, medical
  - i.e., protect a designated region bounded in space, time, and frequency)
- Enforcement functions of spectrum monitoring:
  - Detect an RF incursion
  - Locate in real-time or forensically
  - Classify by type and severity
  - Resolve/Remediate: alert appropriate enforcement organization

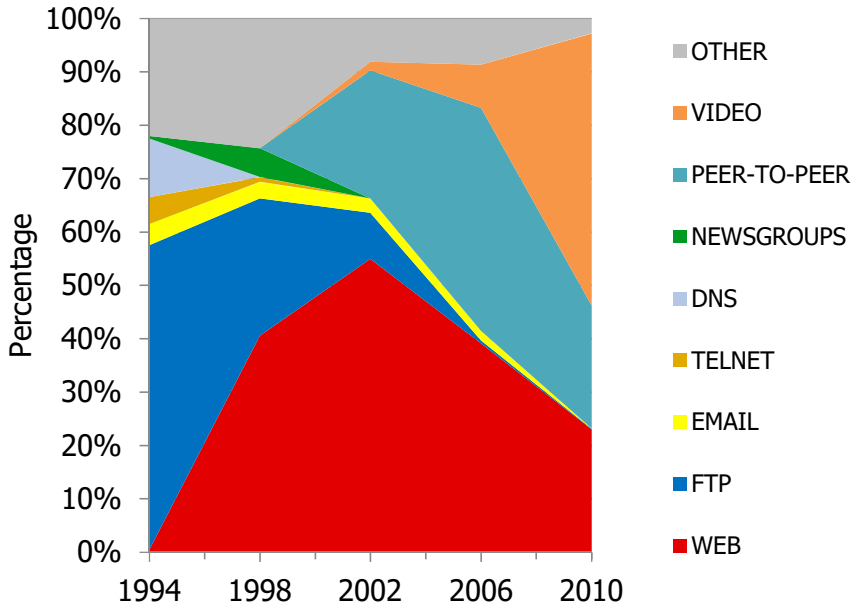


Challenge: Need a cost-effective means to effectively monitor the "RF perimeter" of an "RF reservation"

Spectrum Efficiency Analysis

- Exploit options to make efficient use of spectrum
- Video is dominating communications
  - Bandwidth intensive
  - Demand for increased resolution
    - SD -> HD -> 4K -> ….
- Compression for efficiency
  - MPEG-2 (1996) OTA broadcast
  - AVC/H.264 (2003) blu-ray, satellite
  - HEVC/H.265 (2013) in progress

End-user experience is the bottom line for evaluation of video quality.



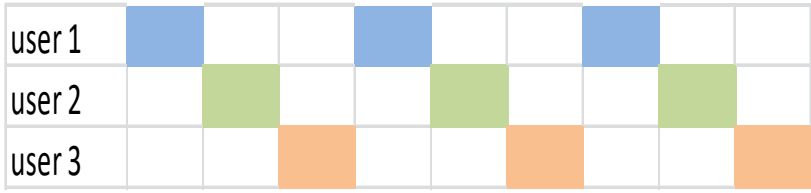
Challenge: Develop automated tools that accurately reflect subjective evaluations of video (and audio) quality.

Spectrum Efficiency (SE)

- **Good News**: Uniformly agreed international SE definition: (useful throughput)/(bandwidth x time x volume) as given in ITU-R SM.1046-2.
- **Bad news**: Really difficult (but not impossible) to actually apply the definition to actual systems
- Both ITU-R and CSMAC have emphasized that only like radio systems (same service type to same sorts of users) can or should be compared to each other.
- SE is based on how much spectrum a transmitter or receiver blocks for other potential users
- Systems that **share more** spectrum **block less**, so are more SE.
- Sharing needs further examination in SE studies

Spectrum Efficiency

- Not as simple as maximizing occupancy or throughput
- Need to measure the amount of sharing and info transfer (overhead) required for sharing
- Traffic type dictates the granularity of sharing possible
- Need to consider
  - Time occupied
  - Spatial extent
  - Transmitter power



Challenge: Automatically compute real-world measurands that enable comparisons of disparate systems.

Spectrum Use Enforcement

- Enable detection, location, classification, and identification of:
  - Inadvertent interference/occupancy
  - Algorithm/technology failures
  - Bad actors
- Translate sharing agreements/licenses into measureable parameters
  - (easy) Enforcement of exclusion zones with RF perimeter monitors
  - (harder) Dynamic sharing using SAS and ESC monitoring systems – geographic + temporal restrictions
  - (hardest) Dynamic sharing in same time/space – e.g., unlicensed spectrum

Challenge: Translate sharing agreements into measurable parameters, and develop software to monitor compliance and detect violations while preserving privacy.

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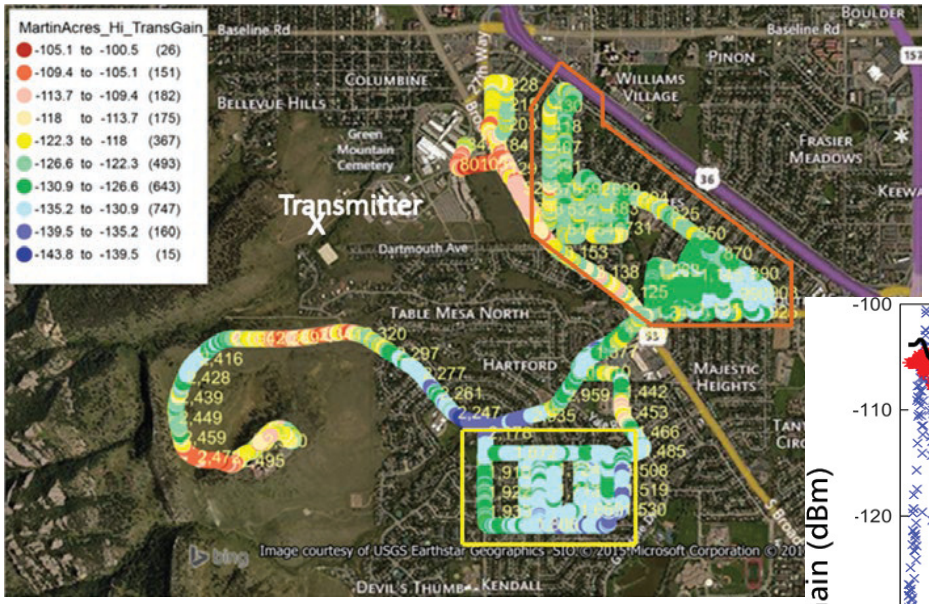
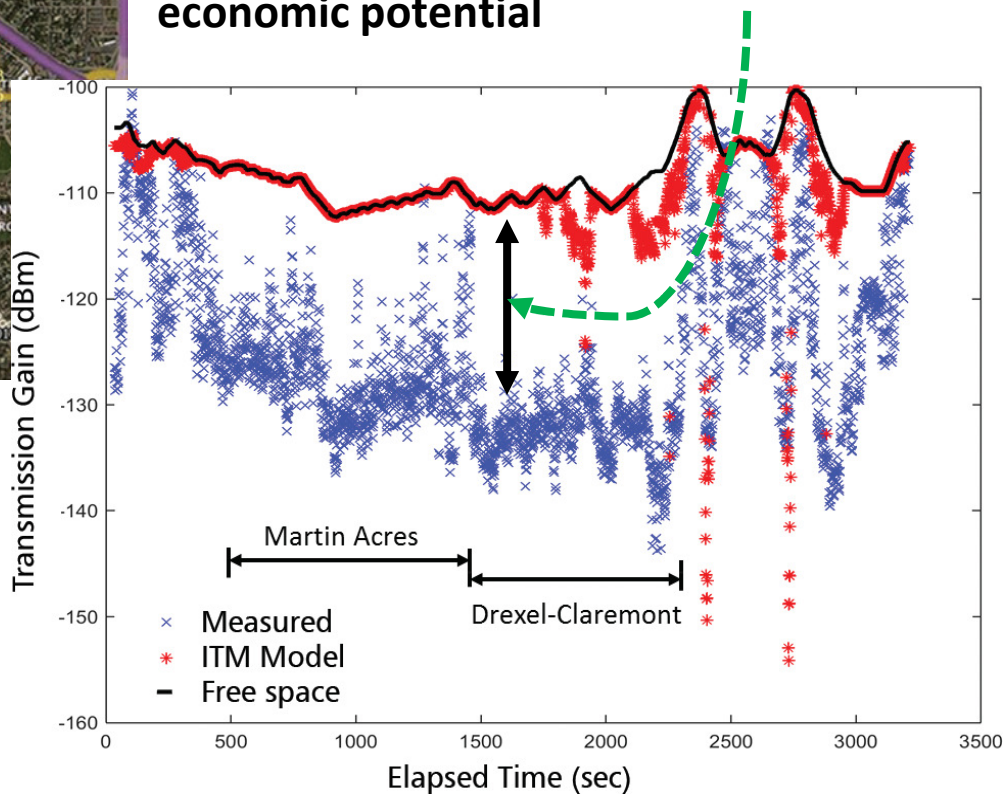
Clutter Loss



- RF propagation is significantly affected by "clutter" – trees, structures, terrain, …
- Understanding the effects of clutter is critical to defining good exclusion zones or maximizing sharing

Propagation loss due to clutter is lost economic potential



Case Study
3.5 GHz Exclusion Zone Analysis

- Protection zone defines the geographic separation between macro-cell networks and radars
- 2010 Fast Track Report
  - Protection zones of 40-60 km
  - Simplified propagation model
- Revised 2014 NTIA analysis
  - Reduced protection zones by >77%
  - Enhanced propagation model
  - Enhanced clutter model
- Ongoing collaboration among NTIA, FCC, DoD, and industry to enable dynamic sharing within protection zones

Fast Track exclusion zone

NTIA revised exclusion zone

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Summary

- Spectrum access is a requirement for 21st century life
  - Key enabler for world-leading consumer technologies
  - Key infrastructure for Federal and non-federal sectors
- Spectrum sharing is the future – a *strategic imperative*
- Spectrum sharing is happening
  - 5 GHz made available for U-NII devices
    - Sharing implemented using dynamic frequency selection (DFS)
  - 1755-1780 MHz band affected 15 Federal agencies
    - Geographic sharing over 10-year transition period
  - 3.5 GHz made available for shared small cell use
    - Spectrum Access System (SAS) and Environmental Sensing Capability (ESC) provide technology for dynamic sharing and interference mitigation

Innovative technologies, policies, and processes will enable effective and efficient spectrum sharing.

Questions?