DEFENSE INFORMATION SYSTEMS AGENCY
The IT Combat Support Agency

# Defense Spectrum Organization

## Innovations in Electromagnetic Spectrum Sharing

# Disclaimer

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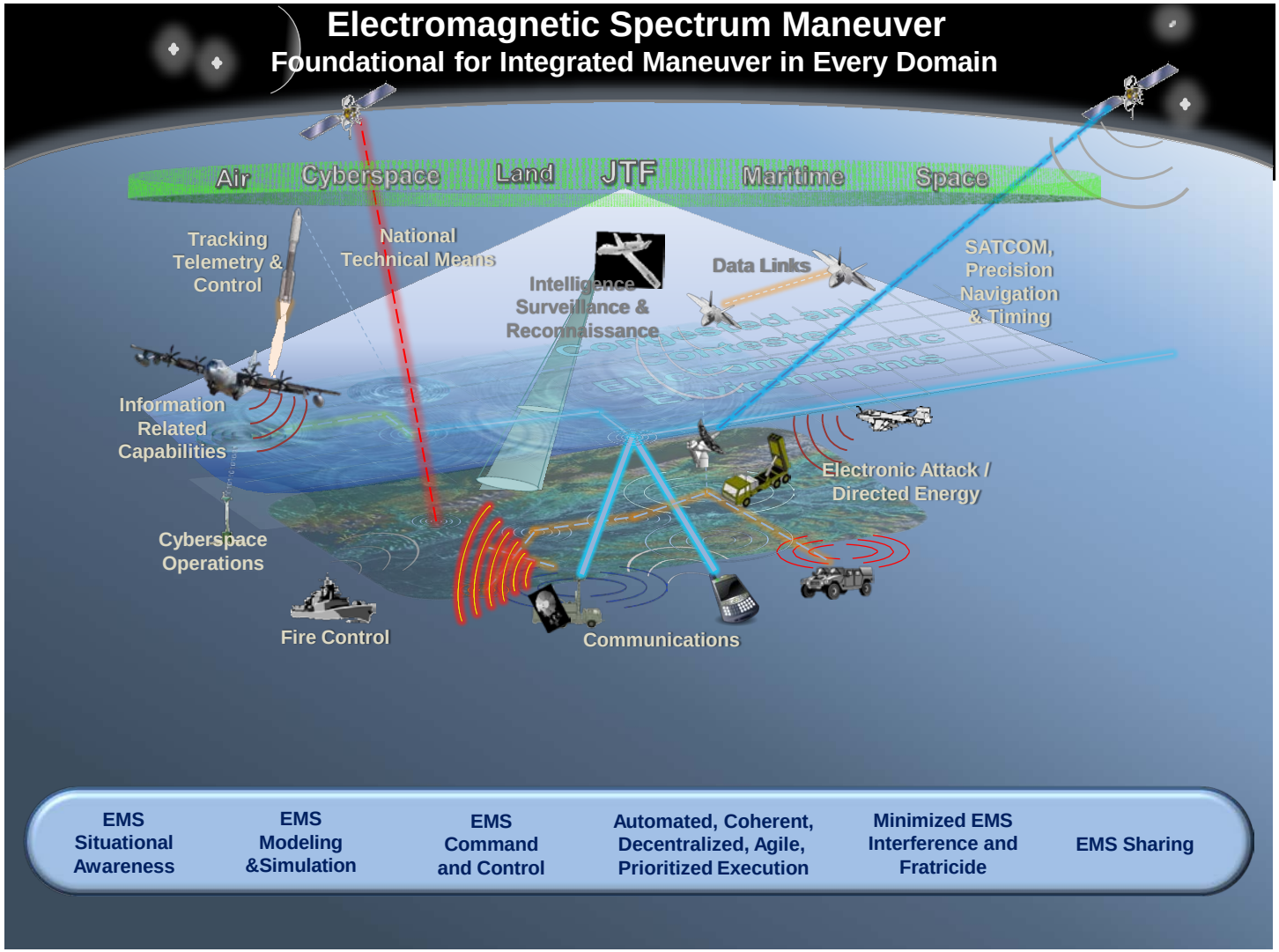
Electromagnetic Spectrum Maneuver
Foundational for Integrated Maneuver in Every Domain
Air
Cyberspace
Land
JTF
Maritime
Space
Tracking Telemetry & Control
National Technical Means
Intelligence Surveillance & Reconnaissance
Data Links
SATCOM, Precision Navigation & Timing
Information Related Capabilities
Electronic Attack / Directed Energy
Cyberspace Operations
Fire Control
Communications
EMS Situational Awareness
EMS Modeling &Simulation
EMS Command and Control
Automated, Coherent, Decentralized, Agile, Prioritized Execution
Minimized EMS Interference and Fratricide
EMS Sharing

# Overview

- Introduction
- Transformations in Spectrum Sharing – Greg Wagner - 5 min
- EMS Algorithm Innovations - 10 min – Stuart Schutta
- EMS Big Data Analytics - 10 min – Betsy Park
- EMS Visualization - 10 min – Rocky Rocksvold
- EMS Sharing System Innovations - 10 min – Howard McDonald
- Q&A - 10 min

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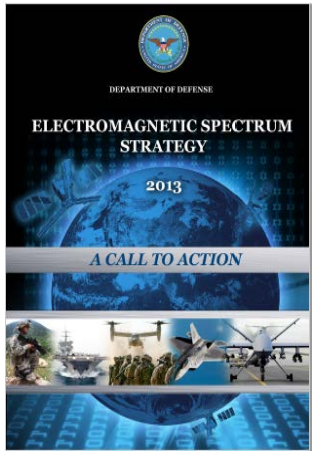
# Spectrum Sharing Transformations

Gregory C. Wagner
Defense Spectrum Organization
16 May 2018

# DOD Spectrum Sharing

**"Spectrum Sharing"**

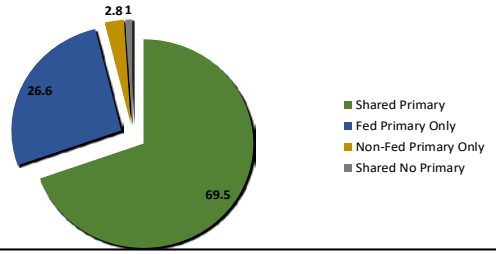



***Goal 1, Objective 2: "Accelerate the fielding of technologies that enable spectrum sharing and improve access opportunities"***

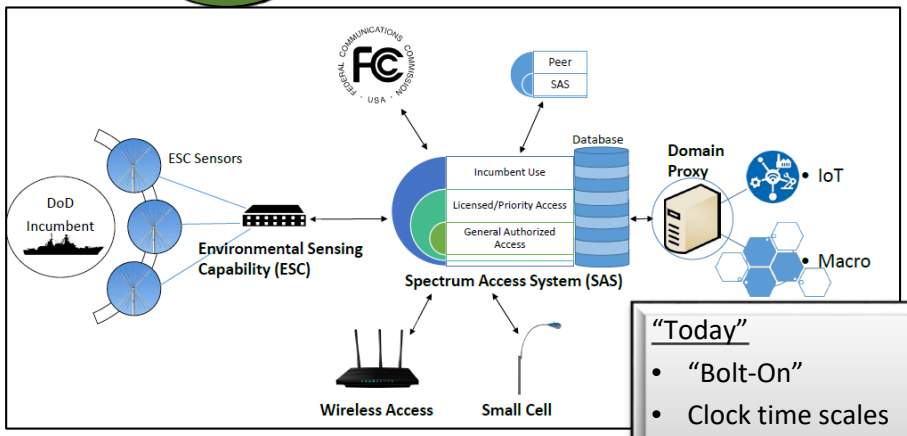
***"Technology innovation will overcome some of today's challenges associated with spectrum sharing, such as the risk of harmful interference."***

***Goal 2, Objective 1: "Develop the ability to perform near-real time spectrum operations"***

***"…DoD will improve its capabilities to plan, manage, and control all dimensions of spectrum use to preserve access to and maneuver within the EME."***




"Yesterday"
- Procedural
- Calendar time scales
- Static




"Today"
- "Bolt-On"
- Clock time scales
- Semi-automated

**"Cooperative Spectrum Use"**

***Spectrum Sharing Increases DOD's Lethality & Improves Information Dominance***

# Spectrum Sharing Evolution

| | Yesterday | Today | Tomorrow |
|---|---|---|---|
| ***Sharing Mechanisms*** | Human-based | Bolt On: Ecosystems | Baked In: Devices |
| ***Time Scales*** | Calendar | Clock | Machine |
| ***Technical Approach*** | Procedural<br>Static | Procedurally defined<br>Semi-automated<br>Incumbent-centric | Policy constrained<br>Autonomous<br>Co-equal access |
| ***Interference*** | Ex Ante:<br>Avoidance | Ex Poste:<br>Detect/Clear | Ex Poste:<br>Detect/React |
| ***Interference Risk Mgmt*** | Avoid | Reduce/Mitigate | Accept/Tolerate/Mitigate |
| ***Analyses*** | Basic techniques, basic data | High-fidelity techniques & data | Behavior-based techniques with high quality data |
| ***Nature*** | Simple | Complicated | Complex |

**EMS** ***Management*** → **EMS** ***Operations***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# Algorithm Innovations

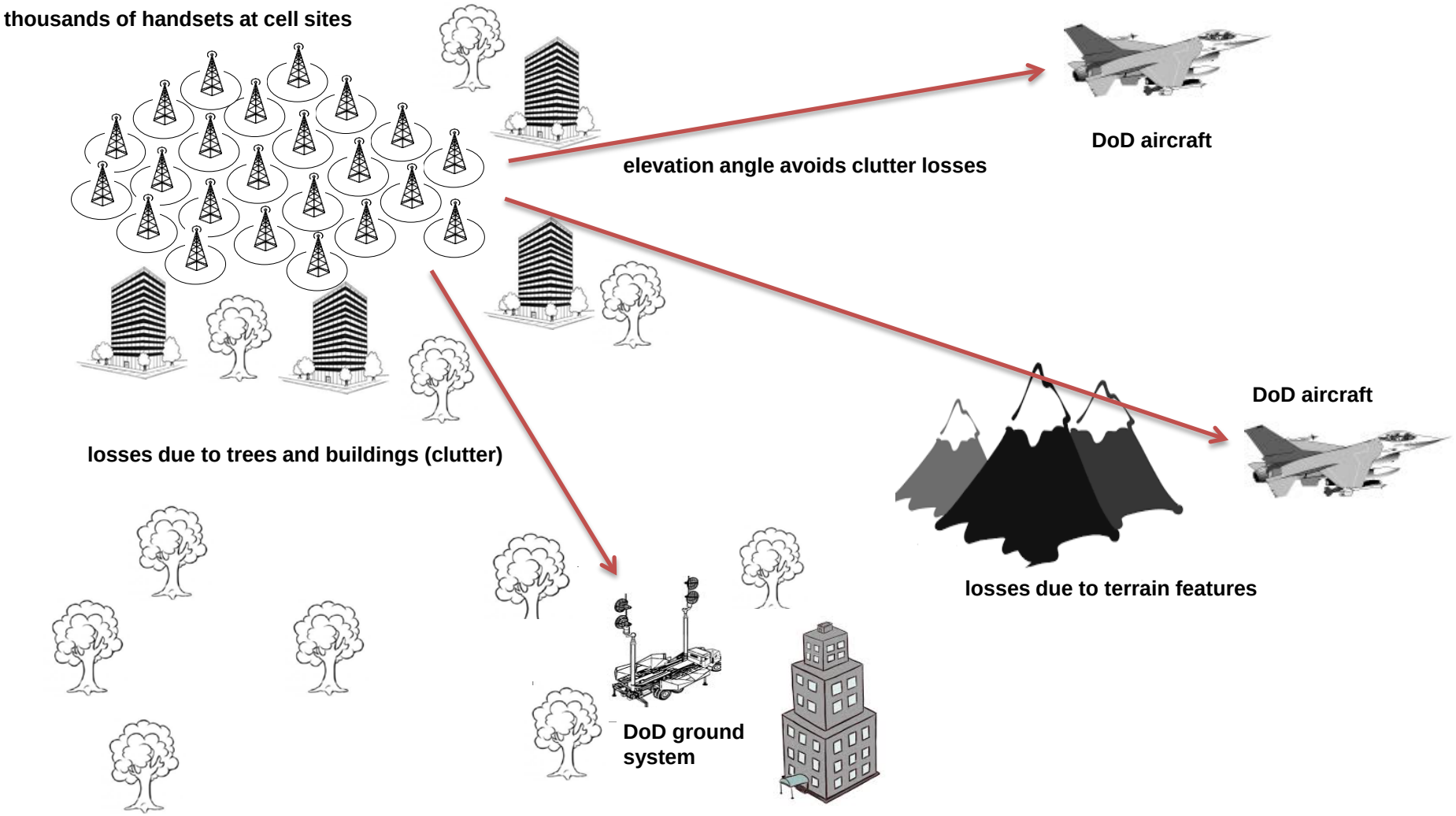
## Analyzing Aggregate Interference

Stuart Schutta

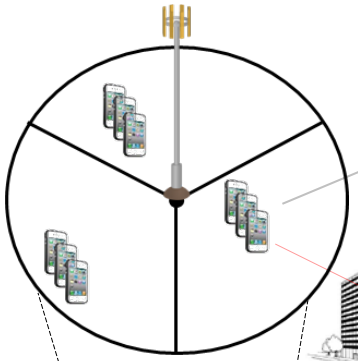
Defense Spectrum Organization

16 May 2018

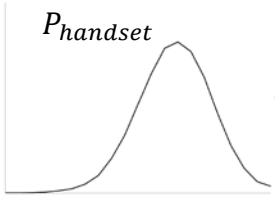
# The Early Entry Problem



# A Statistical Analysis Approach



$P_{handset}$

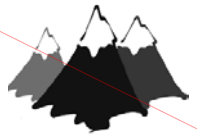


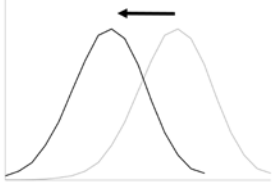
handset transmitted power

$I_{handset} = P_{handset} - L_{path} - L_{clutter} - L_{other}$

clutter losses $(L_{clutter})$

terrain losses $(L_{path})$

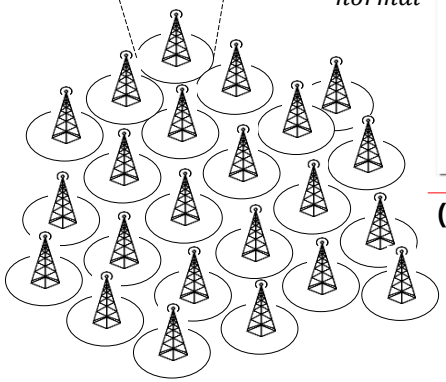


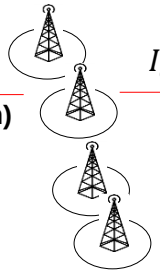


DoD receiver model

interference from a single handset $(I_{handset})$

$I_{normal} \leftarrow \sum_{I_{handset}} \mu, \sum_{I_{handset}} \sigma^2$

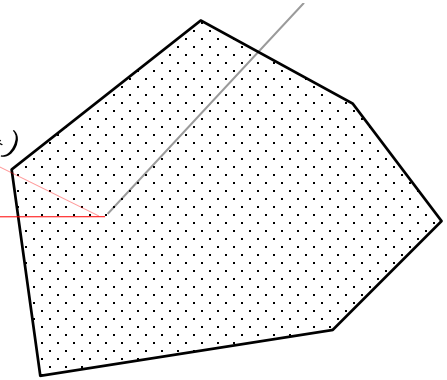




(central limit theorem)

$I_{aggregate} = I_{normal} * I_{handset,ex}$

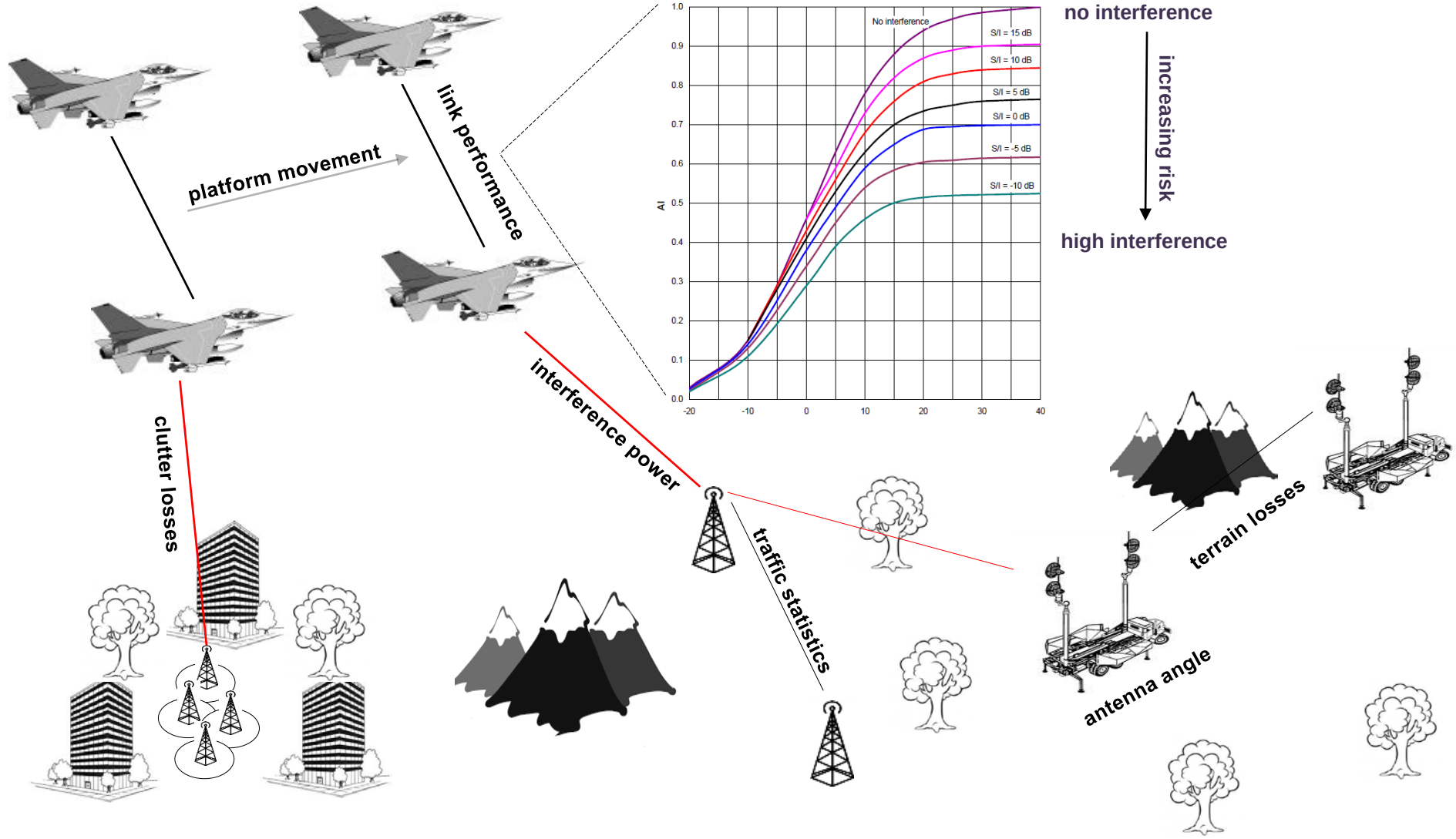
(numerical convolution)



sampled operations area

handsets $(I_{handset,ex})$ excluded from $I_{normal}$
(violate central limit theorem conditions)

# Risk-based Interference Analysis

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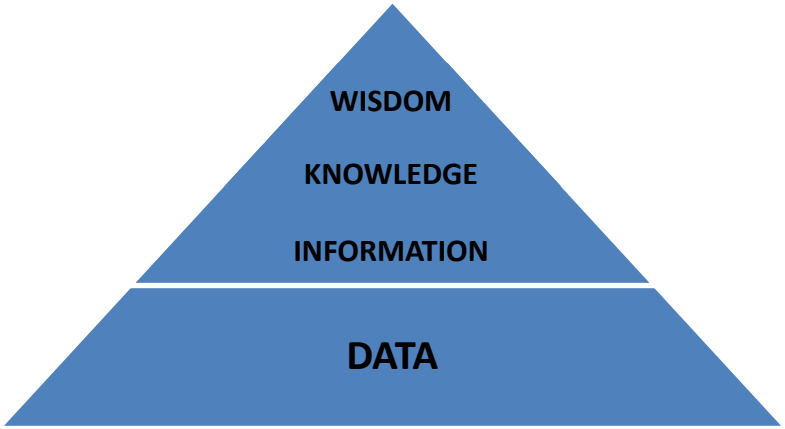
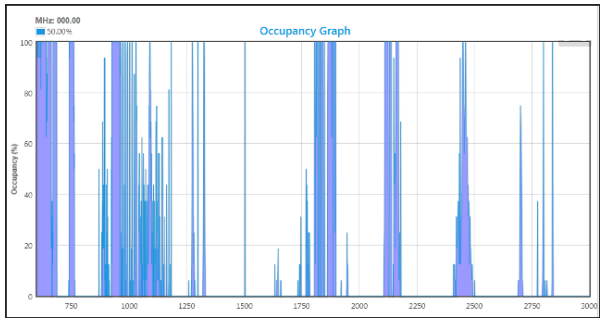
# Big Data and Analytics in the Spectrum Domain

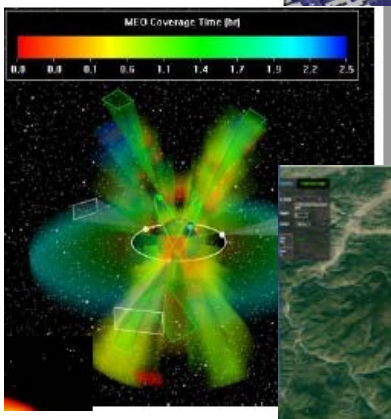


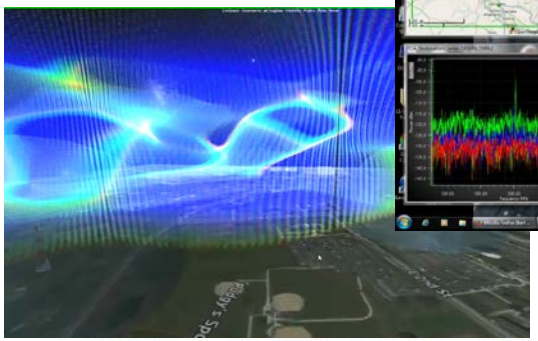

Elizabeth Park
JSDR Product Lead
Defense Spectrum Organization – GEMSIS SE Branch
May 2018

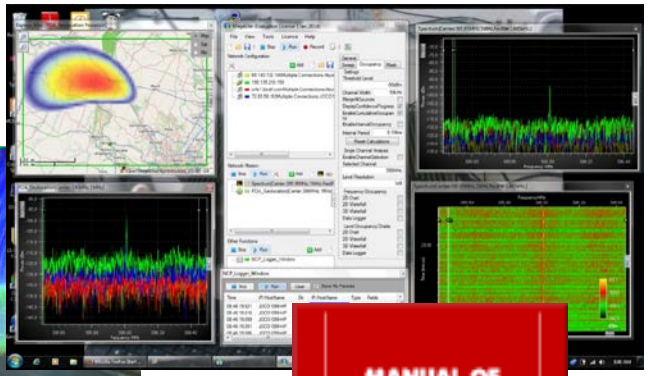
# Spectrum Data: Inherently – Big Data

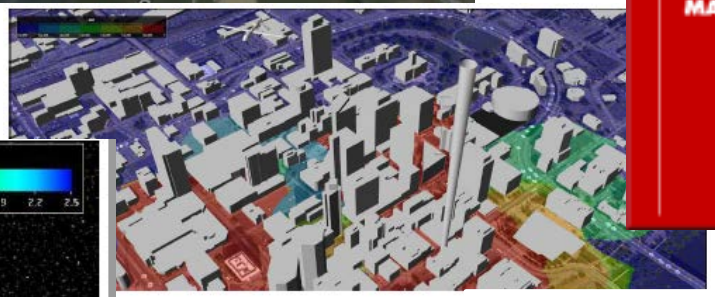
- Regulatory Data
- Frequency Assignments/Channel Allotments
- Equipment Characteristics
- Emitter Position Information
- Interference Reports
- Spectrum Dependent Modeling and Simulation
- Environmental Data
- Spectrum Monitoring Data
- C2, Electronic Warfare

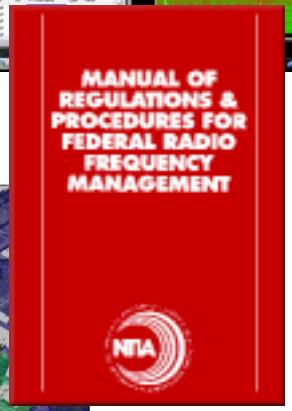








# 4 V's of Big Data

- **What is "Big Data"?**
  - **4 – V's: Volume, Velocity, Variety, Veracity**
- **Volume – How "Big" is your raw dataset?**
  - Most data scientists still deal with datasets in the gigabyte range (2016 KDD Poll)
  - Current spectrum data sets – with exception of monitoring data – are in the GB
- **Variety – How does your data vary?**
  - Most data is still in tables or text (KDD 2017 Poll)
  - Spectrum data – wide variety – structured, unstructured
- **Veracity – How uncertain is your data?**
  - Current spectrum data has ambiguity in structure and value
  - Spectrum domain's greatest challenge
- **Velocity – How often does your data change?**
  - Expect dramatic increase in spectrum data velocity
  - Raw signal or measured data from sensors or logging provide unique challenges


source: https://image.freepik.com/free-vector/big-data-concept_23-2147509540.jpg

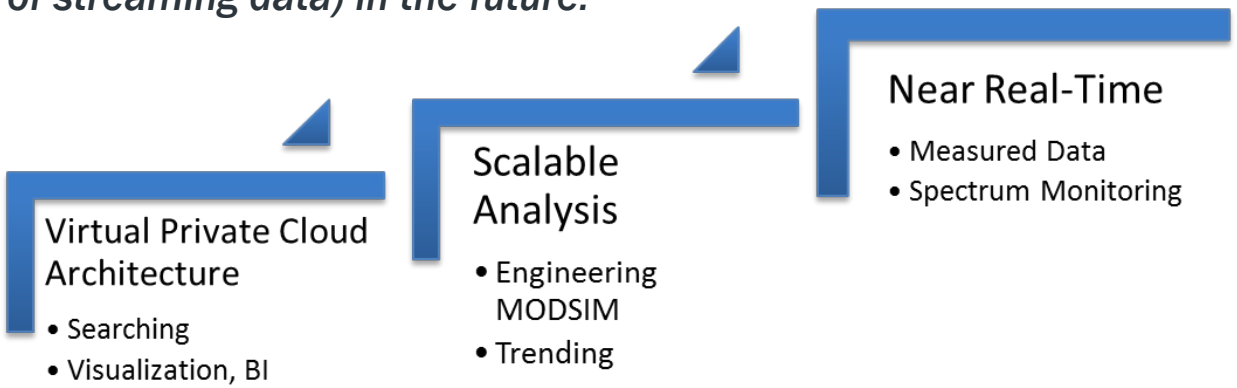
# DSO Initiatives: Joint Spectrum Data Repository

**DSO's Joint Spectrum Data Repository (JSDR) contains DoD, national, and international spectrum-related information up to the Secret level which can be accessed via various interfaces:**

- Structured Queries (Multiple Legacy Data Sources)
- Content Management System
- Business Intelligence and Analytics
- Universal Query
- Business Process Rules Engine
- Geographical Information System
- Engineering Services
- REST API for M2M data import and distribution

**JSDR is currently deployed in MilCloud 1.0 and will migrate to MilCloud 2.0**

*The JSDR architecture handles Volume, Variety and Veracity with an eye toward Velocity (integration of streaming data) in the future.*



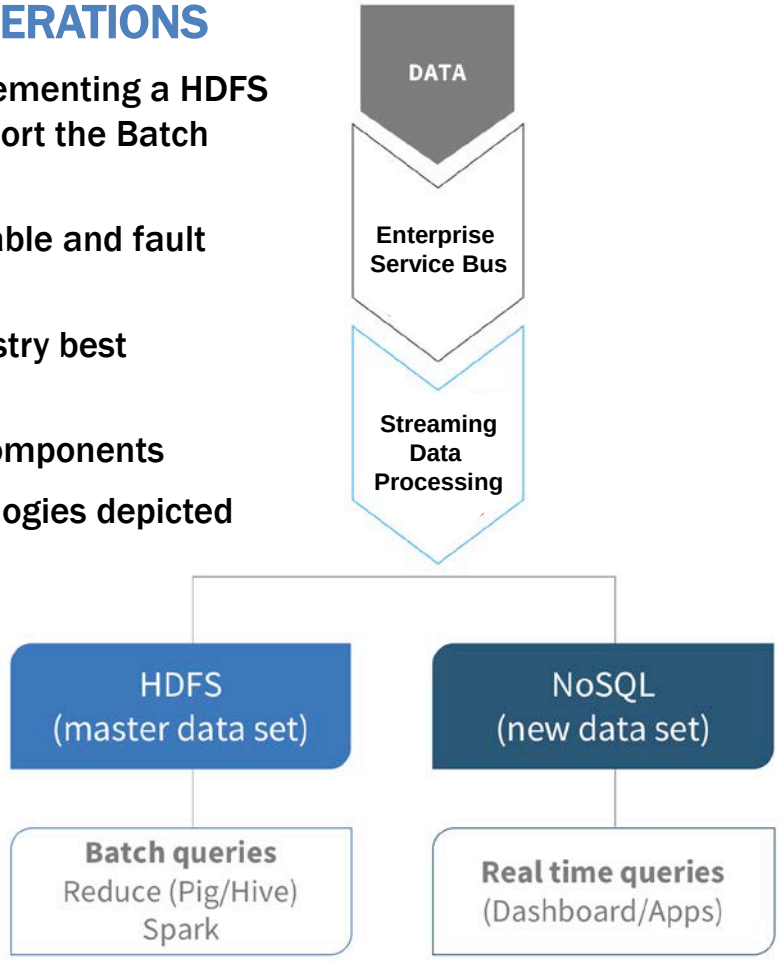
# Future Architecture Considerations

## CURRENT ARCHITECTURE

- JSDR currently provides Speed and Serving layers via:
  - ElasticSearch
  - MongoDB
  - Apache Fuse
- Metadata handling can be added on the data processing/ingest layer. We currently utilize Pentaho Data Integration to provide data processing and ingest into the JSDR.

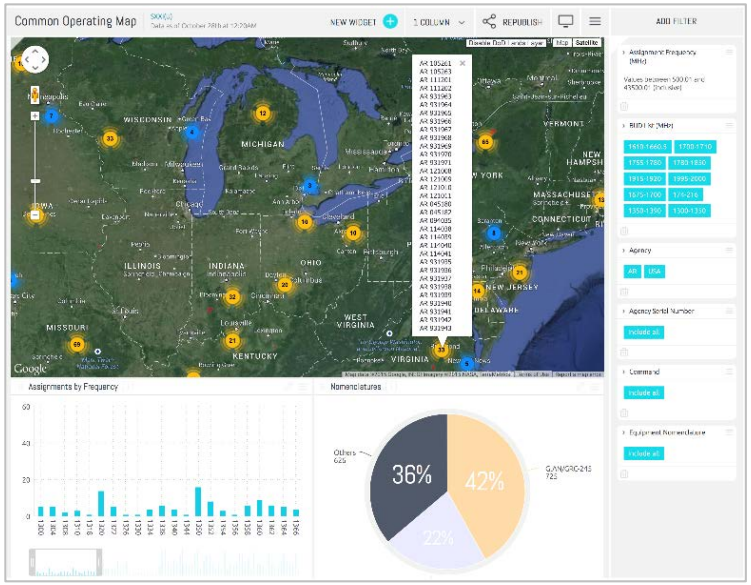
## FUTURE CONSIDERATIONS

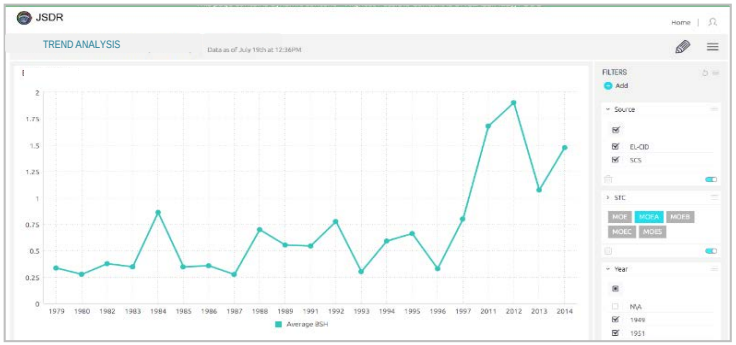
- Look toward implementing a HDFS data store to support the Batch layer
- Each layer is scalable and fault tolerant
- Incorporates industry best practices
- All open source components
- Candidate technologies depicted

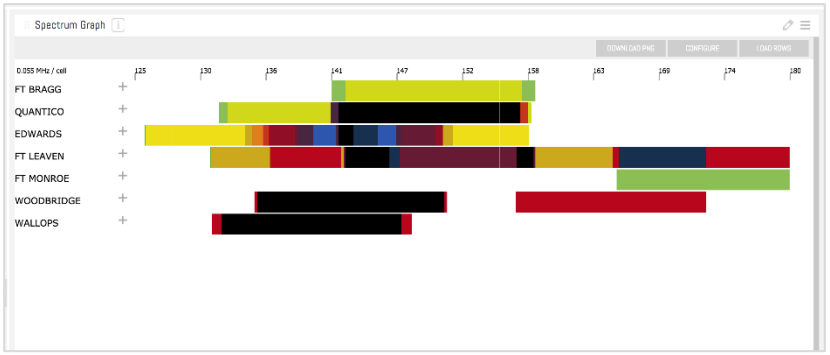


# Strategic Planning Use Cases: Leveraging Data Analytics

- Quantifying DoD EMS equities
- Impact of spectrum regulatory changes on DoD operations (CONUS and OCONUS)
- Historical evaluation of DoD spectrum usage
- Trends/metrics for spectrum efficiency (b/s/hz)
- Prediction of interference events
- Identify data quality issues
- Predict of future constraints
- Identify acquisition risk

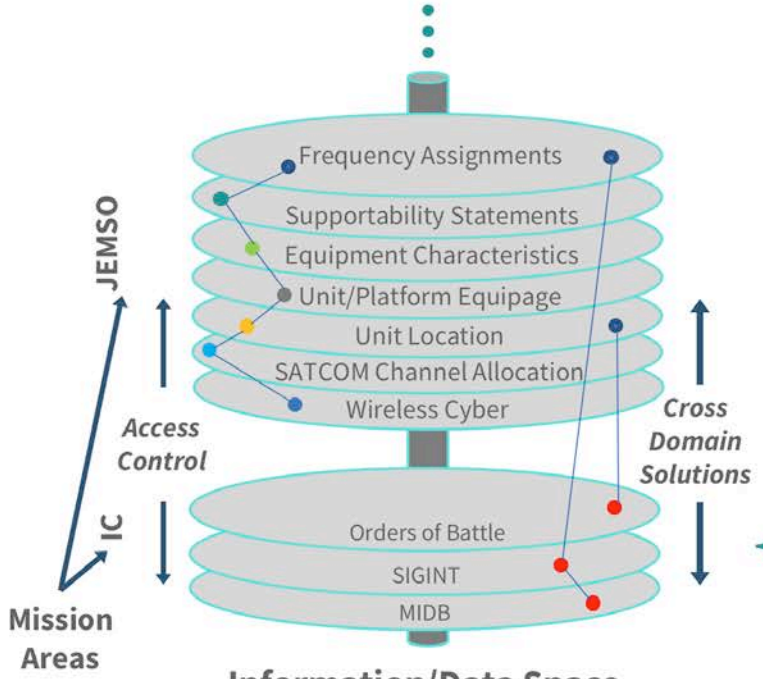


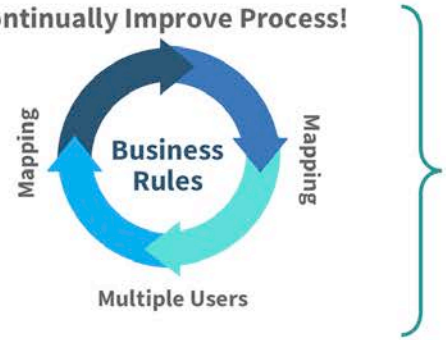
# Decision Support Use Case

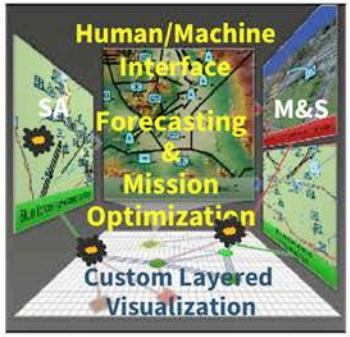
## Spectrum Operations Enterprise View




**Example Enterprise Data / Applications – "Plug & Play"**

***Fusion 'connecting the dots'***




GUIDANCE – WHAT CAN YOU DO

APPLICATIONS

Decision Support Space

| | | | |
|---|---|---|---|
| EM Analysis | Mission planner | Custom Layer Visualization | Situational Awareness |
| System Parametric Data | Mission Conflict ID | Operational Analysis | Intelligence Data |

**Business Process/Access/CM**

**Ops in the EMS**

SIGINT | EW | Space Ops | ISR | Cyber | Spec Man.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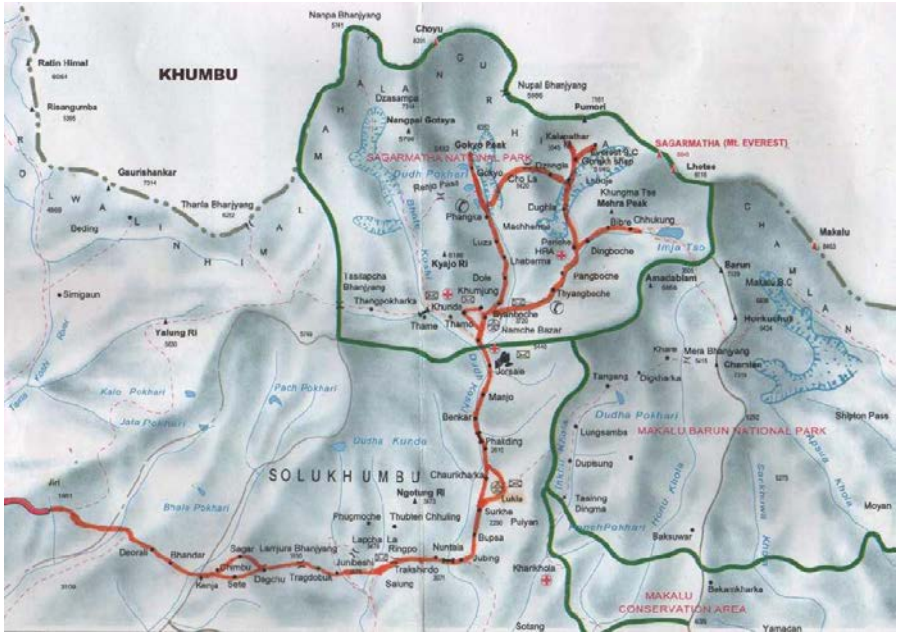
# Spectrum Data Visualization

Edward “Rocky” Rocksvold
International Team Lead, DSO SPD
16 May 2018

# Visualization is Everything

***Planning for a little hike in the mountains***




***I have all the data I need, but…***

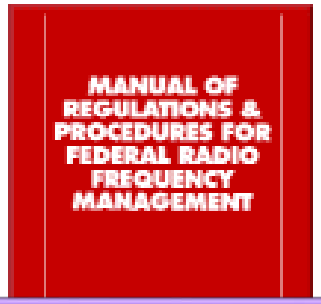
Source: http://www.mappery.com/map-of/Mt-Everest-Map

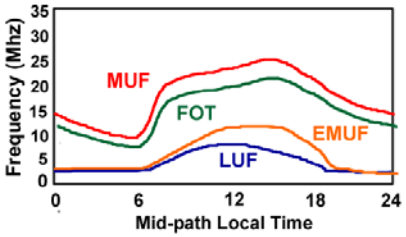
# Visualization is Everything

***The way I visualize the data makes all the difference!!***


Source: https://www.quora.com/How-does-climbing-to-the-Everest-Base-Camp-One-compare-to-climbing-to-the-summit

# Making Sense of the Data

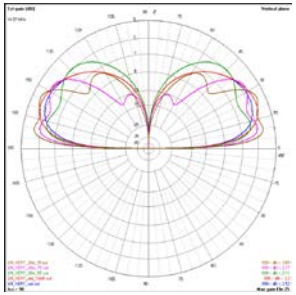



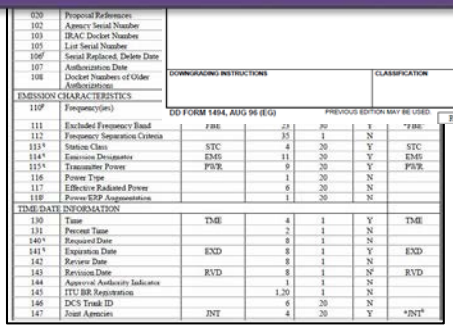


**Visualization brings all this data together**

3 600-4 800 MHz

| Allocation to services | | |
|---|---|---|
| **Region 1** | **Region 2** | **Region 3** |
| **3 600-4 200**<br>FIXED<br>FIXED-SATELLITE (space-to-Earth)<br>Mobile | **3 600-3 700**<br>FIXED<br>FIXED-SATELLITE (space-to-Earth)<br>MOBILE except aeronautical mobile 5.434<br>Radiolocation 5.433 | **3 600-3 700**<br>FIXED<br>FIXED-SATELLITE (space-to-Earth)<br>MOBILE except aeronautical mobile<br>Radiolocation<br>5.435 |
| | **3 700-4 200**<br>FIXED<br>FIXED-SATELLITE (space-to-Earth)<br>MOBILE except aeronautical mobile | |
| **4 200-4 400** | AERONAUTICAL MOBILE (R) 5.436<br>AERONAUTICAL RADIONAVIGATION 5.438<br>5.437 5.439 5.440 | |
| **4 400-4 500** | FIXED<br>MOBILE 5.440A | |
| **4 500-4 800** | FIXED<br>FIXED-SATELLITE (space-to-Earth) 5.441<br>MOBILE 5.440A | |



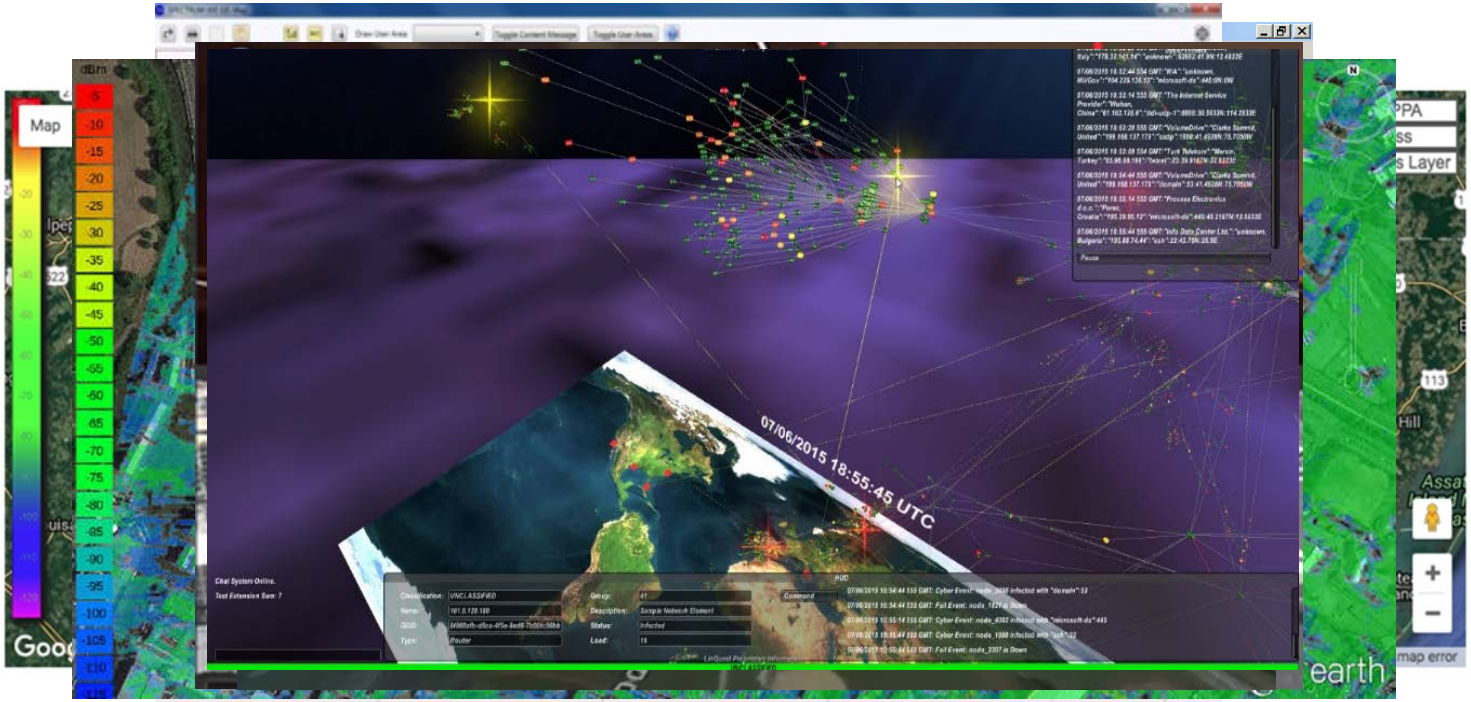



# Spectrum Data Visualization

- **Critical to inform DOD strategic spectrum planning and Electromagnetic Spectrum Management (EMS) C2 decision-making**
- **DoD experiencing higher demands for spectrum**
- **Advancing capabilities to better inform planners and operators in the modern EMS maneuver space**

***The modern EMS environment demands advanced visualization capabilities for the warfighter***

# Path to Innovation

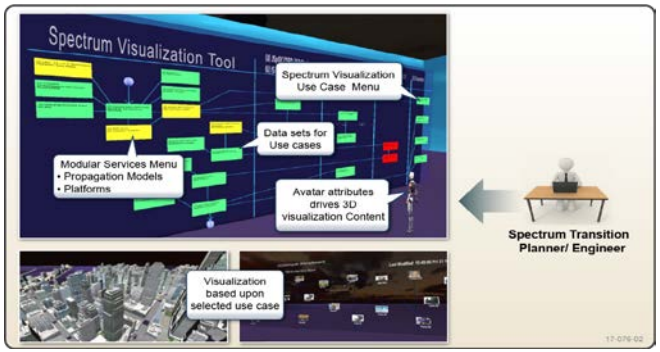



**Traditional (SPECTRUM XXI)** → **Today (JSDR)** → **Innovating for tomorrow**

# DSO Spectrum Data Visualization Efforts

## National Spectrum Consortium Effort

- Spectrum-related use-cases using structured and unstructured data
- Leveraging 3D gaming technology




## DoD Rapid Innovation Fund

- Additional innovative approaches
- Effort is just beginning and generating a lot of interest

***Objective: Improve DOD strategic and operational spectrum management decision-making through innovative visualization***

# Wrap-up

- **Exploring disruptive visualization technology to improve EMS situational awareness through enhanced modeling & simulation**
- **Leveraging commercial industry solutions such as 3D gaming technology**
- **GOAL: Provide improved spectrum data visualization capabilities to support strategic spectrum planning and EMS C2 decision-making**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# Sharing Systems Innovations:,

## 2025-2110 MHz Spectrum Sharing Use Case

Howard McDonald

Defense Spectrum Organization

16 May 2018

# Recent Regulatory Changes 2025-2110 MHz

- **As a result of the Federal Communication Commission (FCC) AWS-3 auction, Federal agency operations are being displaced from 1755-1780 MHz**
  - **Several major DoD systems will suffer the loss of spectrum access**
  - **NTIA identified 2025-2110 MHz as a candidate band for relocation with DoD as co-primary status with Broadcast Auxiliary Service (BAS)**
  - **Many of the DoD activities in the continental U.S. take place in comparatively remote areas and fall into the fixed and mobile radiocommunication services, facilitating sharing this band**
- **These changes required an innovative approach to spectrum sharing.**

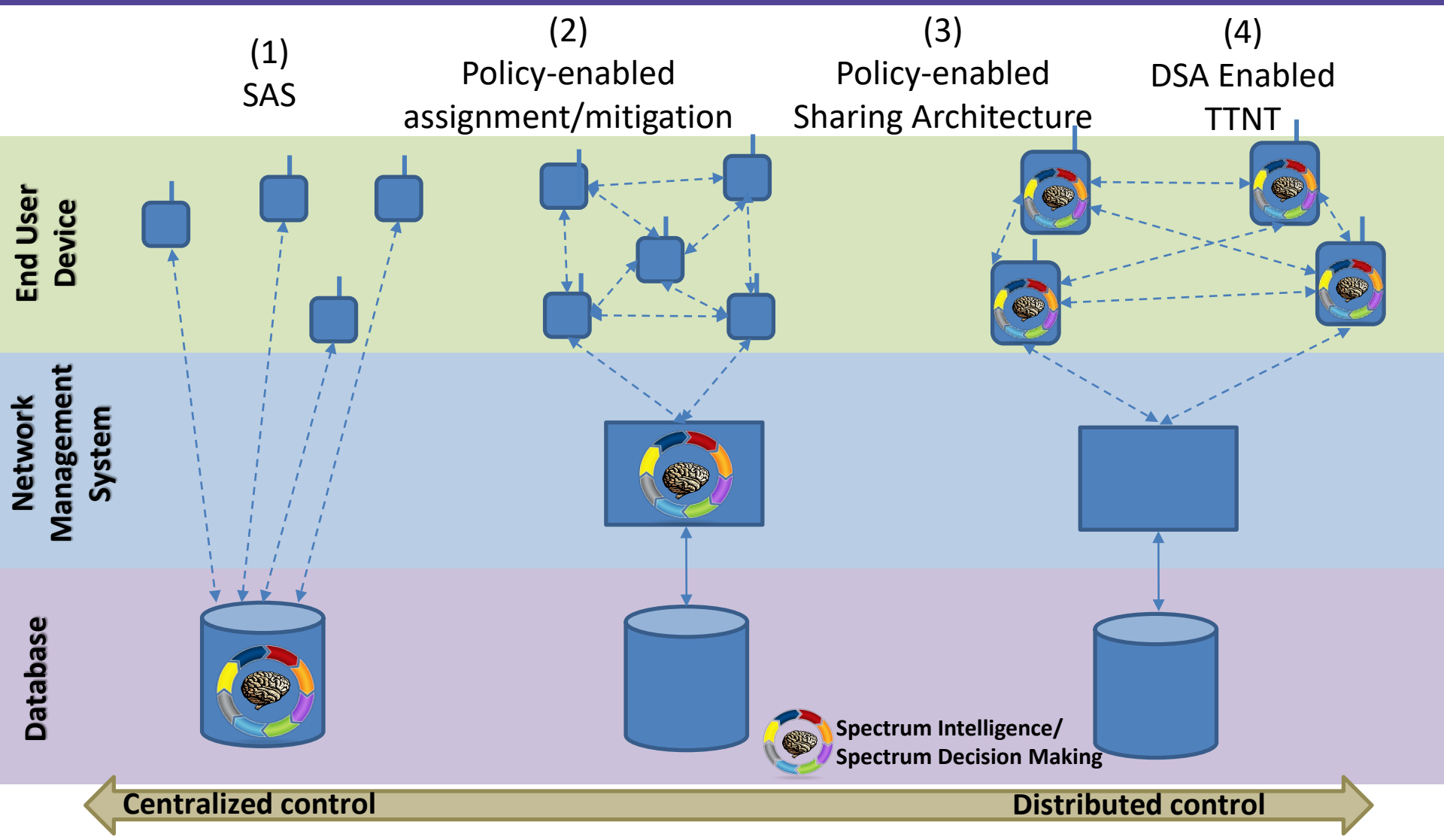
# DoD Systems

- **Four DoD systems planned to share spectrum BAS operations in the 2025-2110 MHz band:**
  - **Tactical Radio Relay (TRR)**
  - **Small Unmanned Aircraft Systems (SUAS)**
  - **High Resolution Video (HRV)**
  - **Tactical Targeting and Networking Technology (TTNT)**

# Advanced Sharing Concepts

- **DSO awarded four contracts for a dynamic sharing system between DoD operations transitioning to 2025 and incumbent ENG services**
  - **National Spectrum Consortium (NSC) Other Transaction Agreement (OTA)**
  - **Prototype architectures and attending concept of operations (CONOPS) and Use Case (UC) materials**
- **Looking for innovative approaches that**
  - Maximizes geographic, bandwidth and time availability for DoD access to 2025-2110 MHz
  - Minimizes/eliminates any required manual interactions by SBE Coordinators and Broadcasters (Coordinators are volunteers)
  - Accommodates additional uses by broadcasters (new RX sites, itinerant use)
  - Supports rapid response to breaking news events and unintended interference to broadcasters or DoD

# Sharing Implementation Framework



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