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ISART 2006

**Metrics-based Regulation of Effectiveness and Efficiency in
Dynamic Spectrum Access Systems;
the Art & Science of Dealing with Radio Complexity**

Kalle R. Kontson
Alion Science and Technology
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Overview

- Background and review of some interesting trends on the regulatory front
- Discussion of a hypothetical policy model
- Discussion of a derivative regulatory model
- Requirements for evaluation metrics implied by these policy and regulatory models
- Summary



Regulatory and Policy “Futurist” View - Background and Review

- Previous work on “Intelligent” Wireless Devices and Impact on Spectrum Management
 - Intelligent Wireless Device Bill of Rights
- Spectrum Policy Task Force
- Increasing Interest in Dynamic Spectrum Access and Secondary Markets
- Increasing maturity of beneficial, spectrum-efficient technologies – Technology is a forcing function



First Draft of an Intelligent Wireless Device Bill of Rights

- **Article 1: Any intelligent wireless device may, on a non-interference basis, use any frequency, frequencies or bandwidth, at any time, to perform its function.**
 - Article 1, Tenet 1: To exercise rights under this Article, intelligent devices must be mentally competent to accurately determine the possibility of interference that may result from their use of the spectrum, and have the moral character to not do so if that possibility might infringe on the rights of other users.
 - Article 1, Tenet 2: To exercise rights under this Article, intelligent devices must actively use the wireless spectrum within the minimum time, spatial and bandwidth constraints necessary to accomplish the function. Squatting on spectrum is strictly prohibited.
- **Article 2: All users of the spectrum shall have the right to operate without harmful electromagnetic interference from other users.**
 - Article 2, Tenet 1: Priority of rights under this Article may be determined by the proper authorities only in cases of National emergency, safety of life or situations of extreme public interest.
 - Article 2, Tenet 2: Rights under this Article may be exercised only when the systems exercising the rights are designed , as determined by the state of the practice, to be reasonably resistant in interference.
- **Article 3: All licensing, auctioning, selling or otherwise disposition of the rights to frequencies and spectrum usage shall be subordinate to , and controlled by Articles 1 and 2, above.**

Emphasis on Intelligent Devices;
What Are the Required Characteristics of the Devices?



Avoiding Unrealistic Expectations

- Achieving a regulatory regime based on an **Intelligent Wireless Device Bill of Rights** will not happen soon.
 - It's a hypothetical end state to pursue, to establish direction
- A step-wise approach makes sense; begin driving toward an *unlicensed but highly regulated* model
- A first step in this direction... a Policy for transforming to:

Technology-Driven Tiered Spectrum Access Rights



Technology-Driven Tiered Spectrum Access Rights

- Definition: A regulatory model that rewards the implementation and deployment of spectrum-efficient technologies by offering incentives in the form of progressively expanded tiers of spectrum access rights in proportion to device performance.
- Analogies and precedents
 - HOV lane access exceptions for hybrid and electric cars
 - FCC Part 15 allowance for higher EIRP for directional antennas
 - FCC Part 15 spectrum access for systems with TPC and DFS
- Advantages:
 - Promotes superior technologies by offering incentives for use
 - Expands capacity of the limited resource
 - Begins an industry-driven migration toward new regulatory models
- Key questions:
 - ***What wireless system characteristics are sufficiently beneficial, measurable and predictable to justify expanded spectrum access rights?***
 - ***How do we evaluate them?***

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Spectrum Scorecard for Evaluation of Spectrum Properties of System Designs

- A method of scoring “spectrum citizenship”
- A standard set of metrics and tools to assess the worthiness of individual devices to reap rewards for good spectrum behavior, and restrict bad behavior



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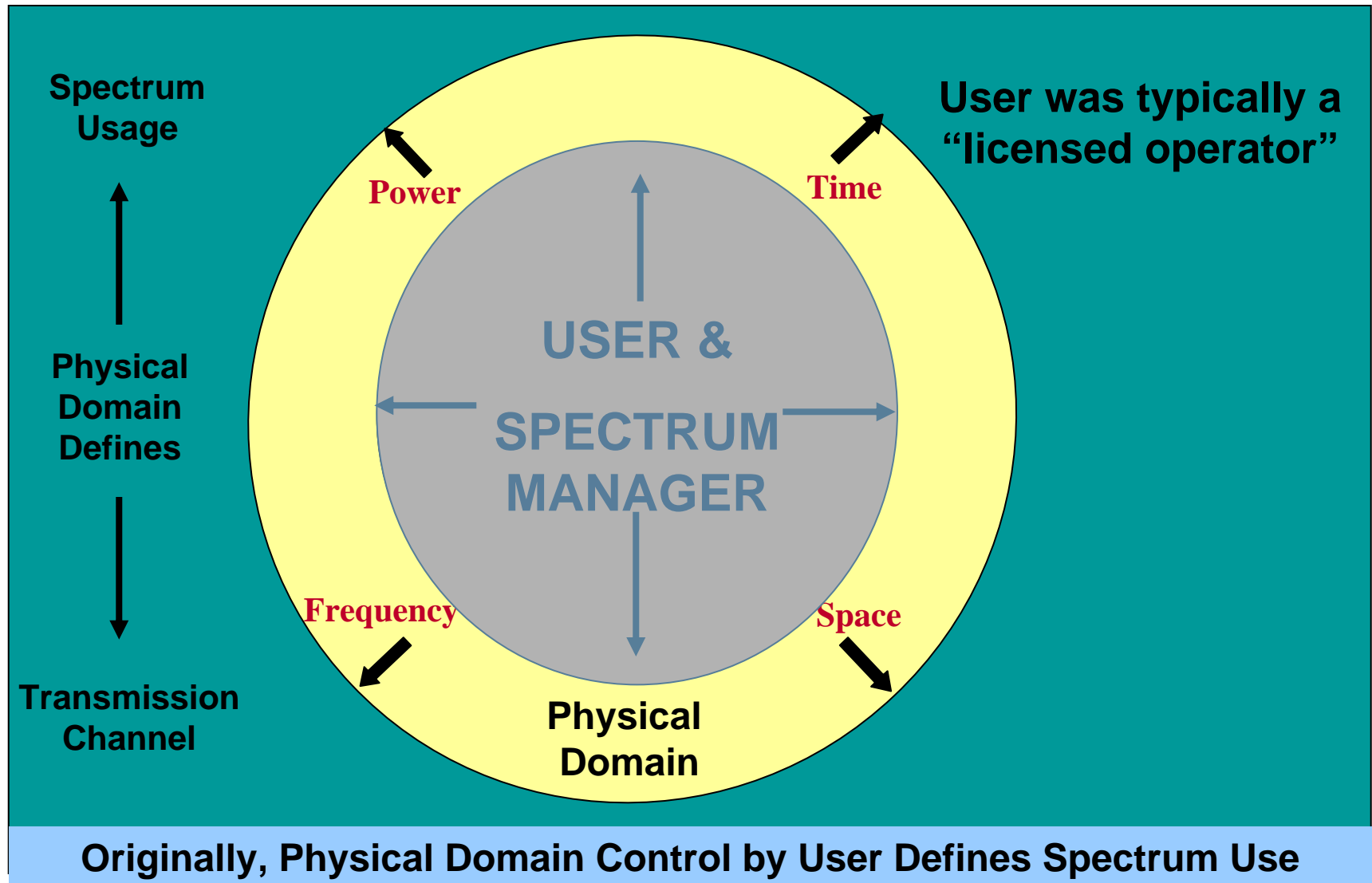


EVOLUTION OF THE "RADIO OPERATOR" ... FROM MAN TO MICROCHIPS



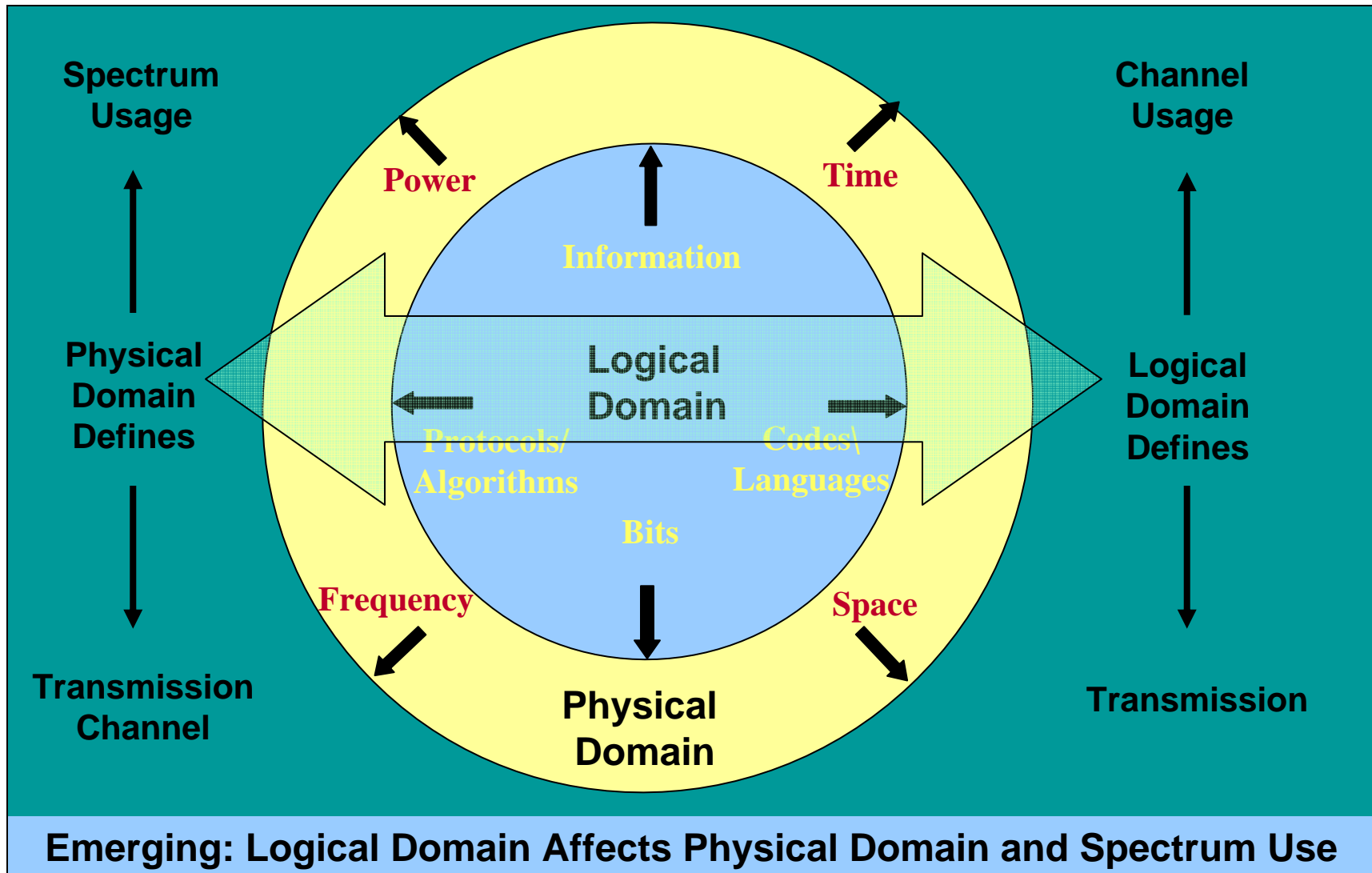


Evolving Dimensions of Signal Resource Space - Past





Evolving Dimensions of Signal Resource Space - Future



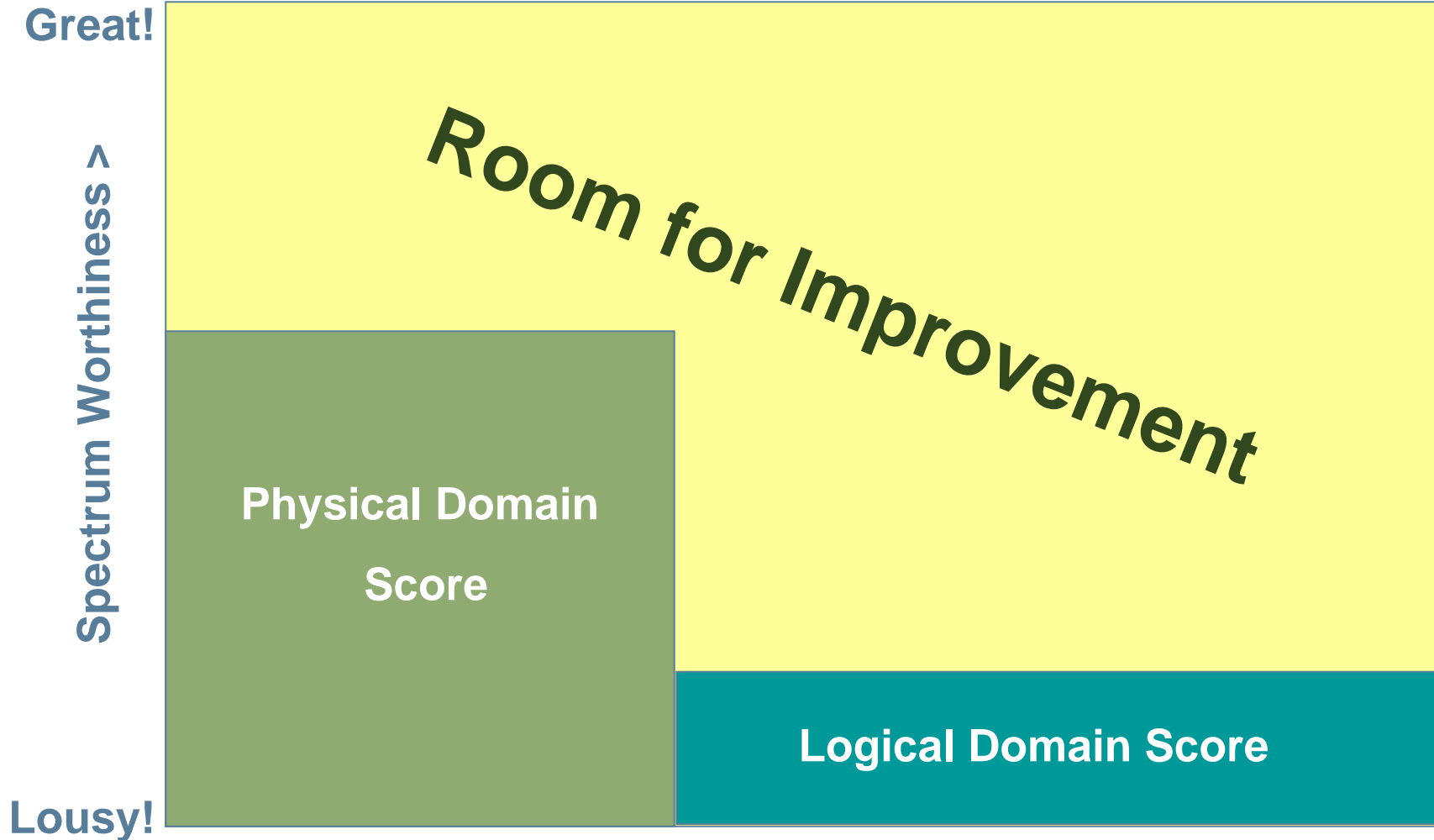


Observations About Convergence: Physical & Logical Resources

- Physical Resources
 - Are limited, there is a finite amount
 - Technical innovations focus on maximizing efficient use of physical resources
 - Regulations manage physical resource use, strict usage rules apply
 - Currently regulated and evaluated: licensing and certification
- Logical Resources (Evolving Spectrum Manager!)
 - New, better versions constantly being created; affected by standards
 - Hardware capabilities (processor speeds, memory size,) can limit or enhance
 - Technical innovations focus on improving effective use of the transmission channel
 - Can **dramatically affect** demands on physical resources
 - Use not currently regulated or evaluated by the spectrum community

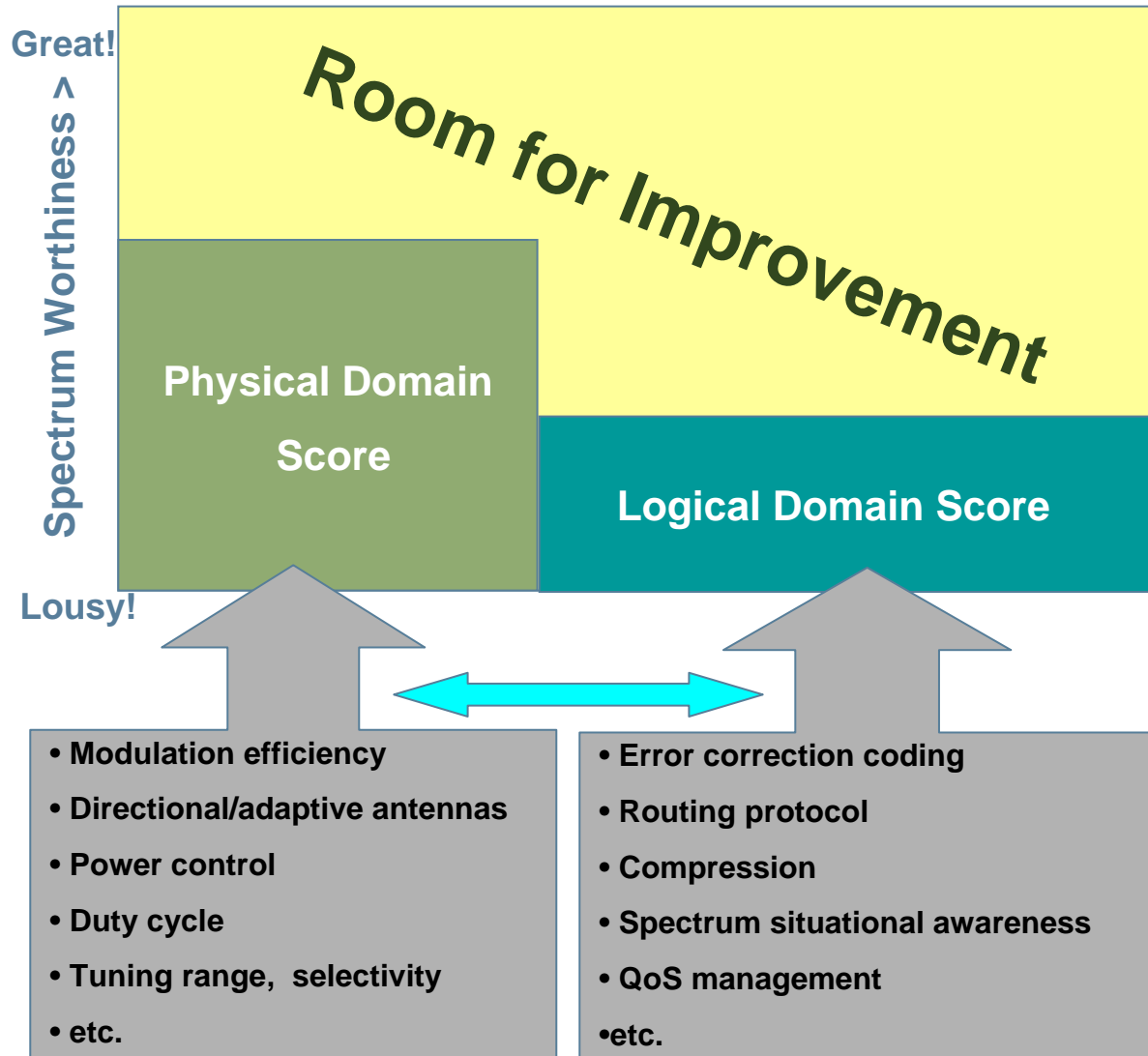


Objective: Top-Down Scoring Presentation; System AN/XYZ





Bottom-up Scoring by Aggregating Multiple Capabilities and Attributes





Addressing Features, Attributes, & Capabilities Affecting Spectrum Access

- RF characteristics - physical domain
- Bits and information – logical domain
- Network management – logical domain
- Cognitive – logical domain



RF Characteristics – Physical Domain

- Frequency Agility
- Bandwidth Management
- Modulation Management
- Power Management
- Antenna Management



Bits and Information Domain

- Digitized bits and packets
- Error correction
- IP header compression
- Application-level bandwidth management



Network Management Domain

- Network Overhead
- Topology Management
- Bandwidth Availability Management

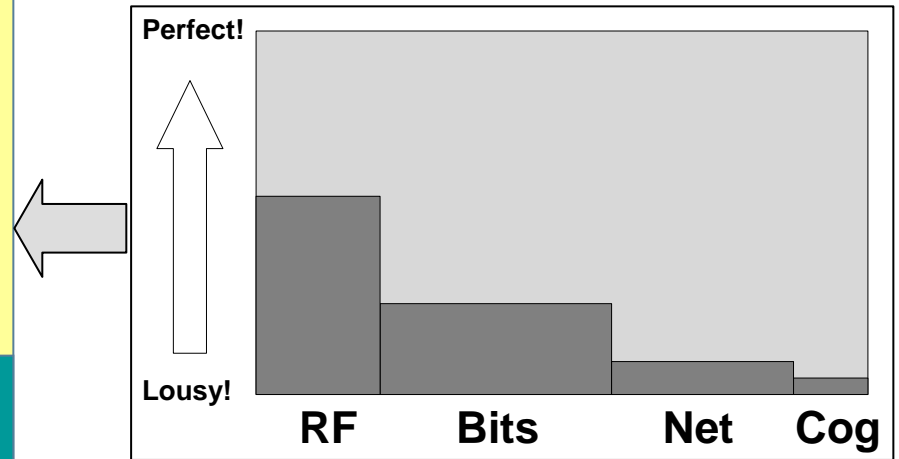
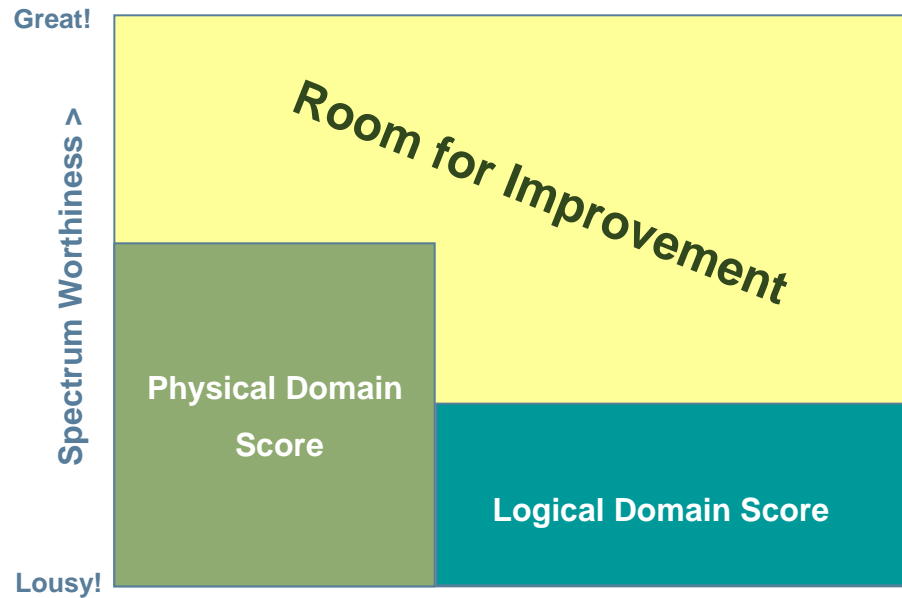


Cognitive Domain

- Geographical Awareness
- Environmental Awareness

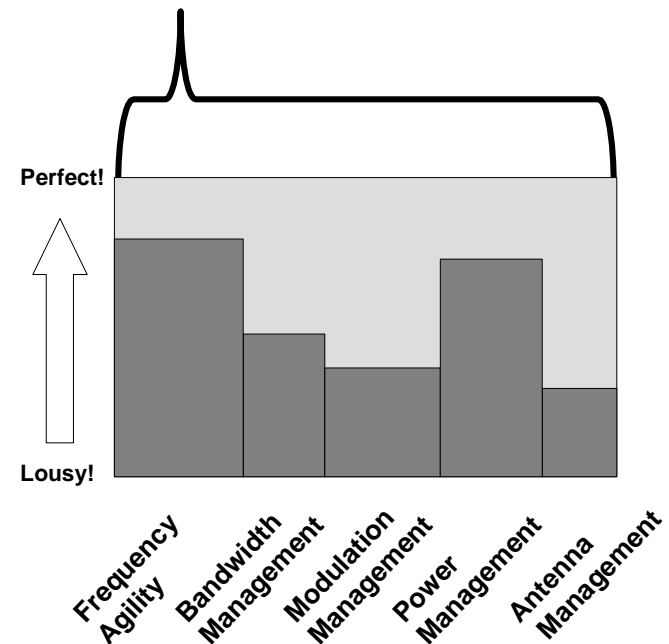
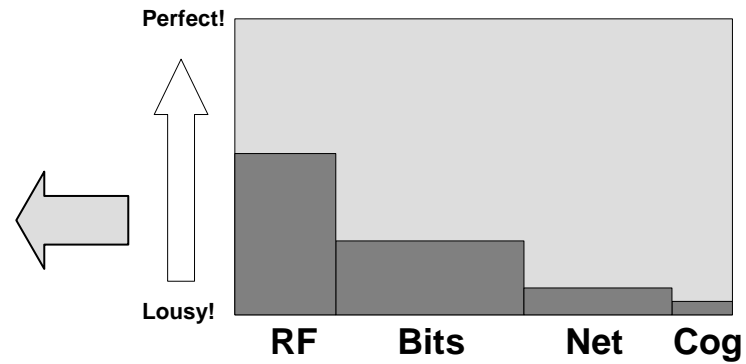
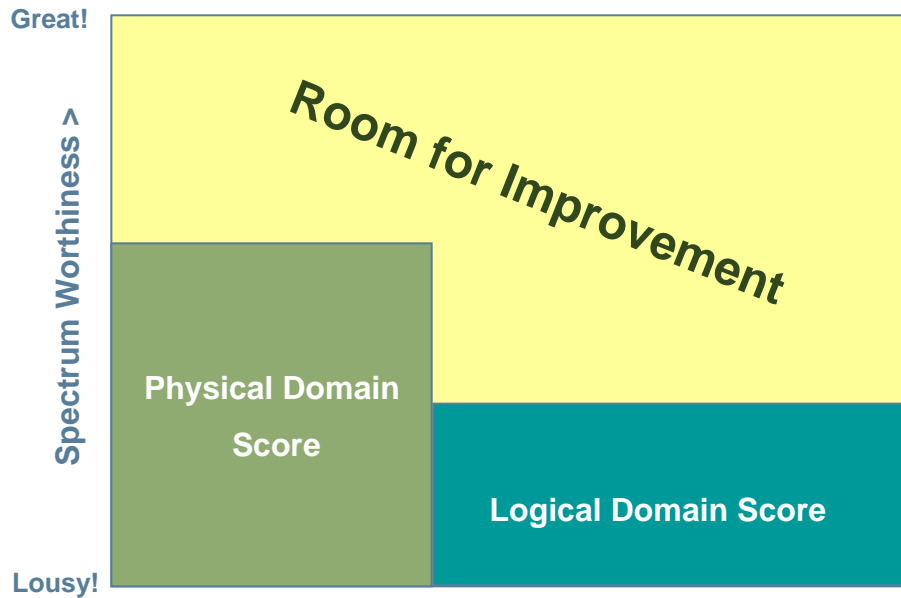


Implementing and Aggregating





Implementing and Aggregating (continued)





Summary and Conclusion

- The tiered spectrum access rights model is suggested as providing motivation to build systems that display good Spectrum Citizenship
 - Incentive to provide design of systems to reap the benefits of new spectrum access paradigms
 - DoD has relied on the spectrum certification process to ensure spectrum-dependent system supportability
 - In the commercial and public safety sectors, the FCC has shown interest in market-driven technology evolution
 - The Spectrum Policy Task Force and other activities lean toward regulatory structures that leverage advances in technology to enable these new ways of granting spectrum access rights
- The Spectrum Scorecard is presented as means to evaluate Spectrum Citizenship within a tiered spectrum access rights model
 - This Spectrum Scorecard identifies and grades the complex ensemble of attributes of a spectrum-dependent system which impact the amount of spectrum required by the system and the efficiency with which the system uses the spectrum
 - A Spectrum Scorecard can provide a structured method of imposing pressure for good Spectrum Citizenship in emerging system design to earn desired levels of spectrum access rights