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Submitted via Regulations.gov

Mr. Scott Blake Harris
Director, National Spectrum Strategy
National Telecommunications and Information Administration
U.S. Department of Commerce
1401 Constitution Avenue NW
Washington, DC 20230

Re: Development of a National Spectrum Strategy; Docket No. NTIA-2023-0003; 230308-0068

Dear Mr. Harris,

Aalyria Technologies, Inc. ("Aalyria") appreciates the opportunity to provide initial input to the National Telecommunications and Information Administration ("NTIA") regarding its Request for Comment ("RFC") on the development of a National Spectrum Strategy ("Spectrum Strategy").[1] Specifically, the RFC seeks comments on the three proposed pillars of the Spectrum Strategy: (i) a spectrum pipeline; (ii) long-term spectrum planning; and (iii) spectrum access through technology development. Aalyria welcomes this proposal, and in addition to providing the requested inputs to help guide the NTIA in the development of the Spectrum Strategy, Aalyria also takes this opportunity to present a technology that can help the agency achieve its objectives thereunder.

1. INTRODUCTION

Aalyria, based in Livermore, California, launched as an independent company in 2022, spinning out two technologies originally developed at Google and Alphabet as part of their wireless connectivity efforts: (i) an atmospheric laser communications technology ("Tightbeam," f.k.a. Sonora) and (ii) a software platform for orchestrating networks across land, sea, air, space, and beyond ("Spacetime," f.k.a. Minkowski).[2] Aalyria maintained the original technical teams following the spin-off—with their decades of experience—augmented by new leadership from engineers with varied technology backgrounds established at Google, Facebook, NASA, Cisco, Lawrence Livermore National

[1] See Development of a National Spectrum Strategy, Request for Comment, 88 Fed. Reg. 16244 (Mar. 16, 2023) ("RFC").

[2] See Press Release, "Aalyria Launches to Revolutionize Communications Networks Across Land, Sea, Air, and Space," BusinessWire (Sept. 13, 2022), https://www.businesswire.com/news/home/20220913005840/en/Aalyria-Launches-to-Revolutionize-Communications-Networks-Across-Land-Sea-Air-and-Space.

Laboratory, and Amazon, enabling Aalyria to expeditiously bring-to-market and commercialize its fully-functional, all-domain network-service-management orchestration platform.

Spacetime is designed to orchestrate and manage the most complex communications networks in the world, helping to extend these networks to places where there is currently limited or no connectivity infrastructure, and at exponentially greater scale and speed than exists today. The platform currently supports communications networks with up to 15 million possible links. In the near future, Spacetime will facilitate the coordination and sharing of network resources across multiple networks with unlimited connections.

Spacetime is the first commercial off-the-shelf software platform for orchestrating and managing steerable-beam mesh networks (including ground stations, aircraft, satellites, ships, urban meshes) using an artificial intelligence powered platform to continuously optimize and evolve the antenna link scheduling, network traffic routing, and spectrum (radio) resource use of a network in order to respond in real time to changing service requirements and environmental conditions. A temporospatial software defined networking ("TS-SDN") system, Spacetime allows network operators to establish and maintain persistent end-to-end connectivity across highly-dynamic and diverse networks of both stationary and mobile nodes. Spacetime achieves resilience by continuously creating new network topologies and optimizing this routing to maximize service fulfillment and avoid or mitigate potential interference events, both within a single network and among co-frequency systems. Spacetime is specifically designed to facilitate interoperability among legacy, nascent, and future networks regardless of where the users, endpoints, intermediate nodes, core networks, or backhaul elements are situated; whether on land, at sea, in the air, or in space, or across all four. Spacetime supports virtually any network architecture—including hybrid space architectures, 5G non-terrestrial network ("NTN"), and FutureG network architectures—and can operate across all radio frequency bands and optical wavelengths. Significantly, Spacetime is asset and domain agnostic; meaning it can orchestrate networks across nearly all connectivity-equipped devices, both on the Earth and in space.

Spacetime is not an abstract, hypothetical future offering. A NASA Technology Readiness Level 9 ("TRL9") software platform, Spacetime is an operationally-proven technology[3] with millions of flight hours deployed in a real-world environment coordinating a high-availability, self-forming, and healing mesh network for uncrewed high altitude platforms ("HAP(s)") in the near-space environment.[4] For three years (while still part of Google), the Spacetime platform successfully ran the entire Loon network, a fleet of constantly moving HAPs, and their supporting ground stations, fiber transport, and core networks. The software continuously choreographed all HAP-to-HAP and HAP-to-ground interconnections, radio resources, and ground segment networking, while considering HAP motion, obstructions, and weather events, to ensure service availability and optimize network performance. The

[3] *See* Frank Uyeda et al. "*SDN in the Stratosphere: Loon's Aerospace Mesh Network*," ACM SIGCOMM (Aug. 2022).

[4] In 2013, Google had several distinct, mostly non-public, aerospace projects that required network orchestration, including (i) Loon, a mesh network of high-altitude super pressure balloons; (ii) Titan, a high-altitude long-endurance solar UAV; (iii) work on urban millimeter wave mesh networks; and (iv) work on LEO satellite constellations for Internet access. Each had a need to continuously evolve the physical link structure of a network of highly-dynamic directional beams, however, only Loon was taken all the way to production.

platform also connected hundreds of thousands of distinct users worldwide with the Loon network—a global, self-healing mesh of HAPs with connected links crossing tens of thousands of kilometers.

Following the spin-off, Spacetime was expanded to support two-sided marketplaces that will incentivize the most equitable and efficient spectrum sharing between operator networks. Built on a digital twin of transceivers to perform three-dimensional, time-dynamic wireless signal propagation on a planet-size scale, Spacetime uses an advanced physics engine to perform faster-than-real-time modeling to forecast the signal strength at the receiver and power flux density across spatial regions for every plausible wireless opportunity. Thus, Spacetime has a full celestial frame of reference to comprehend the critical factors that affect the wireless signal (*e.g.*, motion, position, orientation, propagation, weather, atmospheric characteristics, and the physics of the Earth itself).

Today, Spacetime predicts wireless access, backhaul, and intersatellite link opportunities with full consideration of near-term motion (aircraft bank angles, field of regard obstructions, ground station horizon masks, terrain, sun outages, etc.) and proactively considers link capacities, interference, and detectability to determine the make-before-break limits of each link within the network on an end-to-end basis. With increased network adoption, particularly by non-geostationary orbit ("NGSO") satellite operators, Spacetime will be able to provide network operators unprecedented flexibility to negotiate dynamic spectrum and network resources sharing agreements across space and time.[5]

Spacetime thus facilitates and enables complex network operations at a scale and speed that has never before been possible.

2. PILLAR #1 – A SPECTRUM PIPELINE TO ENSURE U.S. LEADERSHIP IN SPECTRUM-BASED TECHNOLOGIES

2.1 DEFINING "SPECTRUM SHARING" [QUESTION 6]

The RFC proposes to define "spectrum sharing" as "optimized utilization of a band of spectrum by two or more users that includes shared use in frequency, time, and/or location domains, which can be static or dynamic."[6] The RFC goes on to caveat that implementation of such spectrum sharing may require incumbent users to "vacate, compress or repack" in order to "enable optimum utilization while ensuring no harmful interference is caused among the spectrum users."[7] While this has been the historical (and present) reality of most spectrum sharing, emerging technologies—like Aalyria's Spacetime—can better facilitate sharing among incumbent services and enable new entry, without the need for costly removal, compression, or repacking of services in every instance.

[5] Aalyria is currently partnered with several commercial space companies—both geostationary orbit ("GSO") and NGSO—as well as government agencies, to make their networks more resilient, and their spectrum more efficient.

[6] RFC at 16246.

[7] *Id*.

The Citizens Broadband Radio Service ("CBRS") has successfully demonstrated that dynamic spectrum sharing among fixed, terrestrial Federal and non-Federal licensed and unlicensed systems in a single band is possible. Building off CBRS, the Defense Information Systems Agency ("DISA") has begun developing a "spectrum scheduling system and an interference protection, prevention, detection and resolution capability" to "expeditiously communicate spectrum use and resolve interference…through autonomous negotiation with spectrum access systems."[8] While these systems provide a model for spectrum sharing between Federal and non-Federal users, they are limited to fixed, terrestrial applications with low-fidelity directional antenna patterns.

To truly maximize efficiency in the available spectrum bands, dynamic spectrum sharing technologies must be capable of facilitating sharing among as many services as possible—whether terrestrial or space, fixed or mobile. Aalyria has defined and published open APIs that allow network operators to optionally advertise a nowcast of their planned 3D emissions, along time-dynamic link vectors, selectively, on a per-client authenticated basis. Other NGSO satellite operators can also use this information to avoid potential in-line events between co-frequency systems. But, the sharing of this information is strictly optional; even when the absence of information requires trial and error (like in the CBRS SAS), these Spacetime APIs support requests by lower priority users of the spectrum to obtain a "temporospatial lease" on the use of a transmitter across a given geography over time.

2.2 Are There Market-Based Approaches That Would Make It Easier For Federal Agencies To Share Or Make Spectrum Available While Maintaining Federal Missions? [Question 8]

At present, outside of traditional bilateral coordination agreements, there is little incentive for satellite operators to prioritize solutions that minimize in-line events for other users of the spectrum. Spacetime aims to solve that by facilitating a two-sided marketplaces that incentivizes equitable and efficient spectrum sharing between systems. For example, in the event a satellite network operator has a variety of alternatives for beam steering angles for a satellite—all of which satisfy its service level agreements ("SLAs") and provide adequate coverage and service to its users—the Spacetime platform will facilitate an automatic marketplace exchange wherein another user of the spectrum can elect to compensate the satellite operator when the latter selects a mutually beneficial beam steering angle. This approach strives to ensure that valuable, limited spectrum is always put to its highest and more efficient use for the benefit of the American public.

This spectrum and network resource marketplace is also similar to the "Hybrid Space Architecture" proposed by Gen. Jay Raymond.[9] The marketplace is designed to facilitate market-based

[8] Service Catalog, *Electromagnetic Spectrum Enterprise Capabilities and Services*, DISA (2022), https://disa.mil/-/media/Files/DISA/Fact-Sheets/DSO_Spectrum_Booklet.ashx.

[9] *See*, *e.g.*, Theresa Hitchens, "Into the 'outernet': Secure 'internet in space' key to future Space Force hybrid architecture," Breaking Defense (July 14, 2022), https://breakingdefense-com.cdn.ampproject.org/c/s/breakingdefense.com/2022/07/into-the-outernet-secure-internet-in-space-key-to-future-space-force-hybrid-architecture/amp/.

reservations of time, including on idle ground stations or satellite transponders, and resolve competition for resources among space and ground station networks. Authenticated marketplace users will be able to search for and send a request to access or lease temporospatial infrastructure elements or spectrum from other operators.

3. PILLAR #3 - UNPRECEDENTED SPECTRUM ACCESS AND MANAGEMENT THROUGH TECHNOLOGY DEVELOPMENT

3.1 What Innovations And Next-Generation Capabilities For Spectrum Management Models Are Being Explored Today And Are Expected In The Future To Expand And Improve Spectrum Access? [Question 1]

Aalyria agrees with NTIA that the key to ensuring sufficient, long-term access to spectrum is to "embrace innovation and pursue technologies that expand the overall capacity or usability of the radiofrequency spectrum."[10] To that end, Spacetime represent innovative, next-generation capabilities for spectrum management that are available today and yet, as described above, are still very much in their nascent stages of deployment. With increased uptake, these technologies will exponentially enhance the dynamic potential of coordination among complex non-terrestrial network systems.

Spacetime was designed as a common service management and orchestration platform capable of providing consistent models and a shared control plane across operators. While it is TRL9 and has a production heritage for operating real-world networks, the Spacetime product roadmap includes plans for future support of individual instances of Spacetime to coalesce to facilitate situational awareness, spectrum coordination, and internetworking across multiple independent networks to improve survivability and reliability in highly contested and congested spectrum environments.

Beyond advanced, real-time spectrum access and maneuverability in real-world operations, Spacetime supports modeling and simulation in a planet-scale digital twin. In addition to operating real systems and accessing real spectrum, Spacetime can also emulate the operations of virtual systems (new acquisitions, significant modernizations/upgrades of legacy systems, etc.) to model how the systems will change the spectrum environment or perform as part of the overall network architecture.

Spacetime can also resolve many of the issues identified with an enterprise spectrum sharing system for federal and non-federal spectrum, including:

- **Data Sovereignty.** Spacetime's east/west interface provides commercial and government customers full control of their data sovereignty and control over the extent to which they disclose their existing use of the band.
- **Ensuring SLAs.** Spacetime can model, at scale, all of the time-dynamic, three-dimensional wireless link propagation effects related to granting a temporospatial lease on spectrum and verify if such lease would have an impact on the operator's existing SLAs.

[10] RFC at 16247.

- **Pre-Emption for Priority.** Spacetime can establish temporospatial leases of varying duration, including extremely short periods of time (seconds or minutes) to guarantee the higher priority system's rapid access to the spectrum.
- **Open Architecture and Open APIs.** Spacetime uses open APIs and interfaces to maximize interoperability, and the platform is built on an open architecture and other industry open standards.

3.2 What Other Technologies And Methodologies Are Currently Being, Or Should Be, Researched And Pursued That Innovate In Real-Time Dynamic Spectrum Sharing, Particularly Technologies That May Not Rely On Databases? [Question 5]

Ideally, the NTIA would pursue a single solution—like Spacetime—which can conduct the spectrum planning, modeling and simulation, and orchestration needed to facilitate sharing in a shared Federal/non-Federal spectrum environment. However, at minimum, NTIA should consider the following categories of technologies as part of the National Spectrum Strategy:

- **All-Domain Network Orchestrator** for ensuring spectrum tools and systems have the persistent connectivity required to operate globally and avoid jamming;
- **Spectrum Orchestrator** for dynamically moving assets within the spectrum in real-time;
- **Spectrum Estimator & Planning Solution** for compiling the electromagnetic spectrum needs of current and future Federal and non-Federal systems, both in the U.S. and abroad, to facilitate spectrum planning; and
- **Spectrum Modeling Solution** creating a digital twin of each department or agency's spectrum-dependent systems to model and simulate spectrum requirements and configurations to be successful in future multi-domain operations. This solution can also model anticipated future Federal systems early on in, or prior to, acquisition so that the federal government maintains awareness of future spectrum requirements and can properly plan to meet those needs in collaboration with the FCC.

By adopting these technologies, preferably in a single holistic solution, NTIA can increase the efficiency of assigning spectrum across Federal operations and coordinating use with non-Federal systems.

4. PILLAR #2 - LONG-TERM SPECTRUM PLANNING

4.1 Who Are The Stakeholders And How Can Federal And Non-Federal Stakeholders Best Engage In Productive And Ongoing Dialogue Regarding Spectrum Allocation And Authorization, Repurposing, Sharing, And Coordination? [Questions 1 & 3]

Aalyria encourages NTIA and other Executive Branch agencies to work closely with industry to develop and implement its long-term strategic spectrum plan. As demonstrated by the responses herein,

commercial entities, like Aalyria, have dedicated themselves to improving spectrum access through the development of novel and accessible technologies. Hard-earned industry experience and expertise will be critical for the long-term planning and implementation of the Spectrum Strategy.

The NTIA should also recognize key stakeholders in the commercial spectrum access technology industry, including companies like Aalyria that are at the forefront of developing software and other technologies to facilitate dynamic spectrum sharing among complex systems. Moreover, in the event any technical advisory committees are established between the government and industry, the commercial representation on the committees should be comprised of both companies that utilize spectrum and those that facilitate coordination and sharing among spectrum users, like Aalyria.

5. CONCLUSION

Aalyria appreciates NTIA's leadership in developing the National Spectrum Strategy and looks forward to working with the agency and the Executive Branch to increase the availability and efficiency of spectrum for Americans.

Respectfully Submitted,

/s/ Chris Taylor

Chris Taylor
Chief Executive Officer

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Brian Barritt
Chief Technology Officer

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Nathan Wolfe
Chief Technology Officer

Aalyria Technologies, Inc.
7633 Southfront Rd.
Suite 200
Livermore, CA 94551