Please note: The comments presented below are the personal opinion of myself and not necessarily the official stance of any Federal agency or department. Any mention of commercial firms, materials, products, services or standards bodies does not reflect endorsement of such entities or items for any purpose whatsoever by the Department of Defense, its subordinate agencies, or its personnel, nor intent to procure the materials, products, or services so mentioned from any firm at any time.

To whom it may concern:

The Department of Defense (DoD) Spectrum Access Research and Development Program (SAR&DP) has several ongoing projects that may be of interest to the National Telecommunications and Information Administration (NTIA) in regards to this Request for Public Comment. I'll quote the specific requirements of the National Spectrum Strategy outlined in the Presidential Memo titled "D*eveloping a Sustainable Spectrum Strategy for America's Future"* and attempt to answer some of the questions of this Request for Public Comment within my responses to each.

a. *Increase spectrum access for all users, including on a shared basis, through transparency of spectrum use and improved cooperation and collaboration between Federal and non-Federal spectrum stakeholders.*

Response: There are some SAR&DP projects that address the technological aspects of what will be required to accomplish this. Specifically:

- The Dynamic Spectrum Access (DSA) Policy project aims to define how a radio with cognitive abilities can sense its radio frequency (RF) environment and make decisions on how best to access spectrum resources based on the pre-defined policies that it's programed with. This will facilitate the ability for multiple users to share the spectrum environment with pre-defined access rules.
- The DSA Rules project will define several use cases and validate performance of radios and their DSA policies within them. The testbed and methodology developed by this effort can be used to verify and validate radios that intend to operate in a shared-spectrum environment under various conditions.
- The Next Generation Spectrum Situational Awareness System (NGS2AS) project is developing a suite of cost-effective sensors and a highly-scalable open architecture that will enable near real-time insights and feedback on sensed spectrum activity. The system is being designed to be sensor agnostic and to work even over disadvantaged backhaul communication links. The sensed (but not demodulated or associated to a platform) information will be summarized and stored to enable:
    - Providing reports of spectrum utilization in regions, time periods, and frequency bands specified by the requestor.
    - Providing a sensed spectrum usage feedback of data into intelligent spectrum management or access systems
    - Provide an analytics and visualization tool for local spectrum managers to identify conflicts, enforce policy, and have historical and current information to decide how to de-conflict.

        - Enforcement should not only leverage the evidence collected from sensed spectrum data but also provide proof that interferences were significantly detrimental to system operation. Policy or contractual agreements that define what interferences are mutually-acceptable or completely unacceptable need to be defined.
    - The Spectrum Usage Measurement System (SUMS) project is developing a system to leverage existing range spectrum monitoring systems and correlate sensed spectrum usage to planned spectrum usage. This will help to identify unexpected emissions or deviations from scheduled plans for enforcement.

      The real-time and historical information produced and amassed by systems such as NGS2AS and SUMS can be exported for analytics or trend analysis to correlate spectrum demand to other data sources. This system could leverage modern artificial intelligence techniques in order to identify patterns that may not be readily apparent to human analysts. This will enable better prediction of spectrum demands and the preemptive coordination of spectrum resources to reduce interference instances.

b. *Create flexible models for spectrum management, including standards, incentives, and enforcement mechanisms that promote efficient and effective spectrum use, including flexible-use spectrum licenses, while accounting for critical safety and security concerns.*

    Response: There are some currently ongoing (as well as planned) SAR&DP efforts that aim to develop technologies to meet this request. Specifically:

    - The planned Operational Spectrum Comprehension, Analytics, and Response (OSCAR) project will develop a system that leverages the fusing of heterogeneous data sources (planning tools, sensed data, governance polices, spectrum-dependent system and antenna capabilities databases, modeling & simulation, etc.) and determine how best to assign or modify spectrum access parameters and polices. It will keep track of current, past, and predicted future spectrum activity and plan accordingly in near real time. This may be enhanced using modern artificial intelligence and machine learning concepts. Current plans entail having the spectrum access decisions or required policy-tuning to be pushed to the transceivers via a standardized secure protocol. This will allow spectrum management and access to evolve from the slow, non-optimized, human-in-the-loop status quo to more intelligent, efficient, human-on-the-loop, highly-autonomous methods. This will not only facilitate spectrum cohabitation of systems in all three (spectral, temporal, and geospatial) domains but also more efficient and effective use of spectrum resources compared to center point and radius exclusive-use licenses that are common today.
    - A planned effort aims to explore the ability to increase user density using risk-based spectrum compression through advanced planning techniques and real-time risk-informed governance. The project will develop tools and processes to standardize situational awareness and uncertainty characterization techniques. Risk-assessment models and decision-making will allow for increased spectrum usage with non-coherent

systems operating in agreed-upon modes that statistically would not cause more than the mutually-acceptable levels of interference.

- NGS2AS will provide alerting to local spectrum managers of sensed spectral contentions, unexpected emissions, and other spectrum anomalies as well as provide the ability to identify and assist in locating emitters of interest in a given area. This will allow spectrum managers to enforce policies and react to violation of those policies.

Using the systems like those identified above would enable automation and coordination amongst federal-to-federal system operating environments as well as Federal to non-Federal environments. Automation should leverage enhanced modeling and simulation as well as close the loop with sensed spectrum usage in order to make intelligent spectrum access decisions. There are multiple operating models to be considered:

- A completely decentralized mode in which individual spectrum-dependent systems (SDSs) have full autonomy for spectrum access based on their predefined policies;
- A completely centralized mode in which a master system controls all SDSs in a defined range, or;
- Something in between.

The approach that would be ideal in a large majority of scenarios is a hybrid one where a master system with a larger understanding of the full operating environment tunes the DSA policies of the SDSs in real time.

c. *Use ongoing research, development, testing, and evaluation [RDT&E] to develop advanced technologies, innovative spectrum utilization methods, and spectrum sharing tools and techniques that increase spectrum access, efficiency, and effectiveness*

Response: The SAR&DP portfolio includes over 30 ongoing research and development efforts in this area of interest. Most projects include a field-testing aspect and will deliver prototype(s) at a technology readiness level (TRL) of 7 or higher. The majority of products produced are full government purpose rights. Lessons learned and identified capabilities gaps or technology gaps from these efforts can inform future R&D efforts.

d. *Build a secure, automated capability to facilitate assessments of spectrum use and expedite coordination of shared access among Federal and non-Federal spectrum stakeholders.*

Response: OSCAR will be able to marionette systems that are part of the same control network. To facilitate spectrum cohabitation across federal and non-federal domains, a solution must be designed and agreed upon that sufficiently obfuscates sensitive operation properties and business practices and standardizes the interface with which to share intended and actual spectrum usage. Using that information, intelligent spectrum access schedulers can surgically allocate resources so as to minimize or eliminate (depending on implemented policies) interference instances.

A joint DoD/Industry technical concept submission known as the Spectrum Operational Use Protocol (SOUP) has been proposed to try and address the

development of the protocol and architecture for information sharing of spectrum usage intents between Federal and non-Federal systems. There are security issues with sharing of spectrum usage data from the DoD and potential business practice intellectual property that could be inferred from industry sharing. Therefore, agreed-upon levels of obfuscation must be implemented to protect sensitive information but allow for increased spectrum sharing.

Incentives for sharing could be provided by auctioning spectrum licensing that mandates multiple tiers of usage. For example, primary users, secondary users, and unlicensed users. Costs would vary based on type of access but increased access to spectrum on an agreed upon basis would increase the spectrum available to current spectrum service providers but also open cost effective accesses to emerging services.

e. *Improve the global competitiveness of United States terrestrial and space-related industries and augment the mission capabilities of Federal entities through spectrum policies, domestic regulations, and leadership in international forums.*

Response: If the United States leads the development and implementation of highly intelligent autonomous and collaborative spectrum access and management techniques we will be well-positioned to be global leaders in spectrum sharing. However, the US should also elevate their involvement in international standards bodies relating to spectrum access, management, and technologies. Standards bodies such as 3GPP and IEEE define spectrum access protocols and technology standards that are recognized globally and the US should ensure that it has fair representation and expertise within those domains. Standards must be decided upon carefully; too much standardization can stymie innovation but too little will lead to systems that are not effectively interoperable or able to efficiently share spectrum resources.

To summarize, there are many existing R&D efforts and many possible opportunities for continued research, particularly in the testing and full integration of the current SAR&DP outputs. The hyper-connected internet-of-everything ecosystem promised with the 5G horizon will bring dramatic increases to demands of spectrum resources, as will the advancement of capabilities, both in testing and training, required by the DoD and other federal entities. Advancing spectrum access and automation technologies will not only allow for the development of enhanced capabilities and services but also ensure spectrum access for critical systems in contested or congested spectrum environments which is imperative for national security both domestically and abroad.

Very Respectfully,

-Joshua L. Weaver