Before the
DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Washington, DC 20230

In the Matter of	)	
	)	
Public Wireless Supply Chain Innovation Fund	)	Docket No. 221202-0260
Implementation	)	RIN 0693-XC05
	)	

COMMENTS OF THE NSF AERIAL EXPERIMENTATION AND RESEARCH PLATFORM ON ADVANCED WIRELESS (AERPAW) PAWR PLATFORM

The NSF Aerial Experimentation and Research Platform on Advanced Wireless (AERPAW) project appreciates the opportunity to respond to the National Telecommunication and Information Agency's ("NTIA's") request for comment ("RFC") on implementing the Public Wireless Supply Chain Innovation Fund ("Wireless Innovation Fund" or "WIF").

I. INTRODUCTION

The NSF AERPAW platform (aerpaw.org) is one of the four Platforms for Advanced Wireless Research (PAWR) projects that are funded by the National Science Foundation (NSF) as part of a $100 million cumulative investment. The PAWR program was created and funded by the NSF in partnership with a consortium of 30 companies in the telecommunications sector, including major vendors, operators, and device-makers. As the third PAWR platform funded by NSF in 2019, AERPAW is the first wireless research platform to study the convergence of 5G technology and autonomous drones. Awarded over $11M of cash funding through the NSF PAWR Project Office (PPO), and over $6M of additional in-kind contributions from the wireless industry, AERPAW is led by North Carolina State University, in partnership with the Wireless Research Center of North Carolina, Mississippi State University and Renaissance Computing Institute (RENCI) at the University of North Carolina at Chapel Hill; additional partners include Purdue University, University of South Carolina, and several other academic, industry and municipal partners. AERPAW offers its user base an experimentation environment with programmable radio access network (RAN) technologies and programmable unmanned aerial and ground vehicles (UAVs/UGVs) with 5G and beyond technologies. The AERPAW infrastructure can also be used to support a wide range of Open RAN experiments with fully controllable and autonomous vehicles.

To that end, AERPAW is providing comments to the NTIA on the Wireless Innovation Fund, in coordination with the NSF PAWR Project Office (PPO), in the following format:

- Recommendations for program execution and collaboration to achieve NTIA's goals;
- An overview of the Open RAN gaps that exist in the current state of the industry;
- Analysis on how to accelerate integration and interoperability of Open RAN technologies;

- Insight on how AERPAW testbed can be used to support Open RAN trials and proof-of-concept pilots;
- Suggestions on how the NTIA can optimize program execution and monitoring.

II. RECOMMENDATIONS FOR PROGRAM EXECUTION AND COLLABORATION TO ACHIEVE NTIA'S GOALS

The AERPAW team, aligned with the views of the PPO, believes that there are two major categories of Open RAN R&D efforts that are not addressed by current 5G labs and testbeds. The first is interoperability and performance testing in normal and complex deployment and operational settings.. The second is advanced Open RAN research, development and demonstrations to accelerate innovation on open research platforms. In addition, AERPAW team believes that the availability of outdoor Open RAN testbeds with controllable vehicles, large-scale spectrum licenses from FCC, and UAV flight waivers from FAA, will enable a wide range of repeatable experiments. Resulting wireless connectivity enhancements in the 3D airspace and drone corridors will also unlock autonomous navigation capabilities for UAVs that can impact UTM and UAM operations.

All these efforts require research and development funding that can make testing resources available at scale and on demand; drive targeted design, development, testing and research outcomes; and lower the barrier to entry for innovators pursuing network research and development.

To achieve these goals, the AERPAW team recommends funding the following initiatives.

1. Facilitating contributions to Open RAN standards, such as the one maintained by the O-RAN Alliance for ensuring interoperability of R&D efforts. While alternative options should be explored, rigorously researched, presented, and be heard and considered for possible adoption in future releases, eventually a common standard needs to be developed and maintained.
2. Fundamental research and education on Open RAN system implementations, such as RAN control applications adhering to the O-RAN interface conventions and embedded services for portability and adoption in future production systems.
3. In order to achieve the above, at-scale, multi-vendor Open RAN test and development platforms that are openly available to researchers and developers are critical. Leveraging prior investments made through the NSF PAWR program and other testbed initiatives, additional funding would support Open RAN equipment and personnel needs for development, maintenance of such open testbeds that would allow US innovators to demonstrate Open RAN viability through badging and certification, prove system integration capabilities, and develop new features and functions within an Open RAN architecture. This platform may span multiple locations.
4. A neutral organizational entity in charge of working with industry and academic researchers to formulate research, testing, and data collection challenges that are then funded and executed through the test and development platform, as opposed to building a new platform for each new test to be conducted.

5. A grant program to subsidize usage of the test and development platform for smaller organizations, non-traditional vendors, and academic innovators that might otherwise not have the resources to participate in necessary Open RAN R&D.
6. A grant program to create US university-led undergraduate, graduate and certificate programs for workforce development to support Open RAN and related wireless fields of study.
7. Funding to support open source software development, reference architectures, hardware solutions and support services that will lower the barrier of entry for both academic and commercial groups pursuing Open RAN innovation and prototyping.
8. Funding to support applied research carried out by US-based researchers on nationwide Open RAN test and development platforms.
9. Funding that aims to initiate collaborative efforts between academic teams and industry, especially small businesses, to target vertical use cases of Open RAN, including areas such as smart agriculture, Advance Air Mobility (AAM), public safety, and search and rescue, among other areas, enabled by open RAN.

III. AN OVERVIEW OF THE OPEN RAN GAPS THAT EXISTS IN THE CURRENT STATE OF THE INDUSTRY

There needs to be an increase in advanced Open RAN research and development efforts to accelerate innovation and significantly expand the telecom supplier ecosystem. One of the major concerns for Open RAN development cited in a recent study by the National Spectrum Consortium[1] is that most research facilities today are not accessible to non-traditional telecom technology providers. This limits both the speed of innovation that can be achieved in wireless networking and the diversity of participants in the telecom ecosystem.

The Innovation Fund can help with both challenges as described above by investing in an at-scale, multi-vendor Open RAN test and development platform. This could be an extension of the existing system of Open Test and Integration Centres (OTICs) as designated by the O-RAN Alliance. Such a platform or program would need funding for more Open RAN-specific testing equipment and expert personnel, and it would require investments to subsidize access by non-traditional technology innovators.

Ideally, investments should also be directed toward the development of reference architectures, likely including open-source software, to lower the barrier to entry for new innovators in working on Open RAN development. Beyond ensuring interoperability, creating a cycle of continuous innovation with a broader set of technology creators will drive incentives for Open RAN adoption.

Any Open RAN development initiative supported by the Innovation Fund could and should also take advantage of existing network research programs, of which NSF PAWR is a strong example. Through investments by both the National Science Foundation and the wireless industry, the PAWR program has existing infrastructure based on open networking systems. The NSF PAWR

[1] Report on U.S. Resources and Capabilities for Accelerating Open RAN, Executive Summary, January 24, 2023 https://www.nationalspectrumconsortium.org/wp-content/uploads/2023/01/NSC-_Open-RAN-Advisory-Group-Report_Executive-Summary_01.24.23.pdf

testbeds are also open to all researchers and have mechanisms in place to onboard and support users across the startup, academic, government, and enterprise landscape.

Beyond creating a test and development platform, and in answer to NTIA question 3, workforce development is also a critical challenge that the Innovation Fund should address. It is becoming increasingly difficult to find talent in the US to support the research needs of the wireless industry. Creating university-led graduate and certificate programs to support Open RAN and related wireless fields of study would buttress NTIA innovation investments by ensuring a workforce pipeline for continued industry growth and competitiveness. Wireless systems curriculum in most of today's universities lack an experimental component and is not able to keep up with the fast developments in the industry. Funding from NTIA can help develop new and innovative courses that train the next-generation Open RAN workforce with a hands-on and lab-based curriculum. There is a need for open-source and publicly accessible wireless experiments that can be used for teaching, such as the experiment profiles and example experiments that are offered by the NSF PAWR platforms[2] as well as other publicly available open-source teaching modules using software defined radio technologies[3].

IV. ANALYSIS ON HOW TO ACCELERATE INTEGRATION AND INTEROPERABILITY OF OPEN RAN TECHNOLOGIES;

Responding to NTIA questions 9 and 10, the AERPAW team believes that promoting interoperability among radio access network equipment and technologies will require efforts beyond the Open RAN plugfest events that take place today.

Specifically, the wireless community needs access to a wide mix of commercial equipment (traditional RAN and Open RAN) and software available on demand. It is not enough to configure hardware and software for a one-time, pre-planned plugfest. These components must be acquired, installed, and maintained for ongoing usage.

In addition to a test and development platform supporting ongoing interoperability testing, the AERPAW team submits that there needs to be a neutral organizational entity in charge of working with technologists to drive integration efforts and to implement certification and badging initiatives. Having a neutral entity is critical to ensure broad participation from across the technology ecosystem, and to provide assurance to network operators that claims of interoperability can be proven outside of a vendor-sponsored lab.

V. INSIGHT ON HOW AERPAW TESTBED CAN BE USED TO SUPPORT OPEN RAN TRIALS AND PROOF-OF-CONCEPT PILOTS

In response to questions 15 and 16, the AERPAW team cites the findings of the National Spectrum Consortium's Report on US Resources and Capabilities for Accelerating Open RAN. The report found that there is a solid foundation for continued Open RAN development, and for facilitating Open RAN technologies so they can be adopted into commercial networks. However, it also concluded that not everything needed to accelerate Open RAN is available through research facilities today.

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[2] See e.g.: https://sites.google.com/ncsu.edu/aerpaw-wiki/aerpaw-user-manual/4-sample-experiments-repository

[3] See e.g.: https://www.youtube.com/playlist?list=PLywxmTaHNUNyKmgF70q8q3QHYIw_LFbrX

More specifically, among the existing labs and testbeds that make themselves available to external users (i.e., are not vendor-sponsored or internal to mobile network operators), there is a need for additional hardware and software, including Open RAN-specific testing equipment. *No facility currently has the necessary volume and diversity of hardware and software to support wide-scale testing and experimentation, including meaningful Open RAN trials and proof-of-concept pilots.*

Likewise, most existing labs and testbeds do not have sufficient personnel (operational staff and advanced researchers) to accelerate Open RAN development work and support innovative trials and demonstration deployments. The AERPAW team believes that targeted investments in these areas would make it possible to create an at-scale, multi-vendor Open RAN test and development platform. Investments are needed for upgrading infrastructure and for engaging skilled personnel to maintain it, as well as for education for long-term sustainability of this program and its evolution into open 6G networks.

While the NSF PAWR platforms, including AERPAW, have reasonably large funding to hire senior personnel and staff to develop platform capabilities and provide operational support, keeping such personnel for long periods in an academic environment is challenging and requires a large, long-term investment. Such senior personnel can find jobs easily with significantly higher salaries in the industry. Due to the extensive know-how that these personnel have accumulated over the years on developing and operating advanced wireless and Open RAN platforms and experiments, it is important to have targeted investments to support existing testbeds, including the NSF PAWR platforms. Such investments will help retain qualified personnel, including engineers and research professors, at salary levels that are competitive with the industry, and recruit new personnel for scaling up development and operations.

Regarding NTIA question 16, the AERPAW team suggests that input be gathered from across the wireless research community to determine specific outcomes that should be pursued in research initiatives including proof-of-concept pilots and trials. As previously stated, the creation of a neutral organizational entity in charge of working with industry and academic researchers to formulate research, testing, and data collection challenges would be instrumental. Common metrics, measurement techniques, and experiments that can evolve over time need to be defined.

Considering the aerial controlled mobility and communication among fixed and portable nodes that are supported by the AERPAW platform, UAVs will facilitate enhancements to Open RAN with flexible deployments and on-demand, on-time network access. Several use case examples on Open RAN based air mobility scenarios that can potentially be supported by AERPAW are as follows[4].

Scenario 1. UAVs serve as UEs: This use case focuses on exploring the functionalities of O-RAN RICs for managing and orchestrating network components aimed at 3D critical mission operations (e.g., secure, search and rescue) assisted by UAVs, as they are able to exhibit agile, fast, and autonomous behavior by organizing themselves to exchange information. Considering a scenario involving UAVs connected to an Open RAN ground base station (BS), UAVs as user equipment (UEs) can carry high-resolution cameras and/or sensors, collecting real-time video and transmitting it back to the ground BS, e.g., to be used to identify possible targets of interest

[4] See the following for further details: M. J. Mushi, Y. Liu, S. Sreenivasa, O. Ozdemir, I. Guvenc, M. L. Sichitiu, R. Dutta, and R. Gyurek, "Open RAN Testbeds with Controlled Air Mobility", submitted to IEEE J. Select. Areas Commun., Jan. 2023.

through deep neural network object detection model, and in addition report information about application performance to rApps. In the meantime, the E2 nodes of ORAN are responsible for updating UAV control with insights produced by their applications (xApps and rApps) to support the RAN optimization process. In this context, Open RAN is able to support the demands of highly dynamic scenarios of critical-mission operations integrated with UAVs due to its flexibility and characteristics of component dissociation.

Scenario 2. UAVs act as O-RUs: As described in ORAN Alliance specifications, UAVs can play a role as O-RUs and process several simple tasks. As the extension, this scenario focuses on the use of UAVs as O-RUs to handle more complicated network tasks, e.g., to quickly deploy an aerial network to assist or extend the terrestrial network where communication and computing resources can move closer to users to meet diverse and stringent 5G application requirements, such as ultra-low latency and ultra-high reliable connectivity. Considering a scenario in which each UAV is equipped with an O-RU to serve ground mobile users, the objective is to optimize the performance of serving offloading tasks via both controlling UAVs to guarantee the quality of communication channels to ground users and efficiently distributing/offloading tasks to appropriate Open RAN elements (O-DU and O-CU) according to the current association. Because of the 3D air mobility capability of UAVs and disaggregation of Open RAN architecture, they may potentially deliver better data offloading capabilities and better resource utilization.

Scenario 3. UAVs act as O-DUs and O-CUs: 1) Using UAVs as O-DUs allows for flexibly hosting RLC/MAC/High-PHY layers based on a lower layer functional split, where UAVs can dynamically connect to multiple O-RUs allowing on-demand resource pooling for virtual baseband functions of high PHY layer, MAC, RLC, and synchronization; 2) using UAVs as O-CUs helps to easily control the operation of multiple O-DUs within/beyond the coverage area, e.g., the radio resource control for flexibly managing the life cycle of the connection, routing or duplication for split bearers, and the service data adaptation for managing the QoS of the traffic flows through autonomous 3D air mobility capability of UAVs.

Scenario 4. Drone swarm-based Open RAN: This use case envisions multi-role drones without ground facilities that form an ad-hoc/swarm based Open RAN. Based on Scenarios 2-3, we can consider a set of containers to virtualize different ORAN elements such as O-RUs, O-DUs, and O-CUs deployed in drones and distributed computing nodes of the network. Given these containers with different functions, the objective is to create a robust Open RAN testbed in a swarm of drones towards full decentralization and controlled air mobility.

Scenario 5. Flying wireless backhaul in Open RAN: Wireless backhaul as an economically sustainable solution has been included by 3GPP as part of the integrated access and backhaul study item for the 5G NR standard. As an extension in Open RAN architecture, this scenario focuses on building a large-scale, self-organizing network of drones that are connected using a wireless mesh backhaul, which caters to dynamic bandwidth-hungry and latency-sensitive applications. Based on Scenario 4 with role-specific operations, drones can hover above or close to the O-RU and serve as an airborne last-hop link connecting RAN to the core network. Additionally, they can act as relays between two O-RUs separated by a longer distance to extend coverage forming a multi-hop mesh network for communications and control. Multi-drone backhaul in Open RAN is capable of flexibly adapting itself to cater to highly dynamic applications and events, and easily be scaled up to cover urban scenarios using long-range radios.

Scenario 6. D2D communications underlaying drone-assisted Open RAN: Implementation of device-to-device (D2D) communication such as sidelink can be an extension of the network into areas that traditional propagation of the fixed O-RU cannot reach. Particularly, drones can serve as UEs or relays deployed much more swiftly and improve the network throughput performance by dynamically adjusting their locations to provide direct or relayed D2D links to any out-of-coverage users. Additional sidelink capabilities such as multi-hop and multi-link (in 3GPP Rel. 19) can provide higher resiliency in this mode, especially offering a valuable set of capabilities for mission-critical services such as disaster response rescue and operation.

The general capabilities of the testbed that we can identify in order to support such innovative scenarios are as follows: 1) The capability of mobility control and autonomous navigation for custom air vehicles; 2) The ability to emulate not only the RF environment, but also of airflow and UAV flight, and to support real-time interactions between the two emulation modes (e.g. trajectory control based on RF observations, and/or RF control based on trajectory decisions); 3) The inclusion of onboard computers, suitable for integration into UAVs, that can support user programming to create software components of the Open RAN ecosystem; and 4) Availability of a variety of *example experiments, tools, and building blocks to create new experiments* that can be reliably tested in both emulation and testbed environments, of various different Open RAN 5G and nextG research concepts. The AERPAW platform is uniquely positioned to support and scale these features.

VI. SUGGESTIONS ON HOW THE NTIA CAN OPTIMIZE PROGRAM EXECUTION AND MONITORING

The AERPAW team strongly recommends that NTIA include mechanisms through its Innovation Fund awards to encourage collaboration across various stakeholder groups from academia, industry, and government. This could take the form of requiring grant applicants to prove they have representation from multiple stakeholder communities. It could also be done by weighting the evaluation process toward applicants who can demonstrate they are meeting a diverse set of research needs rather than those of a single stakeholder group.

Many of the diverse research and development needs needed to accelerate Open RAN are described earlier in this document. We hope this can serve as a useful reference guide as the NTIA shapes new programs under the Innovation Fund.

Respectfully submitted,

NSF AERPAW Platform

January 27, 2023