WInnComm '16
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WIRELESS INNOVATION FORUM

AIR FORCE RESEARCH LABORATORY

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An Overview of AFRL Topics for Spectrum Access Research & Development

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AFRL

AFRL-Managed Projects for Spectrum Access R&D Program

1) Dynamic Spectrum Access (DSA) Protocol Development

2) Multiple Input-Multiple Output (MIMO) 'Bolt-on' Technologies for JTRS

3) Electromagnetic Spectrum Situational Awareness Operating Picture

AFRL-Managed Projects for Spectrum Access R&D Program

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Operational Problem/Opportunity

- **Summary:** Support the implementation of Dynamic Spectrum Access (DSA) in AWS-3 impacted radio systems through the development of DSA policy rulesets and interfacing with spectrum management tools.
- **AWS-3 risk mitigation:** Reduces risk of spectrum access in a shared and congested environment by developing rulesets so DSA-enabled systems can effectively de-conflict frequency assignments in a dynamic and responsive manner.
- **Opportunity:** By adding DSA into legacy radio systems, spectrum requirements are reduced and systems have greater flexibility to operate in different areas.
- **Stakeholders:** All AWS-3 systems

Proposed Solution Effort

Outcome: This project addresses the DSA integration lifecycle, including ruleset development, integration, testing, and certification.

- Develop techniques to facilitate the integration of DSA radios and spectrum management tools
- Conduct experimentation to assess the gaps in current DSA radios in operationally relevant AWS-3 scenarios
- Develop next generation radio systems meeting policy maker requirements for non-interference
- Evaluate and test next generation DSA radios against a broad set of operational scenarios

Technologies

Existing 1st generation DSA-capable military radios will be used, as well as existing spectrum management tools.

- Policy-based Management tools
- Interfaces to Spectrum XXI and other spectrum management tools
- Wide-band DSA prototypes
- Contiguous and non-contiguous DSA implementations

- Beginning: TRL 5/6 End: TRL 7

Plan of Action & Milestones

Phase 1 (18 Months) – DSA Technical and Policy Assessment

- Analyze key DSA policy requirements
- Establish DSA technical requirements
- Development 2nd Generation DSA architecture
- Deliver prototype requirements for Phase 2 initiation
- Spiral requirements into Phase 2 over last 6 months of Phase 1

Phase 2 (12 Months) – Prototype Development and Testing

- Develop key DSA prototypes and evaluate performance
- Deliver field testing requirements and test plan for Phase 3
- Coordinate with key government stakeholders to secure appropriate test facilities for Phase 3
- Deliver prototype technical overview and evaluation report

Phase 3 (12 Months) – Demonstration and Field Testing

- Test and evaluate the implementation of 2nd Generation DSA prototypes
- Deliver test results final report

Programmatic Laydown

- **Key Accomplishments & Deliverables:**
  - Deliver a comprehensive set of DSA rules to govern behavior of DSA-enabled systems impacted by the AWS-3 transition, a DSA certification process, and spectrum management tool integration.
- **Phases and Decision Gates:**
  - Phase 1 – Gate #1 DSA Policy Design and Development complete for target number of legacy systems
  - Phase 2 – Gate #2 Operational suitability evaluation

Schedule of Major Activities

Total Duration: 36 Months

- FY16 Q2-FY17 Q2 – DSA technical and policy assessment
- FY17 Q2-FY18 Q2 – Develop 2nd generation DSA prototypes
- FY17 Q4-FY18 Q2 – Develop DSA test and certification process
- FY18 Q3-FY18 Q4 – Interference testing of 1st gen DSA systems
- FY19 Q1-FY19 Q2 – Limited field test of 2nd gen DSA systems

Stakeholders

- Lead/Sponsoring Org: EC&P/CIO
- Executing Org: OTA
- PM: EC&P
- Technical Manager: AFRL
- Experimentation Lead: USMC
- Transition Manager: CIO

Planned Integration Path

- This capability can be integrated into many legacy systems operating in the AWS-3 frequency bands
- This project will include a certification process such that program managers can integrate DSA implementations that have been certified against the same criteria

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Multiple Input Multiple Output
MIMO Bolt-On Technology

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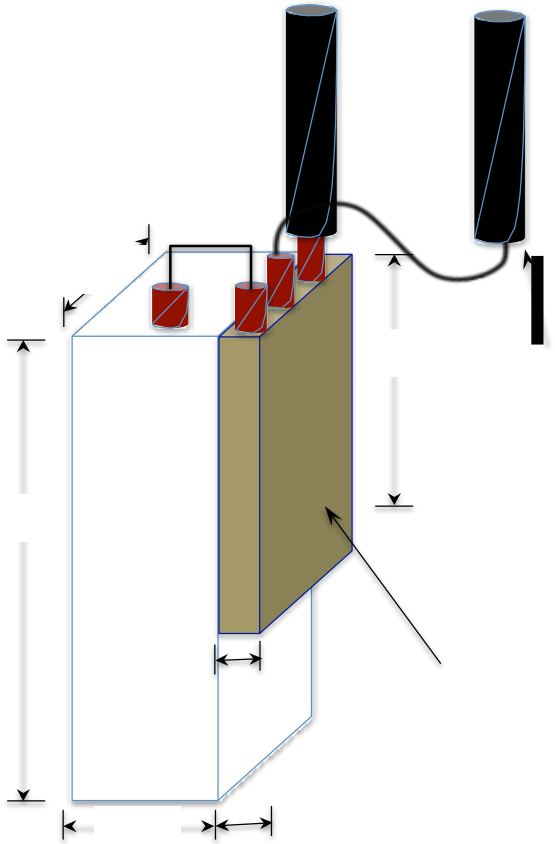
- **Summary:** Leverages commercially mature multiple input, multiple output (MIMO) space-time coding, receive diversity and spatial filtering to extend range, robustness & spectral efficiency of JTRS waveforms by hardening against multipath effects, reducing spurious noise and interference in adjacent bands
- **AWS-3 risk mitigation:** Provides ability to communicate using less bandwidth and power while increasing radio link robustness and throughput, reducing DoD's footprint for JTRS
- **Opportunities:** Increases JTRS's ability to share 1780-1850 MHz band with other compressing DoD systems, providing additional spectrum resources for systems that may have difficulties compressing and facilitating increased commercial access near the six protected sites in 1755-1780 MHz band
- **Stakeholders:** JTRS User Community, Commercial Licensees, Radio Acquisition Programs

Technologies

- **MIMO Radio:** Method to achieve robust bandwidth efficient links
- **Bolt-on Module:** Delivers enhanced MIMO capability without impacting the legacy waveform or hardware
- **Covariance Based Eigen-beamforming:** A means of achieving near optimum MIMO Space-time diversity and array gain without explicit channel estimates.
- **2D Space Time Filtering or Sub-banding:** Techniques that allow us to effectively deal with wideband dispersive channels.
- **Minimum Mean Square Error:** Spatial filtering to mitigate jammer, and interference from other transmitting antennas.
- **(H)/(D)-BLAST MIMO:** Horizontal/Diagonal spatial streams
- **TRL:** Beginning: Component algorithms at TRL4/5
  End: Unified network system at TRL6

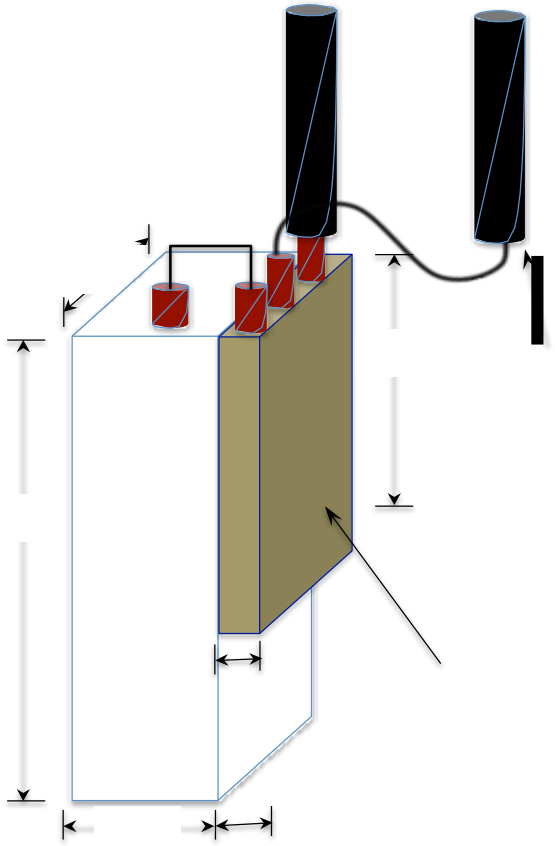
Prototype Goal/Outcome

- A technology demonstration that will show an average 10dB performance improvement for a JTRS radios using spectrally-efficient techniques.
- Low SWaP-C value-added techniques to enhance JTRS radios capability in terms of range, throughput and robustness to interference/jamming.
- Enable JTRS to operate effectively in the 1780-1850 MHz band in close proximity to commercial systems facilitating increased availability of spectrum for commercial usage near six identified overlap areas by reducing JTRS's susceptibility to interference from commercial LTE systems – the technology hardens JTRS for more reliable operations in contested and congested RF environments



Programmatic Laydown

- **Key Accomplishments and Deliverables:**
  - Algorithms and Protocols
  - Hardware Module
- **Phases and Decision Gates:**
  - In excess of 10 dB improvement in realistic simulated environments
  - Low SWAP-C implementation
  - TRL-6 MIMO techniques fully functional



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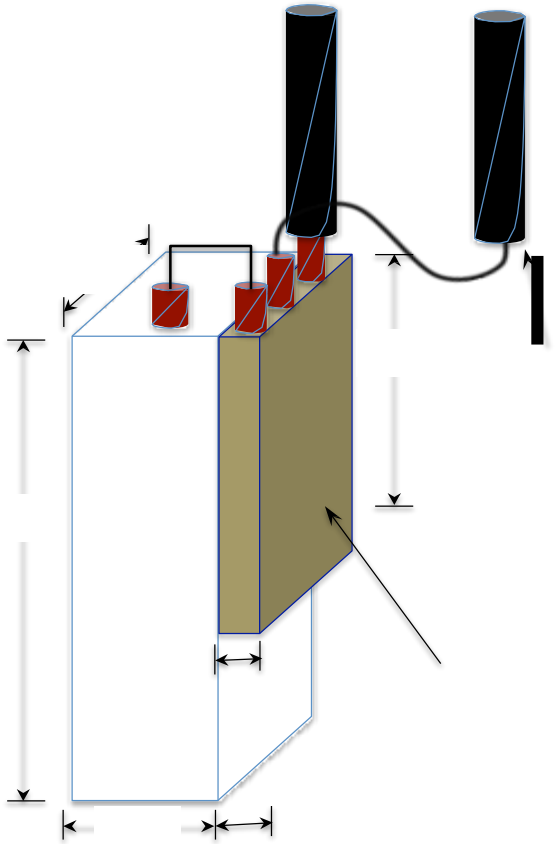
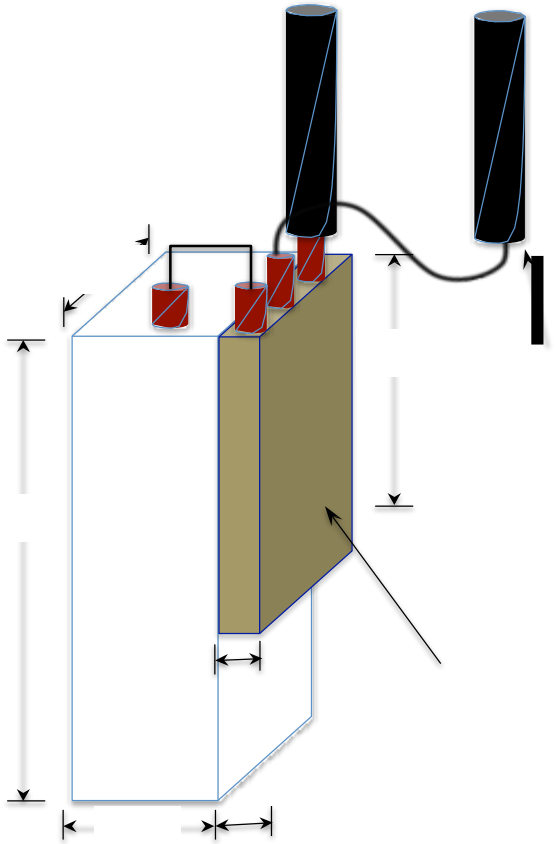


Schedule & Team

Total Duration: 18 Months

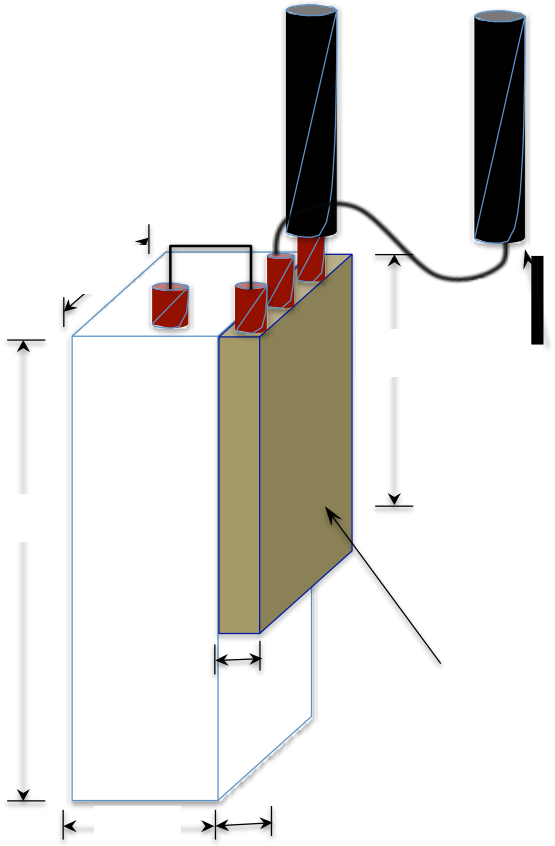
- System Design
- System Implementation
- Integration and Test

- **Lead/Sponsoring Org:** Air Force Research Lab (AFRL), Rome AFB
- **Executing Org:** AFRL/RI
- **PM**: William Lipe, AFRL/RITE
- **TM:** Janek Mroczek, AFRL/RITF



Planned Integration Path(s)

- The project results in a realistic technology demonstration that is expected to show an average 10 dB improvement in the performance of JTRS radios
- Relevant to multiple impacted systems, i.e. Rifleman
- The technology will be presented to joint stakeholders in other JTRS-based radios for incorporation into existing programs of record



MIMO Technologies for JTRS

Work Breakdown Structure	
1. Phase One	
	1.1 Algorithm and Protocol Definition
	1.2 Full End to End Simulation
2. Phase Two	
	2.1 Hardware Platform Development
	2.2 Port of Algorithms and Protocols to Hardware
3. Phase Three	
	3.1 A MIMO Applique Mission Module for JTRS radios
	3.2 Integration with JTRS radios
	3.3 Laboratory Testing with JTRS radios
	3.4 Field Testing and Validation in Mission Relevant Environments with JTRS radios

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Electromagnetic Spectrum Situation Awareness Operating Picture

Operational Problem/Opportunity

- **Summary:** Visualizations that are effective at conveying EMS Situation Awareness (SA) would make Electronic Warfare and Spectrum Management comprehensible to Commanders by improving their understanding of the Electromagnetic Operations Environment (EMOE), improving tactical employment, and providing program support
- **AWS-3 Risk Mitigation:** This capability will be an AWS-3 enabler because of its ability to quickly and accurately display the EMS situation facilitating effective and efficient operations
- **Opportunities:** GOTS S/W and Open Source Standards as a basis; ability to show multiple, linked, simultaneous visualizations; resolving EM congestion CONUS; supporting EW in-theater, fusion of multiple EMS data sources
- **Stakeholders:** Commanders, Network and Communications Personnel, Warfighters

Technologies

- Leverage and extend past AFRL, DARPA, NASA and FAA technology development
- Composeable Visualization Framework (CVF) and Semantic technologies to provide flexible visualization capabilities and ready access to multiple, disparate data sources
  - CVF has been used to represent operational data in a test environment and in operational environments under experimentation

- **TRL4** (Initial) **TRL6** (Effort Completion)

Proposed Solution Effort

Outcome: Develop an EMS SA Operating Picture that will enable spectrum utilization and effectiveness in-theater and also support system suitability analytics (reliability, availability, and maintainability of EM materiel assets) and EM- contested CONUS operations including live, training, and testing modes of operation

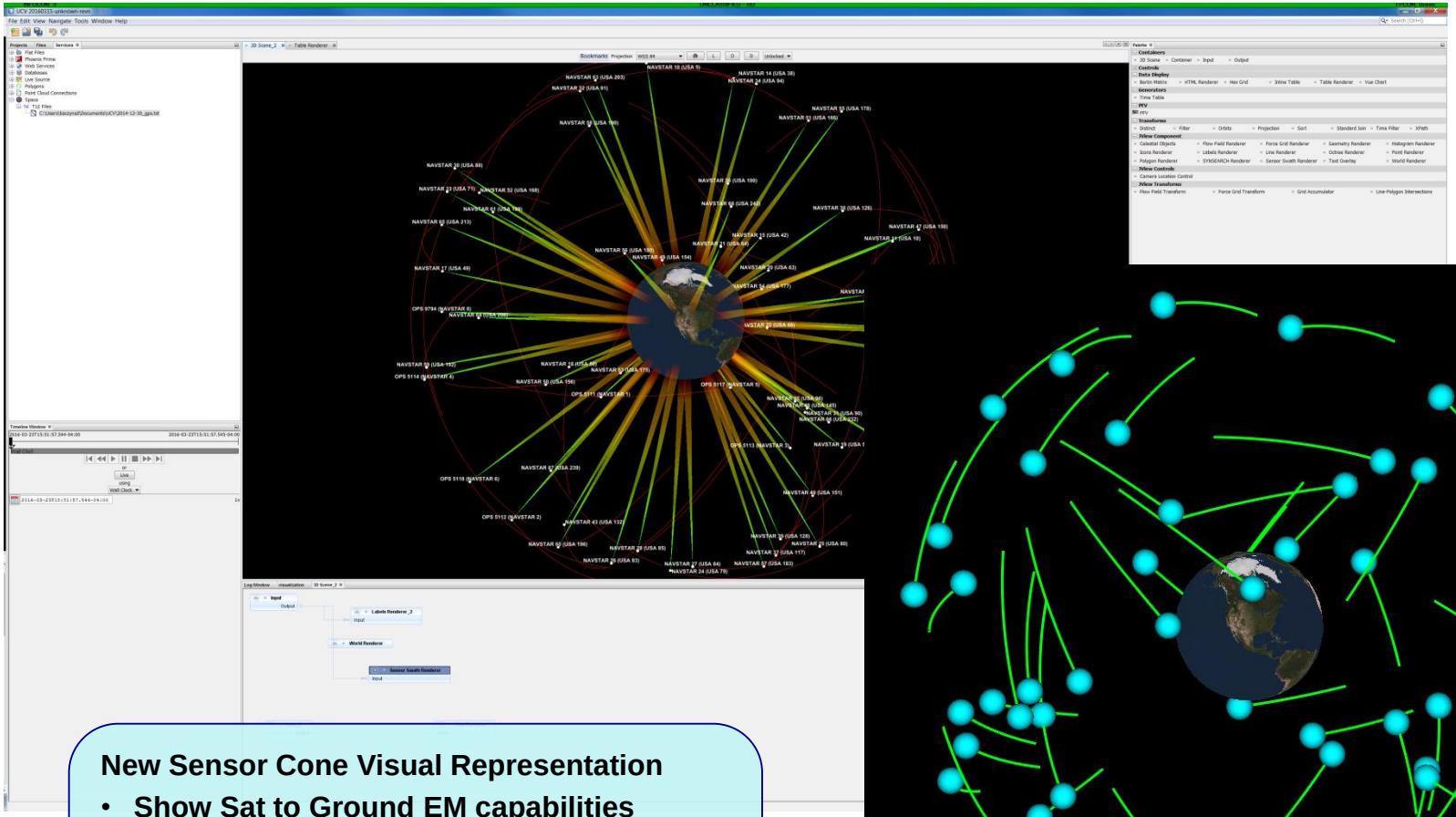
- Fusion of multiple EM data sources
- Perform advanced data analytics and indications and warnings assessment
- Present information with multiple, linked visual representations to insure spectrum understanding

Schedule of Major Activities

Total Duration: 36 Months

- Software Build One (12 Months)
- Initial prototype evaluation (6 Months)
- Software Build Two (12 Months)
- Prototype Integration and Test (6 Months)

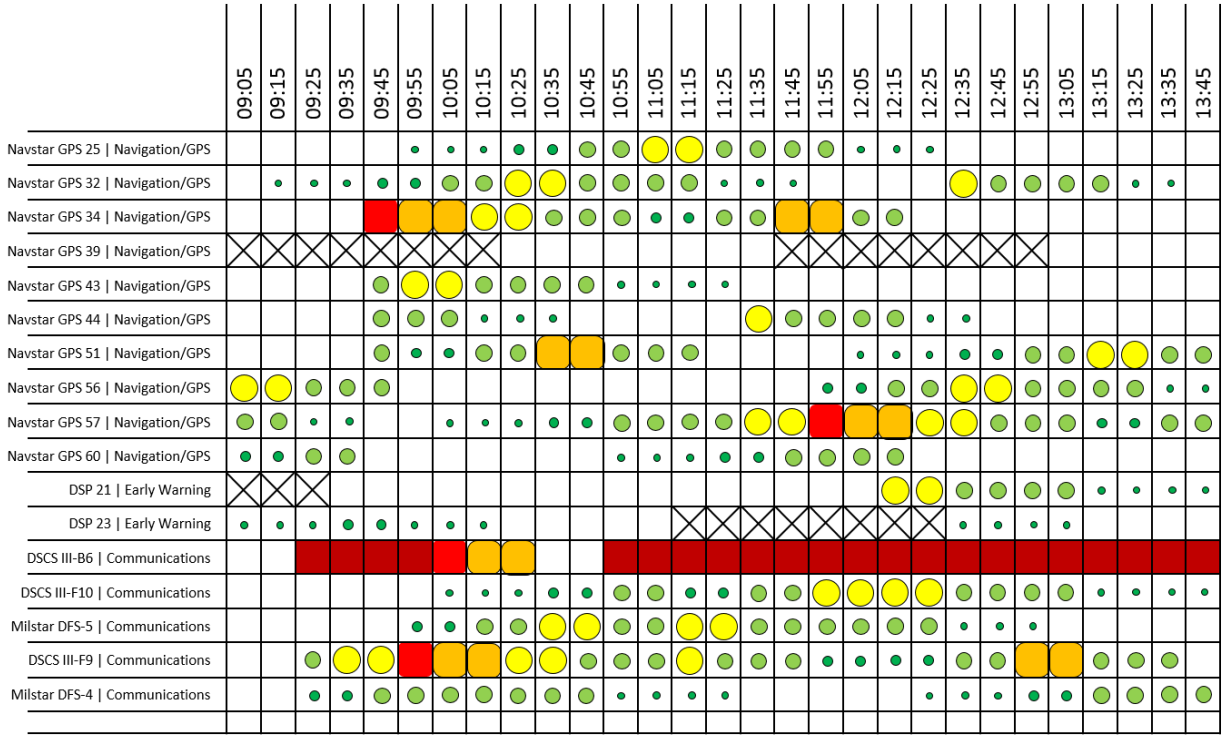
Satellite Visualization

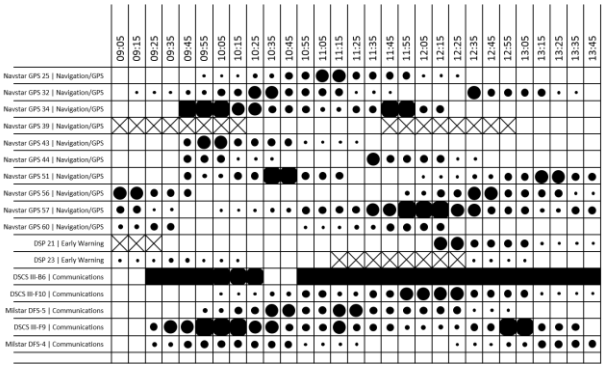


New Sensor Cone Visual Representation

- **Show Sat to Ground EM capabilities**
- **Flexible, configurable color encoding**
  - **Uplink/Downlink status**
  - **Transponders Status**
  - **Space Weather Effects**

Bertin Matrix





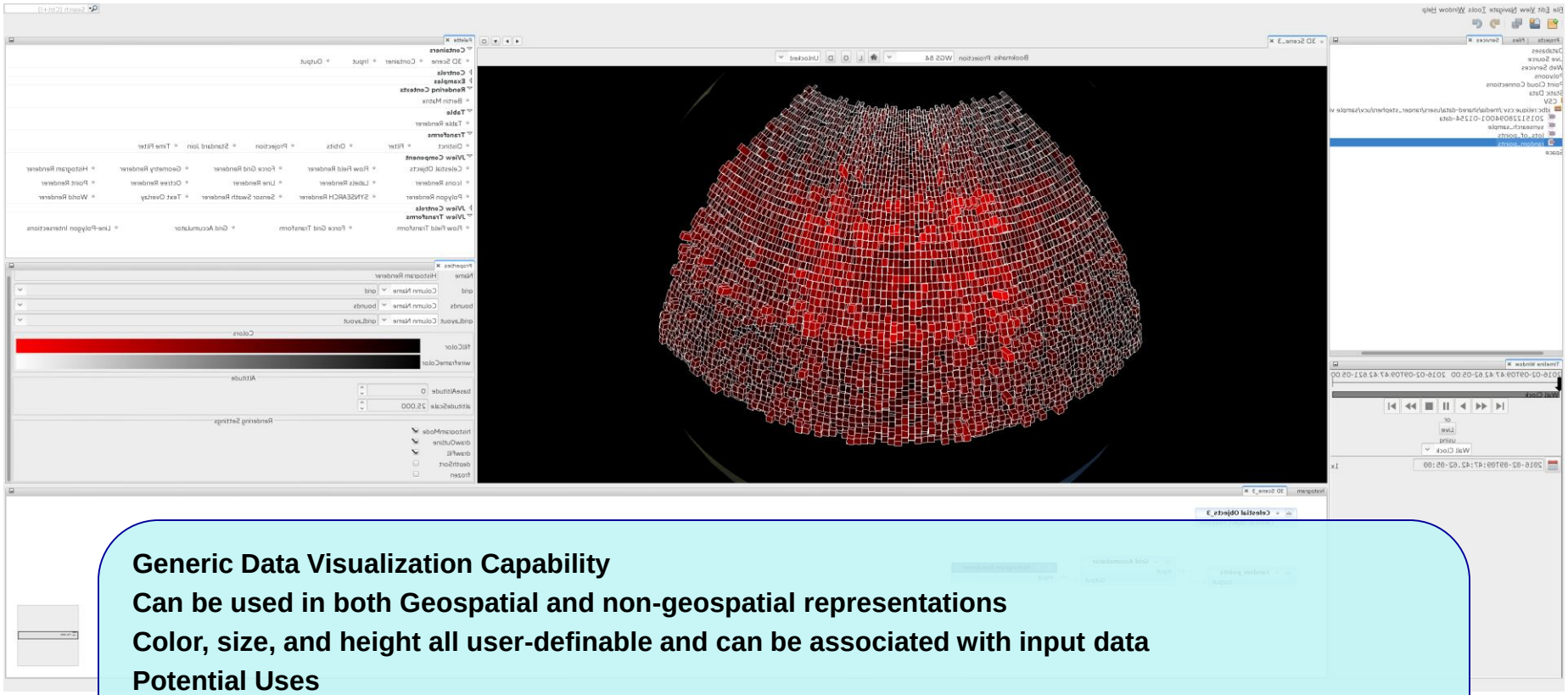
Information-dense Visualization

- **Both interactive analysis tool and non-interactive information summary display**
- **User-configurable visual attributes that can be assigned to input data**

Multiple Use Cases

- **Terrestrial Sensor Coverage of Satellites (shown)**
- **Mission Capability Status**
- **EM Strength/Availability**
- **Others**

3-D Histogram Grid



Generic Data Visualization Capability

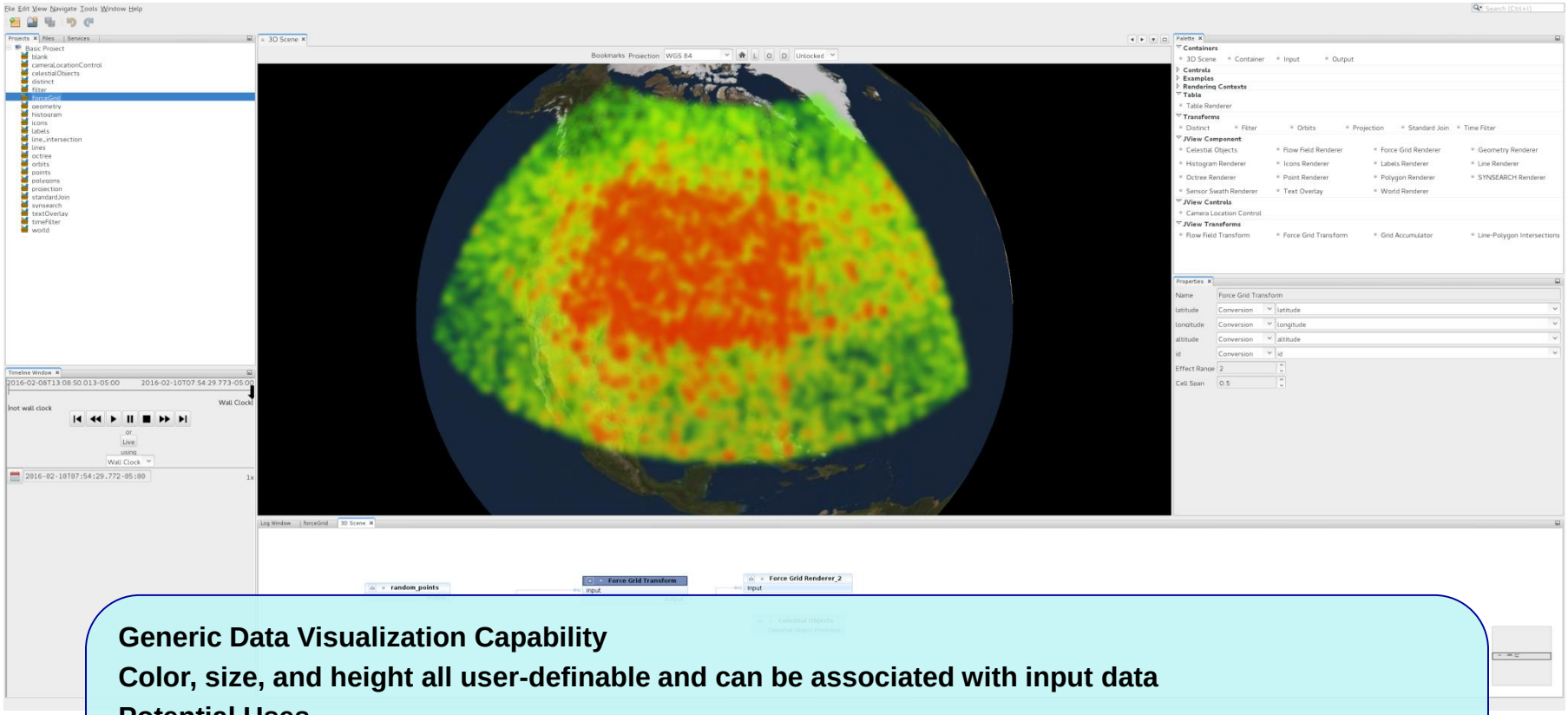
Can be used in both Geospatial and non-geospatial representations

Color, size, and height all user-definable and can be associated with input data

Potential Uses

- **Frequency Coverage Areas**
- **Geo-located EM Strength/Interference**
- **Location Criticality**
- **Usage Areas**

Force Grid



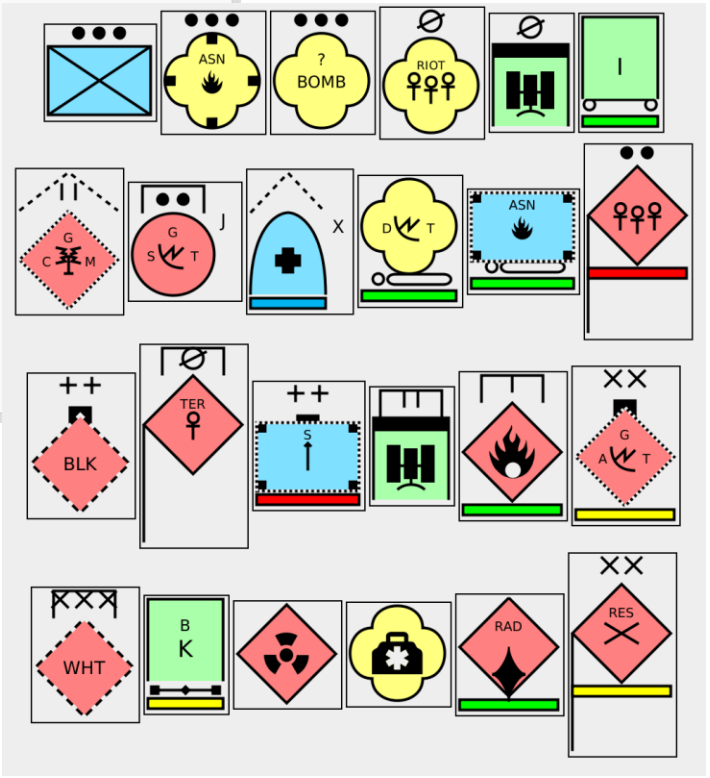
Generic Data Visualization Capability

Color, size, and height all user-definable and can be associated with input data

Potential Uses

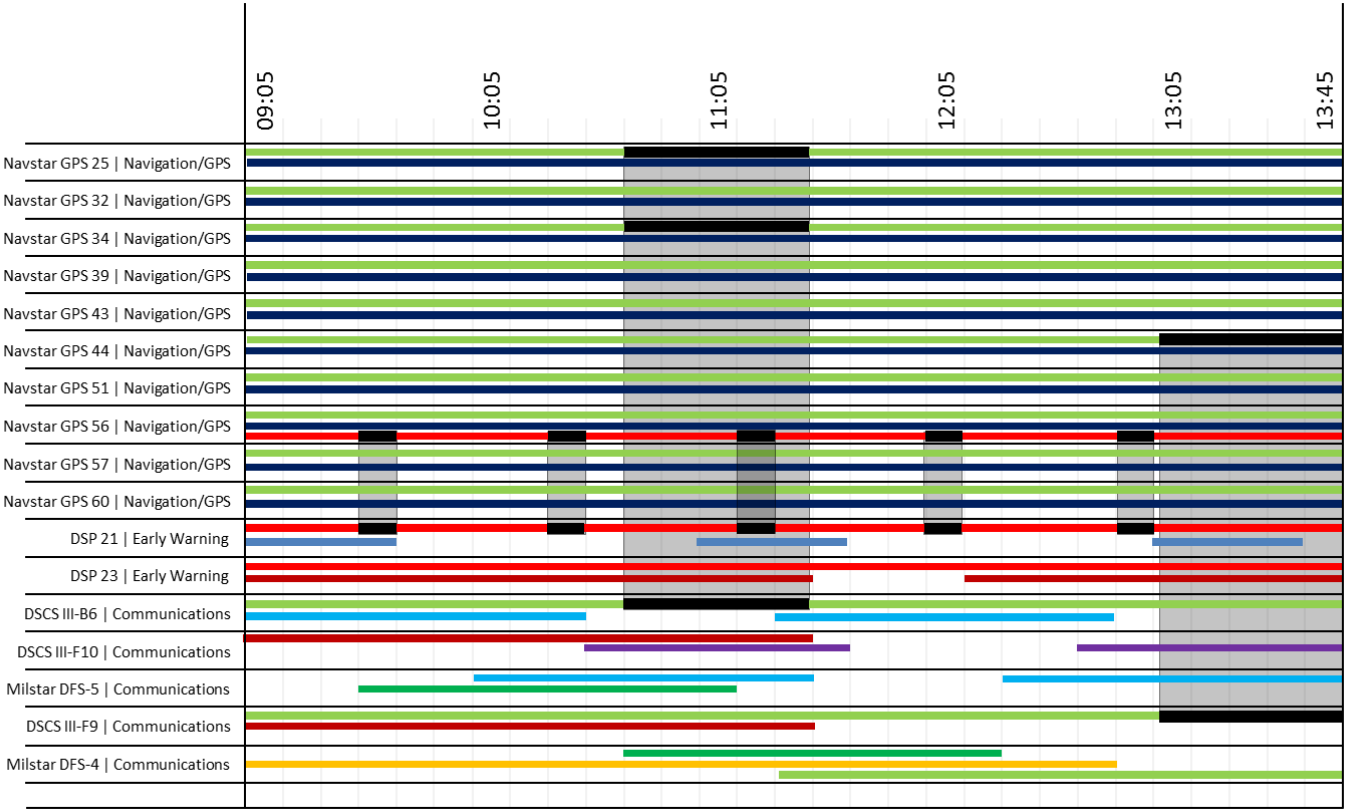
- **Frequency Coverage Areas**
- **Geo-located EM Strength/Interference**
- **Location Criticality**
- **Many more**

MIL-STD-2525D Iconology and In-Scene Labels



- Mapping and Identification of geo-located entities
- Real-time updating
- User-configurable
- Visual attributes can be user-assigned to input data

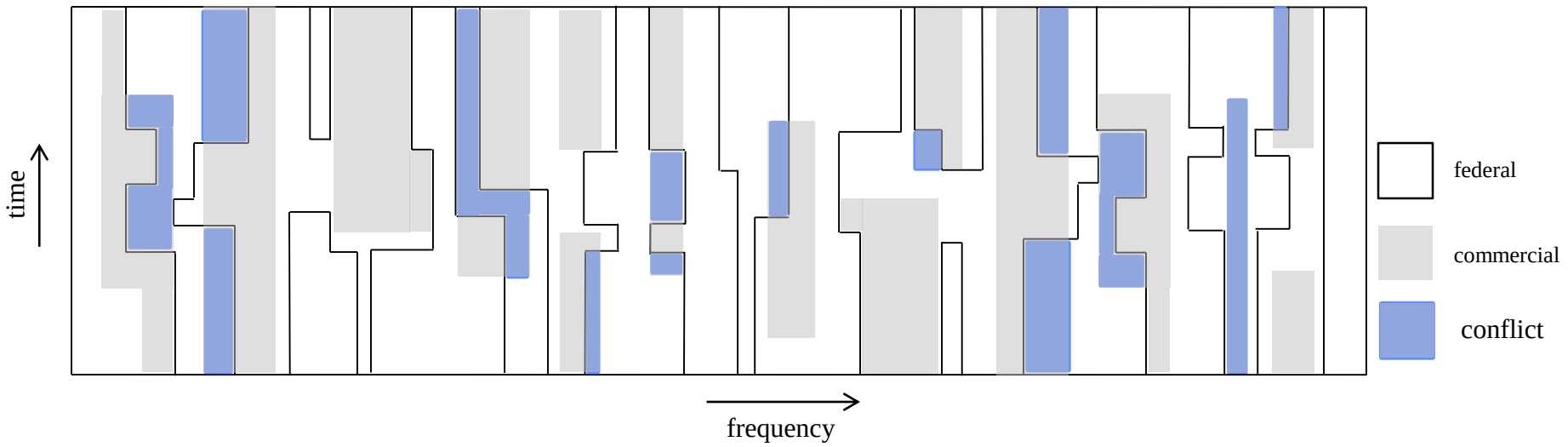
Swim Lanes



EM Conflict Swim Lanes:

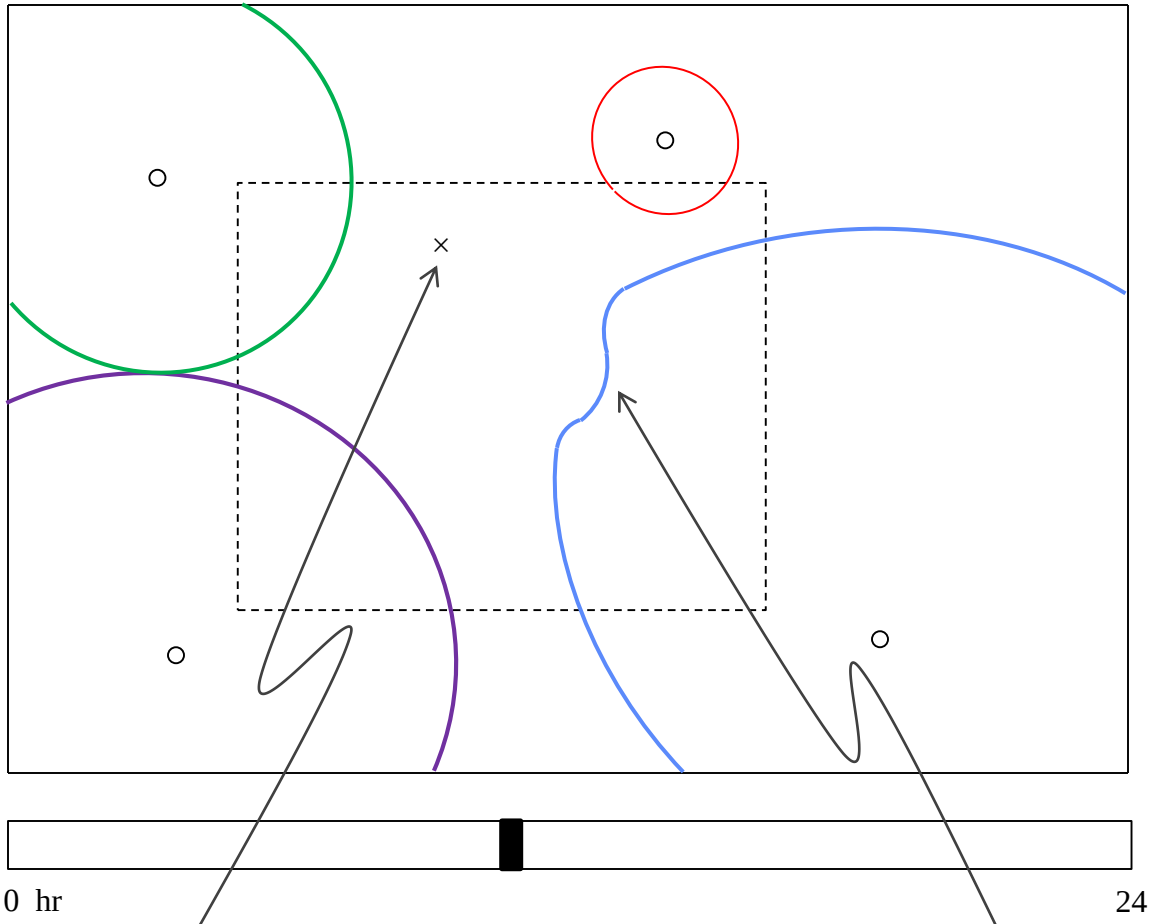
- Frequency Usage
- Mission/Time/Proximity EM Conflict Identification
- Access Times

Spectrum Band Usage



- **Quickly Illustrate Shared Spectrum Contention (conflict alerts)**
- **Possible to easily see under-utilized bands**

Spectrum Management for Test and Training Ranges

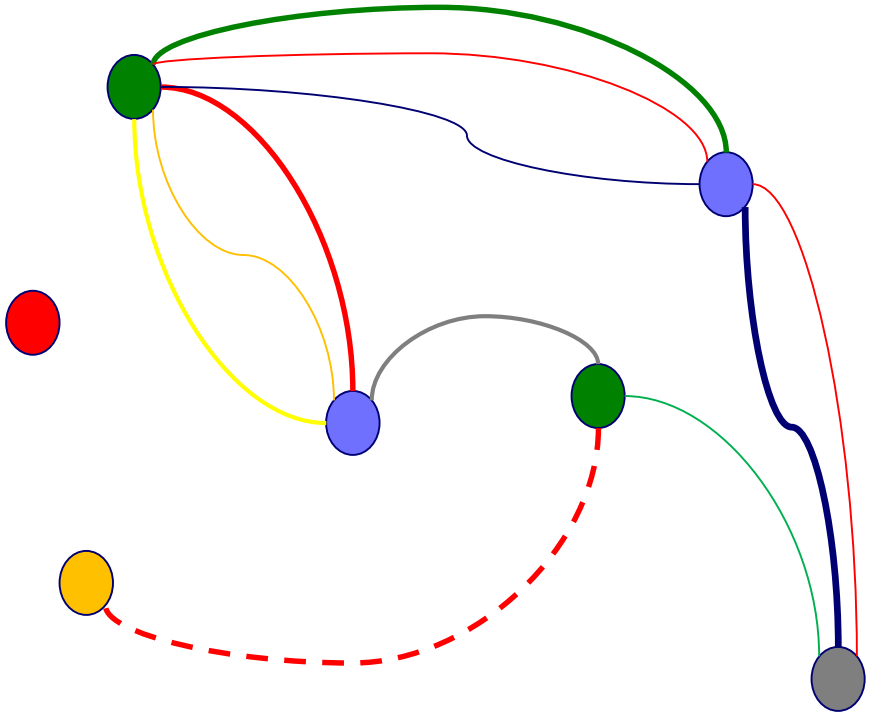


Interrogation could show known point EM sources and types

Interactive point location effects assessment {the picture changes}

Not necessarily round if sufficient understanding of emitter available

Spectrum Allocation Analysis Results Graph



This could be a graph the is the visual representation of spectral allocation algorithms. Graph Analysis could be used to determine optimal frequency usage amongst assets and with respect to the background EM environment.

- Freq. Bands given by color
- Edges represent comms between nodes
- Edge thickness represents bandwidth or less interference within given band
- Dashed lines could indicate time constraints for represented band
- Node color additional indicator of status

Points of Contact

- **Dynamic Spectrum Access (DSA) Protocol Development**
  - **PROGRAM MANAGER:**
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  - **TECHNICAL POC:**
    Dr. Jonathan Ashdown, jonathan.ashdown@us.af.mil, 315-330-4630
- **Multiple Input - Multiple Output (MIMO) Technologies for JTRS**
  - **PROGRAM MANAGER:**
    William Lipe, william.lipe@us.af.mil, 315-330-4878
  - **TECHNICAL POC:**
    Dr. Janek Mroczek, janek.mroczek@us.af.mil, 315-330-4712
- **Electromagnetic Spectrum Situational Awareness Operating Picture**
  - **PROGRAM MANAGER:**
    Tony Dilego, francis.dilego@us.af.mil, 315-330-3683
  - **TECHNICAL POC:**
    Chad Salisbury, chad.salisbury@us.af.mil, 315-330-7804

Questions?