Adaptive Spectrum Radio: A Feasibility Platform On The Path To Dynamic Spectrum Access

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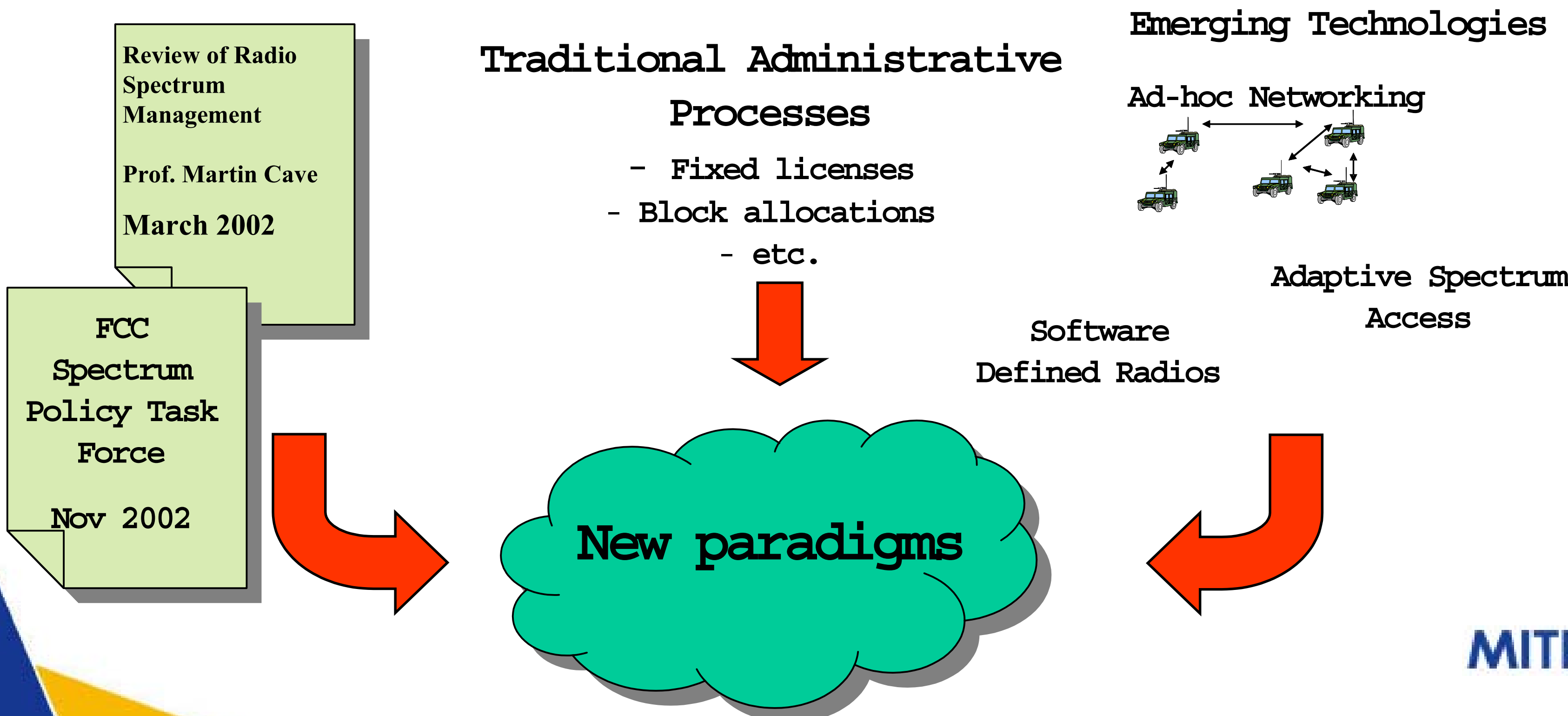
New Paradigms for Spectrum

- New paradigms for managing and allocating the electromagnetic spectrum is now possible due to advances in technology and a receptive environment within regulatory agencies
  - New technology provides a key component to this possibility as it increases the flexibility for radio transmissions to dynamically adapt and access the spectrum



Dynamic & Adaptive Spectrum Access

- **The definition of a fully "dynamic" or "adaptive" system is not clearly delineated, but the capabilities of such a system would include:**
  - **Sensing the radio frequency environment;**
  - **Controlling its transmissions based on measurements and other a priori information in an autonomous, opportunistic, and real-time fashion;**
  - **Adjusting multiple transmission parameters including, but not limited to, frequency, power, modulation, signal timing, data rate, coding rate, and antenna; and,**
  - **Operating in cooperative networked systems and/or environments with non-cooperating systems (i.e., opportunistically accessing spectrum).**

Increasing

Unlicensed devices

2G/3G (e.g., EDGE)

Scheme	Modulation	Maximum rate	Code rate per slot (kb/s)
MCS-9	8-PSK	59.2	1.0
MCS-8		54.5	0.92
MCS-7		44.8	0.76
MCS-6		29.6	0.49
MCS-5		22.4	0.37
MCS-4	GMSK	17.6	1.0
MCS-3		14.8	0.80
MCS-2		11.2	0.66
MCS-1		8.8	0.53

IEEE 802.11 standards

Dynamic Frequency Selection (DFS)

DARPA neXt Generation (XG) program

Future: "Fully" dynamic and adaptive

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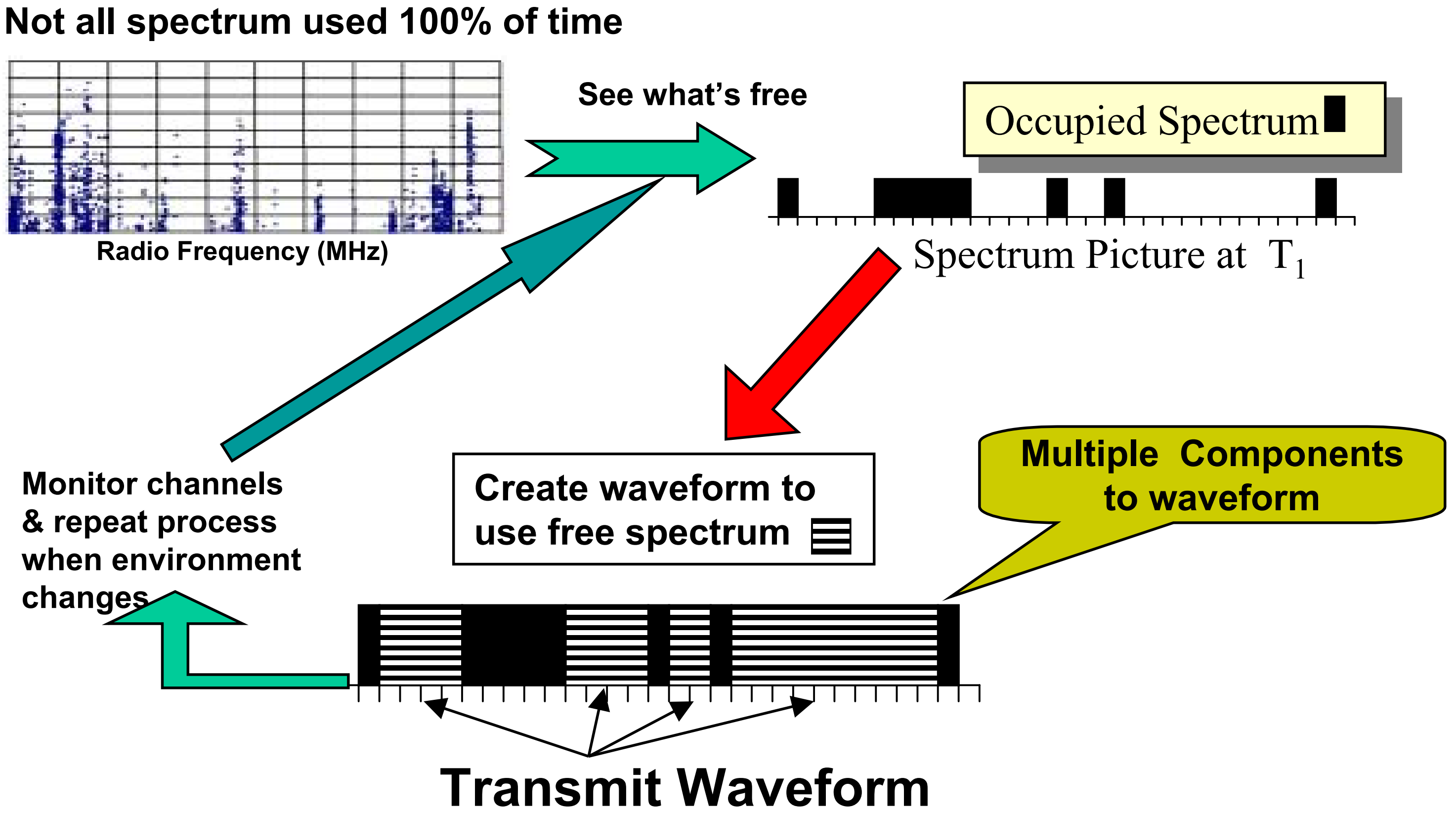
Adaptive Spectrum Operations Concept



Waveform compatible with existing spectrum channelization plans and scalable to support wide range of user data rates using non-contiguous spectrum

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Dynamic & Adaptive Spectrum Access: Benefits & Challenges

- Key benefits for adaptive spectrum access include:
  - Improved spectrum access and utilization
    - By adjusting transmissions, adaptive systems can utilize unused frequencies even if they vary over time
  - Maintain a quality of service in a changing environment
    - Existing examples include EDGE
  - Adjust emissions to reduce or "maintain" levels of interference to other systems
    - Enables interference "temperature" policy concepts
- Key challenge: working with regulatory community to determine appropriate "dynamic" and "adaptive" policies and parameters

"Because new, smart technologies can sense the spectrum environment and because they have the agility to dynamically adapt or adjust their operations, increasing access to the spectrum for smart technologies, such as software-defined radios, can improve utilization, through more efficient access, of the radio spectrum without detriment to existing spectrum users." [FCC Spectrum Policy Task Force]

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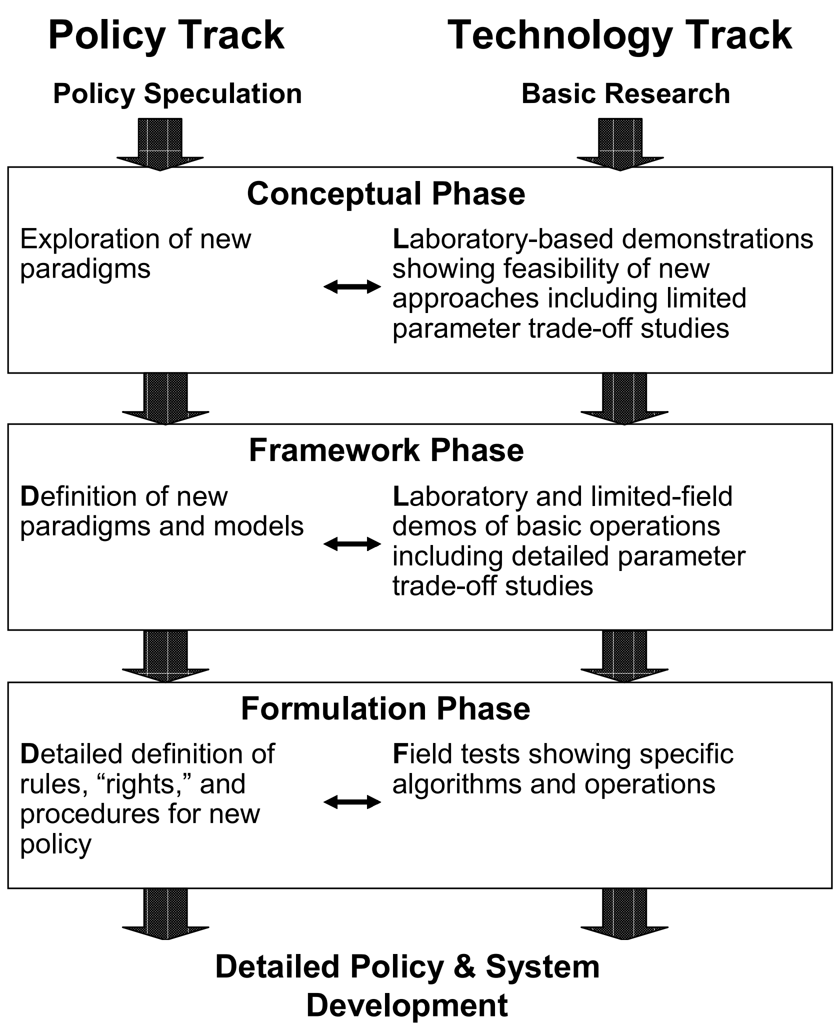
Demonstrations on the Path to New Spectrum Policy

- In order for the policy community to gain confidence in the possibilities of the new paradigms, the technology developers need to demonstrate the capabilities of the systems that enable dynamic spectrum access.
  - The MITRE Corporation has developed a feasibility radio platform that demonstrates the principles for dynamically accessing the spectrum

- Two principal objectives for demonstrations are:
  - Feasibility: Inform the policy and regulatory community of the feasibility for adaptive spectrum access; and,
  - Policy Considerations: Identify and investigate considerations for policies using adaptive radio demonstration platforms.

Parallel Development of Policy & Technology

- A parallel policy/technology development process can mutually benefit all sides by identifying issues early and by preventing contentious proceedings
  - By understanding the capabilities, the policy and regulatory community can better revise and update rules and procedures
  - By understanding policy considerations, technologists can incorporate needs early in development
- Demonstrations are important component of this parallel process



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Emerging Technology & Parallel Policy Example Programs

- **A good example of a new technology awareness program is the DOD's Defense Information Systems Agency's (DISA) Emerging Spectrum Technology program, led by the Defense Spectrum Office (DSO)**
  - **This project intends to proactively understand policy ramifications of new technology having military benefits to ensure that policies do not inhibit their introduction.**
  - **Contact: Rich DeSalvo, 703-325-0435; desalvor@ncr.disa.mil**

- **Other organizations, including the FCC, are also enhancing technology awareness and engagement efforts**

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Policy Considerations of Demonstration Platforms

- **Early Adaptive Spectrum Radio platforms, such as MITRE's, can be used to explore various policy considerations**
  - **Band/Channel Blocking**
    - Do policies that prohibit the transmissions in specific bands or channels, even non-contiguous ones, accommodate or limit the introduction of adaptive spectrum access systems? Can different emission levels be set for different channels?
  - **Technical Parameters**.
    - Should policies define acceptable parameter values associated with the adaptive algorithms (e.g., time required to sense environment, time gap lengths required before "acceptable" to transmit, etc.)?
    - Are such policies necessary for assuring the performance of other systems? If such parameters specifications are necessary, what are the parameters that need to be defined?
  - **Databases of Existing Use**.
    - Do policies need to be adopted that require the availability of databases to assist the operation of adaptive spectrum access systems?
    - Do such radios require a priori knowledge of spectrum usage? Does a priori knowledge improve the performance and interference mitigation capability of these radios?

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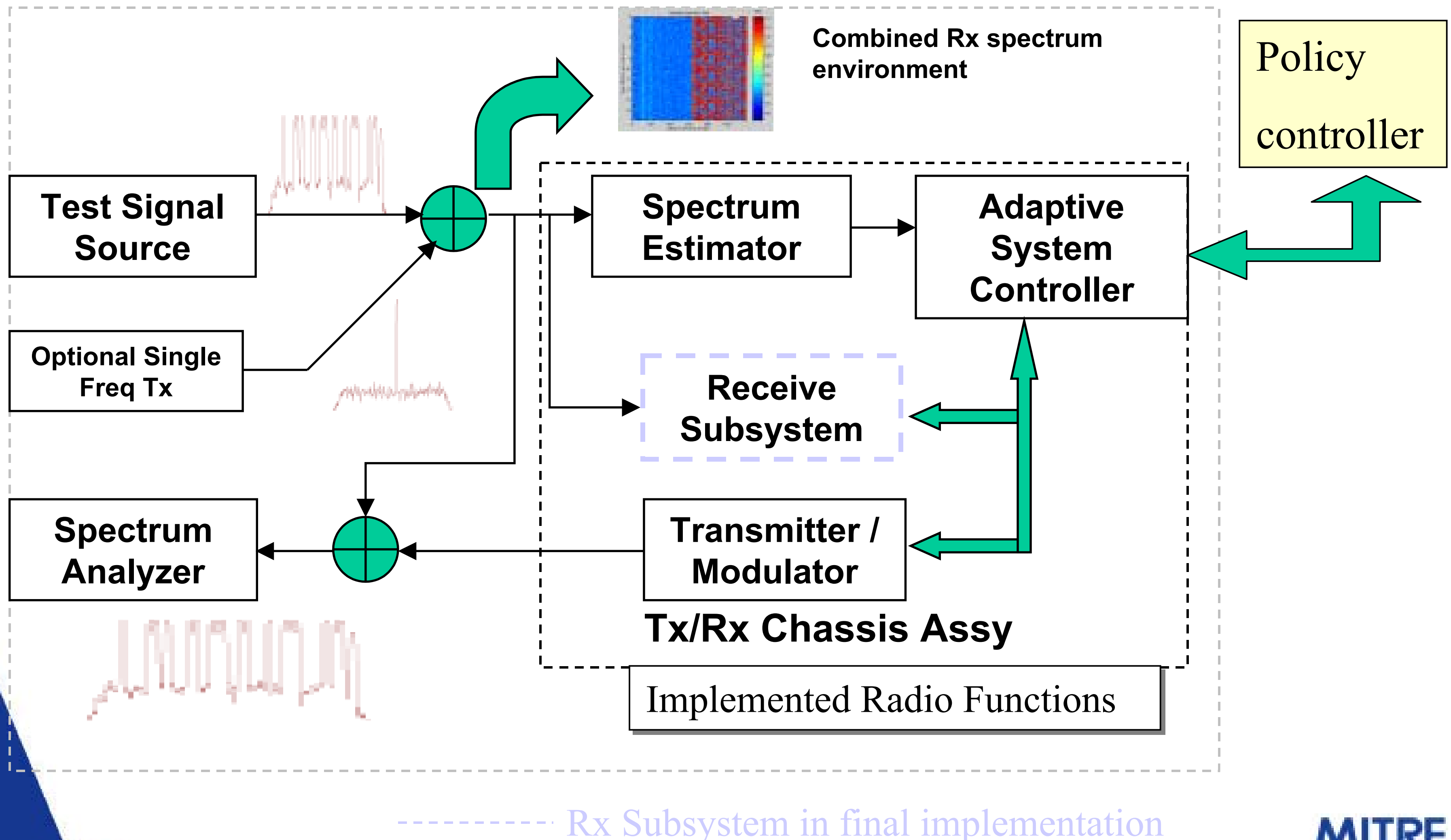
Future Exploration of Policy Considerations Using the Demonstration Platform

- **Interference Temperature**. The FCC Spectrum Policy Task Force introduced the concept of “interference temperature” as a means for defining the environment in which systems must operate.
  - In such a regime, the defined “temperature” and the accuracy of such levels need to be defined--Should policies define permitted limits for transient interference to account for imperfections in the algorithms and protocols for accessing the spectrum?
  - What are the achievable sensitivity levels (i.e., margin of error) for sensing the environment? What are the achievable sensitivity levels (i.e., margin of error) when using propagation prediction?
- **Environments**. What environments can adaptive spectrum access systems operate (e.g., dense voice traffic, radar, etc.)?
- **Refarming**. Can the availability of adaptive spectrum access systems improve the efficiency in certain bands by introducing such systems while allowing legacy systems to continue to operate rather than to relocate them?
- **Secondary/Spot Markets**. Can adaptive spectrum access systems enable secondary/spot market “auctions” and trading?

MITRE ASR/SDR Platform



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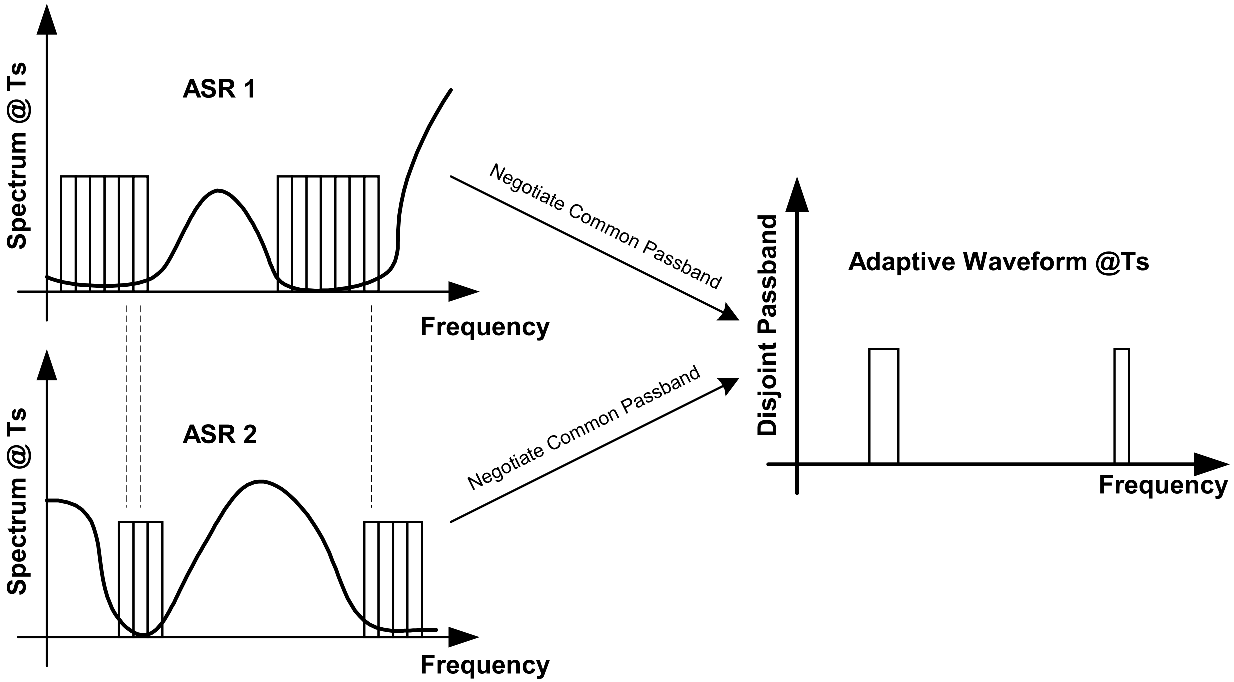
MITRE's Adaptive Spectrum Radio: Overview

- **Observe spectrum to detect idle channels**
- **Adapt waveform**
- **Implement "opportunistic" MAC**

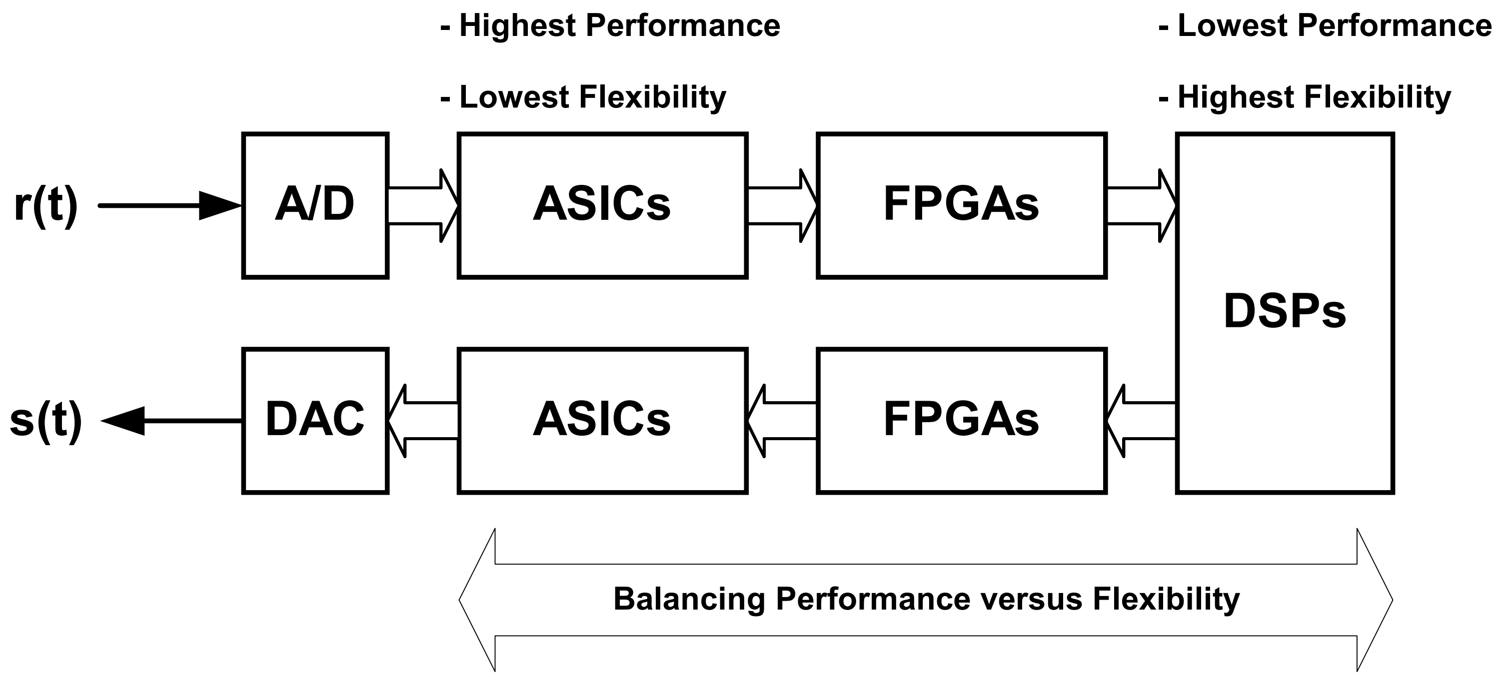
Adaptive Spectrum Approach



ASR Architecture & Design

- Periodic estimation of channel's occupancy state
- Periodic adaptation of a time-limited waveform in response to occupancy state estimates
- Periodic "joint occupancy vector" negotiation w/ subsequent burst data transfer
- Measurement of impairments to primary users

ASR Hardware Architecture



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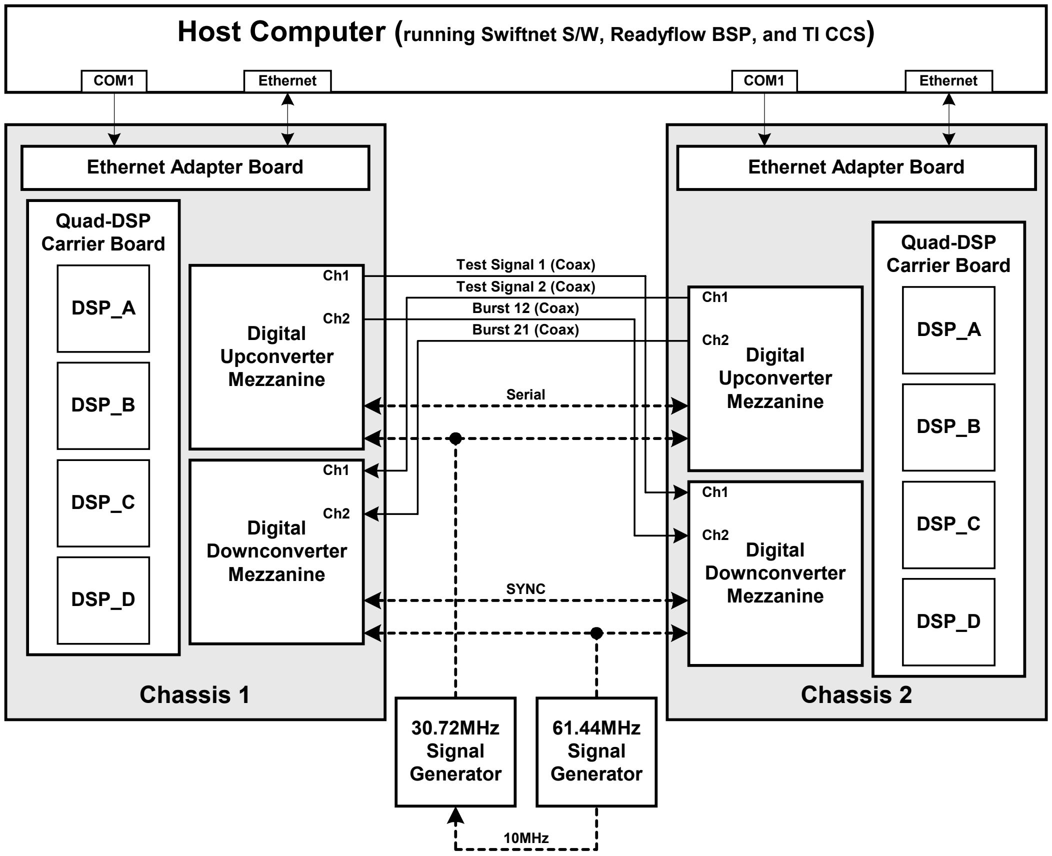
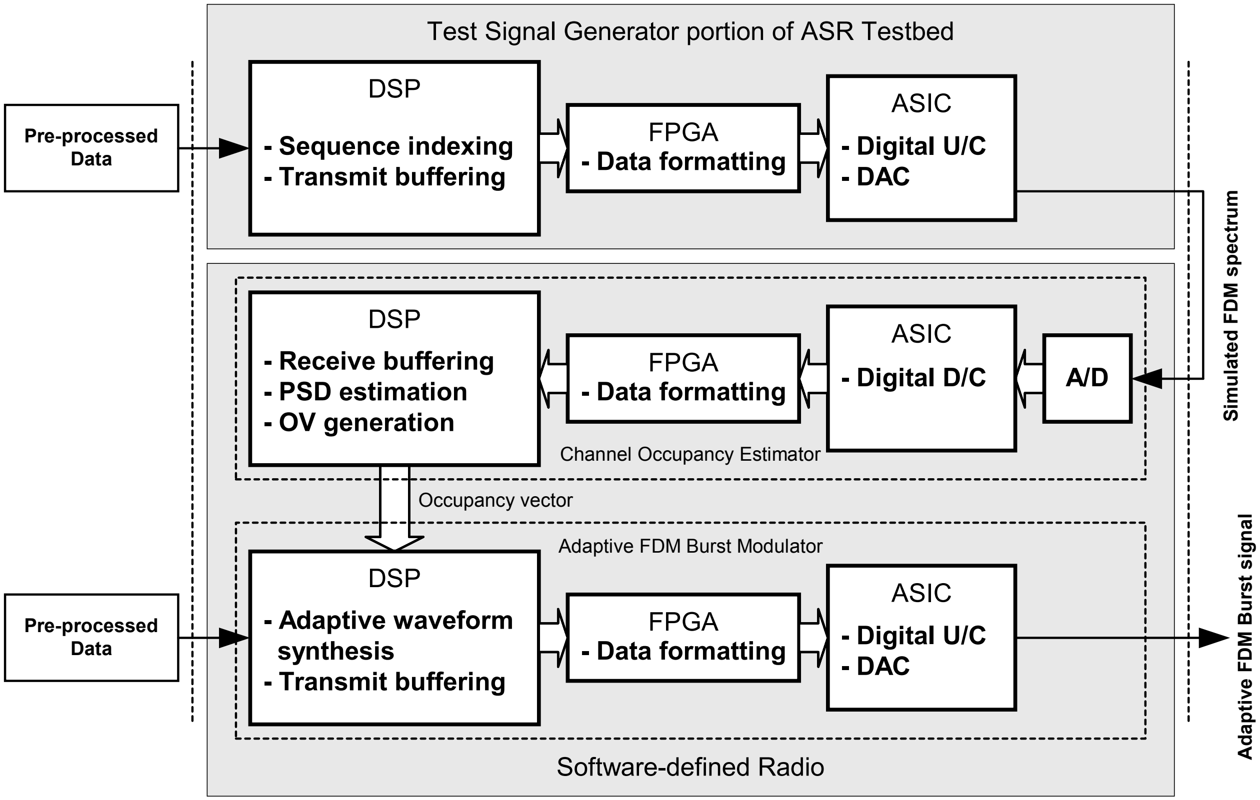
High-Level Testbed Architecture



ASR Tx Functional Partitioning



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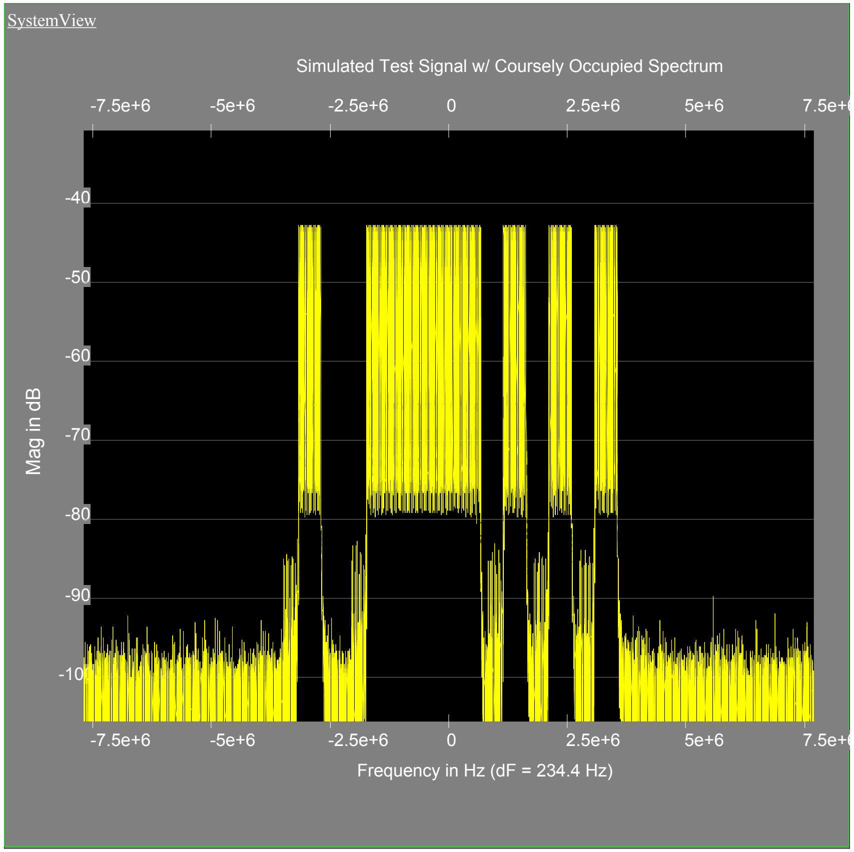
Simulated Test Signal Spectrum



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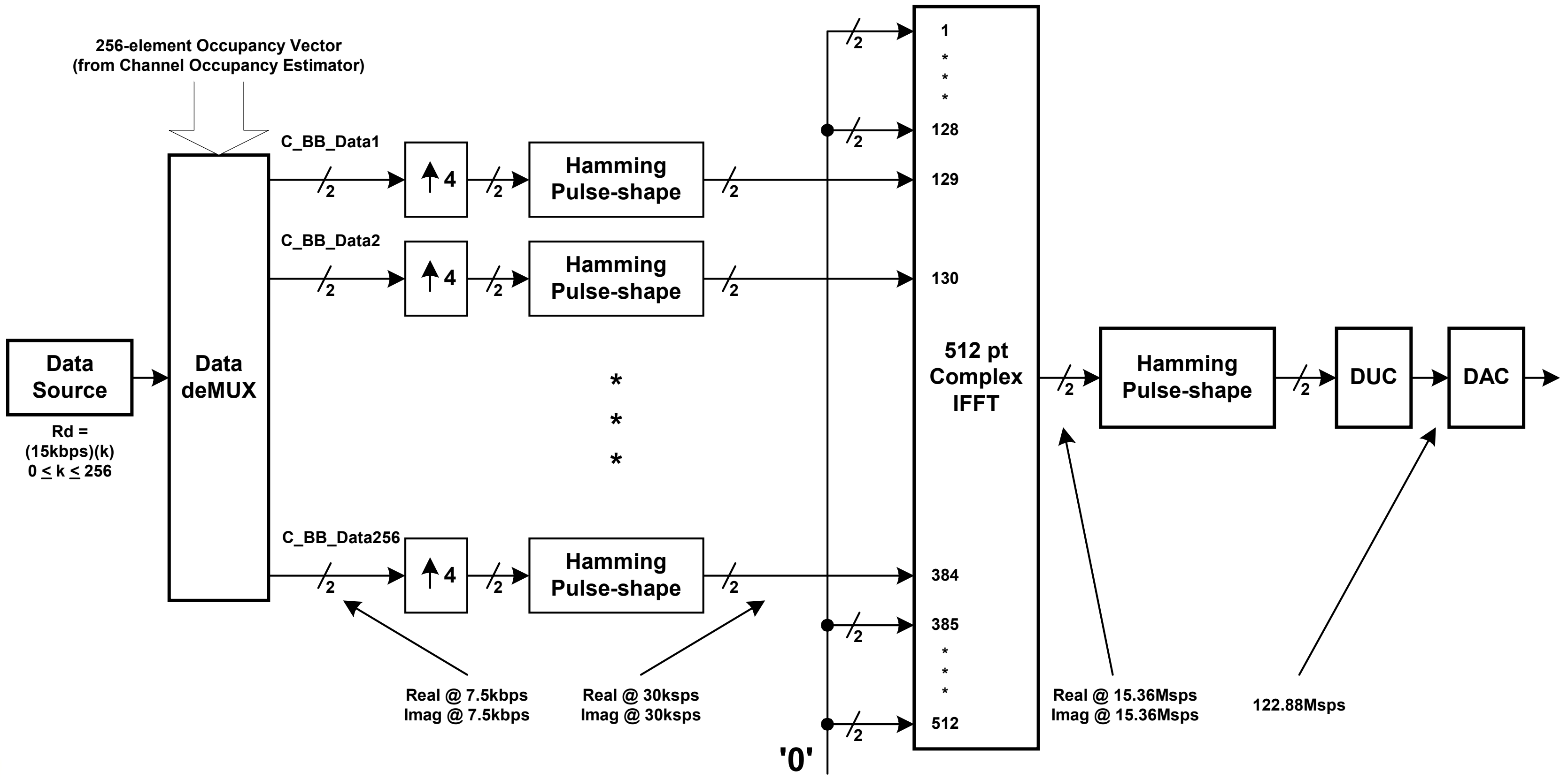
Burst Mod' Signal Processing



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Simulated Burst Mod' Spectrum