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January 22, 2019

To: Department of Commerce, National Telecommunications and Information Administration

Subject: NSC Comments regarding NTIA Docket No. 181130999-8999-01 DEVELOPING A SUSTAINABLE SPECTRUM STRATEGY FOR AMERICA'S FUTURE

The National Spectrum Consortium (NSC) is pleased to provide comments through the individual contribution of our members, and we look forward to engaging with NTIA on a sustainable spectrum strategy.

The NSC is a research and development organization that incubates new technologies to revolutionize the way spectrum is utilized. Through collaboration between industry partners, academia, and Government agencies, and then a competitive procurement, our 219 members solve the toughest problems the nation faces to enable spectrum co-existence and sharing.

The Department of Defense has almost $500M invested in 61 research projects focusing on the effective and efficient use of spectrum through a $1.25 Billion ceiling, National Defense Authorization Act, Section 815 Prototype Other Transaction Agreement (OTA) with the Office of the Under Secretary of Defense, Research and Engineering.

NSC efforts enable the prototyping of spectrum access technologies and the field demonstration of capabilities that provide evidence for and risk reduction of spectrum sharing and spectrum efficient technology outcomes and challenges, thus enabling the early consideration for spectrum policy and regulatory process.

The NSC affirms support for the National Spectrum Strategy goals to increase spectrum access for all, create flexible models for spectrum management, and ensure secure access to spectrum between federal and non-federal users. We agree that the United States, while a pioneer in spectrum sharing technologies, must improve our global competitiveness by continuing to develop and deploy innovative approaches to spectrum access. At the core of these strategies is the continued and sustained R&D investment in spectrum efficient and spectrum sharing technologies.

Attached you will find NSC individual member contributions to your request. All attached responses are individually attributable to each responder's organization to preserve the rich and diverse thinking available across the NSC membership.

Should you have any questions, the NSC Executive Director, Mr. Tony Melita, is our point of contact: Mr. Tony Melita, (703) 338-0294, tony@spectrumconsortium.org.

Salvador D'Itri

Salvador D'Itri
Chairman, National Spectrum Consortium

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NSC Member: ***Silvus Technologies***

In what ways could the predictability of spectrum access for all users be improved?
Interactive databases that provide more real-time usage information.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
My experience is that spectrum is often allocated but unused or not used extensively. Automation to allow assessment could provide a much clearer update to the usage patterns of different bands of frequencies

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
Large users (e.g., military and law enforcement) can apply standards. A spectrum use tax might cause entities to not hog spectrum that they are not fully using and put them up for sharing. Enforcement should be more strict. We have seen many deployments where a rogue radio in adjacent bands causes significant degradation in our ability to use our allocated frequencies.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
You get what you pay for in the government space.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
This issue is above my pay grade.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
Smarter people than me can weigh in on this.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
Our company mostly supports government users. I have no real insight into commercial needs other than more is always better than less when it comes to commercial bandwidth needs.

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NSC Member: ***Georgia Tech Research Institute***

In what ways could the predictability of spectrum access for all users be improved?
Spectrum access predictability could be improved through the development of interactive visualization tools (spectral, temporal, geographic, functional...). Potential application of AR/VR/MR, haptics, use of personal assistant -type verbal interface. Based in physics-based phenomenology. Execution of experiments demonstrating reliable co-existence technologies to generate user confidence.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
Automation is a key component to the practical pursuit of spectrum co-existence strategies due to both complexity of the environment and execution but also the timeliness of meaningful responses.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
The US must seek to strongly influence the underpinning standards for evolving spectrum technologies, applications, and industries. Standards will drive marketplace adoption which will be the primary driver for R&D and global deployment, impacting both national and economic security. Incentives and enforcement are going to be economic based, with the strongest lever being performance-based customer satisfaction. This is also another opportunity for automation and spectrum-sharing/co-existence to create more equal opportunity space.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
RDT&E is critical to understand the implication of commercial investment and evolution (e.g - 5G, IOT). Though commercial R&D will eclipse government investments, USG can still focus on dual-use technology application to allow government users to safely, securely, and reliably maneuver both proactively and reactively throughout the spectrum environment. Spectrum use can be improved both in efficiency and effectiveness, allowing for both domestic and overseas operations. Users will need to generate operational (and acquisition) confidence through prototyping and experimentation with spectrum utilization and visualization tools and techniques. This will include functional areas such as radars, communications, position navigation and timing (PNT), intelligence surveillance reconnaissance (ISR), cooperative swarms of unmanned systems, smart infrastructure, etc.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
The US risks falling behind in global competitive environments, particularly as related to spectrum-related investment and development, due to a lack of national-level engagement and recognition of the economic and security opportunities and threats. Spectrum should be viewed as part of a larger competitive ecosystem that considers both government and industry equities.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission

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requirements and operations of Federal entities?
It appears that only a spectrum co-existence management strategy will meet the needs of both industry and government, allowing for the dissolution of currently highly biased auction models that meet primarily only commercial industry interests, largely burdening government (and in particular, national security entities) users to make do with what remains after the auctions are completed. Prioritization will be a key element of any co-existence strategy and embedding economic models to help drive the automation may be one option to explore. This may also be an ideal use for block chain technology to help ensure appropriate transaction confidence and security

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
I don't think you can predict how much spectrum will be enough, as there will always be an insatiable desire for more, particularly in a data-driven society or operational context.

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NSC Member: ***Oceus Networks***

In what ways could the predictability of spectrum access for all users be improved?
A sustainable bi-directional sharing framework that provides federal users access to non-federal frequencies to purchase and deploy systems based on commercial technology standards. This allows federal users to benefit from billions invested in developing commercial technologies and the economies of scale that drive down costs.Testing and Training- Train as we fightWhile the ability to sublease spectrum is currently supported by rule, there is limited incentive for license holders to negotiate for spectrum. For example, in remote areas, these licenses bring little value and require more resources to administer than their intrinsic value. Remote locations are of special interest to the Department of Defense and the Department of Homeland Security.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
Automation is critical component of promoting shared access. In many cases where a commercial licensee has spectrum but has little incentive to share automated systems could overcome a lack of action due to high transaction costs or sharing studies.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
Standards remain the hallmark to provide guidance, repeatability, and predictability in the development of efficient spectrum use. However, it is often observed that applying standards may result in unintended consequences where the results do not match. This can be objectively measured in rural, remote, and tribal areas which have been termed the Digital Divide between the urban digital capabilities and the lack of services available in remote areas.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
Time-based and usage-based solutions should be considered to commoditize spectrum. There may be opportunities to create continuous revenue streams for the use of available spectrum allowing the highest bidder to provide the most robust service. This service may be able to be sold and resold based on the use and need of the industries making the investment.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
Rigid adherence to the allocation table will leave innovative and niche U.S. industry players behind. Existing policies have resulted in a digital divide where resources are targeted to areas of most economic value. We do not advocate an artificial licensing requirement where large geographic areas are targeted with minimal coverage. However, long-term micro licensing could provide a means to commoditize remote areas and place fallow spectrum into use. Long-term use must be supported to allow this to be economically viable to the license holder and to the micro licensee.

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How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?

As the nation continues development of private LTE and 5G solutions, our spectrum policies will require greater flexibility. Private networks will be developed using both licensed and unlicensed spectrum. These networks will have access to many fixed broadband locations but will require the ability to reach users. Private systems, isolated from the Internet, will control manufacturing, monitor crops, and many other IoT solutions which are yet to be imagined. A critical component of this solution is network isolation to harden networks against cyber intrusion.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?

Oceus Networks sees tactical mobile broadband and military use of IoT as drivers for military spectrum policy. The current exclusive allocation and licensing framework will not support the needs of all users. Increased sharing including bi-directional sharing is the only way that U.S. policymakers can ensure all future needs are met.

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NSC Member: ***Keysight Technologies***

In what ways could the predictability of spectrum access for all users be improved?
The identification of additional spectrum for commercial users and being proactive and what the future requires of spectrum...Leading the vision of spectrum use and access. Also, changing the culture of all federal agencies on the concept of spectrum sharing and access like the DOD has embraced unlike NASA.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
This is extremely important....Autonomous spectrum access and coordination without someone in the loop.....AI/Machine Learning/Quantum spectrum assessment and access!!

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
Standards play a significant role and would resolve most enforcement issues. Enforcement mechanisms are reactive mostly and are controlled by standards and rules. The incentives that would promote are second in either from an auction stand point or from unlicensed spectrum

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
RDT&E Investments would improve spectrum utilization, sharing, and techniques especially if the commercial telecoms benefit. American competitiveness in future generations of technology is adversely impacted by the lack of a clear and effective national policy supporting the general goals of the National Spectrum Strategy above 95 GHz.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
There are no risks but an uphill battle as we are behind the curve when you look at Europe and Asia.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
Just a thought.....A working group or how ever you want to call it...composed of DOD, Federal Agencies (FCC, FAA, NASA) and three our four corporate representatives to formalize a new strategy and way ahead that allows for spectrum sharing at all levels and bands.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
mmWave and larger bandwidths at those frequencies above 95Ghz..

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NSC Member: ***Rivada Networks***

In what ways could the predictability of spectrum access for all users be improved?
Shared networks and shared spectrum are the best ways to ensure predictable network access. Networks must be designed and implemented so that capacity/supply is normally greater than the traffic/demand. This can be accomplished more cost effectively with a single network, vs. multiple networks leveraging fractional spectrum bands that require excessive site splitting cost to grow. The key phrase in the question is 'for all users.' The current dominant paradigm in making spectrum available for communications purposes (2G through 5G and beyond) favors large companies that can spend billions of dollars in a one-time auction to tie up spectrum for decades. This feudal spectrum regime holds back innovation by restricting access for smaller organizations and innovative business models. This oligopoly also wields considerable market power, severely curtailing price competition. There is no doubt that more spectrum needs to be made available for 5G (and beyond) communications. One challenge is that a great deal of commercially licensed spectrum is currently warehoused, underutilized or undeployed. One national carrier recently estimated that it had deployed only half of its available spectrum. Spectrum that is made available needs to be employed efficiently and be made continuously available in all locations and times to all comers. An open-access marketplace for communications capacity/bandwidth can provide a resource to all companies, individuals, entities on a non-discriminatory basis to enable new applications and business models. The proven forerunner of bandwidth trading is the electricity market in the US, where power generation is separated from electricity retailing. Companies produce electricity and sell it on a wholesale and transparent basis to other companies that retail it to consumers. All companies can buy and sell electricity on a transparent market that offers contracts defined by an almost infinite variety of times, locations, and durations. The same approach that has created innovation, lower prices, better reliability, improved efficiency and higher availability for the electricity industry can similarly revolutionize the wireless industry.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
If automation is properly implemented, it will protect Federal access to spectrum on a primary basis while also making excess capacity available for both the Federal and commercial use of 5G Wireless. Automating assessments of spectrum use and coordinating shared access depends on having the relevant data in a machine-readable format and having objective and clear criteria for evaluating usage. Computer based spectrum sharing is performed routinely by the scheduling function within wireless networks and by software used by companies that allocate frequencies used for microwave links. Other software, such as that used by the DSO Joint Spectrum-Management Center (JSC), evaluates the interference impacts between different types of systems, but does not typically involve machine-to-machine communication. The tools exist today for computer-based M2M coordination. This level of automation can be enabled through common systems integration techniques. These tools depend on the accuracy of the models used to calculate the interference impact between systems and the completeness of the data used in the calculations. Improving the models and ensuring the completeness and accuracy of the data used in the models is critical for the automation of shared access coordination. The growing complexity of the spectrum landscape requires evolving the algorithms to attain increased efficiency and is well worth the investment considering the value of spectrum and the cost of changing

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spectrum allocations once systems are implemented. New business practices and additional effort may be required to ensure the quality of the models and the data. This is the cost of automating shared access. The benefits, however, far outweigh the costs. Once the criteria have been established and models tuned, the time to evaluate interference impacts or to recommend frequencies will be much faster and radio frequency systems will operate at increased efficiency. The clarity on how systems impact each other's performance will be more evident and correctable. Beyond these objectives, automation in spectrum decision making and implementation will have other measurable benefits, chiefly it will speed up the entire spectrum coordination process.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?

Incentives are likely the most effective tool for driving efficient and effective spectrum use. In the absence of a market-based approach, the government is forced into a standards-and-enforcement role that has proven cumbersome, time-consuming and ineffective in the past. In a market-based system federal entities can pay for the use of the spectrum they control at a rate that reflects the commercial value of the spectrum. This would incentivize federal users to seek sharing arrangements in cases in which the value of their spectrum dwarfs the benefit the user receives. NTIA should encourage and facilitate such arrangements. Markets are the most efficient method of allocating scarce resources. This is a truth that has been proven repeatedly in human history and is as true for spectrum as it is for food. A large, dynamic and diverse market is required in order to make sure that spectrum is constantly being valued and priced according to its worth and utility to its different consumers. Effective, well-designed markets for spectrum use could drastically reduce the need for traditional enforcement actions against spectrum hoarders.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?

RDT&E is essential for maximizing spectrum utilization. There is a clear relationship between the accuracy of models and performance of spectrum sharing methods. Spectrum sharing has traditionally been accomplished using very crude methods. Spectrum users are allocated blocks of spectrum for use over wide areas for long periods of time. Uncertainty about the interference levels requires larger buffer areas, wider guard bands and longer guard times. When operators are given a block of frequencies for long periods of time there are tremendous inherent inefficiencies. Given the current and growing appetite for wireless bandwidth and the diminishing availability of unencumbered spectrum, we should no longer be tied to antiquated spectrum provisioning systems. Modern networks must utilize every available technology to measure consumption, efficiency and interference in order to have the necessary data to squeeze down the gaps without negatively impacting the quality of wireless services being utilized. RDT&E that improves propagation models and interference performance, improves spectrum utilization by reducing the need for buffer areas. When there is more confidence about propagation and interference performance less distance is required to ensure that the systems do not interfere. The reduction in distance between systems translates into greater spectrum utilization and lower cost to maintain and operate the networks. RDT&E that improves the coordination protocols between systems improves the time utilization of systems. Traditionally a block of frequencies is allocated to a system for a long period of time. The frequencies continue to be allocated to the system during periods of low traffic. An improved coordination protocol allows a system to relinquish its use of the spectrum during low traffic periods. The utilization of the frequencies can be improved by using the spectrum for systems that have less time sensitive communications requirements. In a similar vein,

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network sharing makes more sense than investing in separate networks. Especially in rural environments, where the cost of network deployment and operations is high, and the number of users is low.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?

The United States took the lead in building out extensive 4G networks. That early adoption fostered a business ecosystem of world leading companies pioneering advances in software, services, equipment and applications in wireless economy. If the United States wants to deepen and expand that ecosystem, we must extend our leadership to 5G. But this time around it will be harder because the United States faces competition from extremely aggressive international competitors, primarily China, that are determined to take over that lead by any means necessary. If the US is to effectively compete with China while maintaining a principled and proper separation between the public and private sector, we will need to change our spectrum allocation policies. Traditionally spectrum being considered for commercial use would be identified, discussed, cleared and then given to the FCC to auction, which would then be licensed to a small number of network operators and others for a hefty one-time sum. This traditional process, although adequate in the past, is not ideal in current market and technological conditions. The market for traditional cell-phone subscribers is saturated, the MNO market is highly concentrated, barriers to entry are high, and most remaining low- and mid-band spectrum is occupied, licensed or encumbered. What worked in the 1990s will not work in the 2020s. 5G brings with it a much greater variety of connected devices, use-cases and spectrum needs than traditional phone-based connectivity. With this variety and innovation comes a need for more flexible, faster and more-dynamic spectrum-management and policy actions. If we remain stuck in a system in which it takes a decade to clear spectrum and only a select few auction winners can control access to that spectrum, the U.S. will once again fall behind more nimble international competitors.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?

An open access market-based solution can satisfy both commercial and federal entities, provided the controls are in place to override commercial use, to an appropriate degree, in the case of true emergencies or to ensure vital security. Spectrum management that can satisfy the mission requirements and operations of Federal entities over less critical commercial interests will require automation, decision factors, sensors, policy controls, prioritization and varying degrees of preemption. Legacy wireless technologies are seldom designed to enable the full complement of features required for adequate dynamic traffic allocation or the coordination of these functions between dissimilar wireless technologies. Non-standards-based infrastructures are equally challenging to interoperate and coordinate between, even in their most modern implementations. For mission critical communications to work reliably they must operate dependably and be under the complete control of the mission commander(s). This means the federal government should retain ruthless-preemption rights over the spectrum, especially in emergency situations. This can be achieved through network policies and automated on a day-to-day basis, with the ability to override these policies in times of need using automated administrative capabilities with the proper credentials. For this reason, critical government organizations should never relinquish complete control over their spectrum. This approach does not preclude the sharing of spectrum or network capacity with commercial users but does offer final control to the highest priority Federal users. To ensure that federal users optimize spectrum use and to

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support efficient use of spectrum by the federal government, the federal government should be a customer on their own network, paying for whatever network resources they utilize while funding their use of spectrum, networks, devices, etc., by charging commercial entities a fee for the use of the spectrum they share. If a fair and equivalent market rate is paid by both federal and commercial entities to the spectrum management entity, it will encourage judicious use of the limited resource. This approach will also mesh well with commercial operators, wholesalers of network capacity, and the like, who are able to develop and sustain a business where the costs are modeled on supply and demand economics.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?

Every forecast of spectrum use or needs looking out 15 years is bound to be wrong. Historically, spectrum use has grown much faster than forecasted, even as spectral efficiency has increased. So we should assume that however much spectrum we expect to need in 15 years, we will be wrong on the low side. At the same time, our ideas of what spectrum is 'usable' has also evolved. 5G services are envisioned in millimeter-wave spectrum previously deemed unsuitable for communications uses. That spectrum is not equivalent to more traditional low-band cellular frequencies, but technology is discovering ways to make use of it that were previously unimaginable. Rather than focusing on a specific number, therefore, we'd suggest that the correct approach is that all spectrum be subject to greater flexibility and sharing as we move forward.

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NSC Member: ***Cubic Defense***

In what ways could the predictability of spectrum access for all users be improved?

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
This is very important. To get the most out of our available spectrum, we must move toward dynamic spectrum access while still supporting systems that aren't as flexible. A policy-based spectrum sharing approach is key to ensuring critical data is prioritized. We need the methods, tools and techniques to make this widely applicable.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
Without improving our spectrum-utilization through RDT&E and policy actions, U.S. industries will fall behind. We currently waste available spectrum and could be more innovative if policies were relaxed more.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
New systems should be required to be more flexible built for dynamic spectrum access. Older, more rigid federal systems will have to be accommodated until they are upgraded - perhaps a sunset date.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
I think present allocations are sufficient for now. However, we must have the tools and techniques already discussed.

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NSC Member: ***ANDRO***

In what ways could the predictability of spectrum access for all users be improved?
The 2 key areas of improvement in spectrum prediction are regulatory and technical. To improve spectrum prediction the NTIA should adopt a framework that supports higher prediction models by designating spectrum bands and frequency ranges that specifically accessible to prediction-based spectrum access techniques, such as Dynamic Spectrum Access (DSA). From a technical standpoint adoption of novel prediction-based policies that utilize technical innovations such as advanced sensing and coding would demonstrate advantages of spectrum predictions resulting in a smoother adoption by spectrum users.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
Automation is the key component to the reduction in spectrum assignment time utilizing the current 12-step spectrum deployment life-cycle. By applying automation to key components of the 12-step spectrum deployment life cycle it would allow for spectrum management tools to have availability to incorporate non-federal spectrum stakeholders reducing time to deployment. Under this paradigm, NTIA would oversee—via the IRAC—the regulatory steps used to designate bands involving multiple federal agencies and would coordinate with the FCC for bands involving non-federal allocations.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
These standards, incentives, and enforcement mechanisms already exist. Consider the MCEB Pub 7 Spectrum Frequency Action Format. Work should be done to begin the adoption of MCEB Pub 8

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
Investment in RDT&E is paramount to spectrum efficiency and sharing. Artificial Intelligence is a key component of what the next generation of spectrum-dependent systems will be capable of doing. However, the government currently has very good spectrum access techniques available, such as Dynamic Spectrum Access. The key point is most of the RTD&E funding should go towards testing and evaluation of the current research. These items include policy, enhancements to spectrum management, modeling, and simulations.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
If the government does not adopt the next generation of spectrum-dependent systems and methods that utilize sharing not only DoD to DoD but also commercial users spectrum sell-offs will continue and the U.S. will no longer “own” the spectrum.

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How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
Integration of commercial interests into the current 12-step spectrum management life-cycle.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
The current spectrum assignment will not be enough to manage next-generation spectrum-dependent technologies. It's not that there is physically not enough available spectrum the real issues are the cumbersome assignment, certification, and licensing process. My recommendation is that the NTIA designate a specific set of bands specifically for sharing DoD to DoD only. From this effort, it would then provide the information necessary to determine DoD to non-DoD sharing such as in the broadcaster and frontier bands.

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NSC Member: ***Spectrum Bullpen, LLC***

In what ways could the predictability of spectrum access for all users be improved?
Integrated sensing with a standard modeling and simulation software. Many prototypes (some high TRL ones) are available and have been used in training environments. The reason this is important is that our understanding of the actual congestion and contesting of the spectrum is speculative at best. A second thing that HAS TO BE DONE is modernize Spectrum XXI to bring it up-to-date with current RF technology (DSA, cognitive, new waveforms, etc.) Spectrum XXI will always be the bottleneck for any technology that the NSC brings forward.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
Automation is a great buzzword, but needs to be added to what software we are going to automate. An example of this is the DISA GEMSIS software Coalition Joint Spectrum Management Tool (CJSMPT). This tool provided automation for creating SFAFs to be loaded to SXXI. While this tool is TRL-8/9 it has not been used. This is one type of automation that is just misunderstood. Automation of the interference prediction will require sensors, but here again a software base. Take another TRL-9 tool owned by the USMC: Systems Planning Engineering and Evaluation Device. This tool has all the automation to track moving units (and their associated RF equipment) which can be use to predict and mitigate interference before it happens. Yet again another capability not in use. So, Automation needs to be defined with a software approach, however this software will have to be one that is enforced to be used like Spectrum XXI is for the DoD.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
We have them already, MCEB Publication-7. This is outdated and not as useful as it could be, however its replacement MCEB Publication-8 is not the official document. We need to modernize what we have since what we have is far behind the technologies which are increasing our RF footprint on the battlefield (and training areas).

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
I will reiterate, we must modernize Spectrum XXI. It is the bottleneck and we have to use RDT&E wisely so that when a prototype is ready, we can test its ability to interact with the DoD's only authorized spectrum assignment software. If we take a dual approach of using RDT&E to both do modernizing efforts on SXXI while simultaneously testing this with new innovative approaches to spectrum planning tools (of course adding automation to this as we move forward).

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
We have to grow our ability to manage the spectrum faster than the technology increase in RF capability. Otherwise we will have technology (e.g. DSA) which works fully, but cannot be certified because there is no way to provide it with spectrum supportability in SXXI.

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How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?

We need to bridge the DoD assignment process with civilian processes. That is a difficult road, but where a good use of RDT&E dollars can be use...but make sure you have military experienced SMEs on the team!

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?

I think we need to move away from the concept that we have to pre-allocate . We need good integrated tools with assignment, model and simulation, Machine Learning and sensing tied in to command and control. While this may sound difficult, over the past 20 years there have been many prototypes that have failed because of politics, not technology. We can dynamically assign and deconflict if we modernized our current approaches...that is how we move to the next spectrum management paradigm.

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NSC Member: ***Abside Networks***

In what ways could the predictability of spectrum access for all users be improved?
Spectrum sensing before transmission technology as a requirement along with mandatory geolocation of the radio including TX power. GPS is ubiquitous and cheap therefore potentially utilize GPS for this feature. Include ability for auto-registration mechanism.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
Hugely, the system should be automated by default with manual assignment as a last resort.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
Automatic adherence, similar to how we hande wifi today.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
SDR is cheap. GPS is cheap. Put both into access points / base stations which can scan the spectrum over time and report back aggregated statistics of results.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
Failure to efficiently utilize all spectrum resources will inhibit the US ability to compete in the world market.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
Shared access with automated priority to federal entities, think QoS for RF.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
In dense use areas the spectrum is insufficient for with civilian or federal missions and the current federal use is wildly inefficient due to the lack of timely coordination and allocation. The process should be automated in both space and time with a QoS type structure based on priority of user.

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NSC Member: ***AuresTech***

In what ways could the predictability of spectrum access for all users be improved?
Identify and communicate the different use cases of the spectrum by the different stakeholders. Develop briefs and educate the public in general

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
The automation will be very important. However, should explore new approaches such as machine Learning (ML. Current tools are proprietary, hard to use and are not very effective.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
Standards do not help much. They are usually developed by people who have a high stake and funding. They tend to keep out small players with potential good ideas.However, incentives coupled with enforcements might be a better way.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
This a very important area. Open source need to be encouraged so as to reduce barrier which allows more players and thus reduce costs and bring in new ideas.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
In the commercial world, future radio that do not possess automatic spectrum usage and sharing will not be used. Thus the people who produce them will not have a market.In the military world, the military will have to develop the technology from scratch thus very expensive.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
There should be an entity that follows a similar model as NSC. - Large, medium and small stakeholders as well as universities. The current model FCC has shown its limits since it is really beholden by the major operators (Verizon, ATT etc..)

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
Not sure for now.

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NSC Member: ***AX Enterprize, LLC***

In what ways could the predictability of spectrum access for all users be improved?
(1) Explicitly managing uncertainty (e.g. as measured by entropy).(2) Using efficient & familiar marketplace-based mechanisms to allocate resources (e.g. a [blockchain based] cryptocurrency-like token SpectrumCoin with near real time spectrum auctions).

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
Results oriented investment could reap nearly an order of magnitude improvement in spectrum utilization.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
The 3-tiered model for Citizens Broadband Radio Service (CBRS) with incumbent, Priority Access License (PAL) and general access is a good start. The key issue is ensuring (with strong crypto and other techniques) that critical Government use really gets priority.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
I suspect that Visible Light Communications (VLC) and other very short wavelengths will in time meet our needs, but am an expert neither on such technologies nor on projecting bandwidth demands.

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NSC Member: ***Eridan Communications, Inc.***

In what ways could the predictability of spectrum access for all users be improved?
Current spectrum access protocols limit access to a selection of narrow bands. Even the initial release of Dynamic Spectrum Access has only allowed dynamic band access over less than 100MHz because of the limitations of current transmitters. A breakthrough technology, Eridan's MIRACLE power transceiver, now allows multi-octave dynamic spectrum access at the edge in a single device. This facilitates band sharing in very crowded urban and sub-urban environments and massive improvements in data bandwidth available to rural and remote area users. In total, MIRACLE-enabled full spectrum dynamic spectrum access can improve the accessibility of wireless voice and data by up to 30X.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
Automation is critical to effective sharing. Equally important are the public protocols necessary to execute effective availability planning for Federal and non-Federal users. The public nature of the sharing protocols allows commercial and Federal users alike to understand what is available when, and how.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
The first step is the planning around well behaved users, defined as those users who work within the system to maximize their availability-to-need. This is a matter of establishing and sharing the public protocols. The enforcement of bad behaved users will need to occur at the infrastructure level where the cost of bad behavior can be assessed financially.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
Large scale demonstration experiments are critical and something commercial industry will be hesitant to do, but which the DOD has historically taken the first steps towards. Demonstrating full-octave spectrum sharing feasibility (e.g. ALL of L-band from 1-2GHz) would be a demonstration noted by industry.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
The rest of the world, particularly Europe and Asia, is already moving to dynamic spectrum access. Asserting that a foreign country shouldn't do something because our DOD isn't ready for it is unlikely to be successful. So the principal risk is that we don't move fast enough.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
Perhaps a paradigm that follows the general structure of the maritime passage laws in international waters? Federal users should see the sharing paradigm as an opportunity as well, and the protocols

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referenced above must allow Federal pre-emptive rights under a cascade of conditions from war to localized emergencies (witness the spectrum availability challenges around the Camp Fire in California this winter).

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?

Eridan has put forward an analysis and shared it with the IEEE beyond 5G working group that MIRACLE enables the achievement of the 5G goals completely within the sub-6GHz spectrum if dynamic spectrum access is accounted for. Given that several entities are also developing mmWave 5G systems, we believe the current allocations are sufficient.

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NSC Member: ***Photonics Inc***

In what ways could the predictability of spectrum access for all users be improved?
I think users of mobile phones in the US have become accustomed to far from perfect reliability of cellular networks. The fact that cellular coverage can be poor (few bars) when a user might be situated, for example, very close to I-95, the main corridor of traffic up and down the East Coast, is incomprehensible. The industry should at the very least be embarrassed by this poor reliability. This may not be literally a spectrum access problem, but it is more generally an access problem.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
It is difficult to impose and enforce regulations without having a negative impact on the industry's incentive to innovate. At the very least, the financial cost of ensuring compliance necessitates a decrease in what the industry spends on other things, such as R&D.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
I don't know what specific recommendations to make. I can give an example of what my own company is trying to do. Our IP portfolio includes a technical approach that enables same-channel simultaneous transmit and receive (a.k.a. same-channel full-duplex) which can obviously increase by up to a factor of 2 the usefulness of the existing spectrum. But it is difficult to interest the industry in this as a whole. We approach individual cell phone manufacturers, but such technology would need to be adopted both in the phones and in the cell towers, so that is a barrier.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
One risk is the cost of doing business with US companies and the US government. If this cost is much higher than the cost of doing business elsewhere, US industries will lose this business as industries in several other fields have. Part of this cost is actually not literal cost but time (which equals money, of course). Contracts with the US government, for instance, seem to take longer and longer to get generated and negotiated.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?

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NSC Member: ***MaXentric Technologies, LLC***

In what ways could the predictability of spectrum access for all users be improved?
1- Clear regulatory designation of the new spectrum or re-purposed spectrum 2- Schedule of when such new or re-purposed spectrum will be made available3- International coordination to do the same in different countries4- Clear rules on how to share the spectrum5- clear procedures how to resolve interference issues or right of use issues (will drive automation to make coexistence possible)

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
I take automation to mean using SW/HW to allow shared spectrum use without formal coordination or licensing requiring a human based process. If that's correct, automation is the only way to allow efficient utilization of shared spectrum in any meaningful way.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
standards are key to making automation work by allowing HW makers and engineers to make intelligent systems that make spectrum sharing possible using the same criteria for what coexistence mean. Otherwise we end up with an infinite loop of finger-pointing who is not playing nice in the sandbox. Enforcement at the end is a necessity as there will be players who will not play nice.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
Sophisticated electronics and application of ML and AI based algorithms are necessary to make spectrum efficiency and sharing work. Similar to the type of development that is going into driver-less cars.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
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How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?

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NSC Member: ***EWA GSI***

In what ways could the predictability of spectrum access for all users be improved?
Closer coordination of spectrum use scheduling for all users in a geographic area. Better understanding of sensitivities of systems to in-band or near-band interference. Better enforcement to ensure that signals stay within their allotted bandwidth and guard channels.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
If the automation system's input was from a scheduling system, it could help. If it is based on monitoring, that is more problematic as some user's signals are very difficult to detect (e.g. low power telemetry signals from distant vehicles) without the use of large antennas.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
It would be difficult without the ability to closely monitor spectrum use. As mentioned above, some signals, while critical, may be very difficult to monitor without specialized equipment.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
More spectrally efficient waveforms have been being worked on for a very long time. It's unclear how much more can be wrung from that area. New methods for free space transmission of large amounts of data such as free space optics and even better MIMO technologies may allow federal users to vacate much more spectrum while maintain capability.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
Unsure

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
Recognize where the really hard issues are, such as absolute need of a particular part of the spectrum for warfighting system use, and work those. Understand that some of those solutions may be difficult and expensive.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
Space and DoD systems are very different from commercial products for two reasons. First, they have an extremely long development time and subsequent life cycle. changes to them can be very expensive if not anticipated during development. Second, these systems have a world wide footprint, particularly DoD warfighting systems. Decisions at the U.S. National level to support commercial use may not anticipate the impacts to systems intended to be used in other theaters of operation.

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NSC Member: ***Purdue University***

In what ways could the predictability of spectrum access for all users be improved?
Investment in research on beamforming, spectrum sharing, and secondary spectrum markets. Development of a common protocol for control communication between different networks enable spectrum sharing. Regulatory encouragement of commercial spectrum sharing and secondary spectrum markets.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
This could be a major innovation if done correctly. The ability to speed up assessment could enable non-traditional players to innovate.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
The problem is enforcement, which is currently almost non-existent. If software radios became more popular, we could have chaos. -Secondary spectrum markets, which could be closely linked to incentives, could have a major impact. Standards currently lead The way for commercial systems. They indirectly drive government systems too.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
A strategy including:- Encouraging university research on REAL models for spectrum sharing and utilization.- Encouraging commercial investment and standardization on spectrum models. - Encouraging the gov to work with commercial and university in a collaborative way.could spur major innovation.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
Other countries are investing in wireless, positioning, and radar research much more than the US. At some point, this might catch up with US competitiveness.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
N/A

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
NTIA should encourage innovation in technology as the primary solution, instead of spectrum reallocation. Spectrum efficiency and improved network deployment are key.

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NSC Member: ***DeepSig Inc.***

In what ways could the predictability of spectrum access for all users be improved?
There needs to be an automated real-time geographically specific method for users to request access to spectrum. A casual scan of the spectrum shows that for the vast majority of time, huges swaths of bandwith are unused in even the most densely populated areas.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
Spectrum access needs to be fully automated. This will allow small innovative enterprises to develop wholy unthought of applications for the spectrum. The current process for experimental licensing is outdated and cumbersome. The National Spectrum Consortium is developing the key technology required for this automation.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
With a proper automated spectrum clearing house and monitoring systems using technology under development by the National Spectrum Consortium, it is completely feasible to implement effective and efficient spectrum usage.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
With proper design, spectrum could be allocated for very short timeframes to enable vastly more efficient usage of this precious resource.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
If the US isn't first in developing and deploying this technology others will. This will affect not only the ability of US Defense forces to operate worldwide but will result in significant economic loss to US business.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
The National Spectrum Consortium has studied this problem extensively and has a detailed understanding of how to properly allocate spectrum between Federal and commercial needs. They are the ideal group to provide direction in developing policy.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
Due to the vastly differing propagation properties of portions of the spectrum, more allocations in the lower bands below 2 GHz would aid certain business pursuits that could easily be accomodated with dynamic spectrum access.

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NSC Member: ***Astrapi***

In what ways could the predictability of spectrum access for all users be improved?
By improving spectral efficiency, thereby increasing the capabilities of existing spectrum. Growing the pie gives everyone a better chance of getting a piece of the pie.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
N/A

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
N/A

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
Spectrum-utilization investments should be directed at increasing spectral efficiency, to increase carrying capacity, rather than towards more sophisticated ways of dividing an overloaded resource. This may require taking a longer-term view and focusing on fundamentally new solutions.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
The information age is really the information transfer age. Data that does not move is useless. For many applications spectrum is essential to data transfer, and therefore essential to U.S. industry. For this reason, the effectiveness of spectrum management and policy directly and crucially affects the U.S. economy and global competitiveness.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
While spectrum sharing is important and necessary, the fundamental solution is to increase spectral efficiency in order to make the necessary trade-offs between commercial interests and Federal entities less painful.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
Demand for data transfer is and will continue to grow exponentially. No linear increase in available spectrum will be able to adequately meet demand, leading to lost opportunities and lost economic growth. The solution is to focus less on spectrum re-allocation, and more on increasing spectral efficiency.

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NSC Member: ***Virginia Tech***

In what ways could the predictability of spectrum access for all users be improved?
Our NSC work has shown that channel models are one if not the key factor dominating estimates of spectrum sharing loading. To maximize usage and certainty, channel models need to go beyond what the standards provide and should be something that can be estimated for a specific situation.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
Not sure that I understand the vision, but automation certainly has many roles in improving coordination. This includes channel characterization, enforcement, channel selection and frequency coordination, and others.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
I think that more importantly would be to specify spectrum goals and then provide standardize examples to show how to meet those goals, but allow for freedom in innovation.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
Several things.1. Every band is different and solutions need to be tailored to those bands.2. The way that spectrum is used, i.e., on land, in the air, or at sea impacts the way that it can be managed. Each has to be studied in its own.3. Different applications are going to drive us to different spectrum management techniques that will consider reliability, power, and latency and other issues. Vehicular communication is a great example of where these issues have to be considered.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
I think that this issue is probably going to be key to Rel. -18 of 3GPP and nailing down the IP is going to be very important. DoD needs to be prepared for this, it is an opportunity as well as a threat if done wrong in managing expeditionary forces' communications.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
Certainly, under today's paradigm the military has priority access in bands such as CBRS. There may need to be contingency national emergency situations that give federal entities priority even though they are generally secondary users. I would urge caution on completely denying public access to the spectrum during crises. Lack of communications can lead to irrational behaviors on the part of the public.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?

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I think there is enough in the pipe for now. We need to figure out how we share before we go on to identifying more spectrum. However, in the past spectrum policy decisions have been made with insufficient R&D beforehand. These are big decisions and the R&D beforehand to make the transition smoother and less costly is a drop in the bucket compared to future costs and benefits from the transition. These decisions need to be made at the technical level, not the political level.

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NSC Member: ***Pathfinder Wireless***

In what ways could the predictability of spectrum access for all users be improved?
Just one way would be carefully selected more flexible spectrum regulatory regimes.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
To the fullest extent. Automation, and more importantly computational-intelligence assisted systems not only improve assessments and expedite coordination, but also are arguably a requirement for their effectiveness.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
Standards are essential. Open specifications are a great benefit. And Open Source code is a key tool. RDT&E not only leverages these other areas, it helps the U.S. contribute to them, fill in gaps in the efforts and research, and provide essential test and validation.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
Without evolving U.S. spectrum management policy fairly rapidly towards dynamic spectrum sharing where applicable, U.S. users, technology and business solution providers, and partners will likely be at an accelerating disadvantage.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
While a general spectrum management paradigm will require selection from a portfolio of approaches, a spectrum access and sharing paradigm utilizing a multi-tier assured access and prioritization approach will be an effective strategic direction to pursue. The US CBRS paradigm of the WInnForum Spectrum Sharing Committee--of which Pathfinder Wireless is a Founding Steering Group Member--is but one useful early example, though greater generalization and further enhancement/evolution is desirable. For example, explicit beam-forming based (spatial-domain) directional network oriented sharing is an emerging requirement for both effectiveness and efficiency. More refined sharing in the time domain is desirable as well. Three-tier sharing is an instance of multi-lateral sharing where multiple spectrum managing entities may operate in parallel with each other and must effectively coordinate.This is a type of distributed system with the benefits inherent in any distributed system. There are, though, significant though manageable challenges associated with the simultaneous capture of both the benefits of a globally optimal policy-based centralized control approach and the benefits accruing to distributed control. Capabilities addressing these challenges that are necessary though not sufficient include

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though are not limited to PHY-layer security, low-latency and deterministic control algorithms and associated reliable control-plane approaches.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?

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NSC Member: ***Booz Allen Hamilton***

In what ways could the predictability of spectrum access for all users be improved?
RF spectrum is a commons. Even in the event that spectrum is 'owned' that spectrum remains a global resource that could one day be used for other things. As such, spectrum users should have certain requirements that would be analogous to a tax or other desirable community behavior. As an example, one could require that all spectrum owners 'slot' quiet timeslices into their waveforms to ease identification, and help when trying to determine primary vs secondary users. This slotting could be something more complex like a simple common modulation shift or other identifying characteristic. This might allow others (military law enforcement) to code for spectrum sharing even in urban environments.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
The notion of dynamic spectrum access is not a good model for organizing spectrum sharing. Listeners cannot be identified and weak transmitters cannot be heard across the entire area of operation. In order to have a true, dynamic spectrum use, government should consider spectrum sensors placed where they can monitor spectrum use, detect abuse, and provide realtime information to transmitters on what frequencies are in use and where. These could leverage existing antennas and providers with all of them reporting spectrum use back to a primary tracking database for sharing with other, licensed transmitters.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
There are currently no effective methods of identifying spectrum abuse quickly (or 'taxing' spectrum use). Coming up with a toll mechanism to track use, tax use, report and locate offenders would open the door to improved spectrum reuse.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
Consider 'renting' spectrum to users at reduced rates based on sharing. Some examples:a. Allow a vendor to occupy certain timeslots within a waveformb. Require 'sharing' vendors to leave certain slots open for discovery/control.c. Have partial use vendors use their xmit/rcv assets to also report local spectrum conditions (or deploy co-resident antennas for same)d. Reduce cost for vendors that can use optical receive techniques to narrow their transmit and receive characteristics and reduce power requirement

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
If we continue to sell spectrum as an 'all or nothing' proposition, the owners of these assets will have no incentive to innovate and make better use of their space. As such, we'll run out of space and new vendors will not be able to squeeze in more effective waveforms. A 'tax' on spectrum would require

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current owners to give back some spectrum periodically so that they are incentivized to innovate and continue to reduce or share spectrum.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
See tax idea above (#9)

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
We should expect to see antenna innovations that will allow us to use optical techniques for receiving data (see micro channel plasma antennas)

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NSC Member: ***Nokia of America Corporation***

In what ways could the predictability of spectrum access for all users be improved?
In order for spectrum access for all users to be improved, using an organization like the NSC and its members to look at current, as well as future areas where spectrum usage is impacted, and trying to come up with solutions to solve these issues is one excellent way to do this. Having the diverse mix of industry, government and academia working together on spectrum related matters allows the government to take full advantage of the results that come from these collaborative efforts. The only drawback currently is that the NSC is focused on looking to solve problems resulting from the AWS-3 spectrum auction. The NSC's role should be expanded to allow for work to be done in all spectrum related areas to truly be able to have a greater impact on helping to improve spectrum access and efficiency. Also, there could be a Spectrum Security Lab created that is used to test various use cases with different technologies and vendor's equipment to see how things behave in certain environments. You could also use this lab to help with threat detection since supply chain is a huge cyber security concern and it would be a great way to assess, validate and mitigate the threats that are out there. This lab could also be used help address question number 7 by helping to develop a standards body and create specifications on spectrum access and spectrum management solutions based on their research and testing.

To what extent would the introduction of automation facilitate assessments of spectrum use and expedite the coordination of shared access, especially among Federal and non-Federal spectrum stakeholders?
Project SOUP: The AWS-3 spectrum sale sets aside geographic exclusive use zones for ACTS systems in the 1755 â€“ 1780 MHz portion of the band with the spectrum available for commercial communication systems in areas outside the exclusion zones. Since the ACTS system is not in continuous (24/7) use, the spectrum in the exclusion zones is available whenever aircrew training is not being conducted and could be available for the commercial LTE-A operator(s) having access to the spectrum surrounding a given exclusion zone. A standardized Spectrum Operational Use Protocol (SOUP) is proposed that would be used to selectively disable commercial systems within a given frequency allocation when range use is scheduled and enable the use of those frequencies by a commercial operator when the range is not using them.

What is the practical extent of applying standards, incentives, and enforcement mechanisms to promote efficient and effective spectrum use?
In almost all technology areas there is a standards body that is in place to help create a standard method of how the technology should work and how it should be deployed. For cellular technology there is the Third-Generation Partnership Project (3GPP) that develops the standards and specifications, which vendors like Nokia actively participate in, contribute to and follow. These standards are what allow different vendor's equipment to interconnect and work together because we are building our hardware and software based on those standards even though there are differences between these vendor's solutions.From a spectrum perspective, having a standards body, which the NSC most definitely could become, would then create a path forward on helping to develop these standards and specifications. Developers of spectrum management solutions would then need to adhere to these standards in order to be considered a viable solution that could be used in an operational environment.

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If built on a global standard, these solutions could then be taken and used wherever the DoD and government operates as well as here within the United States giving them a Common Operational Picture (COP) from a spectrum standpoint.

How might investment in RDT&E improve spectrum-utilization methods, and spectrum-sharing tools and techniques?
Our current projects with the NSC are based on using 4G LTE in the mid C-band frequency range for the transmission of telemetry data at the test range at Edwards Air Force Base. We can expand this capability across all the test ranges to improve spectral efficiency and spectrum usage by leveraging existing frequency bands currently in use by the DoD. While there is a big push to share multiple spectrum bands between commercial and government organizations, both entities would still need spectrum that is set aside and only available to them for certain use cases, so the risk of interference or other potential conflicts could be reduced. How much spectrum that should be and what frequency bands should be set aside for their sole use would need to be determined based on their respective requirements.

What are the risks, if any, to the global competitiveness of U.S. industries associated with spectrum management and policy actions?
Nokia will be developing their own response on this item and will not submit a response through the NSC.

How could a spectrum management paradigm be structured such that it satisfies the needs of commercial interests while preserving the spectrum access necessary to satisfy the mission requirements and operations of Federal entities?
Nokia will be developing their own response on this item and will not submit a response through the NSC.

What are the likely future needs of spectrum users, both terrestrially and for space-based applications, within the next 15 years?
Nokia will be developing their own response on this item and will not submit a response through the NSC.