Risk-Informed Spectrum Sharing and Management Capability

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***Abstract*—MITRE developed a risk-informed spectrum sharing and management capability to support decision makers in minimizing interference risk while maximizing spectrum utilization. The capability is an analytic approach and framework that enables the characterization of risk to critical operators and operations and optimization of spectrum decisions based on multiple factors. The capability provides a structured workflow that incorporates interference analysis into risk-informed mission-aware spectrum decision making. The framework improves on existing spectrum management approaches by addressing the mission risk to critical operators and operations in decision making.**

Keywords—risk, risk-informed, spectrum, spectrum sharing, spectrum management, spectrum risk, electromagnetic interference

I. Introduction

Managing interference risk is a primary concern for spectrum stakeholders from both government and industry. Historically, spectrum incumbents adopted a risk-averse interference assessment methodology to minimize their operational risk. These methodologies, which are based on worst-case deterministic representation of the interference source, victim, and propagation effects, are effective at minimizing interference risk at the expense of greater use of available spectrum. These approaches limit the ability to share spectrum.

In this abstract, we describe a comprehensive Risk-Informed Spectrum Sharing and Management (RISSM) capability. It will enable spectrum decision makers to address interference and other risk factors involving regulations, allocation, policy, acquisition, certification, sharing, operational planning, and execution. The RISSM capability applies risk analysis practices that draw on economics, utility and decision theory, probability theory, and engineering management science.

The RISSM capability provides a consistent, risk-informed approach to prevent, prepare for, respond to, and recover from electromagnetic interference or other risk factors. The approach identifies critical spectrum operators (e.g., units, individuals) and operations (e.g., flight safety, mission essential task) and the hazards that can impact them. It then probabilistically characterizes the hazards and facilitates optimization that enables the most effective and efficient use of allocated spectrum while minimizing mission risk to critical operators and operations. Current analytic approaches are technical focused and do not address the criticality of operators and operations in their analysis.

The RISSM capability includes a well-defined workflow to help make risk-informed decisions throughout the spectrum life cycle. The capability is a tailorable and flexible framework that facilitates the plug and play of different analysis approaches to complete each step of the workflow. This capability introduces a structured way to characterize the mission risk that operators and operators experience due to interference. This risk analytic approach enhances and builds on traditional interference analysis by translating technical results into the mission impact on operators and operations.

II. Risk-Informed Spectrum Sharing and Management Capability

The RISSM capability provides a structured framework for risk-informed decision making and optimization. The workflow outlines the analytic steps required for risk-informed and optimized spectrum operations. Our capability's workflow can be applied to single decision points (e.g., what to auction, sharing rules, and power levels) or used continuously to evolve and adapt regulations, policies, and operations to improve the effectiveness and efficiency of spectrum utilization. The seven RISSM capability steps are outlined in Figure 1.

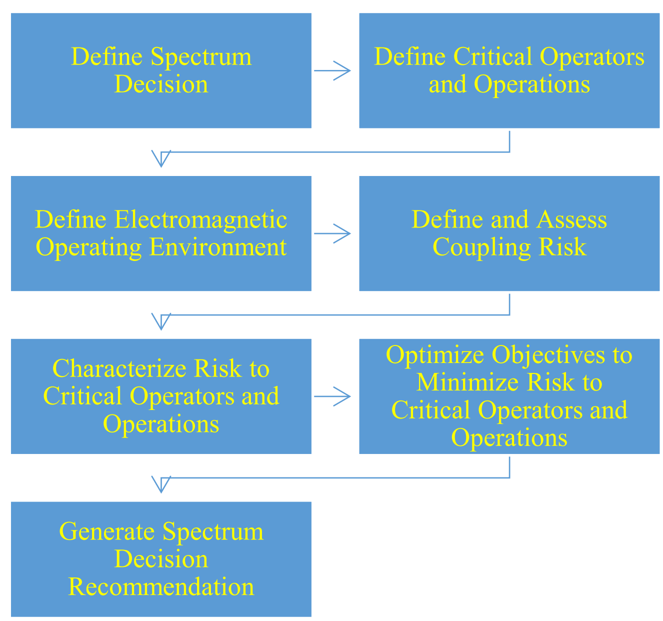

Figure 1:

Risk-Informed Spectrum Sharing and Management Capability

A. Define Spectrum Decision

The critical first step of the RISSM capability is to determine what type of spectrum decisions are needed, including:

- **Regulatory,** e.g., determine how to allocate spectrum, synthesizing the sharing rules
- **Acquisition,** e.g., inform trades on performance effects/ survivability of spectrum-dependent systems
- **Implementation,** e.g., determine design considerations and policies for the spectrum-sharing ecosystem
- **Execution,** e.g., inform planning and operations and ecosystem evolution

The capability supports single decision points, or it can be integrated into a continuous evaluation approach to regularly improve the use of spectrum throughout the spectrum-sharing life cycle. The approach is flexible and iterative and supports standardization and data-driven decision making.

B. Define Critical Operators and Operations

The RISSM capability requires the identification and evaluation of the mission critical operators and operations within the Electromagnetic Operating Environment (EMOE). Users must define what spectrum dependent systems (SDS) need to be protected from disruption or degradation and the systems' significance in successfully executing the mission. Critical operators and operations can be associated with both government and commercial systems. There can be multiple levels of criticality, allowing decision makers to prioritize which operators and operations are most important.

C. Define Electromagnetic Operating Environment

In this step, users identify all other operators and operations in the targeted EMOE that can impact the critical operators and operations. These can be other government or commercial SDS, as well as adversarial SDS that can result in the disruption or degradation of the critical operators and operations. The relationships among critical and non-critical operators and operations form the foundation of the coupling matrix, an abstraction for quantifying the impacts of cause-and-effect relationships.

D. Define and Assess Coupling Risk

The RISSM capability is flexible enough to address multiple sources of coupling risk. The coupling represents the source that either disrupts or degrades the performance of the critical operator or operations. This is represented as a probability of disruption or degradation from a given coupling. The disruption or degradation can result from many sources, including interference, economic, and cyber.

The capability supports the plug and play of different analysis approaches and models that can derive the probability of disruption or degradation. These analysis approaches can be measurement-based, models, or heuristics and can be run at various levels of fidelity, depending on data availability and processing-time requirements. The Advanced Wireless Services Spectrum Sharing, Test, and Demonstration program's application of statistical techniques to characterize LTE user-equipment aggregate emission and clutter loss is an example of an analysis that could be characterized as a coupling risk and incorporated in the workflow.

E. Characterize Risk to Critical Operations and Operators

To characterize risk to critical operators and operations, the RISSM capability utilizes the coupling risk and the level of criticality of each element to create a risk measure for each critical operator and operation. This measure reflects the decision makers' priorities on what must not be disrupted and degraded. The measure will indicate that a critical operator of the upmost importance (e.g., flight safety) is high risk and a non-critical operator is low risk at a given probability of disruption. The capability directly incorporates value functions that reflect an organization's risk tolerance and then translates probabilities of occurrence into relevant risk measures. The output at this point can be used to make decisions without the application of optimization. This step introduces a structured approach to connect interference risk to its mission impact on operators and operations. Our approach improves on traditional interference analysis, which does not connect the technical analysis to mission risk.

F. Optimize Objectives to Minimize Risk to Critical Operators and Operations

The RISSM capability facilitates optimization to minimize the amount of risk to critical operators and operations and to optimize additional criteria (e.g., amount of spectrum used, number of operators able to share, time restrictions, and powers levels). These criteria inform optimization analysis.

The capability supports the use of different optimization algorithms (e.g. greedy, genetic, and particle swarm) to identify the optimal solution. Different approaches are more suitable for different decision time horizons and the scope of the EMOE being evaluated. These approaches will result in minimizing the overall risk to the critical operators and operations and optimizing decision makers' objectives.

G. Generate Spectrum Decision Recommendation

The RISSM capability can generate recommendations to inform users' regulatory and operational decisions. Multiple perspectives can be generated by changing the optimization objectives and time horizons, which will provide additional rigor to evaluating different courses of action. Additionally, users can conduct this step interactively to continuously inform regulations, policies, and operational decisions.

III. Conclusion

The Risk-Informed Spectrum Sharing and Management capability provides a foundation for an evolutionary approach to spectrum regulation, sharing, and operations. The RISSM capability enables spectrum decision makers to prioritize spectrum resources that support mission-critical operators and operations. The capability provides a decision framework that is adaptable to a variety of analytic approaches and can be matured by the spectrum community over time. The RISSM capability also provides a consistent way to examine spectrum tradeoff scenarios across different decision time horizons.