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Request for Information on the National Spectrum Research and Development Plan

DeepSig Inc.

Before the
National Science Foundation
Alexandria, VA 22314

In the Matter of	)
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National Spectrum Research and Development Plan	)
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Comment of DeepSig Inc.

DeepSig Inc. ("DeepSig") appreciates the opportunity to submit comments to the National Science Foundation ("NSF") Request for Information ("*RFI*"), *National Spectrum Strategy Research and Development Plan ("Plan")*.[1]

I. INTRODUCTION AND BACKGROUND

The release of the *National Spectrum Strategy ("Strategy")*[2] was an important step to ensure the United States remains the leader in global spectrum innovation. Wireless innovation is happening at unseen levels globally. A reliable pipeline of commercially available spectrum is critical to maintaining leadership and achievable with investment in efficient and effective technologies. The *Strategy* calls for the development of a National Spectrum Research and Development Plan to provide guidance for government investments in spectrum-focused research (and innovation, by extension).[3] In accordance with the instructions for the *RFI* to which this comment is in response, we respond to selected items listed in the *RFI* in order. This document is approved for public dissemination. The document contains no business-proprietary or confidential information. Document contents may be reused by the government in the National Spectrum R&D Plan and associated documents without attribution.

[1] *Fed. Reg.* 89:34 (Feb. 20, 2024)
[2] *National Spectrum Strategy*, The White House (Nov. 13, 2023), https://www.ntia.gov/sites/default/files/publications/national_spectrum_strategy_final.pdf ("Strategy")
[3] *Id.* at 15

DeepSig Inc. is a product-centric company that develops wireless processing software solutions using machine learning techniques to transform 5G, edge sensing, and critical wireless applications. By weaving AI machine learning into radio signal processing functions, DeepSig develops solutions that inject intelligence into the network, creating efficient, autonomous, and affordable solutions for 5G and lays the foundation for 6G native AI enhancements. Open RAN allows for this transformation to occur by disaggregating and virtualizing the majority of 5G base station functionality on commercial servers or in the cloud. DeepSig's OmniSIG is an ML software offering real-time RF signal identification, classification, and localization for various radio systems, facilitating automated alerts and reactions with open-standards based signal activity descriptions.

II. RECOMMENDATIONS FOR EFFICIENT, THROUGH, AND EFFECTIVE RESEARCH

DeepSig understands that maximal spectrum efficiency is critical to a sustainable pipeline of commercially-available spectrum. Broadly, we propose a set of core objectives that, if adopted, will keep investment focused on achieving maximal efficiency: (i) real-time spectrum monitoring in a cost-sensitive and realistic manner; (ii) accurate spectrum sensing information is needed to optimize access, sharing, and scheduling of spectrum; (iii) architectures for future spectrum sharing and unlicensed spectrum band coordination should use the forms of intelligence in objectives I and II. Most importantly, NSF should fund technology R&D with a clear path to commercialization to ensure efficient use of research funds, with an emphasis on amplifying and accelerating market driven solutions.

A. Methods to increase coordinated investment in R&D between all stakeholders

The introduction of a federal fund-matching program will encourage private investment in spectrum technology. By providing federal funds to match private sector investment on a 1:1 basis or greater, the program would de-risk investment in nascent technologies while increasing the impact and potential return of private research and development ("R&D") expenditures, and could focus on accelerating the maturation and insertion of key technologies to enable spectrum sensing, spectrum sharing, dynamic spectrum optimization, maximization of spectrum efficiency, and other key enabling technologies.

Furthermore, creating incentives for large organizations (e.g. network operators and system integrators) to adopt and deploy new innovative technologies is essential for ensuring widespread adoption and real-world impact, and can serve to help de-risk early technology adoption costs. One way to accomplish this is through subsidies or requirements that tie the adoption of technologies to access of the newly-freed spectrum bands. These incentives can go beyond the private sector. Federal agencies should have access to emerging technologies without complex and time-consuming procurement processes. DeepSig stands ready to provide further suggestions for a smooth, spectrum-wide implementation

B. Realigning Spectrum R&D Towards Industry Application And Innovation

In advocating for a robust and future-proof National Spectrum R&D Plan, DeepSig Inc. posits that a recalibration of current structures and processes is imperative to maximize the return on investment and to ensure the deployment of practical spectrum solutions.

Structural and process improvements are necessitated within the organization and promotion of both Federal and non-Federal spectrum R&D initiatives. The National Science Foundation (NSF) has traditionally focused its efforts on university-centric basic research. While this is an important aspect, especially for fresh thinking and basic research foundations, we believe the maturation and commercialization of spectrum technologies, and investment to accelerate industry and small business efforts to realize these technologies is also critically important. Research, development, and product integration are essential to propel innovation from ideation to market-ready solutions, and to move new spectrum technologies into sustainable and valuable industries for the nation.

The current commendable coordination among agencies such as NSF, DOD-OUSD R&E, DOD CIO, and NTIA must evolve to include and even emphasize industry participation and commercial solutions, particularly for the development of mature solutions. This has not always been the case within past initiatives such as NSF RINGS, which focused exclusively on university basic research precluding our participation or information sharing despite private investment in directly related spectrum technologies. Collaboration across these stakeholders is crucial for aligning R&D with real-world applications and accelerating the commercialization adoption and deployment process.

To refine the R&D focus, a more diligent approach is necessary—one that prioritizes impact and maturation, minimizes redundancy, and fast-tracks mature solutions that promise substantial advances in network technology. Reducing duplicative efforts will streamline the R&D process, conserving resources for novel initiatives that demonstrate a clear trajectory toward marketplace success and sustainable economic models and accelerating and complementing rather than competing with private technology investment.

Lastly, industry-centric proof of concepts that synergize operators, network technologies, and new, commercially viable spectrum solutions are paramount. These proofs of concept should not only demonstrate technical feasibility but also the potential for rapid adoption, compliance with regulatory standards, and financial sustainability. Such a prioritization strategy ensures that R&D translates into tangible benefits for the spectrum industry and society at large, fostering an ecosystem where innovation flourishes and propels the United States to the forefront of the global spectrum arena.

III. RECOMMENDED PRIORITY AREAS FOR SPECTRUM RESEARCH

For sake of clarity, this section deviates from the standard format of this document to list our five priorities: enhancing MIMO and air-interface technology, creating OpenRAN solutions, a study of FR2 and FR3 bands, increased spectrum situational awareness, interference mitigation, and coexistence modeling.

Enhancing MIMO and air interface Technologies: Advancements in intelligent or AI-driven MIMO, Massive MIMO, distributed MIMO, and air interface technologies are essential. These technologies serve as the backbone for increasing capacity and should be prioritized for R&D. Accompanying these, technologies that support sensing, digital twinning for spectrum mapping, wireless propagation modeling, and spatial/beam control to optimize co-occupancy of the spectrum are critical. Such technologies ensure that existing and new systems can coexist more efficiently and interoperably. Particularly in consideration of next-G air interface technologies, research and development of AI-Native air interface technologies, leveraging MIMO, offers possibilities to better share, re-use, and exploit spectrum within and between networks and technologies more efficiently, and is a key technology where the US must obtain and maintain leadership.

OpenRAN Solutions: The promotion of commercially viable OpenRAN-based solutions and platforms is vital. These solutions offer a pragmatic approach to transitioning from basic research to solutions that have a real-world impact. OpenRAN architectures facilitate the prototyping and maturation of advanced wireless technologies, enabling a more agile and cost-effective ecosystem for innovation, allowing US innovations and research to reach the market more easily and achieve impact and value creation. OpenRAN offers a strong platform on which to build, prototype, and deploy key spectrum optimization technologies, and to rapidly deploy new technologies and spectrum sharing models effectively across diverse vendors and network operators.

Reevaluation of Spectrum Utilization: A continuous reevaluation of spectrum utilization is needed to improve efficiency. Studies focusing on the FR2 and FR3 bands should explore the potential for more relaxed licensing models, including fully unlicensed utilization, to enhance spatial re-use and densification and diversity of solutions and operators where feasible. Such an approach could allow multiple entities to efficiently share and reuse spectrum, and combination with MIMO and beam-steering technologies can help to mitigate interference between users effectively in these deployments. Studies looking at more dynamic spectrum sharing in mid-band and FR1 as well should be considered as well, but likely need a more structured approach for instance a new CBRS-like generation which leverages more pervasive sensing and information sharing to efficiently allocate spectrum between users.

Spectrum Situational Awareness: Achieving spectrum situational awareness at scale is fundamental to the ability to effectively allocate, share, and maximize the utility of spectrum. It necessitates the deployment of efficient edge sensing and intelligence solutions, such as DeepSig's AI-based OmniSIG signal classifier, which can be implemented at a low incremental cost through deployment alongside existing devices and infrastructure, reducing the need for deployment, maintenance and operation of dedicated sensors akin to ESCs. By embedding sensing capabilities at scale within the network, ideally within the actual radio units (RU's), and enabling new information sharing interfaces between in-network sensors and inter-network orchestration services such as a next generation SAS, a real time operating picture of spectrum usage may be built and sustained, allowing for pervasive and real time understanding of spectrum usage which can be used to ensure efficient allocation and usage between vendors, and maximizing the value of spectrum for everyone.

Interference Mitigation: The rapid and automated mitigation of interference issues is closely tied to situational awareness and the ability to re-allocate and maximize the usage, value, and density of spectrum. By utilizing intelligent sensing at the network's edge, technologies like

OmniSIG can swiftly and effectively identify and address interference and facilitate adjacent spectrum usage with the knowledge that interference can be detected and mitigated rapidly and in automated means, and that spectrum need not lay vacant based on overly “safe” assumptions about occupancy, usage, and propagation – leading to greatly improved dynamic spectrum sharing.

Coexistence Modeling: The development of real-time AI-driven and data-driven propagation models, combined with sensing and information sharing from infrastructure, potentially within a RAN Digital Twin framework, represents a significant opportunity. Improved models for spectrum propagation are envisaged as enablers for more sophisticated coexistence analysis, facilitating better spectrum reuse and allocation, especially in complex and dense urban environments with the highest spectrum needs. Coordinated network information and data-informed decisions are essential to lay the groundwork for a next-generation Spectrum Access System (SAS) and to lay the foundations for a sharing-native 6G service which makes the most out of our finite and valuable spectrum resources for the maximum number of users .

IV. FEEDBACK ON SPECTRUM R&D ACCELERATORS

DeepSig recognizes the imperative need for strategic alignment and resource optimization in spectrum R&D activities. In the sphere of public datasets (in fact we have published several widely known public open datasets in the area for the greater good, and we have also invested significant resources in the development of non-open datasets in order to provide competitive products), it is crucial that such data collections are not treated as ends in themselves. The creation of datasets and open datasets can be valuable, but must serve clearly defined roles within broader R&D objectives, thus ensuring they provide actionable insights and true utility rather than standing as resource-intensive pursuits with limited applicability or clearly defined objective or purpose.

Turning to the realm of open-source software and projects, while these resources can indeed serve as powerful enablers of innovation, their primary role should not be misconstrued as the ultimate goal. The promotion of open-source should be carefully calibrated to foster an environment where sustainable products, solutions, and intellectual property rights (IPR) are developed—assets that carry intrinsic commercial viability and longevity and sustainable economic models to drive industry growth and job creation. Investment and R&D should weigh the benefits of open source for commoditized capabilities which serve a common good, while allowing the creation of not-completely open solutions which offer differentiation and unique innovative value in the ecosystem. This mirrors the guidance of the leading economists in the open source economic modeling. Utilizing open platforms and interfaces, notably OpenRAN, should be strongly encouraged to expedite the integration and interoperability of diverse and innovative solutions into a cohesive system that support rapid industry evolution, as opposed to the hitherto approach which has led to less diverse, less nimble and more centralized ecosystems.

In the context of flexible radio platforms, affordability and practicality must anchor the deployment of wireless infrastructure. The R&D undertaken in this sector must not only validate the societal value through enhanced spectrum utility but also must present a realistic adoption curve. By forming synergies with international hardware developers and concentrating on high-volume, commercially-oriented radio systems rather than on high-cost, specialized equipment, we can foster broad and impactful advancements in spectrum utilization which will visibly see wide scale deployment and adoption without significant costs to vendors or operators.

The track record of benchmarks and competitions in the field highlights the necessity for these initiatives to be carefully orchestrated and adequately funded. Unfortunately, we have had several negative experiences participating in spectrum centric data competitions run by USG which were poorly planned and executed, with erroneous data, implementation, or evaluation leading to significant time investment with no positive outcome for either party - and even the silent discontinuation of the competition by the organizers at one point. For benchmarks to be truly valuable, they must be founded upon concrete real-world scenarios, with rigorous and sufficiently resourced implementation, and measured against universally accepted performance metrics, ensuring relevance and actionable outcomes, and well executed with sufficient planned outcomes and incentive for competitors.

Lastly, while investments in testbeds are commendable, they must be astutely directed to ensure that the focus remains squarely on the key issues confronting spectrum utilization. Encouraging collaborations between industry and operators to validate and refine approaches in practical settings is paramount. Such partnerships are instrumental in propelling mature Proof of Concepts (PoCs) that showcase viable spectrum optimization models, therefore, advancing the national R&D agenda in a manner that is both effective and attuned to the market realities.

V. DYNAMIC SPECTRUM SHARING DEFINED

We propose the following definition for the term "Dynamic Spectrum Sharing" as applied from its use in the *National Spectrum Strategy*:

> A system which shares spectrum allocations dynamically based on demand, current usage, prioritization, spectrum user requirements, and the ability to deconflict interference between them. There are several forms of this, including CBRS style DSS between networks and other spectrum users – within-network DSS e.g. for spectrum sharing between 4G,5G and other technologies – and future-CBRS style DSS which may employ more sensing and information sharing regarding spectrum usage and requirements to enable more dense and efficient spectrum re-use and assignment through DSS.

VI. CONCLUSION

Access to new spectrum is critical to enable technology innovations for government and commercial stakeholders alike. DeepSig looks forward to working with NSF and other spectrum stakeholders to foster efficient use of spectrum for years to come. DeepSig is well-positioned as a leader in the wireless ecosystem and will continue to invest in key spectrum technologies.

DeepSig applauds the swift action of the NSF and NSF's investment in critical next generation wireless and spectrum technologies. We look forward to working with NSF and other spectrum stakeholders to foster and accelerate the spectrum R&D ecosystem and next generation wireless technologies.

Respectfully submitted,

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