



# Cognitive Radio Access and Management for Public Safety Systems

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Product Exposition

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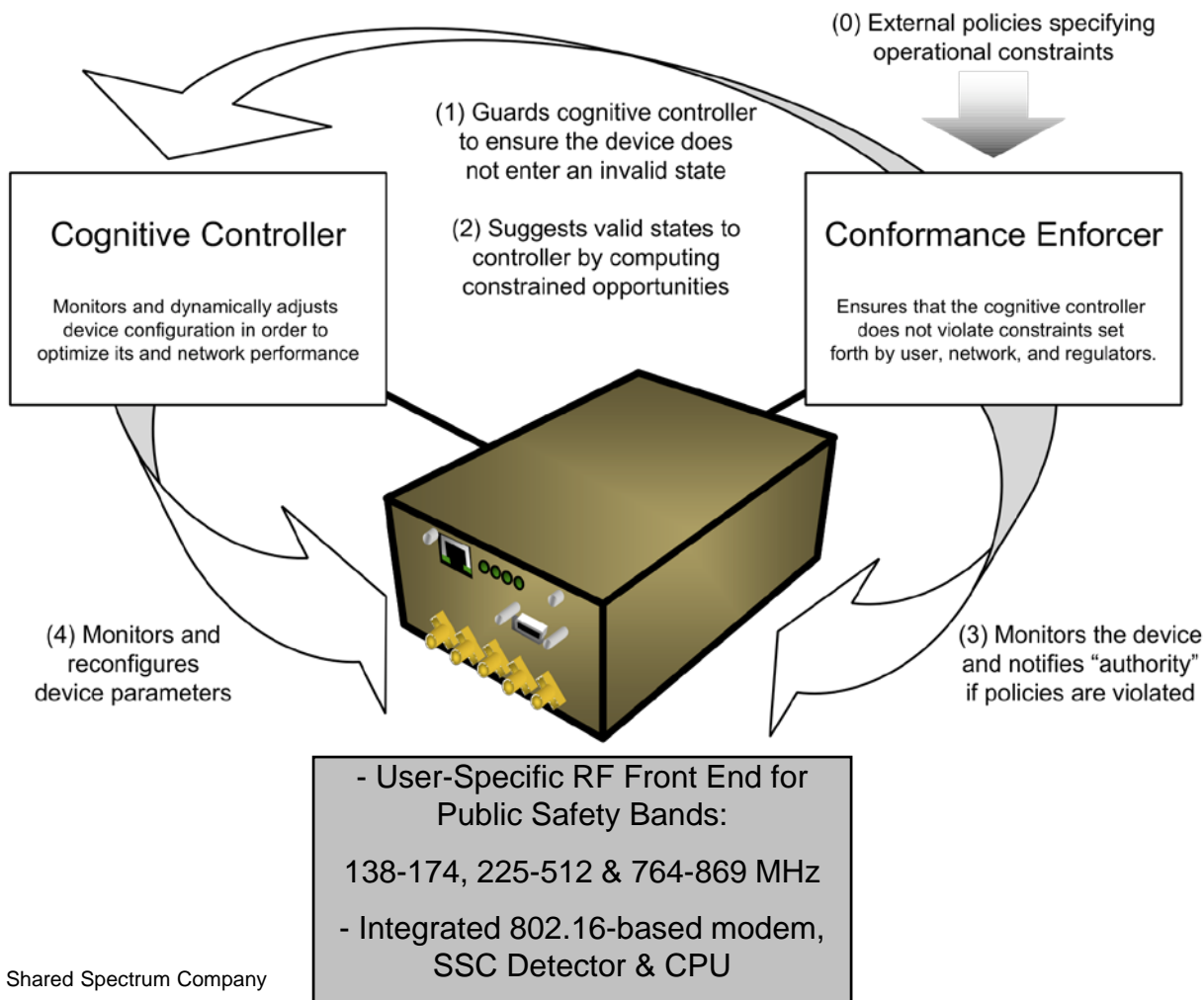
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# Overview of CR Device

## Multi-band cognitive device includes Cognitive Controller and Conformance Enforcer



- **RF Interfaces:**
  - 1 or 2 Antenna Ports
  - External PA for > 100mW
- **Control interfaces:**
  - 1 Ethernet Port
  - GPS Timing Port
- **Power:** 12V (~15W w/o PA)



# CRAM Overview

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- CRAM scenario and role players
- Policy language background and overview
- System architecture and control flow
- Policy Development & Dissemination Suite
  - Policy Authoring Tool (PAT)
  - Policy Validation Simulator (PVS)
  - Policy Administration Console (PAC)

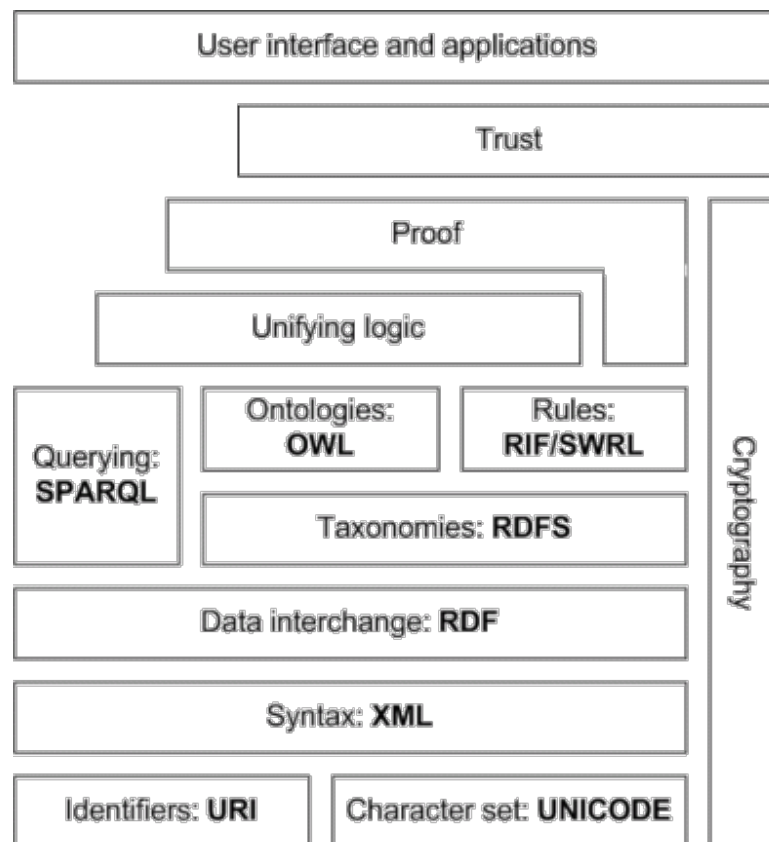


# Policy-Based Cognitive Radio Authentication Access

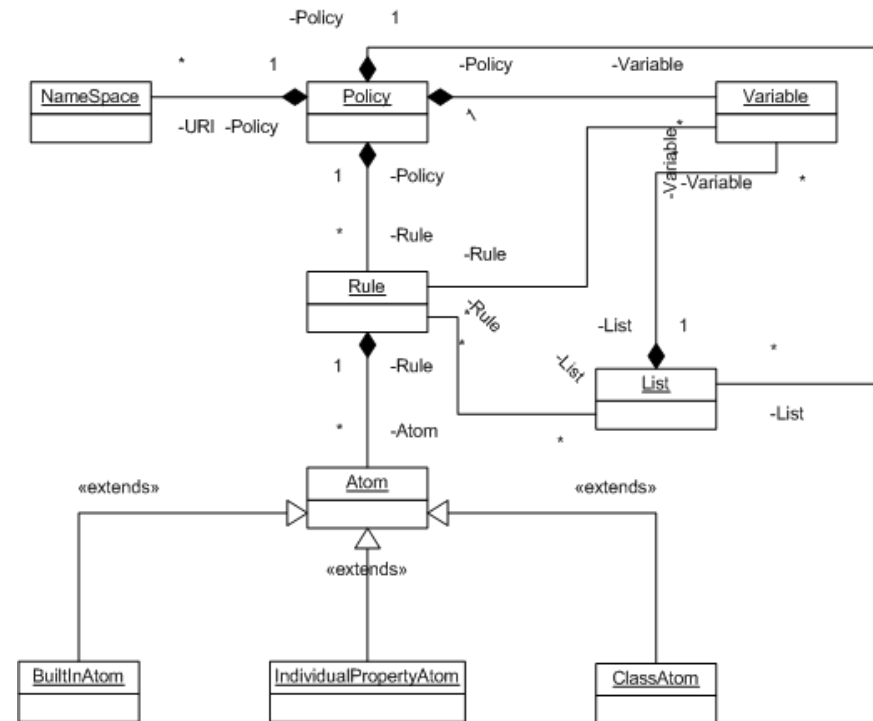
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- Policy Authors (Regulators, Frequency Coordinators, RPCs, SIACs, etc.)
  - Designate potential policy behaviors and identify spectrum access rules (Frequency, Time of Day, and Location)
  - Authenticated access to authoring console and validation tools
- Policy Administrators (Network/Spectrum Managers)
  - Generate local policies, verify, and deploy policies to certain CR devices
  - Authenticated access to administration console and validation/log analysis tools
- Incident Commanders /Communications Leader (user)
  - Verify current operational state of active CR devices; Identify unknown behavior, review logs
  - Adds or removes policies to or from an agent
  - Approve or deny network join
  - Synchronizes device modes and policies
  - Authenticated access to administration console and log analysis tools

- Policy Language and Architecture Standards Committee IEEE 1900.5
- Joint Spectrum Committee STANDARD SPECTRUM RESOURCE FORMAT
- MCEB Pub 8
  - XML formatting to represent data elements
  - W3C standards be met in data element types
- W3C Ontology Web Language (OWL)
- W3C Semantic Web Rule Language (SWRL)
- Languages use XML for its syntax



- Defines a policy as a set of organized rules, atoms, variables, identified by unique URIs
- Allows us to represent a CR device by components, state, and capability
- SSC CR devices are equipped with a reasoning agent which takes one or more policies as input
- A policy consists of one or more rules when applied to a CR device equipped with a reasoning agent, prohibits or permits transmission
- In addition to device representation, devices may report spatial, temporal, and other environmental data
- If specified in a policy and the device which the policy is applied is capable of providing such data, reasoning agent regulates





# Policy Language Constraints

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- Frequency Constraints

- FrequencyBasedPolicy.owl- Permits, frequency range 350.00 – 370.00 MHz, requires device transmitter, signal detector, and signal evidence.

- Geospatial Constraints

- GeospatialPolicy.owl- Prohibits, frequency range 350.00 – 370.00, at location 38.926:-77.246:0.0 (altitude usage dependent on device capability), requires device transmitter, signal detector, signal evidence, location detector, and location evidence.

- Time Constraints

- TimeBasedPolicy.owl- Permits, frequency range 350.00 – 370.00 MHz, between the hours of 1100-1200, requires device transmitter, signal detector, signal evidence, time detector, and time evidence.

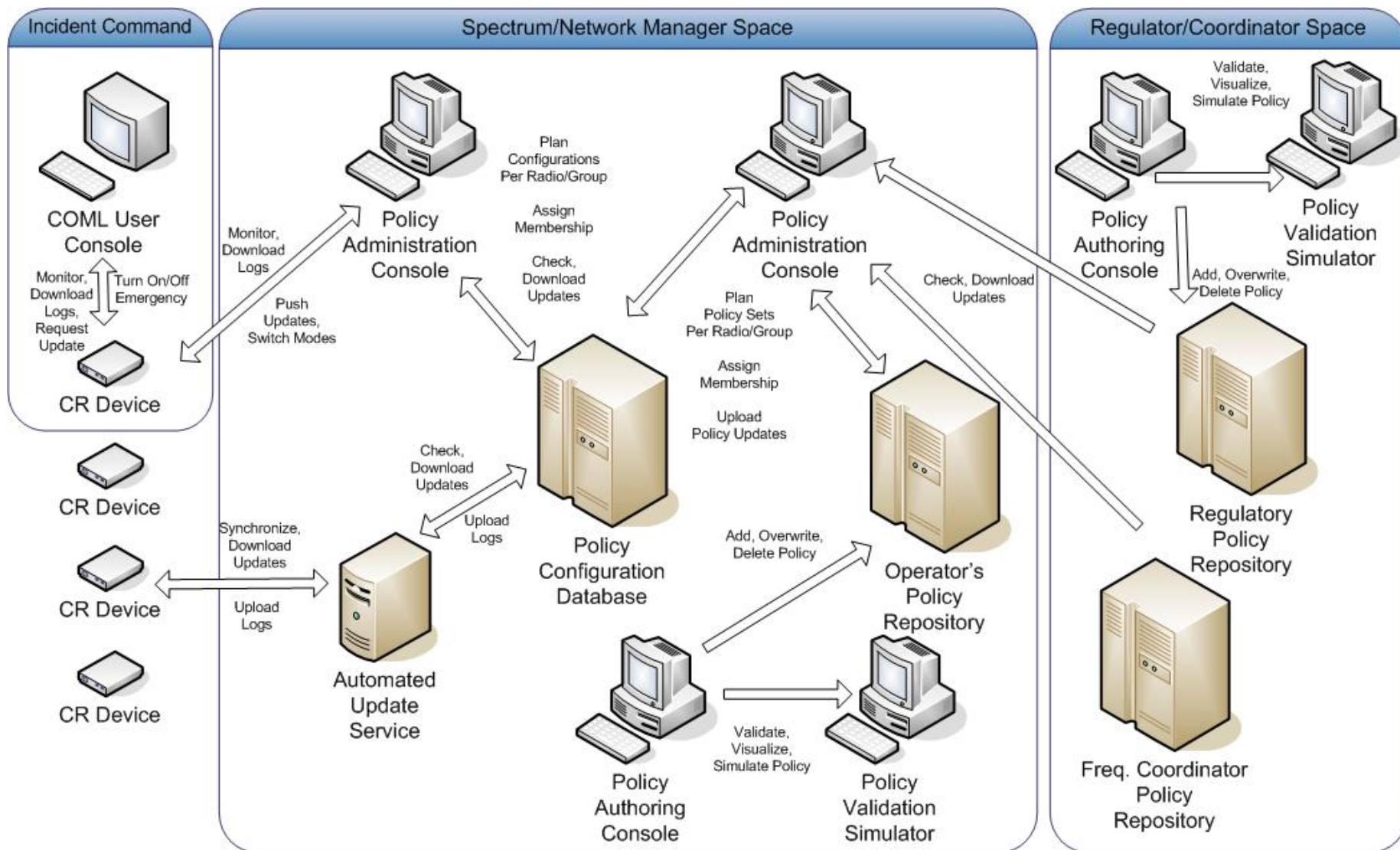
- Transmission Constraints

- Power Limit- This defines the maximum limit on the radio's transmit power.
- Bandwidth- This defines the maximum limit on the radio's transmission bandwidth.
- Max On Time-This defines the limit on how long a radio can consecutively transmit before turning off its transmission.
- Min Off Time- This defines a limit on how long the radio should be quiet between transmissions.
- Signal Type- This defines the type of signal the radio should be transmitting.
- GPS Validation Interval- This defines a duration in which GPS evidence is useful if reported.

Note: constraints may be combined into a single permissive or prohibitive policy

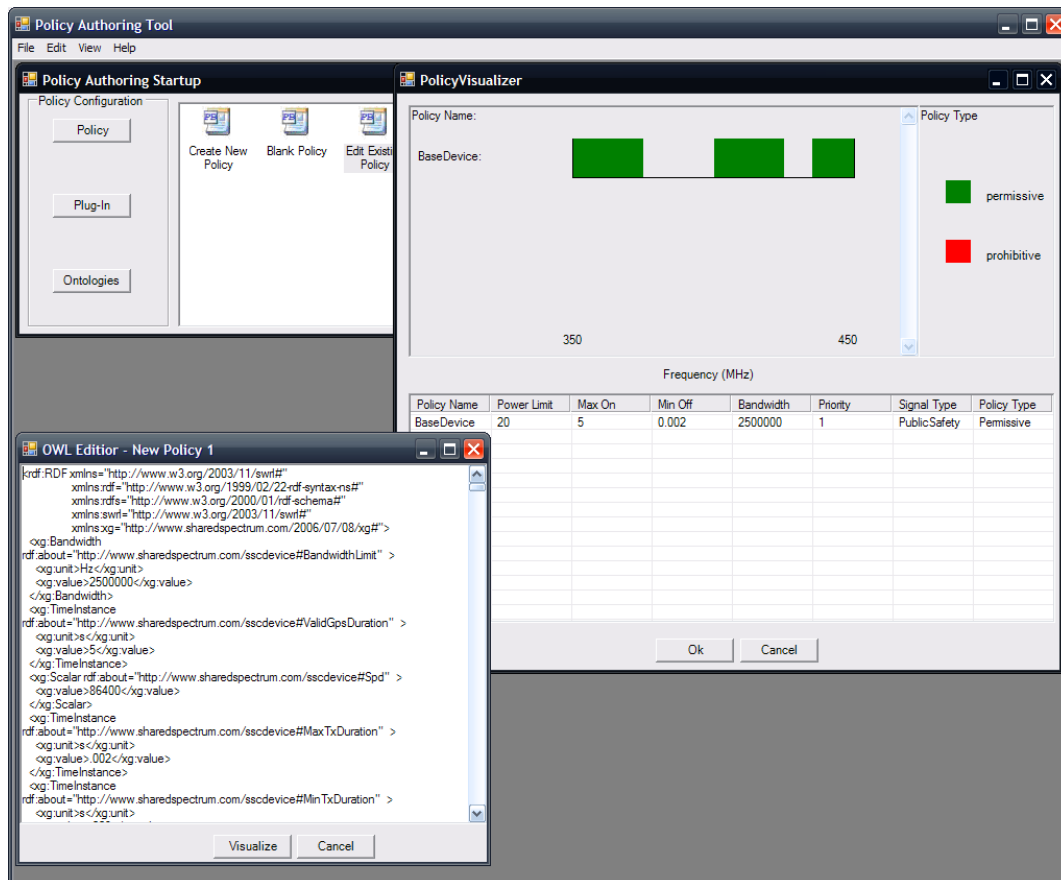


# CRAM Architecture



# Policy Authoring Tool

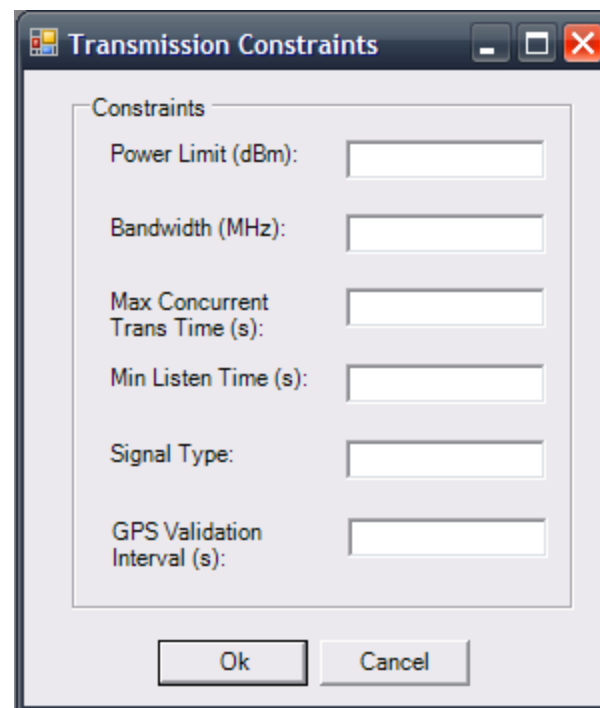
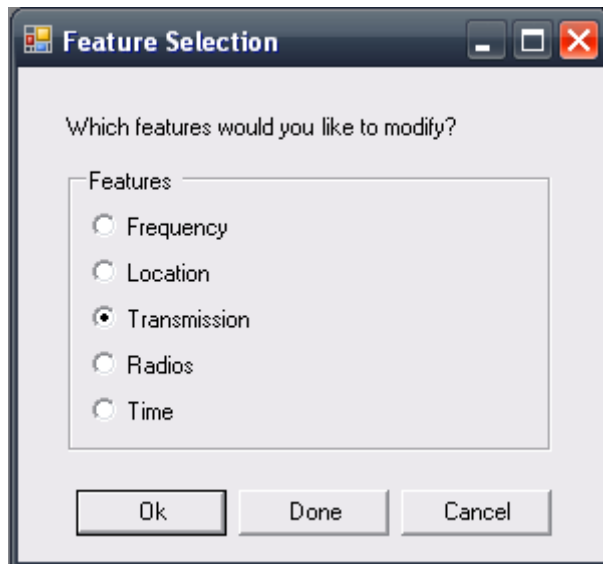
- Generate new policies
- Edit existing policies
- Visualize new and existing policies
- All policies conform to the policy ontology and are readable by the CR device reasoning component





# Policy Authoring Tool Features

- Automated constraint generation using wizards
- Single transmission constraints
- Additional features, frequency, location, devices, time





# Policy Authoring Tool Features

- Specify one or more features to which the policy applies
  - Frequency ranges
  - Devices
  - Time periods

**Frequency Ranges**

Input at least one start and end frequency range (MHz), or select all to have the policy apply to all available frequencies.

☐ All

From	To

Add Delete

0.00 0.00

Ok Cancel

**Radios**

Add radios that you would like the policy applied to.

☐ All

Radios

Add Delete

Ok Cancel

**Time Constraints:**

Please input the start and end times you would like this policy to be active (0000)-(2359):

☐ All (0000-2359)

From	To

Add Delete

0000 2359

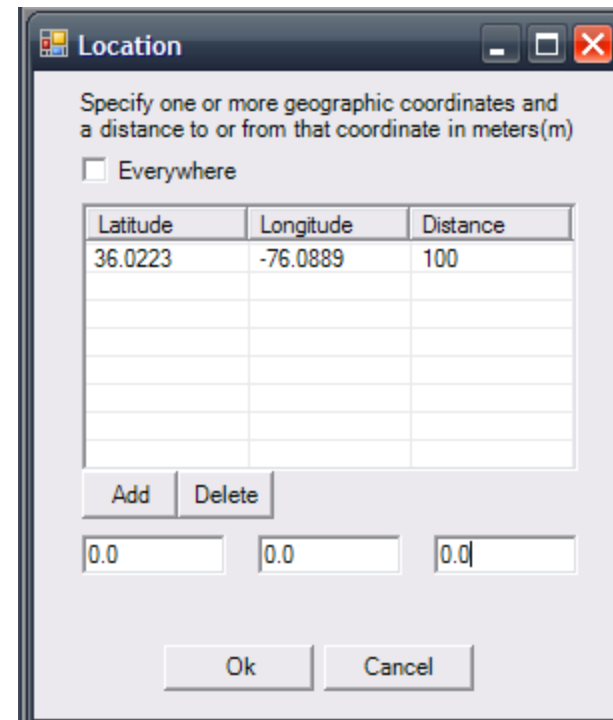
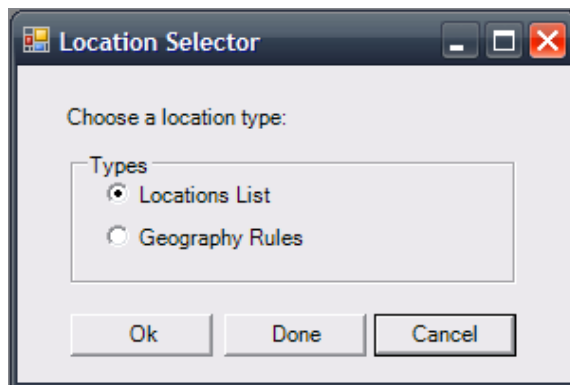
Ok Cancel



# Policy Authoring Tool Geo-Constraints

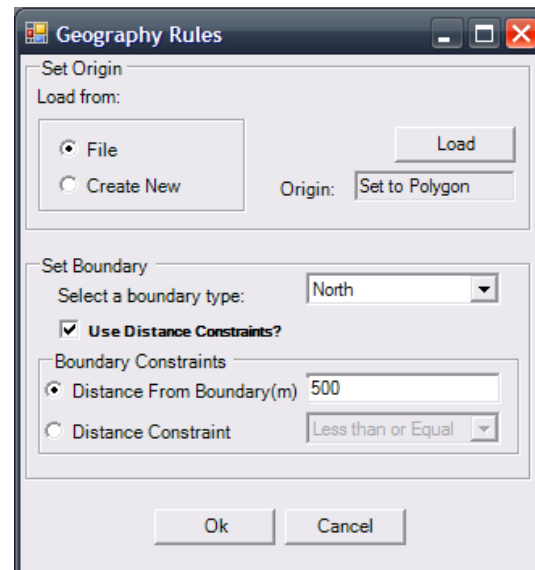
## Specify geospatial constraints

- Location list
- One or more latitude/longitude coordinates, and distance
- Policy applies if device location is within the specified distance of the coordinate
- Everywhere indicates that no location rules are generated



## Specify geospatial constraints

- Geography rules
  - ESRI Shapefile- Publicly accessible, large database, standardized format
  - Shape Builder- ESRI Shapefile compliant
  - Boundary Constraints- inside, outside, north, south, east, west
  - Distance Constraints- Any distance, exact, no further than (less than or equal to), at least (greater than or equal to)



**Geography Rules**

Set Origin

Load from:

☒ File ☐ Create New

Load

Origin: Set to Polygon

Set Boundary

Select a boundary type: North

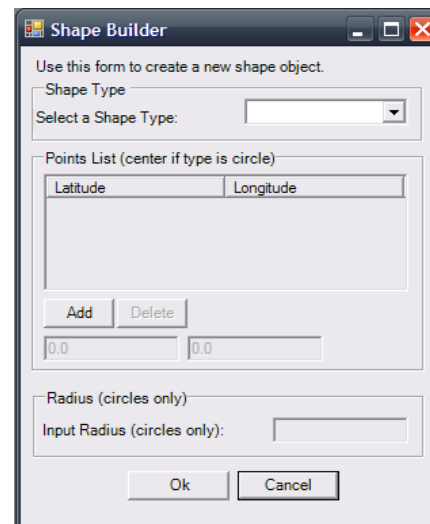
☒ Use Distance Constraints?

Boundary Constraints

☒ Distance From Boundary(m) 500

☐ Distance Constraint Less than or Equal

Ok Cancel



**Shape Builder**

Use this form to create a new shape object.

Shape Type

Select a Shape Type:

Points List (center if type is circle)

Latitude	Longitude
0.0	0.0

Add Delete

Radius (circles only)

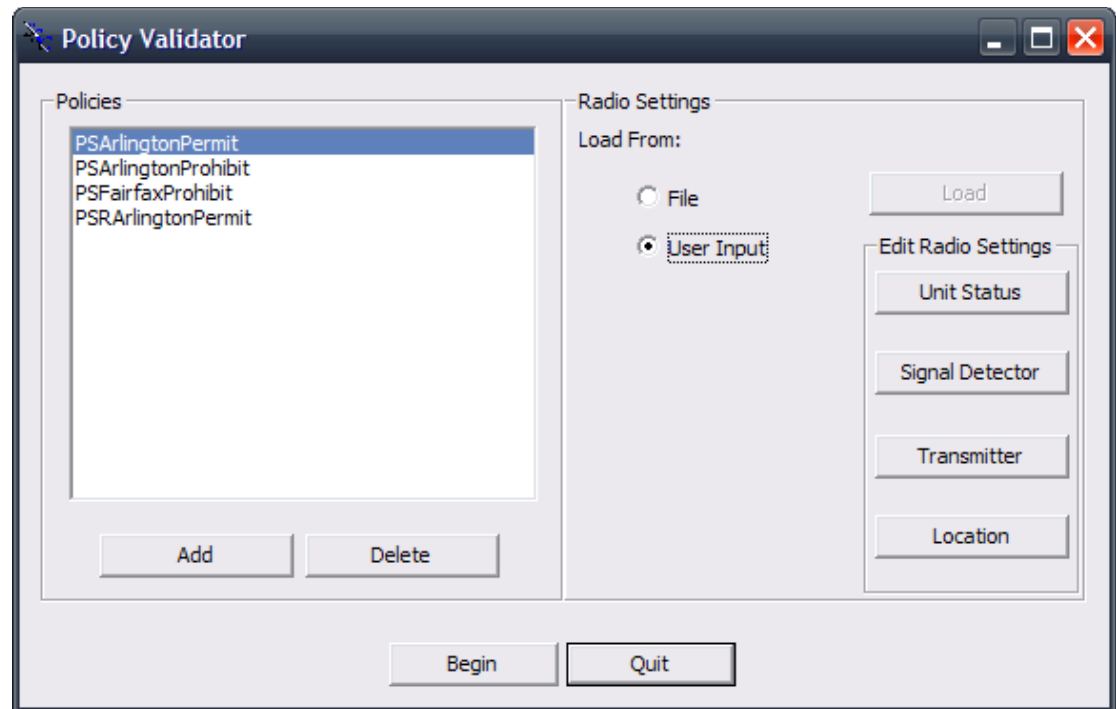
Input Radius (circles only):

Ok Cancel



# Policy Validation Simulator

- Simulates the behavior of a device with a specific configuration
- Visualize the effects of modifying radio operating conditions
- Allows multiple policy configurations
- Input signal detector evidence, location, time, and transmitter settings
- Uses same reasoning agent as CR device





# Policy Validation Simulator Configuration

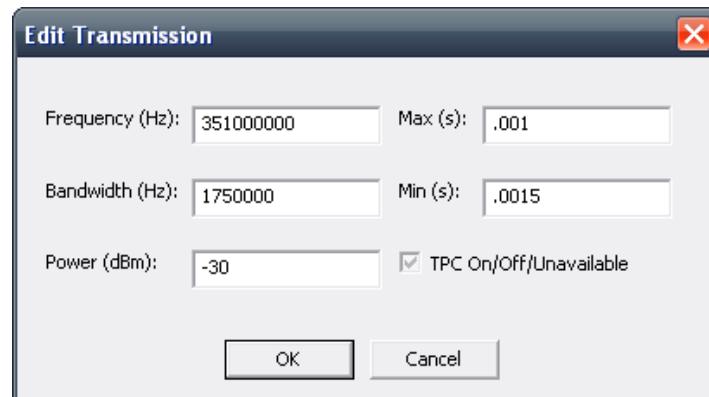
Configure the simulated device by loading a .pvf configuration file or by manually specifying values for each input field

- Device ownership and policy language settings
  - Owner- Device owner, if defined should be specified in policy and device reportable
  - Authority- If defined, specifies Certificate Authority for PKI authentication
  - Compatibility Version- Reasoning agents policy ontology version
- Location settings

The 'Modify Radio Unit' dialog box contains three text input fields: 'Owner' with the value 'CRAMAgent', 'Authority' with the value 'SSC', and 'Compatibility Version' with the value '1.0'. At the bottom are 'OK' and 'Cancel' buttons.

The 'Edit Location' dialog box contains three text input fields: 'Latitude (°)' with the value '38.926', 'Longitude (°)' with the value '-77.246', and 'Altitude (M)' with the value '0'. At the bottom are 'OK' and 'Cancel' buttons.

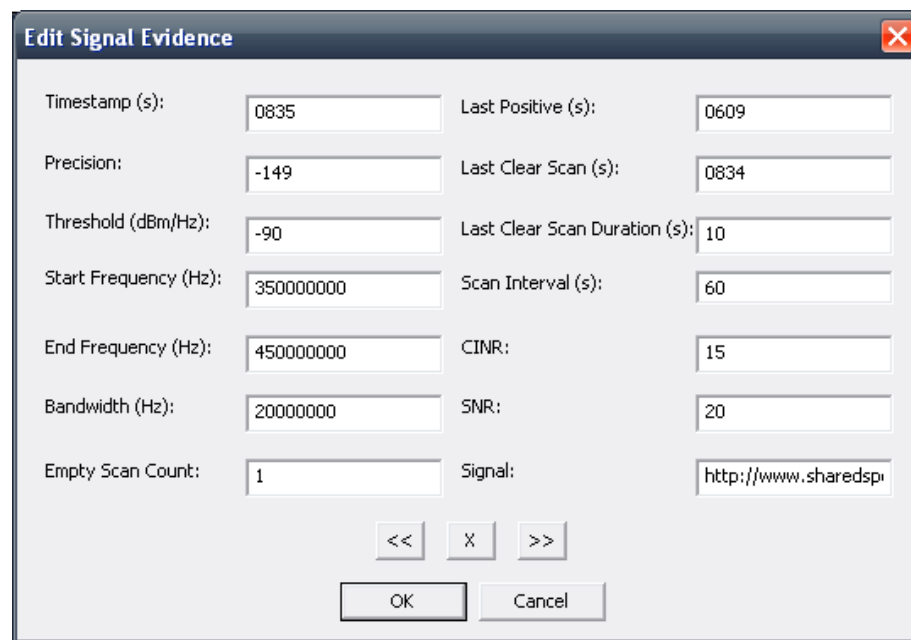
- Transmission constraints
  - Each value specified will be reported for policy conformance if policy regulates the given value
- Signal evidence
  - To closely simulate device behavior in a specific environment
  - Load one or more signal evidences using signal detection evidence from real world tests
  - Simulator will assume policy regulates the lowest start frequency and highest end frequency of all evidence (user may change during simulation)
  - Signal types are string classifications, each individual signal type is added to the known classifications, if there is only one evidence provided and the signal type is provided the device assumes that signal type



**Edit Transmission**

Frequency (Hz):	351000000	Max (s):	.001
Bandwidth (Hz):	1750000	Min (s):	.0015
Power (dBm):	-30	<input checked="" type="checkbox"/> TPC On/Off/Unavailable	

OK Cancel



**Edit Signal Evidence**

Timestamp (s):	0835	Last Positive (s):	0609
Precision:	-149	Last Clear Scan (s):	0834
Threshold (dBm/Hz):	-90	Last Clear Scan Duration (s):	10
Start Frequency (Hz):	350000000	Scan Interval (s):	60
End Frequency (Hz):	450000000	CINR:	15
Bandwidth (Hz):	20000000	SNR:	20
Empty Scan Count:	1	Signal:	http://www.sharedsp

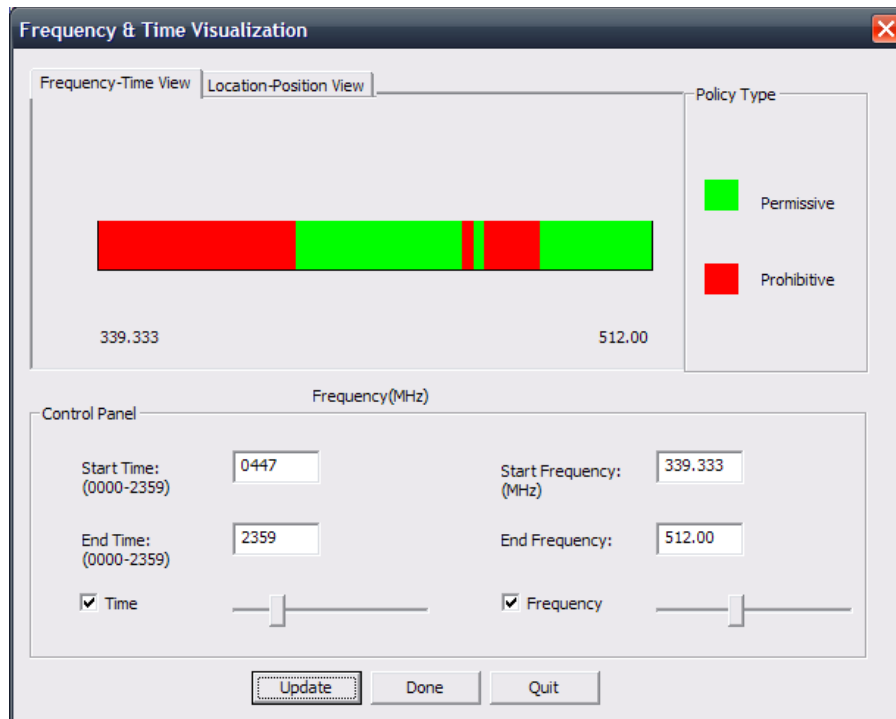
<< X >>

OK Cancel



# Policy Validation Simulator Visualization

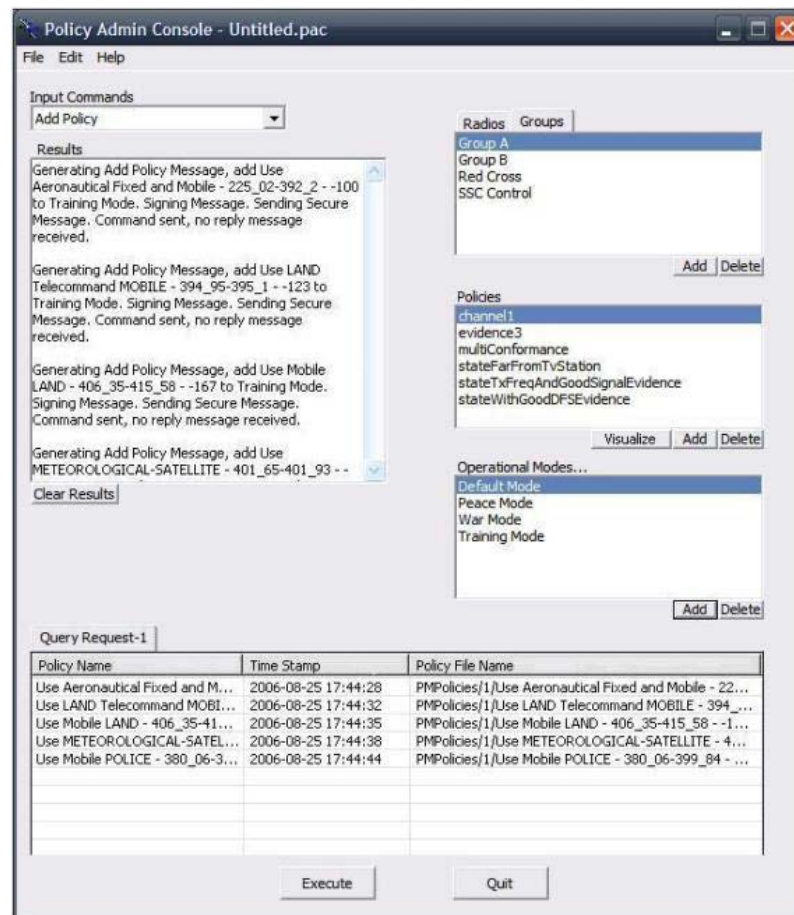
- Visualize device behavior as time, location, and transmission constraints change
- Time and frequency view use the observed start and end values or sliders, location is held constant
- Location view uses device configuration constants, time and frequency remain at the last observed start values as device position changes





# Policy Administration Tool

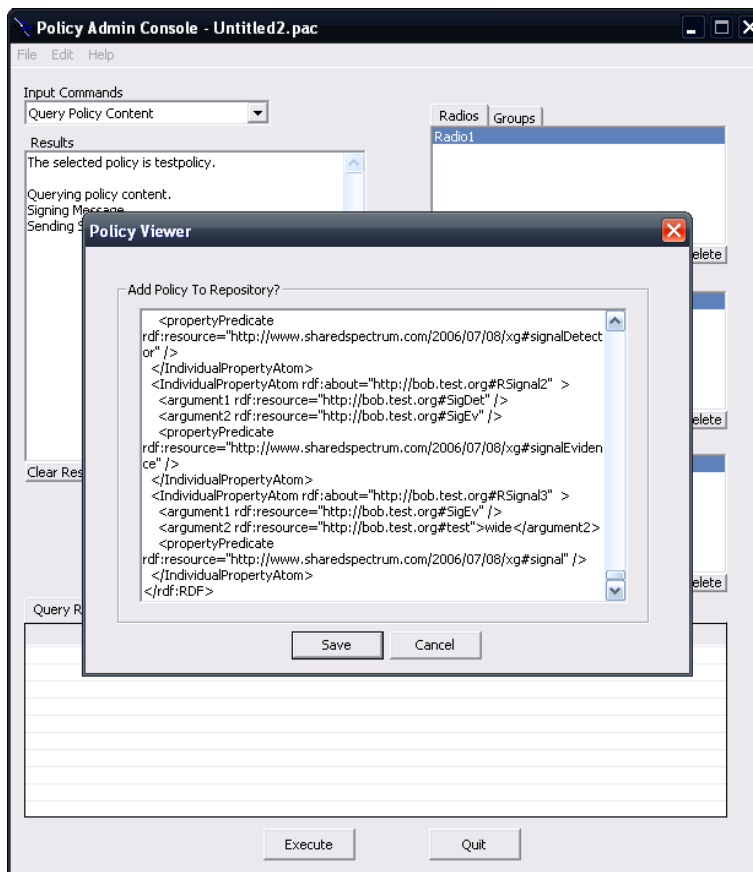
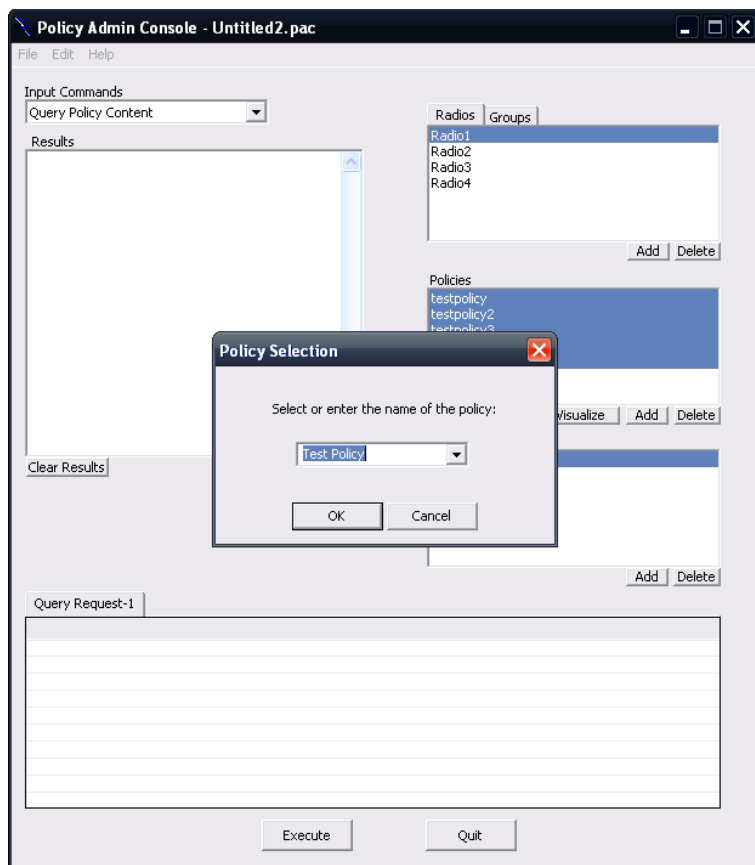
- Disseminates policies
- Connects with remote devices
  - Connection is secure and verified
- Add, remove, query device configuration and policy content
  - Allows mode changes and synchronization
- Visualize policies
  - Compare and contrast the behavior of known policies
- View policy content
  - View policy content and meta data to determine configuration settings





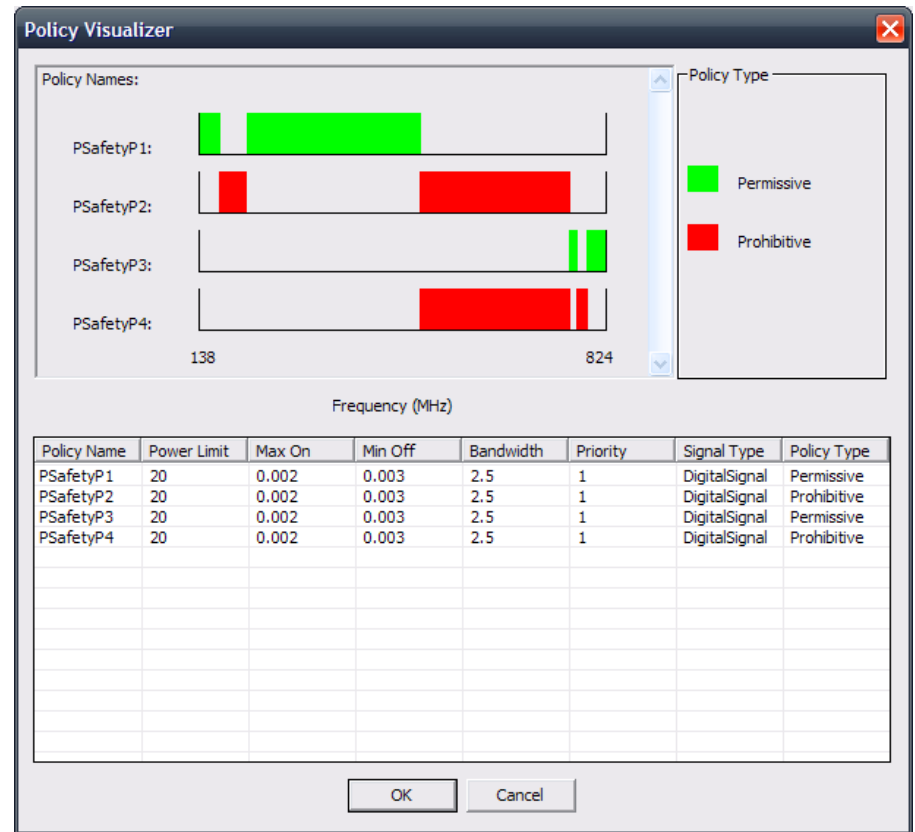
# Policy Administration Tool

- Querying and viewing policy content
- Save policies to repository



# CRAM Policy Administration Tool Visualization

- Visualize multiple policies
- Observe policy constraint table
- Quickly configure modes based on the visualizer frequency maps
- Synchronize devices upon network join request





# CRAM Policy Development Suite Reliability

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- Policy enforcement guaranteed through policy conformance reasoning agent
- Do no harm, if conflicts arise at the policy level default policy behavior prohibits any transmission if not resolved by priority
- Secure dissemination, policies are encrypted, compressed, and authorized by a third party
- Modes retain operational configurations providing interoperability between agencies using CR devices using a standard policy language and reasoning agent



# Conclusions

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- We present a design of an end-to-end, multi-band cognitive radio management system that solves Public Safety problems related to interoperability among disparate systems and agencies, and shortage of dedicated frequency bands
- Using the CRAM policy development suite, Shared Spectrum Company is able to provide proof of concept by demonstrating the required functionality producing the following overall advantages
  - Simplicity- no need to do careful planning, the radios plan out spectrum usage themselves
  - Speed of deployment- easier to copy and paste policies than writing new configurations from scratch



# Future Work

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- Conduct live field demonstrations of CR system during first responder exercises in urban environments
  - Collaborate with federal, state & local officials
  - Show how CR and network policies provide secure and reliable command and control
- Leverage SSC's 802.16-based multi-band radio platform for incident area test and evaluation of broadband applications
  - Prove interference avoidance and coexistence with legacy systems
  - Ensure building penetration and link range/quality
  - Rapidly deploy ad hoc network and backhaul
- Integrate DSA software in advanced military/public safety radios (e.g., Thales Liberty radio and Harris Unity radio)
  - Show interoperability with legacy systems with both waveform and frequency agility



Are there any questions or  
comments?



# Thank You!

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