Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Enabling Next-Generation Terrestrial	)	RM-________
Positioning, Navigation, and Timing and 5G:	)	
A Plan for the Lower 900 MHz Band	)	
(902-928 MHz)	)	

PETITION FOR RULEMAKING OF NEXTNAV INC.

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Executive Summary

The Federal Communications Commission has a unique opportunity to reconfigure the 902-928 MHz band ("Lower 900 MHz Band") to enable a high-quality, terrestrial complement and backup to the U.S. Global Positioning System ("GPS") on which the nation relies for the positioning, navigation, and timing ("PNT") services underpinning national security, the economy, and public safety. Reconfiguring the band plan and adopting rules that enable flexible use will also provide 15 megahertz of low-band spectrum for use by mobile wireless networks, a significant addition to the low-band spectrum pipeline. With the proposed changes to the Lower 900 MHz rules as described in this petition, NextNav Inc. ("NextNav"), as the leader in terrestrial PNT technology and the largest licensee in the band, will be empowered to use its technical know-how and its spectrum resources to enable the rapid deployment of a nationwide terrestrial PNT network that backs up and complements GPS that is vital to our national security and economic resiliency. The NextNav proposal is an innovative, market-based solution that requires FCC action but does not require taxpayer money or legislation.

The United States needs a terrestrial PNT network to complement and back up GPS. This government-funded, space-based system plays a pivotal role in U.S. PNT architecture, and its ubiquitous use across critical infrastructure sectors—and the broader economy—underscores its importance. Americans and American businesses rely on positioning information for a variety of purposes, including navigating around towns, managing supply chains, and supporting logistics. Public safety uses accurate location information to deliver assistance exactly where it is urgently needed and help first responders maintain situational awareness. Precise timing is critical for many essential services, including telecommunications, electricity, and banking.

Without GPS, essential economic and security functions would be significantly impaired or disabled entirely. The impact of GPS on the U.S. economy has been estimated at over $1 trillion, and the potential economic impact of the loss of GPS is estimated at $1 billion per day. Yet GPS does not work well indoors or in urban canyons, and GPS signals are subject to jamming, spoofing, and other targeting events. Private- and public-sector experts have concluded that the United States needs robust terrestrial PNT to complement and back up GPS because space-based PNT systems' coverage gaps and vulnerabilities pose significant risks to U.S. national security, economic, and public safety interests.

There is also wide consensus that making additional spectrum available for wireless networks would be advantageous to the U.S. economy and the country's global competitiveness, and the Commission has successfully repurposed multiple bands to this end. The Lower 900 MHz Band is an ideal candidate for swift FCC action as it is currently underutilized due to an outdated band plan and technical and service rules that limit the use of the band for fifth-generation ("5G") technologies.

NextNav is the main geographic licensee in the Lower 900 MHz Band and has used its existing licenses to develop distinctive PNT expertise and products. NextNav's next-generation PNT network is being designed to operate as an integral component of 5G technologies and deployments. But, despite the compelling need for robust terrestrial PNT services and previous incremental FCC actions to enable terrestrial PNT in the Lower 900 MHz Band, it is not economically feasible to deploy a widescale, standalone terrestrial PNT network. GPS is free to users (limiting price), so there is limited incentive for equipment and software developers to incorporate PNT-specific protocols into the vast array of user devices utilizing PNT services (limiting subscribers). Because of these limitations on price and subscribers, generating sufficient revenue in sufficient time to cover the capital and operating expenditures necessary to build and maintain an at-scale, terrestrial, PNT-only network is not commercially viable. While GPS is fully supported by the U.S. government, it is unlikely that the U.S. government will subsidize an extensive, standalone terrestrial PNT network. But there is a path to a widescale terrestrial PNT network if the FCC updates the rules for the Lower 900 MHz Band in a manner that allows it to be used for 5G so that the PNT network will be integrated within NextNav partners' broadband networks.

Indeed, using the Lower 900 MHz Band in terrestrial, mobile-broadband networks creates a unique, economically viable opportunity to meet the urgent need for widescale terrestrial PNT services without substantial federal investment. This rulemaking petition's proposed re-banding and accompanying rule modifications would create 15 megahertz of frequency-division-duplex spectrum within the Lower 900 MHz Band to support terrestrial PNT *and* 5G broadband. Revising the rules would enable NextNav's next-generation ("NextGen") terrestrial PNT network to use widely adopted 5G technology to extend PNT reach where GPS and other space-based systems are limited and otherwise complement GPS, including as a backup if necessary, while also supplementing the country's mobile broadband capacity. Using a 10-megahertz downlink spectrum block, NextGen can—uniquely for a terrestrial PNT system—reliably supply integrated, highly accurate, and consistent 3D positioning indoors and outdoors, along with precision timing.

In short, NextNav's proposal enables high-quality terrestrial PNT, with the potential for widespread and inexpensive adoption in many use cases because it will use the 5G standard. Further, as NextNav's NextGen PNT solution uses a small amount of capacity in the 10-megahertz downlink, mobile network providers can use the vast majority of the downlink capacity for broadband, making the spectrum appealing for integration into existing networks and thereby accelerating the availability of terrestrial PNT services. The 15-megahertz band plan is necessary for this broadband deployment, which enables an at-scale PNT network to be deployed efficiently, providing a unique path to resolving the coverage, cost, and user device issues that have prevented broad terrestrial PNT usage to date.

Over recent years, it has become increasingly clear that the current Lower 900 MHz Band plan is not conducive for either terrestrial PNT or mobile broadband—its shortcomings include fragmented geographic-licensing arrangements and outdated command-and-control requirements, as well as other unnecessary restrictions. To deploy this spectrum more productively, the geographically licensed spectrum blocks need to be consolidated into a 15-megahertz nationwide configuration for both PNT and 5G broadband. Therefore, NextNav proposes the Commission take the following general steps:

- Update the band plan to support a 15-megahertz spectrum block with a 5-megahertz uplink in the 902-907 MHz band and 10-megahertz downlink in the 918-928 MHz band;
- Revise the outdated rules for Multilateration Location and Monitoring Service to enable flexible use at full macro power limits, permitting the band to be used for a combination of PNT and mobile broadband;
- Arrange a spectrum swap to convert NextNav's current extensive holdings into a nationwide license for NextNav; and
- Direct that federal operations and incumbent licensees will be protected.

The Lower 900 MHz Band spectrum can support higher and better use cases for government and commercial stakeholders alike. Modernizing the Lower 900 MHz Band can simultaneously enable a high-performing terrestrial PNT network to complement and back up GPS and add 5G mobile broadband capacity. Economic and national-security interests will benefit from a strengthened and more resilient national PNT architecture, and repurposing scarce low-band spectrum for broadband use will serve consumers, enterprises, and the national interest. The alternative to NextNav's plan is that the Lower 900 MHz Band will continue to be underutilized and that the country will continue to lack terrestrial PNT that is accurate and widely available.

There is an overriding public interest benefit to meeting urgent national security, economic, and public safety needs for terrestrial PNT service to complement and back up GPS. The FCC can provide this benefit by pursuing its core mission of enabling spectrum to be put to its highest and best use.

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PETITION FOR RULEMAKING OF NEXTNAV INC.

Positioning, navigation, and timing[1] ("PNT") services underpin the U.S. national security, economy, and public safety. Refreshing the 902-928 MHz band ("Lower 900 MHz Band") will unlock a reliable and precise terrestrial PNT solution for the nation that leverages fifth-generation ("5G") wireless network technologies. NextNav Inc. ("NextNav") proposes that the Commission update the Lower 900 MHz Band to make state-of-the-art terrestrial PNT a reality by making 15 megahertz of frequency-division-duplex ("FDD") spectrum available for incorporation into broadband networks. NextNav's next-generation ("NextGen") solution will, among other things, become a critical terrestrial complement and backup (as necessary) to the U.S. Global Positioning System ("GPS") satellite constellation, delivering ground-based 3D-location data for a variety of positioning uses as well as precise timing.[2] NextNav's proposed changes would modernize the

[1] PNT includes horizontal positioning on the x/y axes, vertical positioning on the z axis, and timing. It can also include navigation (i.e., getting from Position A to Position B). This petition focuses on the x/y and z axes and timing. Different PNT technologies may offer one or more of these aspects.

[2] *See* 47 C.F.R. § 1.401. NextNav is filing this petition with the consent of the only other active licensee in the band, Telesaurus Holdings GB LLC ("Telesaurus") (listed in the Universal Licensing System under this name and "Telesaurus Holdings GB, LLC"). Contemporaneous with this petition, Telesaurus is filing an application for FCC consent to the assignment of its A Block licenses from Telesaurus to NextNav.

underutilized Lower 900 MHz Band while aligning the Commission's rules with current spectrum-use policies and today's PNT and wireless broadband needs.

I. BACKGROUND

The United States has been developing and deploying space-based positioning and navigation systems since the early 1960s. The U.S. government has been operating its global navigation satellite system ("GNSS"), GPS, since 1978.[3] GPS was designed to provide PNT information to military and defense users but was later made available for civilian use.[4] GPS delivers remarkable PNT capability but has well-known vulnerabilities, including low signal strength, interference risk, and spoofing. Given these shortcomings, government and industry alike are seeking to identify both space-based and terrestrial technologies that can complement and back up GPS. Using a 10-megahertz downlink spectrum block, NextNav can reliably supply widescale, integrated, highly accurate, and consistent 3D positioning indoors and outdoors, along with precision timing.

These capabilities present an opportunity to transform the nation's PNT services, providing a complement and backup to GPS with stronger signaling and fewer vulnerabilities to interference and spoofing, while also offering more sophisticated 3D positioning. But what primarily prevents this network's realization is the existing challenged and outdated Lower 900 MHz Band rules. By modernizing the rules governing this low-band spectrum, consistent with its stated goals and statutory mission, the Commission can unlock the band's potential for both robust terrestrial PNT and broadband.

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[3] *See A Brief History of GPS*, Aerospace Corp., https://tinyl.io/ATWz (last visited Mar. 18, 2024).

[4] *See id.* ("In 1983, President Ronald Reagan authorized the use of Navstar (or GPS as it became known) by civilian commercial airlines in an attempt to improve navigation and safety for air travel.").

A. GPS, a Tremendous Success for the United States, Has Vulnerabilities Associated with National Security and Economic Risks

Modern society cannot function without reliable, ubiquitous PNT services. PNT is used to synchronize communications networks, timestamp financial transactions, and support safe travel by car, ship, and train.[5] The Cybersecurity and Infrastructure Security Agency ("CISA") has recognized that PNT is "necessary for the functioning of the nation's critical infrastructure,"[6] with GPS-based PNT powering most of the nation's sixteen critical infrastructure sectors.[7] GPS's availability and reliability have led to infrastructure designs that assume its continued and un-interrupted availability and accuracy for various national security, economic, and public safety activities.[8] Table 1 captures sample PNT use cases.

Table 1: Sample PNT Use Cases

	Government	Commercial
Positioning	• Enhanced ("E911") caller position • Smart city asset tracking • Military asset tracking	• Logistics and transport tracking • Enterprise asset tracking • Lone worker and worker safety tracking • Consumer tracking tags
Navigation	• First responder situational awareness and navigation • Warfighter situational awareness and navigation	• Consumer smartphones and wearable navigation and tracking applications • Autonomous vehicle navigation • Drone navigation

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[5] *Responsible Use of Positioning, Navigation and Timing Services*, NIST, https://tinyurl.com/24f6yc7r (last visited Mar. 4, 2024).

[6] *Positioning, Navigation, and Timing*, CISA, https://tinyurl.com/2c8h6e2d (last visited Apr. 14, 2024).

[7] *GPS Disruptions: Efforts to Assess Risks to Critical Infrastructure and Coordinate Agency Actions Should Be Enhanced*, GAO, GAO-14-15 (2013), https://tinyurl.com/22trevp8.

[8] *Understanding Vulnerabilities of Positioning, Navigation, and Timing*, CISA, https://tinyurl.com/24uh75zn (last visited Mar. 4, 2024).

	Government	Commercial
Timing	• Land-mobile radio base station synchronization for public safety • Electric substation synchronization for utilities and smart grids	• 5G core and radio-access network, including small cells, synchronization • Data center synchronization and timestamping for banks and enterprise

But GPS is often unavailable indoors and in other areas with limited satellite reception, such as urban canyons, and disruptions to GPS signals could degrade or cause critical infrastructure to malfunction and disrupt commercial, civil, and national security activities.[9] Any GPS loss would be dramatic:

> There would be increased costs for most goods and services. There would be delays in accessing your funds from banks and retirement accounts. Shortages would soon occur for goods transported by ship, truck or train. Even the digitally imposed first-down line on televised football games would go away. Without GPS shipping would slow to a crawl, since the choreography of ships and trucks transporting imported goods is based on an intricate GPS-derived schedule and GPS-enabled tracking and coordination software.[10]

In 2019, the National Institute of Standards and Technology ("NIST") issued a report on the significant economic benefits of GPS and the consequences of an outage inside the United States.[11] As Figure 1 details, the report found that "GPS has generated roughly $1.4 trillion in economic benefits (2017$) since it was made available for civilian and commercial use in the 1980s."[12]

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[9] *Id.*

[10] Lt. Col. Robert Wray, *Imagine if GPS got lost. We at Space Force worry about it so you don't have to*, USA Today (Dec. 8, 2023), https://tinyl.io/ATGG.

[11] *See Economic Benefits of the Global Positioning System (GPS): Final Report*, NIST (2019), https://tinyurl.com/27ehfd6x.

[12] *Id.* at ES-1.

Figure 1: NIST Summary Economic Benefits of GPS for Private-Sector Use, 1984 to 2017[13]

Sector	Specific Analytical Focus	Benefits ($ million)
Agriculture	Precision agriculture technologies and practices	$5,830
Electricity	Electrical system reliability and efficiency	$15,730
Location-based services	Smartphone apps and consumer devices that use location services to deliver services and experiences	$215,702
Mining	Efficiency gains, cost reductions, and increased accuracy	$12,350
Maritime	Navigation, port operations, fishing, and recreational boating	Negligible
Oil and gas	Positioning for offshore drilling and exploration	$45,922
Surveying	Productivity gains, cost reductions, and increased accuracy in professional surveying	$48,124
Telecommunications	Improved reliability and bandwidth utilization for wireless networks	$685,990
Telematics	Efficiency gains, cost reductions, and environmental benefits through improved vehicle dispatch and navigation	$325,182
Total		**$1,354,830**

The report also found that "the loss of GPS service would have a $1 billion per-day impact," as outlined in Figure 2.[14]

[13] *Id.* at ES-2.

[14] *Id.* at ES-4.

Figure 2: NIST Estimate of Potential Economic Impact of a 30-Day GPS Outage[15]

Sector	Specific Analytical Focus	Potential Losses ($ million)
Electricity	Electrical system reliability and efficiency	$275
Finance	High-frequency trading	Negligible
Location-based services	Smartphone apps and consumer devices that use location services to deliver services and experiences	$2,859
Mining	Efficiency gains, cost reductions, and increased accuracy	$949
Maritime	Navigation, port operations, fishing, and recreational boating	$10,411
Oil and gas	Positioning for offshore drilling and exploration	$1,520
Surveying	Productivity gains, cost reductions, and increased accuracy in professional surveying	$331
Telecommunications	Improved reliability and bandwidth utilization for wireless networks	$9,816
Telematics	Efficiency gains, cost reductions, and environmental benefits through improved vehicle dispatch and navigation	$4,137
Total, Excluding Ag.	**If the outage were not to occur during critical planting seasons**	**$30,298**
Agriculture	Precision agriculture technologies and practices	$15,122
Total, Including Ag	**If the outage were to occur during critical planting seasons**	**$45,420**

Note: Range of potential losses is $16 to $35 billion, before accounting for losses of about $15 billion if a 30-day outage were to occur during critical planting seasons for U.S. farmers.

As detailed in Appendix B, for three decades, U.S. government agencies, notably the Department of Defense ("DOD") and Department of Transportation ("DOT"), alongside industry experts, have recognized the urgency of protecting, toughening, and augmenting GPS for national security, economic, and public safety purposes. For example, in 2020, President Trump issued Executive Order 13905 to protect the national and economic security of the United States arising from disruptions to PNT services by "strengthening national resilience through responsible use of positioning, navigation, and timing services" in critical infrastructure because "the disruption or manipulation of [PNT] services has the potential to adversely affect the national and economic security of the United States."[16] In 2021, the National Security Telecommunications Advisory Committee ("NSTAC") reported to President Biden that GPS is susceptible to jamming,

[15] *Id.* at 14-3.

[16] Exec. Order No. 13905, 85 Fed. Reg. 9359 (Feb. 12, 2020), https://tinyurl.com/2cbmmudq.

manipulation, and spoofing by malicious actors.[17] In March 2024, DOT issued a request for quotes ("RFQ") for "operationally ready" complementary PNT ("CPNT").[18] DOT specified that the evaluation criteria would include consideration of "situations where GPS/GNSS service is disrupted or manipulated and CPNT-specific threat vectors are introduced."[19]

The DOT RFQ is notable for at least two reasons. *First*, it shows that significant sectors (e.g., transportation, financial services, communications) increasingly rely on GPS for their PNT needs, underscoring that accurate, reliable, and cost-effective PNT is vital to the U.S. economy. *Second*, it confirms that GPS alternatives are not widely available.[20] The Commission now has a unique opportunity to address these issues here.

B. Any Comprehensive Plan to Secure the Nation's PNT Infrastructure Must Include Both Space and Terrestrial Components

PNT services can be delivered from space and/or terrestrial infrastructure. GPS has been—and will continue to serve as—the foundation of modern U.S. PNT infrastructure. But a comprehensive public and private effort is necessary to support the deployment of complementary terrestrial PNT solutions in the United States that are reliable and precise enough to mitigate vulnerabilities common to space-based PNT technologies.

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[17] *See NSTAC Report to the President on Communications Resiliency*, NSTAC (May 6, 2021), https://tinyurl.com/2b8bzrwt.

[18] *Call for Proposals Operationally Ready Complementary PNT Services*, DOT, https://tinyurl.com/28utxveo (last updated Mar. 21, 2024).

[19] *Id*.

[20] *See* Exhibit B.

1. GPS Delivers Critical PNT Information Inside the United States

The U.S. government currently maintains at least 24 operational GPS satellites and replenishes them as needed.[21] It has also added new military and civilian signals for "enhanced signal reliability, accuracy, and integrity."[22] Today, GPS offers broad outdoor coverage,[23] supports a wide range of enabled devices, including smartphones, internet-of-things ("IoT") devices, and navigation equipment, and GPS.gov reports a typical accuracy of within 4.9 meters (x/y axis) "under open sky" conditions, but "their accuracy worsens near buildings, bridges, and trees."[24] It also distributes the U.S. Naval Observatory Coordinated Universal Time ("UTC").[25]

Very few space-based alternatives to GPS exist. The European Union operates the 23-satellite medium-Earth orbit ("MEO") Galileo system that delivers GNSS signals inside the United States.[26] Other countries have deployed GNSS constellations: China (BeiDou), India (NavIC), Japan (QZSS), and Russia (GLONASS).[27] But none of these systems have received U.S. market access rights, and they are not intended to serve U.S. national security, economic, and public safety interests.

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[21] *Space Segment*, GPS.gov, https://tinyl.io/ATG3 (last modified June 28, 2022).

[22] *Id*.

[23] Global Positioning System Standard Positioning Service Performance Standard, DOD § 3.3.2 (5th ed. 2020), https://tinyl.io/AT7D.

[24] *See GPS Accuracy*, GPS.gov, https://tinyurl.com/y7nl4ycj (last visited Apr. 14, 2024); *see also id.* ("User accuracy depends on a combination of satellite geometry, URE, and local factors such as signal blockage, atmospheric conditions, and receiver design features/quality.").

[25] *Id.*

[26] *See What is Galileo*, European Union Agency for the Space Programme, https://tinyurl.com/4239u447 (last visited Mar. 10, 2024); *Constellation Status*, European Union Agency for the Space Programme, https://tinyurl.com/4ppysca5 (last visited Mar. 10, 2024).

[27] NavIC and QZSS are regional GNSS systems that serve those countries and surrounding areas.

While space-based PNT solutions perform well in many scenarios, they are less reliable in others.[28] GPS signals, which are weak even when received outdoors due to the propagation losses from space, are often obstructed or weakened by physical barriers, like ceilings, walls, and even dense tree canopies, limiting the availability of positioning or timing data in indoor locations. Tall buildings, particularly in dense downtown areas, can create "canyons" that reflect[29] or outright block GNSS signals and reduce accuracy. Further, factors like ionospheric and tropospheric delays can distort signals and affect measurement accuracy as they pass through the Earth's atmosphere. Natural space weather events (such as coronal mass ejections or solar flares) can also impede GPS and other satellite systems.[30]

Other risks include accidental satellite destruction by space debris, deliberate destruction during war, anomalies, and failures. U.S. national security leaders have emphasized the threat to U.S. space assets that our nation's adversaries present. For example, Gen. Stephen Whiting, Commander of the U.S. Space Force, recently testified that China "is growing its military space and counterspace capabilities at breathtaking pace to deny American and Allied space capabilities when they so choose."[31]

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[28] All space-based systems share certain challenges and limitations due to the physical limitations of satellite communications systems, and thus any satellite-based PNT service could benefit from a terrestrial PNT complement.

[29] Reflected signals cause inaccuracies due to a signal arriving at a receiver from multiple paths, potentially leading to interference and phase shifting.

[30] *See generally Space Weather*, NASA, https://tinyl.io/AcYS (last updated Mar. 2024).

[31] Testimony of Stephen N. Whiting, United States Space Command, Senate Armed Services Committee Hearing on United States Strategic Command and United States Space Command in Review of the Defense Authorization Request for Fiscal Year 2025 and the Future Years Defense Program, at 6 (Feb. 29, 2024), https://tinyurl.com/2692jej3.

2. Terrestrial PNT Is Integral to Any National PNT Capability, and NextGen Is the Only Viable Solution

Terrestrial PNT systems can offer performance characteristics that are complementary to satellite-based PNT solutions. Use of these solutions can help ensure accurate, available x/y-axis and z-axis positioning and timing, even when satellite-based services are disabled, disrupted, or cannot be received. The following are some of the characteristics of terrestrial PNT solutions.

Improved accuracy in high-density areas. Satellite signals can be obstructed or weakened in urban environments with tall buildings. Terrestrial PNT systems can provide reliable and accurate positioning data in such areas.

Enhanced security. By relying on localized infrastructure, terrestrial PNT solutions can be more secure against certain types of disruptions, such as intentional jamming or spoofing attacks targeting satellite signals.

Indoor coverage. Satellite signals struggle to penetrate indoor environments effectively. Terrestrial PNT systems can provide accurate positioning data indoors where satellite signals may not reach reliably.

Complementary to space-based PNT systems. Terrestrial PNT solutions can complement satellite-based systems, providing redundancy capabilities. This hybrid approach enhances overall system resilience and reliability, especially in scenarios where satellite signals may be temporarily unavailable or degraded.

Other radiofrequency (“RF”) and fiber-based technologies can support some—but not all—aspects of PNT. For example, fiber-optic systems can be used for timing; other technologies like cell triangulation, Wi-Fi, and Bluetooth can provide positioning information in some circumstances.[32] But these systems are often expensive (e.g., running fiber can require significant capital outlays) or limited in performance and coverage (e.g., Wi-Fi), making them unsuitable as a widescale terrestrial PNT complement and backup to GPS.

One relatively common, RF-based terrestrial PNT technology is Long Range Navigation ("LORAN"). LORAN is a radionavigation system operating between 90-110 kHz that uses a long-range antenna to broadcast at high power to provide x/y positioning and timing data.[33] Because the technology is deployed in very low radio frequencies (90-110 kHz), its antennas require a large form factor that would be difficult to adapt to smaller devices like smartphones or IoT devices. As such, since its inception, LORAN technologies have mainly delivered PNT coverage to maritime (and some aviation) applications.

In contrast, NextNav has developed a PNT offering designed to be compatible with everyday consumer devices and small-form-factor, cost-effective enterprise devices. NextNav's current approach, TerraPoiNT, is a resilient terrestrial beacon system ("TBS") using the 919.75-927.75 MHz band,[34] that provides x/y positioning and timing. TerraPoiNT's terrestrial transmitter network enables positioning by "multilateration"[35] using radio-positioning signals from three or more transmitters. In addition, NextNav's Pinnacle service determines accurate altitude using a

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[32] *See* Andrew Hansen et al., *Complementary PNT and GPS Backup Technologies Demonstration Report: Sections 1 through 10*, DOT, DOT-VNTSC-20-07, at xxvii (2021), https://tinyurl.com/2b35j86k ("2021 DOT Report").

[33] Mitch Narins, Chief Systems Engineer – Navigation, Presentation at U.S. National Space-Based Positioning, Navigation, and Timing Advisory Board Meeting, at 3 (June 3, 2014), https://tinyl.io/ATAL.

[34] *See NextNav TerraPoiNT*, NextNav, https://tinyurl.com/246msy83 (last visited Mar. 16, 2024).

[35] Multilateration is the process of locating an object by computing the difference in arrival times of signals received from three or more transmitters. This is also the same principle underlying the positioning information derived from GPS.

purpose-built sensor network and the barometric sensors in phones, tablets, and many other devices and applying differential barometric techniques to determine the receiver's z-axis location.[36]

In 2016, the Commission's fifth Communications Security, Reliability, and Interoperability Council assessed an earlier version of TerraPoiNT and found several advantages to using a terrestrial PNT system that uses sub-1 GHz spectrum:

> NextNav's [TBS-based Timing-as-a-Service ("TaaS")] provides high-precision timing and frequency in GPS-challenged areas, such as Indoors and Urban Canyons and as a backup to GPS in other areas. The TaaS system can deliver very precise time and frequency synchronization. The received TBS signals from multiple terrestrial transmitters (30 W [ERP]) is significantly more powerful than space-based GPS signals and provides for geographic redundancy of the signal. . . . As a ground-based system, TBS is insensitive to space weather phenomena. The sub-1 GHz signals penetrate buildings well, enabling deep indoor time and frequency coverage. The high-power TBS signals are more difficult to jam than GPS, and multiple beacon overlap provides geographic redundancy mitigating a single beacon being jammed. Signal encryption and authentication protect against spoofing.[37]

In 2021, DOT found TerraPoiNT to be the only alternative PNT technology among other space and terrestrial PNT offerings to meet all the identified needs, with NextNav offering uniquely sophisticated capabilities.[38] For its assessment, DOT evaluated twelve PNT technologies, including TerraPoiNT. DOT concluded that "[a]ll [Technology Readiness Level]-qualified vendors demonstrated some PNT performance of value, but only one vendor, NextNav, demonstrated [PNT performance] in all applicable use case scenarios."[39] As shown in Figure 3,

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[36] *NextNav Pinnacle*, NextNav, https://tinyurl.com/27dc2oqk (last visited Mar. 16, 2024). Barometric sensors measure air pressure (i.e., the weight of air above it) and can help accurately measure altitude when combined with other data.

[37] *CSRIC V Working Group 4: Communications Infrastructure Resiliency Subgroup B: Network Timing Single Source Risk Reduction Final Report*, at 3-4 (Dec. 2016), https://tinyurl.com/22jeo7qc.

[38] 2021 DOT Report.

[39] *Id.* at 194.

NextNav's TerraPoiNT ranked number one overall based on DOT's weighted metrics—a combination of accuracy, availability, product readiness, resilience, and security.[40]

Figure 3: Summary of DOT Assessment of Various "Complementary PNT and GPS Backup" Technologies[41]

			TIMING(1)		POSITIONING(2)		TIMING(3)		PNT(4)		TIMING(5)		PNT(6)	
			Performance		Performance		Ground broadcast		Ground broadcast		Broadcast		Broadcast	
			Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score
NEXTNAV	UHF terrestrial RF	(920-928 MHz)	1	91	1	91	1	82	1	82	1	82	1	82
ECHO RIDGE	LEO commercial S-band	(2483.5-2500 MHz)	-	-	5	38	-	-	-	-	-	-	-	-
HELLEN systems	eLORAN terrestrial RF	(90-110k Hz)	6	62	-	-	3	66	-	-	4	66	-	-
opnt.	Fiber optic time service	(white rabbit PTP)	2	87	-	-	-	-	-	-	-	-	-	-
PHASORLAB	802.11 terrestrial RF	(2.4 HGz)	6	62	3	-	4	-	2	-	5	-	3	-
Satelles	LEO commercial L-band	(1616-1626.5 MHz)	4	78	2	78	-	-	-	-	2	80	1	82
serco	R-made terrestrial RF	(283.5-325 KHz)	-	-	-	-	-	-	-	-	-	-	-	-
SEVEN Solutions	Fiber optic time transfer	(white rabbit PTP)	3	84	-	-	-	-	-	-	-	-	-	-
SKYHOOK	802.11 terrestrial RF	(900 MHz, 2.4 & 5 GHz)	-	-	4	-	-	-	-	-	-	-	-	-
TRX	UWB & IMU map matching	(3.1-5 GHz)	-	-	5	38	-	-	-	-	-	-	-	-
UrsaNav	eLORAN terrestrial RF	(90-110KHz)	5	69	-	-	2	70	-	-	3	70	-	-
GPS (SPS PS)	MEO government, L-band	(1575, 1227, 1176 MHz)	-	67	-	-	-	-	-	-	-	-	-	-

Also in 2021, NextNav successfully demonstrated TerraPoiNT's timing precision and resilience in a Department of Homeland Security Science & Technology Directorate assessment.[42] The testing, an industry first, assessed TerraPoiNT's timing redundancy in multiple scenarios, including GPS outages, spoofing, and jamming instances. It validated TerraPoiNT's capabilities and NextNav's expertise.[43] Specifically, during a simulated 72-hour GPS outage, TerraPoiNT's timing accuracy was better than 50 nanoseconds in urban and semi-urban environments and successfully met timing requirements for various applications, including 5G network timing, power grid synchronization, and financial exchanges.

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[40] *Id.* at 185.

[41] *Welcome to Next Generation GPS*, NextNav, at 37 (June 10, 2021), https://tinyurl.com/223xcpbj.

[42] Gillian Smith, *NextNav Demonstrates World's First GPS-Free PNT Network in Department of Homeland Security Trial*, NextNav (Aug. 16, 2021), https://tinyurl.com/2dqg3356.

[43] *Id.*; *see also Terrestrial Timing System: Secure, Resilient Solution For Position, Navigation, and Timing*, NextNav (May 8, 2022), https://tinyurl.com/2ays7hgp.

Most recently, a 2023 European Joint Research Centre report highlighted NextNav's TerraPoiNT as a technology that met or exceeded relevant benchmarks for serving as a resilient layer for existing GPS and other GNSS technologies.[44] Based on its testing, the report valued dedicated terrestrial PNT spectrum usage:

> There is a strong advantage in the dedicated spectrum band for terrestrial PNT services within the EU, something that at the moment is not available. . . . Not only does this offer better legal protection against [RF interference ("RFI")] but also allows for more transmission power—reducing the chance of RFI, extending the signal range and in-building penetration.[45]

These government studies illustrate NextNav's expertise in developing terrestrial PNT services that can serve as a backup to GPS and be available where GPS and other satellite-based services are not, including indoors and in dense urban areas.

It is worth noting that many other countries have recognized the need for terrestrial systems as part of their national PNT capabilities and are ahead of the United States in deploying solutions to complement and supplement space-based PNT. For example, Australia, China, the European Union, Iran, Russia, Saudi Arabia, South Korea, and the United Kingdom have each taken several prominent steps to improve their terrestrial PNT options.[46]

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[44] Lukasz Bonenberg et al., *Assessing Alternative Positioning, Navigation and Timing Technologies for Potential Deployment in the EU*, European Commission Joint Research Centre, JRC132737 (2023), https://tinyurl.com/2c9otc7b ("JRC Report").

[45] *Id.* at 78.

[46] *See* Matt Higgins, President of the IGNSS Association of Australia, Presentation at U.S. National Space-Based Positioning, Navigation, and Timing Advisory Board Meeting, at 16 (Dec. 2023), https://tinyl.io/AVwn; JRC Report at 52, 78; Chaozhong Yang et al., *Analysis of the Development Status of eLoran Time Service System in China*, Applied Sciences (Nov. 27, 2023), https://tinyl.io/ATBC; MohammadReza Azali, *Iran Launches Local Navigation System to Reduce the Country's High Rate of Road Accidents*, TechRasa (Sept. 13, 2017), https://tinyl.io/AXbH; Tracy Cozzens, *Russia expected to ditch GLONASS for Loran in Ukraine invasion*, GPS World (Feb. 17, 2022), https://tinyl.io/AQw6; Press Release, UK Department for Science, Innovation, and Technology, Critical services to be better protected from satellite data disruptions through new Position, Navigation and Timing framework (Oct. 18, 2023), https://tinyl.io/AQv1.

C. The FCC Has Sought Ongoing Improvements in Location Data Accuracy to Support Public Safety

As cellular networks have become ubiquitous and the primary form of communication for many, FCC policy has focused on improving the ability to locate wireless callers during emergencies.[47] At first, network providers relied on cell tower triangulation to provide location coordinates that could be accurate to within several hundred meters.[48] In partial response to evolving FCC requirements to relay ever more accurate x/y-axis or dispatchable location data, device manufacturers began to add GPS receivers for additional accuracy for both inbound calls and first responder situational awareness.[49] In 2015, the Commission adopted comprehensive rules and deadlines for improving E911 wireless location accuracy.[50] Today, all nationwide commercial mobile radio service ("CMRS") providers must provide x/y-axis horizontal location information within 50 meters for 80% of all wireless E911 calls.[51]

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[47] *See, e.g.*, *Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems*, Report and Order and Further Notice of Proposed Rulemaking, 11 FCC Rcd 18676 (1996).

[48] *Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems*, Third Report and Order, 14 FCC Rcd 17388 ¶ 6 (1999) ("When the Commission adopted its Phase II rules in 1996, it was believed that location information could only be effectively provided by technologies based in or overlaid on carrier networks, using approaches such as triangulation of the handset's signal."). Triangulation is the calculation of an object's position by computing the angles between the object and the known position of two or more points.

[49] *Wireless E911 Location Accuracy Requirements*, Fifth Report and Order and Fifth Further Notice of Proposed Rulemaking, 34 FCC Rcd 11592 ¶ 3 (2019) ("The Commission has been working with the public safety community and industry partners to ensure the accurate delivery of 911 vertical location information for the better part of a decade.").

[50] *Wireless E911 Location Accuracy Requirements*, Fourth Report and Order, 30 FCC Rcd 1259 ¶ 2 (2015) (concluding that the major transition from traditional landline telephony to wireless mobile communications resulted in a "gap in the performance of 911 location service" that "needs to be closed" because "the public rightfully expects 911 location technologies to work effectively regardless of whether a 911 call originates indoors or outdoors").

[51] *See* 47 C.F.R. § 9.10(i)(2)(i)(A).

The 2015 rules required, for the first time, vertical location information for indoor 911 calls.[52] In describing this requirement, the Commission noted that NextNav had shown that it could determine and transmit vertical location accurately.[53] Based in part on the positive results associated with NextNav's technology, the Commission adopted a vertical location, or z-axis, accuracy metric of ± 3 meters for 80% of all wireless E911 calls.[54] The z-axis requirements follow from years of study and experimentation rooted in the Commission's long-held concern that, for "millions of wireless 911 callers seeking emergency assistance, time is of the essence and they expect that first responders will be able to find them."[55] By 2021, NextNav had deployed its z-axis service in 4,400 cities and towns across 105 cellular market areas, over 90% of commercial properties in the United States that exceed three stories.[56] This z-axis capability is also available to public safety through FirstNet (built with AT&T).[57]

[52] *Wireless E911 Location Accuracy Requirements*, Fourth Report and Order, 30 FCC Rcd 1259 ¶ 112 (2015) ("Based on the record, we find that there is a need for vertical location information in connection with indoor 911 calls, and that adopting clear timelines for providers to deliver vertical location information is in the public interest.").

[53] *See* Letter from CTIA, AT&T, Sprint Corporation, T-Mobile USA, and Verizon to Marlene H. Dortch, Secretary, FCC, PS Docket No. 07-114 (Aug. 3, 2018), https://tinyl.io/AcZX.

[54] *Wireless E911 Location Accuracy Requirements*, Fifth Report and Order and Fifth Further Notice of Proposed Rulemaking, 34 FCC Rcd 11592 (2019).

[55] *Wireless E911 Location Accuracy Requirements*, Sixth Report and Order and Order on Reconsideration, 35 FCC Rcd 7752 ¶ 1 (2020).

[56] Ben Ball, *NextNav Rolls Out Vertical Location Services to 4,400 Cities Across the US, Exceeding FCC's Z-Axis Coverage Requirements Ahead of Schedule*, NextNav (Mar. 26, 2021), https://tinyurl.com/28s3zvrl.

[57] *Summary of 'Report on Stage Z'*, NextNav at Executive Summary (2021), https://tinyl.io/AXcY.

D. The Lower 900 MHz Band Is Underutilized Due to Outdated Service and Technical Rules

In 1995, the Commission established the Location and Monitoring Service ("LMS") in the Lower 900 MHz Band.[58] The decision defined the two types of LMS systems: (1) multilateration LMS system ("M-LMS") and (2) non-multilateration system ("non-M-LMS"):

> [M-LMS] use[s] spread-spectrum technology to locate vehicles (and other moving objects) with great accuracy throughout a wide geographic area. This technology is used, for example, by trucking companies to locate and track their vehicle fleets, by municipal governments to pinpoint the location of their buses, and by entrepreneurs who are developing subscriber-based, stolen vehicle recovery systems. [Non-M-LMS] use[s] narrowband technology to transmit data to and from vehicles passing through a particular location. This technology is now providing valuable services to state and local governments operating various types of automated toll collection systems . . . and by the railroad industry in the monitoring of their systems' railway cars.[59]

Various users share the Lower 900 MHz Band with M-LMS and non-M-LMS users under a spectrum usage rights hierarchy. This band is allocated on a primary basis to federal radiolocation systems and industrial, scientific, and medical ("ISM") equipment.[60] Federal fixed and mobile services are allocated on a secondary basis to federal radiolocation systems and ISM equipment.[61] LMS is lower priority than federal users and ISM devices and may not cause interference to and must tolerate interference from these users and devices.[62] Amateur radio operations are lower priority than LMS.[63] Unlicensed devices have the lowest priority and cannot

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[58] *See generally Amendment of Part 90 of the Commission's Rules to Adopt Regulations for Automatic Vehicle Monitoring Systems*, Report and Order, 10 FCC Rcd 4695 (1995).

[59] *Id.* ¶ 4.

[60] 47 C.F.R. §§ 2.106, 18.301, 18.111(c).

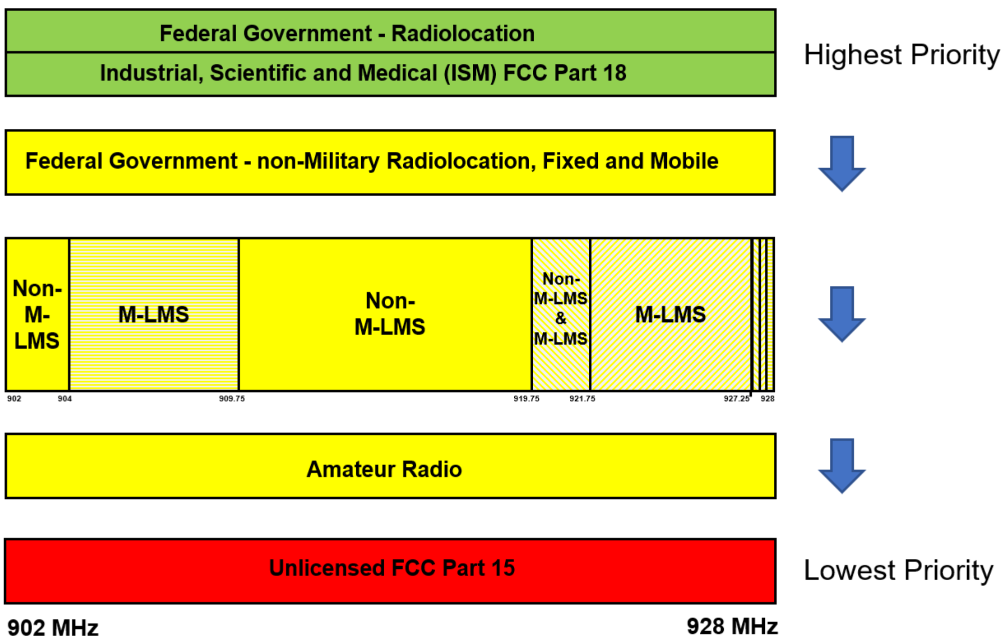
[61] *Id.* § 2.106.

[62] *Id.* § 90.353(a).

[63] *Id.* § 97.301.

claim interference rights, except for unacceptable interference from M-LMS licensees in some cases,[64] and may not cause harmful interference to M-LMS and non-M-LMS licensees, amateur operations, or other licensed systems.[65] Figure 4 reflects the current Lower 900 MHz Band plan and hierarchies.

Figure 4: Current 902-928 MHz Band Plan and Sharing Priorities



The LMS band plan divides the band into five spectrum sub-bands: two for use by M-LMS, two for use by non-M-LMS, and one for use by both M-LMS and non-M-LMS.[66] The available M-LMS sub-bands (i.e., the 14-megahertz M-LMS band) are licensed in three blocks as follows:

- *A block.* 904.00-909.75 MHz band paired with a 0.25-megahertz narrowband channel in the 927.75-928.00 MHz band;

[64] *Id.* § 90.353(d).

[65] Users of Part 15 devices do not have any allocation status in the Commission's rules. Instead, the Commission makes spectrum available for Part 15 devices on an unprotected and non-interference basis. Under Part 15, unlicensed devices may not cause harmful interference to LMS licensees, amateur operations, or other licensed systems in the Lower 900 MHz Band. *See id.* § 90.361.

[66] *Id.* § 90.357.

- *B block.* 919.75-921.75 MHz band paired with a 0.25-megahertz narrowband channel in the 927.50-927.75 MHz band; and
- *C block.* 921.75-927.25 MHz band paired with a 0.25-megahertz narrowband channel in the 927.25-927.50 MHz band.

The available non-M-LMS sub-bands are 902-904 MHz and 909.75-919.75 MHz, and the available equally shared sub-band is the 919.75-921.75 MHz B-block portion. "The Commission intended that this band plan would assign [non-M-LMS] spectrum to portions of the band where use of spectrum by Part 15 devices, amateur operations, and federal radiolocation operations was greatest."[67]

When adopting the current rules nearly three decades ago, the Commission expected that M-LMS and non-M-LMS operators would play an integral role in transportation-related services that would "improve the efficiency and safety of our nation's highways, reduce harmful automobile emissions, promote more efficient energy use, and increase national productivity."[68] This specific vision directly contributed to the Commission's decisions to implement restrictions that are now inhibiting development and innovation in the band.[69] For example, the Commission crafted service rules for the Lower 900 MHz Band to support traffic delay notifications, alternate

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[67] *Amendment of the Commission's Part 90 Rules in the 904-909.75 and 919.75-928 MHz Bands*, Notice of Proposed Rulemaking, 21 FCC Rcd 2809 ¶ 7 (2006) ("*2006 M-LMS NPRM*") (citing *Amendment of Part 90 of the Commission's Rules to Adopt Regulations for Automatic Vehicle Monitoring Systems*, Report and Order, 10 FCC Rcd 4695 ¶ 24 (1995)).

[68] *Amendment of Part 90 of the Commission's Rules to Adopt Regulations for Automatic Vehicle Monitoring Systems*, Report and Order, 10 FCC Rcd 4695 ¶¶ 5, 24-27 (1995); *see also 2006 M-LMS NPRM* ¶ 7.

[69] *Amendment of Part 90 of the Commission's Rules to Adopt Regulations for Automatic Vehicle Monitoring Systems*, Report and Order, 10 FCC Rcd 4695 ¶ 26 (1995) ("We will permit communications necessary to provide accurate, timely and complete status and instructional information relating to the vehicle being located or the occupant(s) of the vehicle, including voice communications. . . . We find that such use of LMS will be invaluable to the implementation of [Intelligent Transportation Systems] of the future.").

route recommendations, and other “Intelligent Transportation System” (“ITS”) applications that were then under development.[70] But the technical requirements the Commission established were not suited to the technologies that could best provide this service, and subsequent innovation in the Commission’s spectrum use policies made other bands more attractive for ITS applications and connected cars.

Today, the Lower 900 MHz Band is neither fully nor efficiently deployed. Higher-priority federal users operate in some areas, and non-M-LMS operations, which are site-based, are active in geographically discrete areas, largely supporting electronic highway tolling, railroad car tracking, and vehicle access to restricted areas. Lowest-priority Part 15 devices also use the Lower 900 MHz Band for multiple purposes, including for RFID readers, utility and meter reading devices, and telemetry and security devices. Even so, the band remains largely underused in many parts of the country because of vehicle-sector-specific operational rules that no longer reflect contemporary needs.

The Commission’s approach to spectrum policy has significantly evolved since it adopted the prescriptive, command-and-control LMS rules in 1995. The Commission now recognizes that spectrum will generally be put to its highest and best use when licensees have maximum flexibility.[71] With a few exceptions (e.g., bands designated for public safety use), the Commission has largely abandoned narrowly prescribing the services a licensee can offer and narrowly detailing

[70] *Amendment of Part 90 of the Commission’s Rules to Adopt Regulations for Automatic Vehicle Monitoring Systems*, Report and Order, 10 FCC Rcd 4695 ¶ 5 (1995).

[71] *Principles for the Reallocation of Spectrum to Encourage the Development of Telecommunications Technologies for the New Millennium*, Policy Statement, 14 FCC Rcd 19868 ¶ 9 (1999) (“In the majority of cases, efficient spectrum markets will lead to use of spectrum for the highest value end use. Flexible allocations may result in more efficient spectrum markets. Flexibility can be permitted through the use of relaxed service rules, which would allow licensees greater freedom in determining the specific services to be offered.”).

the licensee's technical operations. For example, the Commission's early decision to "encourage innovation and experimentation through a broader, more flexible standard"[72] enabled mobile carriers to "better respond to market demand and increase competition in the provision of telecommunications services."[73] Just as the Commission rightfully concluded then that the "public interest is better served by not attempting to limit potential use of CMRS spectrum to specific applications,"[74] it should now recognize that restrictive service and technical rules only hinder the highest and best use of the Lower 900 MHz Band.

II. NEXTNAV'S NEXTGEN PNT SOLUTION WILL BE STATE OF THE ART AND BEST IN CLASS

A. Refreshing the LMS Rules and Updating the Band Plan Will Facilitate Both a Widescale PNT Network and Additional 5G Services

Combining NextNav's 3D positioning and timing experience, expertise, and technologies with the power of 5G (and future sixth-generation ("6G")[75]) broadband technology overcomes the economic challenge of building a terrestrial PNT network. Compared to other GPS alternatives, NextNav's NextGen PNT system will provide more features, wider availability, and greater resiliency—all while making a 15-megahertz block of low-band spectrum available nationwide for mobile broadband services. NextNav proposes to accomplish this deployment by leveraging a

[72] *Commercial Mobile Radio Services*, Report and Order and Notice of Proposed Rulemaking, 11 FCC Rcd 8965 ¶ 19 (1996).

[73] *Id.* ¶ 1.

[74] *Id.* ¶ 19.

[75] The 3rd Generation Partnership Project ("3GPP") introduced signaling features to support positioning for Long-Term Evolution in Release 9 and since that time has continued evolving those features for 5G. In 6G, features to support even more robust and precise positioning is a key focus, and some expect the positioning features in 6G to unlock new use cases and applications. Marius Corici et al., *Next-Generation Positioning Within 6G*, Fraunhofer Institute for Integrated Circuits IIS (2023), https://tinyurl.com/27wfduqd. Having deployed the positioning features of 5G, NextNav will have a clear path toward leveraging the positioning features of 6G.

partnership with mobile network operators with existing 5G networks. NextNav believes this approach is an economically viable way for the United States to create a widescale terrestrial complement and backup to GPS.

As discussed above and detailed in Exhibit B, there is a solid consensus that the United States needs a terrestrial PNT service that can complement and back up GPS and other space-based PNT systems, which have similar vulnerabilities and performance limitations (e.g., indoors and in urban canyons). But the economics of building a widescale, standalone terrestrial PNT network are insurmountable for at least four reasons. *First*, GPS is free and limits revenue potential for alternatives. *Second*, building a new, widescale, standalone terrestrial PNT network is cost-prohibitive, especially in the absence of revenues from PNT services. *Third*, driving adoption into user devices would be difficult if PNT-specific protocols (i.e., non-3GPP standards) are used. *Fourth*, there appears to be no path to congressional appropriation for the billions of dollars in outlays or subsidies needed for a federally funded terrestrial backup.

NextNav is proposing a model that can support the incremental capital and operating expenditures required to provide terrestrial PNT based on a 5G broadband deployment, which is the only way to make an extensive, non-federally subsidized network viable to deploy and maintain. This approach simultaneously addresses network coverage, economic, and ecosystem considerations without requiring federal funding. Under this proposal, network partners would integrate NextNav's Lower 900 MHz Band spectrum into their 5G networks, and NextNav would implement, operate, and manage additional PNT-optimized infrastructure over the 5G network.

One partnership option NextNav envisions would be analogous to a "hybrid MVNO" arrangement. As shown in Figure 5 below, NextNav's spectrum and PNT infrastructure would be integrated into the partner's 5G network, but both parties could retain control of their respective network elements.[76] This arrangement creates opportunities for revenue generation while making a high-performance and resilient terrestrial PNT service available to public and government operators—a sustainable public good using a private-partner model.

B. The NextGen Network Will Combine PNT and Standardized Mobile Broadband Features

NextNav's NextGen positioning and timing solution will be a 5G New Radio ("NR")-based PNT system (with a seamless transition path to 6G) that uses 5G positioning reference signals ("PRS")[77] to determine location and timing based on time of arrival ("ToA").[78] The NextGen solution will operate according to 3GPP standards and will benefit from PRS functionality, as well as other positioning-related enhancements built into the 5G standard.[79] This approach will lead to more rapid market uptake because standards-based 5G PNT will drive scale economies and

[76] For example, this model could be effectuated through a spectrum leasing arrangement.

[77] PRS will replace the terrestrial beacon transmissions used in the TerraPoiNT system. *See, e.g.*, TS 37.355, *LTE Positioning Protocol (LPP) (Release-18)*, 3GPP § 6.4.3 (2024), https://tinyurl.com/2wrp2hfj; TS 38.211, *NR; Physical channels and modulation (Release-15)*, 3GPP § 7.4.1.7 (2018), https://tinyurl.com/2zzddtws; TS 38.214, *NR; Physical layer procedures for data (Release-15)*, 3GPP § 5.1.6.5 (2018), https://tinyurl.com/mrxye7f7.

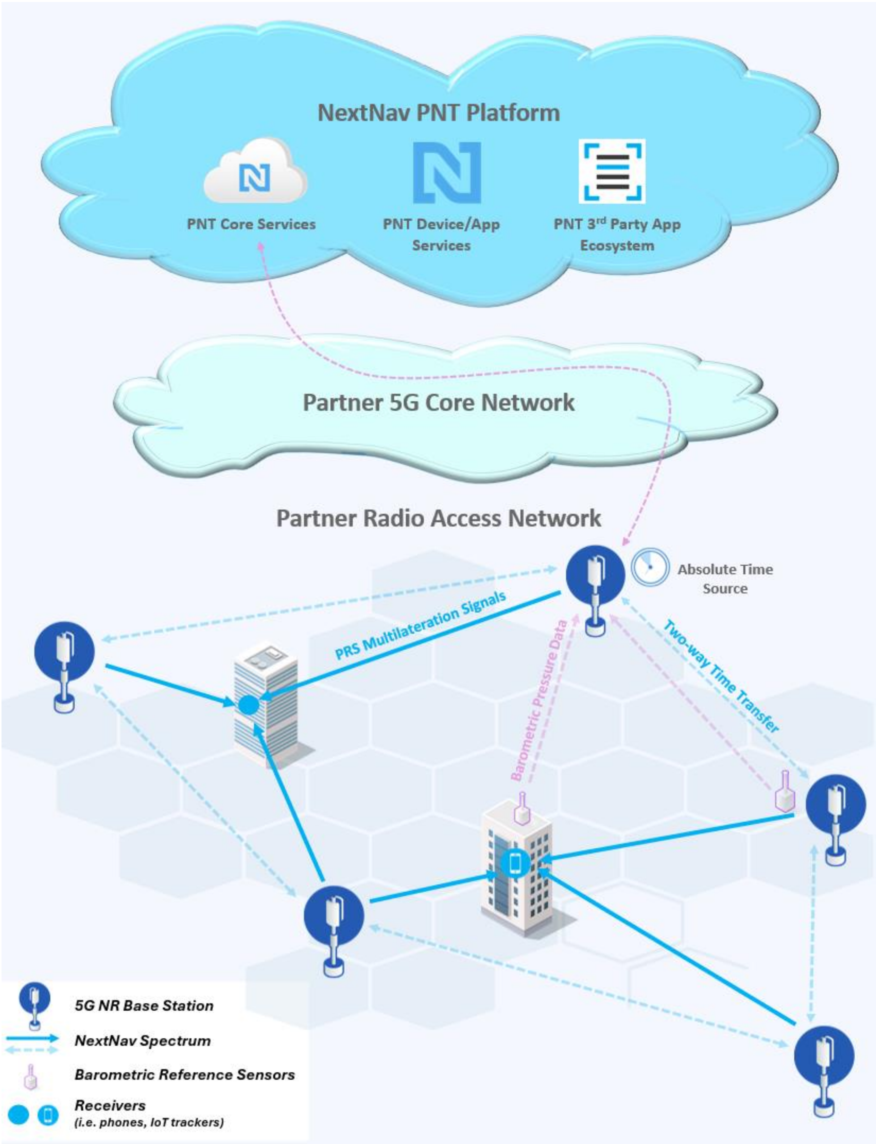
[78] Section 2 of the Technical Appendix provides details on 5G PRS and the NextGen system's use of this technology. Exhibit A at A-4. The use of 5G NR and incorporation of 5G PRS provide an important foundation for the NextGen network, but building an accurate, resilient, and cost-effective PNT network involves many careful considerations beyond simply electing to transmit PRS as the positioning reference. The NextGen network will be hardened and differentiated by NextNav's PNT-related intellectual property and years of operational experience.

[79] 5G includes other positioning features, such as multi-cell round trip time ("Multi-RTT"). NextNav can measure the round-trip time using multiple cells to deliver positioning information. *See* Jakub Nikonowicz et al., *Indoor Positioning in 5G-Advanced: Challenges and Solution towards Centimeter-level Accuracy with Carrier Phase Enhancements*, arXiv (Feb. 26, 2024), https://tinyl.io/AXX6 ("[A 5G NR base station ('gNB') and user equipment] perform [receive-transmit ('Rx-Tx')] time difference measurement, using PRS and [sounding reference] signaling, for the signal of each cell. [The location management function] initiates the procedure whereby multiple gNBs and a [user equipment] perform the gNB Rx-Tx and [user equipment] Rx-Tx measurements, respectively."). Multi-RTT "has higher accuracy than [time-difference-of-arrival]-based methods and relaxes requirements on time synchronization." Satyam Dwivedi et al., *Positioning in 5G networks*, arXiv, at 5 (Feb. 5, 2021), https://tinyl.io/AXVH.

adoption. An added benefit of the NextGen system's use of 5G PRS is that PNT services can be available both to devices connected to the NextNav partner's network (i.e., in-network) and to user devices connected to other operators' networks (i.e., out-of-network).[80]

As shown in Figure 5 and detailed below, the NextGen PNT network will be capable of leveraging partners' 5G network facilities (e.g., towers, backhaul, and core network).

Figure 5: Overview of 5G PNT Network Architecture



[80] *See* Exhibit A at A-4.

The planned NextGen PNT network will have a topology that resembles other 5G networks. This will facilitate partnerships with existing providers and permit NextNav to leverage the providers' existing deployments. NextNav will augment the network for PNT using its intellectual property and expertise. For example, base stations will be tightly synchronized to the antenna port for accurate ToA estimation, which is essential to calculate the x/y location of user equipment, which relies on the ToA from three or more base stations. For the system to have time resiliency—in addition to resilient synchronization—atomic clocks with long holdover[81] times, such as cesium clocks, will be available at one or more sites in a geographic market, and all the sites in a market will be interconnected by a fixed-wireless mesh.[82] Only a few sites per market will require an independent timing source.

NextNav's NexGen network will focus on high availability PNT services; wide-area coverage, including indoor areas, aided by sub-1 GHz propagation; robust network synchronization; and resiliency in the presence of interference. NextNav will leverage its PNT experience,[83] including its ranging and positioning technology, sub-10-nanosecond

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[81] Michael Bartock et al., *Foundational PNT Profile: Applying the Cybersecurity Framework for the Responsible Use of Positioning, Navigation, and Timing (PNT) Services*, NIST, NIST IR 8323r1 (2023), https://tinyurl.com/22rw5nmp.

[82] *See Time Transfer Using a Terrestrial Beacon System: A Resilient Timing Solution*, NextNav (Mar. 2023), https://tinyurl.com/29yoetqy. A wide-area timing synchronization system will underpin the NextGen system's operations. The timing synchronization operates as follows: a "Leader" is precisely clocked with a NIST-derived time source (or local atomic clock source) and wirelessly transfers time through a mesh network to other "Follower" stations or signal sensors. A resilient network is possible given the time transfer between base stations and the availability of a local atomic clock in only a few Leaders per market to deliver PNT capabilities when GPS fails or is absent.

[83] The network could also be supplemented by opportunistic beacon-only positioning signal deployments to augment 5G-based PNT operations.

synchronization techniques to the antenna port, and two-way authentication to protect against spoofing.[84] It will also offer a precision timing service that distributes UTC.

The network will also incorporate NextNav's z-axis solution to provide a comprehensive, fully integrated 3D offering and better service experience. The z-axis solution uses a network of fixed outdoor barometric reference sensors to help calibrate the z-axis location of a user's mobile device (or other user equipment with a barometric sensor). The NextGen network would leverage its native 5G data connectivity to relay sensor readings, including x/y positioning data and reference assistance data. The sensor readings are processed either in the cloud or on the user device to determine the user device's estimated z-axis height above ground level.

C. The NextGen System Will Offer Superior Positioning and Timing Performance

Offering transformative features, the NextGen solution will be a highly effective terrestrial complement for and backup to GPS that can readily be incorporated into everyday mobile device chipsets and 5G networks. The native x/y-axis position data should improve z-axis accuracy through an innovative approach that bases the barometric calculation of absolute height above mean sea level on a more accurate x/y position relative to the fixed reference sensors. This approach also more accurately estimates ground elevation based on a terrain database to calculate the relative height. The 10-megahertz downlink channel will provide significant performance improvements (i.e., accuracy, availability, and resiliency) for positioning and timing.

As detailed in the Technical Appendix,[85] NextNav has validated through a simulation study that *a 10-megahertz configuration can provide a single-digit-meter positioning and sub-20-*

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[84] *See generally CSRIC V Working Group 4: Communications Infrastructure Resiliency Subgroup B: Network Timing Single Source Risk Reduction Final Report*, at 3-3, 3-4 (Dec. 2016), https://tinyurl.com/22jeo7qc.

[85] *See* Exhibit A at A-7.

nanosecond timing accuracy at a 95% confidence level.[86] The simulation study includes 3GPP-standard scenarios for urban and rural environments in which a user device is located indoors, which are considered to be the most challenging for PNT.[87]

While there are other terrestrial systems that can get to single-digit x/y positioning accuracy, such as Wi-Fi, Bluetooth, and ultra-wideband ("UWB"), these can only offer limited (i.e., fragmented) coverage and are not scalable for seamless PNT solutions for use in wide areas or suitable for time distribution.[88] As discussed above, GPS and other space-based alternatives are inherently limited in certain common scenarios (e.g., urban canyons). Only the NextGen system can provide the sort of widescale PNT services that can complement and back up GPS while also addressing the scenarios in which GPS and other space-based alternatives are limited.

A crucial benefit of this proposal is that the improved PNT services using 10 megahertz of downlink bandwidth would require only a small portion of the overall spectrum capacity, leaving the remainder open for voice and data services through integration with mobile network operators' existing 5G networks. In fact, *because 5G PRS uses only a small part of the 5G network's capacity, at least 95% of the spectrum capacity will be available for additional services*. A 15-megahertz FDD block will provide a strong incentive for a network partner to integrate the Lower 900 MHz Band into its network.

Finally, because of these PNT performance improvements, the NextGen solution is consistent with the Commission's E911 objectives. The data shows that the system would provide

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[86] The studied scenarios included the delivery of PNT services to user devices located indoors in both urban and rural environments.

[87] For example, the simulation study included indoor loss of 20-32 dB to account for building penetration losses and distance between the user device and base station in urban settings.

[88] Tim Meng, *Wi-Fi, UWB and Bluetooth, which indoor positioning accuracy is strong?*, LinkedIn (Apr. 20, 2020), https://tinyurl.com/23gan785.

3D positioning accuracy that would meet the Commission's 3-meter z-axis and 50-meter x/y axis indoor location requirements.

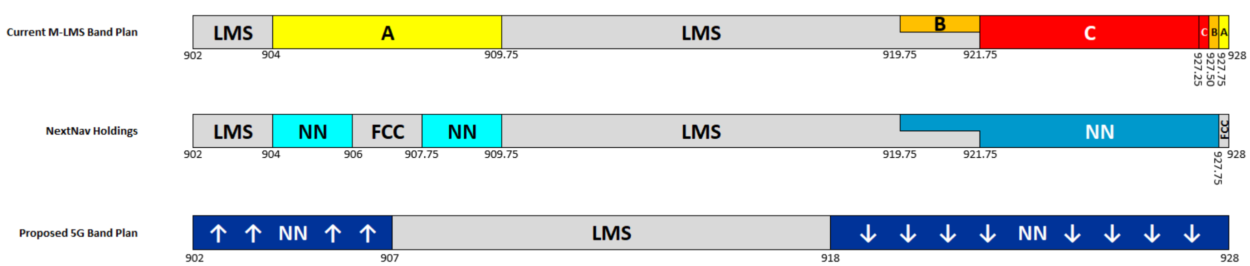
III. THE NEXT-GENERATION PLAN FOR THE LOWER 900 MHZ BAND

A. Updating the Lower 900 MHz Band Plan to Support an Economically Viable Widescale PNT Network and the 5G Ecosystem

The current band plan has divided M-LMS spectrum into three blocks that are neither suited for broadband service nor aligned with 3GPP specifications. Consequently, NextNav proposes that the Commission reconfigure the M-LMS band into a 3GPP-compliant 15-megahertz band to support its hybrid network vision.

Figure 6 shows the current and proposed band plans. The new band plan increases the M-LMS segment from 14 megahertz to 15 megahertz and consolidates the non-M-LMS segment into a contiguous 11-megahertz spectrum block. The result will be a 10-megahertz downlink paired with a 5-megahertz uplink consistent with standard 5G channel sizes.[89]

Figure 6: Current and Proposed LMS Band Plan[90]



[89] TS 38.101-1, NR, *User Equipment (UE) radio transmission and reception (Release 15)*, 3GPP, https://tinyurl.com/282r8vyr (2018).

[90] This graphic assumes that NextNav will acquire the A-block licenses and rights held by Telesaurus.

B. Refreshing the M-LMS Rules to Support a Widescale Terrestrial PNT Network

Certain rule changes can maximize M-LMS band use to afford NextNav the flexibility to deploy a widescale terrestrial PNT network that also supports broadband services. The M-LMS service and technical rules should align with the Commission's flexible-use rules (e.g., Part 27) for mobile and/or fixed broadband operations, including full macro power limits and standard out-of-band-emissions limits. They should also eliminate the restrictions on real-time interconnection obligations, services that may be provided, and the amount of M-LMS spectrum that a licensee can hold.[91]

C. Rationalization of M-LMS License Holdings

NextNav seeks a nationwide license, including spectrum sitting fallow in FCC inventory, to unlock the Lower 900 MHz Band's current terrestrial PNT potential. As discussed above, NextNav's NextGen system requires a 5+10-megahertz band plan supported by only one licensee using M-LMS spectrum. NextNav first acquired M-LMS licenses in FCC auctions 21 and 39.[92] It holds approximately 64% of all B- and C-block licenses (approximately 92% of the MHz-POPs

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[91] The application for assignment of the A-block licenses to NextNav requests a waiver of the spectrum aggregation limit.

[92] *See* ULS File No. 0000006894 (lead call sign WPQP847) (granted Nov. 3, 1999); *see also Wireless Telecommunications Bureau Grants 228 Location and Monitoring Service Licenses to Progeny LMS*, Public Notice, 15 FCC Rcd 12807 (WTB 2000). *See generally Public Coast and Location and Monitoring Service Spectrum Auction Closes*, Winning Bidders Announced, Public Notice, 16 FCC Rcd 12509 (2001); *Location and Monitoring Service Auction Closes, Winning Bidders in the Auction of 528 Multilateration Licenses in the Location and Monitoring Service*, Public Notice, 14 FCC Rcd 3754 (1999).

in the B and C blocks).[93] Concurrent with this petition, NextNav is seeking to acquire all active M-LMS A-block licenses.[94]

The current M-LMS band plan does not support robust PNT or integration into broadband networks. NextNav therefore requests a "swap" in which NextNav will return all active licenses and associated applications and petitions in exchange for a nationwide license consistent with the new 15-megahertz band plan configuration. Specifically, the Commission would direct the Wireless Telecommunications Bureau to issue a new 15-megahertz license conditioned on NextNav fulfilling various obligations, including enabling a terrestrial PNT service and protection of federal operations and incumbent licensees. NextNav would also need to fulfill its spectrum coexistence obligations.

D. Commitment to Working with Other Stakeholders and Providing Appropriate Protections

NextNav will work with Lower 900 MHz Band incumbents,[95] including federal (radiolocation, fixed, and mobile), ISM, and non-M-LMS, amateur, and unlicensed (as identified in Figure 4, *supra*).

Federal operators. NextNav commits to protect federal users.

Part 18 ISM devices. In reviewing all devices for which information was available, NextNav identified a limited number of Part 18 ISM equipment authorizations that include the Lower 900 MHz Band. These devices use the spectrum for wireless power transfer ("WPT").

[93] Excluding U.S. territories and possessions.

[94] *See Skybridge Spectrum Foundation, Telesaurus Holdings GB LLC, Verde Systems LLC, Environmentel LLC, Environmentel-2 LLC, Intelligent Transportation & Monitoring Wireless LLC, and V2G LLC et al.*, Memorandum Opinion and Order, 37 FCC Rcd 4731 (EB 2022).

[95] As discussed in the following section, the Commission has enforced these sorts of commitments through license conditions.

Because Part 18 of the Commission's rules excludes the use of RF energy for telecommunications purposes,[96] a WPT receiver is not like a typical radio receiver but instead is most often a resonant coil that absorbs energy from an electromagnetic field generated by alternating current flowing through the wires of a similar coil at the power source. Thus, electrical energy can be transferred across a gap, but that energy is not a modulated radio signal transferring information, and FCC rules do not allow it to be. Any communication between the WPT power source and the device (e.g., charging status, command, and prioritization) must use a radio authorized under Part 15. As a result, many WPT systems include both a Part 15 and a Part 18 component. Thus, the Part 18-authorized functionality of a WPT device includes very little, if any, signaling that can be a victim of RF interference.

Non-M-LMS operators. NextNav believes that coexistence between non-M-LMS and NextGen operations is attainable because (1) NextNav's understanding is that most (if not all) non-M-LMS equipment is frequency agile and (2) a contiguous 11-megahertz block will still be available for non-M-LMS operations—without any co-channel operations from NextNav. NextNav is completing technical analyses intended to guide outreach to non-M-LMS users on the potential impacts and mitigation measures, including by paying for retuning or relocation.

Part 15 devices. Coexistence between the NextGen system and unlicensed Part 15 operations should be achievable. Part 15 devices must coexist with one another in addition to other operations in the band. As a result, Part 15 devices need to be robust and adapt to ever-present interference, including mutual Part 15 interference, which is unpredictable by nature. NextNav is completing technical analyses intended to address representative Lower 900 MHz Part 15 uses and will work with unlicensed users to understand their spectrum requirements.

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[96] 47 C.F.R. § 18.107(c).

Amateur operators. In 2013, the American Radio Relay League acknowledged "M-LMS 'was already allocated with a higher priority'" and opted not to file comments in the proceeding weighing whether [NextNav] could deploy M-LMS in 919.750-927.750 MHz.[97] Since then, nothing has shifted the band hierarchy. Updating the Lower 900 MHz Band M-LMS framework will not impede amateur operations.

E. Nationwide M-LMS Licensing under Existing FCC Authority

The Commission can strengthen national security, improve public safety, and make additional spectrum available for a widescale PNT solution without conducting an auction. The Commission has broad authority to issue a nationwide M-LMS license without relying on an auction, and the lack of auction authority does not bar this reconfiguration.[98] Indeed, the Wireless Telecommunications Bureau's recent public notice seeks input on various ways to issue licenses "in bands previously licensed for wireless services through auctions" while reflecting the Commission's broad discretion to decide how to assign licenses.[99]

The Communications Act, as amended, governs the Commission's process for issuing wireless licenses.[100] It gives the Commission discretion to adopt spectrum management approaches tailored to specific bands. Section 309(j)(6)(E) states that the Commission has an

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[97] *Location Service Deployment May Constrain 902-928 MHz Amateur Use*, American Radio Relay League (June 11, 2013), https://tinyl.io/AReZ.

[98] *See, e.g.*, *Review of the Commission's Rules Governing the 896-901/935-940 MHz Band*, Report and Order, Order of Proposed Modification, and Orders, 35 FCC Rcd 5183 (2020) ("*900 MHz R&O*").

[99] *Wireless Telecommunications Bureau Seeks Comment on Ways to Facilitate Access to Currently Unassigned Auction Inventory Spectrum for Wireless Radio Services in Light of the Ongoing Lapse of Auction Authority*, WT Docket No. 24-72, Public Notice, DA 24-215 (WTB rel. Mar. 7, 2024); *see also* Press Release, *Chairwoman Rosenworcel Highlights One-Year Expiration of Agency's Spectrum Auction Authority and Potential Creative Solutions to Maintain U.S. Leadership*, Office of the Chairwoman, DOC-401006 (rel. Mar. 7, 2024).

[100] *See* 47 U.S.C. § 309.

"obligation in the public interest to . . . use engineering solutions, negotiation, threshold qualifications, service regulations, and other means in order to avoid mutual exclusivity in application and licensing proceedings."[101] Further, when relying on this provision, the Commission has confirmed its broad discretion to "determine the licensing approach that is most appropriate for the services being offered, taking into account the dominant use of the spectrum, administrative efficiency[,] and other related licensing issues."[102]

Precedent supports the agency's authority to use various means to avoid mutual exclusivity. For example, the Commission recently relied on this authority to create a framework when issuing broadband licenses in 897.5-900.5 and 936.5-939.5 MHz.[103] There, a licensee holding nearly all the narrowband licenses within a license area could relinquish those licenses in exchange for a single broadband license.[104] The Commission reasoned that creating a broadband segment within the band would "facilitate increased efficiency and encourage innovation for utilities and other industrial users," including "support[for] wireless technical standards, such as [Long-Term Evolution]" that, in turn, would facilitate services like "broadband data" and "exploit

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[101] *Id.* § 309(j)(6)(E).

[102] *See Amendment of the Commission's Rules Regarding Multiple Address Systems*, Report and Order, 15 FCC Rcd 11956 ¶ 12 (2000) (citing *DirecTV, Inc. v. FCC*, 110 F.3d 816, 828 (D.C. Cir. 1997)); *see also Metropolitan Transportation Authority*, Proposed Order of Modification and Order on Reconsideration, 31 FCC Rcd 1436 ¶ 56 (2016) ("It is well-established that Section 309(j)(6)(E) provides 'the Commission broad authority to create or avoid mutual exclusivity in licensing, based on the Commission's assessment of the public interest.'") (quoting *Improving Public Safety Communications in the 800 MHz Band et al.*, Report and Order et al., 19 FCC Rcd 14969 ¶ 85 (2004) ("*800 MHz/1.9 GHz Swap R&O*")).

[103] *See 900 MHz R&O*.

[104] *See id*.

commercially available equipment and existing infrastructure, thereby reducing costs and allowing consumer savings."[105]

The same principles apply here. NextNav is in the process of acquiring all M-LMS rights available in the market and proposes to modernize M-LMS rules to support a next-generation widescale terrestrial PNT service and more spectrum for broadband, serving key public-interest goals.

A similar approach was taken in the 800 MHz/1.9 GHz modernization proceeding in which the Commission modified the licenses of a single licensee that was fundamental to the band restructuring plan envisioned in the framework. In doing so, the Commission clarified that, "as an alternative licensing approach toward the same end, [it] could have exercised [its] authority to grant [the spectrum] rights . . . as an initial license, without subjecting the spectrum to competitive bidding procedures."[106] It also noted "that the auction requirements of Section 309(j), with their statutory limitations and qualifications that recognize the existence of potentially higher public uses for spectrum, do not preclude our furtherance of the public interest by adopting a band restructuring approach that avoids mutual exclusivity[and] promotes public safety."[107] These considerations also apply here.

Indeed, when overly restrictive rules hamper incumbent licensees' spectrum use, the Commission's practice is to use its licensing authorities to create more flexible rights rather than start from scratch. For example, recognizing that the 218-219 MHz service rules were too stringent and undermined the use of the band, the Commission added a mobile service frequency

[105] *Id.* ¶ 28.

[106] *800 MHz/1.9 GHz Swap R&O* ¶ 74.

[107] *Id.* ¶ 73.

allocation[108] and then permitted common carrier operations (rather than a strictly private radio service).[109]

The Commission's actions to liberalize the 2.5 GHz band highlight how granting flexible use can yield long-term benefits.[110] In 1995, the Commission expanded the protected service area contour for site-based Multichannel Multipoint Distribution Services ("MMDS") licensees from a 15-mile radius to a 35-mile radius.[111] Subsequent technology advances allowed Instructional Television Fixed Service ("ITFS") and MMDS licensees to provide multiple video programming channels and high-speed data applications.[112] Two years later, the Commission authorized two-way operations on ITFS/MMDS frequencies to effectively enable voice, video, and data services.[113] Noting that these and other regulatory changes led to more than "$2 billion dollars

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108 *Amendment of Part 95 of the Commission's Rules to Allow Interactive Video and Data Service Licensees to Provide Mobile Service to Subscribers*, Report and Order, 11 FCC Rcd 6610 ¶ 9 (1996).

109 *Amendment of Part 95 of the Commission's Rules to Provide Regulatory Flexibility in the 218-219 MHz Service*, Report and Order and Memorandum Opinion and Order, 15 FCC Rcd 1497 (1999).

110 *See, e.g.*, *Amendment of Parts 1, 21, 73, 74 and 101 of the Commission's Rules to Facilitate the Provision of Fixed and Mobile Broadband Access, Educational and Other Advanced Services in the 2150-2162 and 2500-2690 MHz Bands et al.*, Report and Order and Further Notice of Proposed Rulemaking, 19 FCC Rcd 14165 ¶ 30 (2004) ("*2004 2.5 GHz Order*").

111 *Amendment of Parts 21, 43, 74, 78, and 94 of the Commission's Rules Governing Use of the Frequencies in the 2.1 and 2.5 GHz Bands Affecting Private Operational Fixed Microwave Service, Multipoint Distribution Service, Multichannel Multipoint Distribution Service, Instructional Television Fixed Service, & Cable Television Relay Service*, Second Order on Reconsideration, 10 FCC Rcd 7074 (1995).

112 *Request for Declaratory Ruling on the Use of Digital Modulation by Multipoint Distribution Service and Instructional Television Fixed Service Stations*, Declaratory Ruling and Order, 11 FCC Rcd 18839 (1996).

113 *Amendment of Parts 21 and 74 to Enable Amendment of Parts 21 and 74 to Enable Instructional Television Fixed Service Licensees to Engage in Fixed Two-Way Transmissions*, Report and Order, 13 FCC Rcd 19112 ¶ 1 (1998) ("[W]e are: (1) permitting both [M]MDS and ITFS licensees to provide two-way services on a regular basis; (2) permitting increased flexibility on permissible

[invested] in the acquisition, by purchase or lease, of MMDS and ITFS channel rights covering 60 million households" since 1998, the Commission then added a mobile service frequency allocation to the band in 2001.[114] In 2004, the Commission implemented geographic licensing[115] and permitted blanket licensing of mobile operations (which otherwise required separate authorization).[116] The band is now core to T-Mobile's multiband 5G strategy.[117]

Other relevant examples are the AWS-4 and Spectrum Frontiers proceedings. In the AWS-4 proceeding, the Commission enabled licensees to convert their Mobile-Satellite Service rights (which included an Ancillary Terrestrial Component) into full standalone flexible-use licenses.[118] And the Commission's 2016 *Spectrum Frontiers* proceeding shows why it serves the public interest to give incumbent licensees more flexibility.[119] For *Spectrum Frontiers*, the Commission granted mobile operating rights to fixed Local Multipoint Distribution Service and 39 GHz band licensees—licensees whose fixed service rights were initially acquired through competitive

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modulation types; (3) permitting increased flexibility in spectrum use and channelization, including combining multiple channels to accommodate wider bandwidths . . . .").

[114] *Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 GHz for Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Services, Including Third Generation Wireless Systems*, First Report and Order and Memorandum Opinion and Order, 16 FCC Rcd 17222 ¶ 21 (2001).

[115] *2004 2.5 GHz Order* ¶ 54.

[116] *Id.* ¶¶ 111-12.

[117] *See Why multi-spectrum 5G networks matter for all businesses*, T-Mobile, https://tinyurl.com/3kburbsf (last visited Feb. 14, 2021).

[118] *Service Rules for Advanced Wireless Services in the 2000-2020 MHz and 2180-2200 MHz Bands et al.*, Report and Order and Order of Proposed Modification, 27 FCC Rcd 16102 (2012).

[119] *Use of Spectrum Bands Above 24 GHz for Mobile Radio Services et al.*, Report and Order and Further Notice of Proposed Rulemaking, 31 FCC Rcd 8014 (2016).

bidding. The Commission reasoned that granting incumbents mobile service rights would minimize transaction costs and accelerate in-band 5G deployment to benefit consumers.[120]

On top of its broad authority to issue and modify licenses to support more flexible spectrum uses, the Commission also has broad authority to adopt licensing conditions, like those proposed above, to further its public policy objectives.[121] Here, the Commission would condition a nationwide M-LMS license on enabling terrestrial PNT service and protecting federal users and incumbent licensees. The Commission has broad authority to impose these obligations as a condition of accepting the license.

IV. REFRESHING THE 900 MHZ RULES WILL SERVE SEVERAL MAJOR FCC PUBLIC POLICY OBJECTIVES

A. The FCC Can Relaunch the Lower 900 MHz Band to Promote National and Economic Security, Public Safety, and Private Sector Innovation

Modernizing the Lower 900 MHz Band will promote various public interest benefits. It can enable superior, next-generation terrestrial PNT that will serve as a GPS complement and backup, providing resiliency capability with better availability, accuracy, precision timing, and user adoption potential compared to other PNT approaches. And as detailed above, the United States needs a high-quality terrestrial PNT solution. This vital national security goal is achievable only if the FCC helps unlock the Lower 900 MHz Band's potential.

Uniquely, the NextGen solution can enable ubiquitous standard 5G NR chipset-equipped devices to generate position and timing data for various mass market use cases at scale. Some NextGen use cases include situational awareness and navigation for first responders, lone workers,

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[120] *Id.* ¶ 38.

[121] *See, e.g.*, *Expanding Flexible Use of the 3.7 to 4.2 GHz Band*, Report and Order and Order of Proposed Modification, 35 FCC Rcd 2343 (2020).

and workers in hazardous environments. Additional use cases include supply chain tracking of vehicles and goods and high-value asset tracking for enterprises. By providing both outdoor and indoor coverage, NextGen's positioning can provide widescale, universal tracking not possible with any existing solutions. For example, tracking in urban canyons may not be feasible using GNSS or indoor technologies. Tracking a pallet inside a moving truck is not possible using current hybrid solutions such as GNSS plus Bluetooth Lower Energy or UWB. Further, by communicating tracking context via in-band data, the NextGen solution can reduce operating costs by eliminating the need for indoor infrastructure deployment and maintenance required by dedicated indoor data networks such as Wi-Fi systems.

Some NextGen timing use cases include time synchronization for critical infrastructure, such as data centers, banks, and enterprise servers. NextGen's indoor capability can bring UTC time directly to a server cluster, eliminate the cost of RF coaxial cable runs and recurring rooftop siting costs of an outdoor GPS antenna, and further remove the capital and operating expenditures for an in-building, fiber-based time distribution network (e.g., via precision time protocol).

B. Rebanding Will Put the Lower 900 MHz Band to More Intensive Use Consistent with FCC Spectrum Policy and U.S. National Spectrum Strategy

The proposed updates to the Lower 900 MHz Band reflect the ever-growing demand for low-band spectrum that is vital for providing high-speed mobile broadband service. The Commission has already identified 900 MHz spectrum as a vital ingredient for broadband; in its recent 900 MHz proceeding, the Commission found that "[h]igh-speed broadband is essential for robust business growth, and providing an opportunity for broadband in the 900 MHz band could enable a wide variety of businesses to unlock the full potential of broadband and its applications."[122]

U.S. policy calls on federal agencies to make more spectrum available for wireless broadband. The National Spectrum Strategy's first pillar reflects this mandate: "[t]o continue our Nation's economic growth, to maintain and improve our global competitiveness, and to support critical public services and missions, we must make spectrum available for innovative new uses and to meet growing demand."[123] The Commission's 2023 spectrum policy statement similarly prioritizes making efficient, effective, and equitable use of the airwaves today to meet tomorrow's spectrum demands.[124]

Mobile carriers rely on a combination of low-band, mid-band, and millimeter-wave spectrum to build a comprehensive network. Low-band spectrum is a fundamental building block in a mobile carrier's inventory because of its superior building penetration and propagation characteristics, which offer greater indoor and wide-area coverage. For this reason, low-band spectrum is essential both for coverage in less populated areas and for indoor coverage in built-up

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[122] *Review of the Commission's Rules Governing the 896 901/935-940 MHz Band*, Notice of Proposed Rulemaking, 34 FCC Rcd 1550 ¶ 7 (2019); *see also Review of the Commission's Rules Governing the 896 901/935-940 MHz Band*; *900 MHz R&O*.

[123] *National Spectrum Strategy*, White House, at 3 (2023), https://tinyurl.com/3y9exttn; *see also Implementation of the National Spectrum Strategy*, Notice, 88 Fed. Reg. 85266 (Dec. 7, 2023) ("Sufficient access to spectrum is vital to national security, critical infrastructure, transportation, emergency response, public safety, scientific discovery, economic growth, competitive next-generation communications, and diversity, equity, and inclusion. Increased spectrum access will also advance U.S. innovation, connectivity, and competition, create high-paying and highly skilled jobs, and produce improvements to the overall quality of life. Access to more spectrum, in short, will help the United States continue to lead the world in advanced technology and enhance our national and economic security.").

[124] *See Principles for Promoting Efficient Use of Spectrum and Opportunities for New Services et al.*, Policy Statement, ET Docket No. 23-122 et al., FCC 22-37 ¶ 1 (rel. Apr. 21, 2023), https://tinyl.io/AQty.

areas.[125] In both environment types, the available sub-1 GHz spectrum is key to user data rates.[126] Moreover, the Commission has characterized the 900 MHz band and low-band spectrum generally as "associated with network reliability and reduced infrastructure costs."[127]

Despite FCC action to make additional sub-1-GHz spectrum available for broadband services, including targeted changes to the 600 MHz band[128] and the 900 MHz band,[129] not enough low-band spectrum is available. Adopting the rule changes proposed here would enable NextNav to bring a substantial low-band spectrum block into the market.

This additional low-band spectrum is available for flexible voice and data use even without auction authority. The proposed band plan and rules, adapted to 5G (and eventually 6G) technologies and use cases, make the band more attractive for innovation and investment. It enables 5G, including PRS, so that NextNav and its partners can add the band to existing networks and build device support for incorporation in the U.S. ecosystem.

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[125] *Vision 2030: Low-Band Spectrum for 5G*, Global System for Mobile Communications Association (2022), https://tinyurl.com/2davk3ac.

[126] These attributes contribute to why, on a global basis, mobile operators are paying a higher average price per MHz/POP for low-band spectrum than mid-band spectrum (the highly coveted "goldilocks" bands). Kelly Hill, *The Most Expensive 5G Spectrum is … Low-Band?*, RCR Wireless News (Apr. 13, 2023), https://tinyurl.com/555v235w.

[127] *900 MHz R&O* ¶ 25.

[128] *Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Report and Order, 29 FCC Rcd 6567 ¶ 2 ("Our central objective in designing this incentive auction is to harness the economics of demand for spectrum in order to allow market forces to determine its highest and best use.").

[129] *900 MHz R&O* ¶ 1 (2020) (realigning the 900 MHz band to make additional spectrum for the deployment of broadband services and technologies "to meet the ever-increasing spectrum capacity demands of a wide range of industries").

V. CONCLUSION

The United States needs a robust, widescale terrestrial PNT option to complement and back up GPS and ensure that public safety can access robust, reliable, precise, customizable 3D positioning and timing data—whether space-based data is available or not. NextNav's network, technologies, and expertise can provide that solution, and launching a rulemaking to explore this petition's proposals will jumpstart the process toward meeting major public interest objectives.

Respectfully submitted,

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EXHIBIT A – TECHNICAL APPENDIX

As summarized below, NextNav's next-generation ("NextGen") terrestrial network will combine several different network elements and NextNav's technical expertise to deliver widescale, accurate positioning, navigation, and timing ("PNT") services. This appendix provides an overview of the NextGen network's design, its use of the 3rd Generation Partnership Project's ("3GPP's") fifth-generation ("5G") New Radio ("NR") PNT signals, and a summary of simulation data.

Section 1: NextNav NextGen PNT Network

NextNav's NextGen network plan is a 3GPP NR-based widescale PNT network, covering both indoor and outdoor locations for 3D location services as well as precise timing services distributing the Coordinated Universal Time ("UTC").[1] The network is based on 5G NR and aligned with 3GPP global standards, enabling and ensuring broad access to global ecosystem partners for chipsets, equipment, software, and hence rapid adoption. The use of 5G NR technology and incorporation of 5G positioning reference signal ("PRS") (detailed in the following section) provide an important foundation for the NextGen PNT network, but building an accurate, resilient, and cost-effective PNT network involves many considerations beyond simply electing to transmit PRS as the positioning reference. For that reason, NextNav's NextGen PNT network will be hardened and differentiated by NextNav's PNT-related intellectual property, technical expertise, and years of operational experience.

NextNav has developed many core PNT capabilities over the years while developing and operating a Terrestrial Beacon System ("TBS").[2] A TBS consists of a network of dedicated, highly synchronized transmitters that transmit spread spectrum signals using a combination of code-division multiple access ("CDMA") (using different Pseudo-Random Noise ("PRN") codes when transmissions overlap), time-division multiple access ("TDMA"), and frequency-offset multiple access.

The 5G NR PRS transmissions are based on the same concepts, including using (1) CDMA with different PRN sequences for PRS transmission from different base stations ("BSs") to reduce the correlation of the orthogonal frequency-division multiplexing ("OFDM") PRS symbol transmissions that occur in the same frequency and time, (2) TDMA (through PRS muting), and (3) frequency-offset multiple access (through the comb patterns used for PRS transmission). Due

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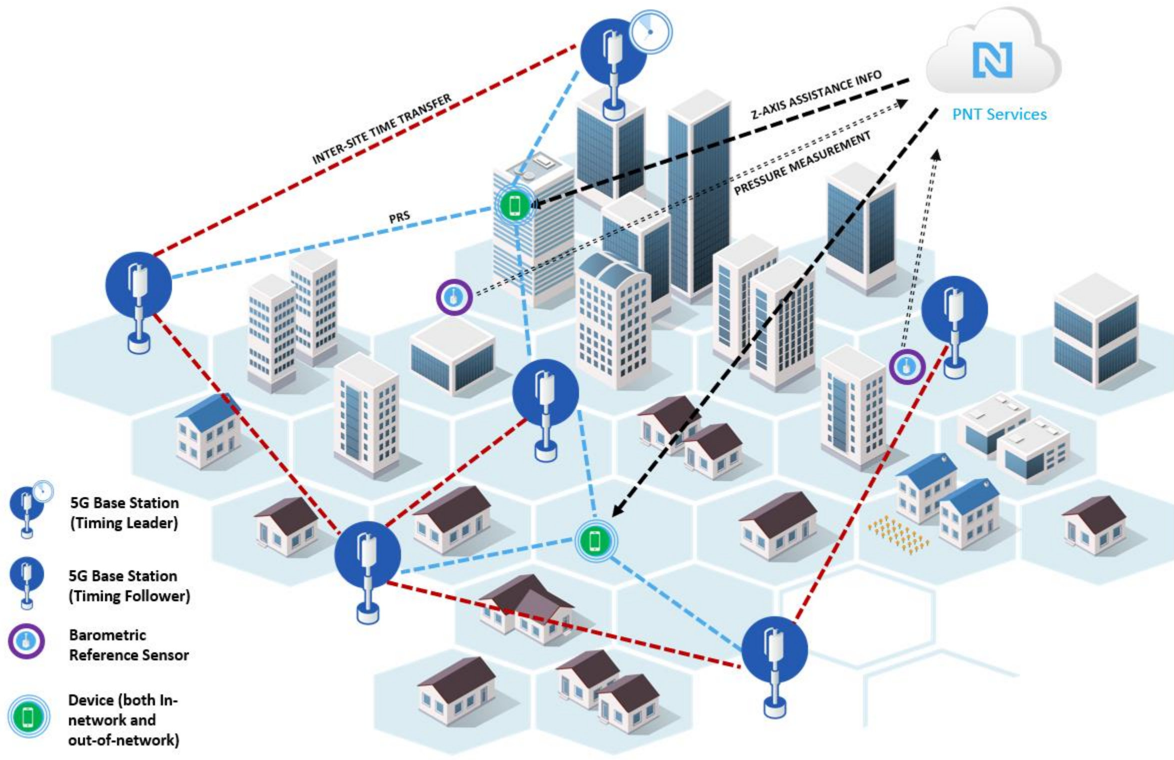
[1] UTC is the primary global standard for time and is defined by the International Telecommunication Union.

[2] ATIS contribution ESIF-ESM-2015-0038R001, MBS-ICD, NextNav Metropolitan Beacon System (MBS). Copies of this contribution can be obtained upon request to the ATIS Document Center Administrator at doccenter@atis.org with subject "request for MBS ICD."

to the similarity of the TBS and PRS systems, the techniques and algorithms developed by NextNav can be readily translated from TBS to the planned NextGen PNT network.

Figure 1 shows an overview of NextNav's NextGen PNT network with key characteristics that are explained further below.

Figure 1. NextNav's NextGen PNT Network



Very tight network synchronization is essential to accurately and reliably estimating a particular position.[3] NextNav can maintain relative and absolute time synchronization using a leader-follower network of BSs with a UTC-sourced clock at the leader BS (e.g., a NIST-derived cesium atomic clock, a time-distribution-over-fiber disciplined clock). The leader-follower topology is a wireless mesh network that maintains timing synchronization through the capability at each BS to listen to neighboring BSs' PRS transmissions that are within range. The coordinates of the antennas of the BSs are determined at sub-meter accuracy (typically better than 50 cm) to enable high-precision timing and position multilateration.

Fourth-generation ("4G") and 5G NR cellular systems traditionally only require BS synchronization on the order of a microsecond, but NextNav has developed a scalable and

[3] Each nanosecond of error in timing results in about a 0.3 m error in ranging measurements. This is because radiofrequency signals travel at the speed of light (~3 x 10^8 m/s) and therefore cover about 0.3 m in 1 nanosecond.

economical synchronization technique that is orders of magnitude more precise than what could be implemented into an NR network to enable a robust and accurate PNT service.[4] In addition, NextNav has developed techniques not only to transfer time wirelessly in a mesh network of BSs but also to enable tight transmission synchronization of the PRS signals through precise estimation of the delay the signals experience as they pass through transmitter hardware, cables, and connectors all the way to the phase center of the antenna.

Another aspect of the NextNav NextGen network involves the design and selection of PRS configurations, including PRS sequences, comb patterns, and muting designs for various BSs in the network to manage PRS interference. These configurations will enable the reception of a sufficient number of good-quality PRS signals to achieve the targeted PNT accuracy within the coverage area. For its legacy TBS system, NextNav developed network-design techniques for the selection of transmit parameters that minimize interference while enabling best-in-class PNT performance for receivers in the network coverage area. These network design techniques can be applied to the selection of PRS configurations to minimize interference between PRS transmissions and facilitate best-in-class PNT performance. Also, based on its experience with the legacy TBS system, NextNav has developed sophisticated receiver processing algorithms for accurate ranging measurements as well as for multilateration/timing and has demonstrated superior PNT performance in various demonstrations and trials.[5] In addition, NextNav has also recently developed technology for ranging and multilateration using OFDM reference signals in 4G and tested them in the field for use in PNT.[6]

Another important differentiation of the NextGen PNT network is that it can offer a full 3D positioning service, which includes a barometric-sensor-based z-axis solution. All terrestrial systems and, to a lesser extent, space-based systems like GPS are limited with respect to estimating the height of the user equipment ("UE") through multilateration because they operate from the same plane. It is well known that standalone space-based systems have a relatively limited vertical

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[4] Time and phase synchronization aspects of telecommunication networks show a 1.5 μs time synchronization requirement for TDD. For reference, 1 microsecond equals 1,000 nanoseconds. ITU-T G.8271/Y.1366, *Series G: Transmission Systems and Media, Digital Systems and Networks Packet over Transport Aspects – Synchronization, Quality and Availability Targets; Series Y: Global Information Infrastructure, Internet Protocol Aspects, Next-Generation Networks*, ITU, at 5 Table 1 (Mar. 2020), https://tinyurl.com/y5jrz4v7.

[5] Andrew Hansen et al., *Complementary PNT and GPS Backup Technologies Demonstration Report*, DOT (2021), https://tinyurl.com/y57jd7vz; Lukasz Bonenberg et al., *Assessing Alternative Positioning, Navigation and Timing Technologies for Potential Deployment in the EU*, European Commission Joint Research Centre, JRC132737 (2023), https://tinyurl.com/2c9otc7b; *TerraPoiNT: Terrestrial Navigation System*, Institute of Navigation ("ION") Intl. Tech. Meeting, (2022); *A Novel Method to Transfer Time Using the Terrestrial Timing System* ION Precise Time and Time Interval Systems and Applications Meeting (2022).

[6] *See Resilient 3D Navigation and Timing System using Terrestrial Beacons and Cellular Signals*, ION GNSS+ Meeting (2023).

accuracy relative to horizontal accuracy due to poor Vertical Dilution of Precision ("VDOP") because of the relative lack of vertical diversity, given that satellites are only visible above the Earth's surface. Terrestrial systems have a similar limitation with respect to estimating the height of the UE through multilateration since terrestrial transmitters are roughly on the same plane. While some height differences in terrestrial transmitter deployment can help in improving the VDOP, the altitude accuracy is limited for traditional terrestrial systems. More importantly, indoor locations where UE height information is most relevant and critical are challenging environments for both space-based systems and terrestrial PNT systems but much more so for space-based systems due to limited signal availability indoors. To overcome these challenges, NextNav has developed a unique barometric pressure sensor-based z-axis solution that delivers precise "floor-level" vertical positioning and is currently serving commercial customers. This z-axis solution will be tightly integrated into NextNav's NextGen PNT network to offer comprehensive and full 3D position solutions to the market. By leveraging 2D positioning data and native NR data connectivity, NextNav will be able to fully integrate the z-axis positioning into the NextGen PNT solution.

NextNav's NextGen network will make its PNT service accessible to all compatible UEs, whether UEs are registered on the NextNav network or on other networks. That is, the NextNav PNT service's PRS signals can be made available to UEs that are serviced by other operators' networks (i.e., out-of-network). Specifically, through operator agreements, an out-of-network UE can provide its coarse location to the NextNav PNT network (e.g., from the "Cell ID" of the home network) and then obtain over-the-top local PRS assistance[7] for the NextGen system from a NextNav assistance server. The UE would then tune to NextNav's Lower 900 MHz Band to measure the PRS signals using the PRS assistance and then use the PRS measurements to determine timing/positioning on the UE. Alternatively, the UE's location could be computed by NextNav's positioning server using the PRS measurements sent by the UE.

Section 2: Introduction to 5G PRS

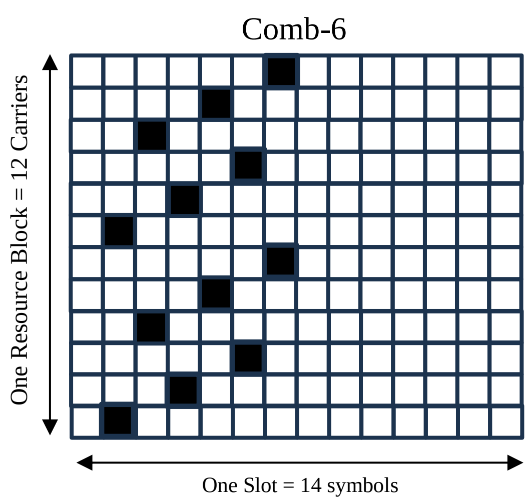
NextNav will use 5G NR's PRS functionality as a critical source for PNT data. PRS is an optional feature defined in the 5G NR specifications that provides a class of physical signals developed for positioning and timing measurements. PRS consists of a group of specially designed reference signals, which are broadcast by 5G BSs. These signals are designed to be easily decodable in the presence of other signals, allowing 5G UEs to measure and extract location and timing information accurately. By analyzing the timing (which is equivalent to measuring the distance), angle, and strength of the received PRS, the 5G UE or a location server in the core network can calculate and extract the UE's location via various algorithms such as multilateration.

While other reference signals, such as cellular reference signal in Long-Term Evolution ("LTE"), can potentially be used for time-of-arrival ("ToA") measurements, the PRS signal was introduced

[7] Typical PRS assistance consists of parameters such as reference and neighbor cell information including PRS configuration and, optionally, their geographic coordinates.

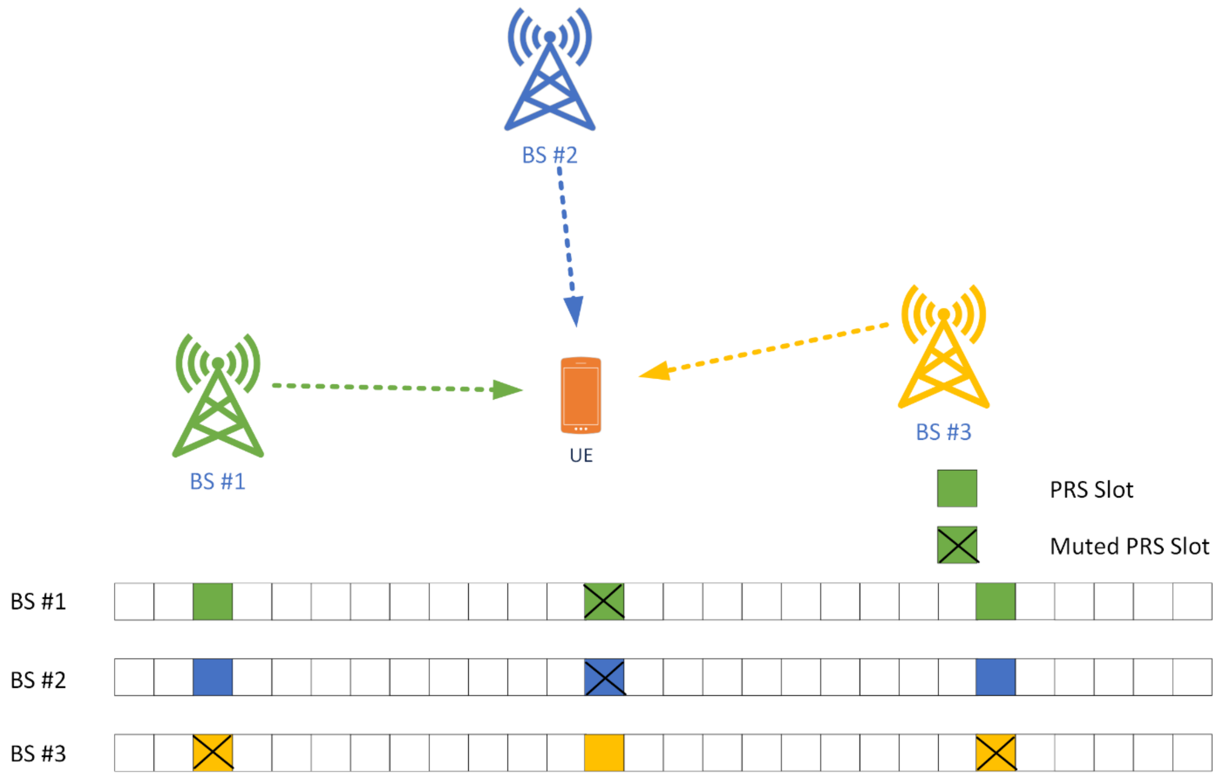
in LTE to overcome the common "near/far interference" problem in which very strong reference signals from nearby BSs "drown out" the much weaker signals from BSs farther away. In NR, the PRS configuration enables UEs to "hear" the weaker reference signals (1) through flexible comb patterns in the frequency domain to separate transmissions from different BSs and (2) by muting transmissions from BSs according to the muting pattern selected to reduce the near/far interference. Figure 2 shows an example of one slot of a comb pattern (comb-6) that repeats every 6 sub-carriers in the frequency domain. Note that this pattern is repeated across the bandwidth of the PRS. Figure 3 shows an example of various PRS configuration parameters being utilized to improve PRS receivability. In the figure, BS #1 and BS #2 use orthogonal comb patterns, which allow them to transmit PRS in the same slots without interfering with each other, whereas BS #3 relies on other BSs to be "muted" while it is transmitting its PRS and vice versa to achieve the needed orthogonality.

Figure 2: Example Physical Resource Block in a Dedicated PRS Slot Showing a Comb-6 Pattern Transmission from 1 BS[8]



[8] Note that the figure shows a single Physical Resource Block pattern of PRS resource elements within a dedicated PRS slot. This pattern will repeat across the full PRS bandwidth. Other slots not dedicated to PRS can contain data and are not shown in this figure. Note that 1 slot equals a 1-ms subframe for a 15-kilohertz carrier spacing in 5G NR.

Figure 3: Example showing various configuration aspects of PRS



PRS on the downlink was first introduced in 3GPP release 9 in the LTE standard to provide dedicated reference signals for positioning use cases.[9] Release 16 introduced PRS signals for 5G NR with greater flexibility and parameter configuration to enable better accuracy and reduced interference.[10] To improve PRS receivability, these PRS signals are transmitted in dedicated positioning slots within the NR transmission, during which other signals are not transmitted, thus limiting collisions with non-PRS signals.

Position computation involves combining ToA measurements of reference signals from multiple BSs at the UE (e.g., multilateration) to estimate position. The position computation can be done at the UE or at the location server connected to the core network (e.g., the Enhanced Serving Mobile Location Centre or Location Management Function[11]) by using the known coordinates of each BS and the time synchronization among their transmissions. Similarly, timing at the UE is

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[9] TS 36.355, *Evolved Universal Terrestrial Radio Access (E-UTRA); LTE Positioning Protocol (LPP) (Release 9.0)*, 3GPP (2010), https://tinyurl.com/45s6tznt.

[10] TS 38.211, *NR: Physical channels and modulation (Release 15.0)*, 3GPP (2020), https://tinyurl.com/2zzddtws.

[11] TS 38.305, *NG Radio Access Network (NG-RAN); Stage 2 functional specification of User Equipment (UE) positioning in NG-RAN (Release-17.7)*, 3GPP (2024), https://tinyurl.com/ytccsepv.

traceable to the timing of the BS network using PRS signals by measuring ToA along with the coordinates of the BS.

NextNav's PNT system is based on using PRS signals within the 3GPP NR framework. This allows the NextGen PNT solution to take advantage of the 3GPP standardized NR ecosystem of BSs and UEs, leading to a cost-effective solution. NexGen receivers can use standard PRS algorithms or advanced algorithms developed by NextNav for ranging and multilateration to further improve PNT performance. For example, standard NR chipsets can be configured via software to support PRS measurement signal processing capability that can be used to estimate position. In the 5G NR BS ecosystem, the 3GPP specifications allow flexible and dynamic allocations of PRS within the network resources so that PRS deployments can be optimized for various positioning requirements. The BS is responsible for configuring and scheduling PRS transmissions, including PRS periodicity, repetition, and bandwidth, among other things.

The use of PRS in an NR system adds overhead compared to the use of an NR system only for data. Computations of PRS overhead can be estimated based on NextNav's experience with the legacy TBS system in combination with the NR PRS link budget and expected inter-site distances (generally, a function of morphology such as urban, suburban, rural, and the target build-out). The NextNav CDMA-based TBS has been proven to be accurate across diverse network topology settings, both indoors and outdoors, with each transmitter transmitting for 100 milliseconds every 1 second (i.e., each transmitter transmits for 100 milliseconds out of ten 100-millisecond occasions with the other nine occasions muted). As NextNav's NR technology can transmit at higher effective isotropic radiated power ("EIRP"),[12] similar or superior outdoor and indoor PRS coverage is attainable with a much smaller PRS transmission duration. However, ensuring the orthogonality between the multitude of PRS transmissions from different geographic coordinates, thereby averting self-interference to improve performance, necessitates periodic muting (i.e., a quiet period without any transmission) of certain PRS transmissions. While muting increases the effective duration of channel occupancy by the PRS, using the same muting percentages as in the TBS system in combination with higher transmit EIRP ensures the total PRS overhead is expected to be in the range of 2-5% depending on the BS density and morphology, preserving efficient spectrum utilization.

Section 3: Simulation Data

To estimate the performance of the PRS-based PNT system, a widely accepted and standardized evaluation framework is required because there are a large number of factors that could affect the simulated performance. In 3GPP's evaluation framework, PRS-based Observed Time Difference of Arrival ("OTDOA") positioning performance has been studied in 3GPP as part of the LTE and NR PRS standardization. Specifically, positioning performance for PRS and TBS in LTE was

[12] TBS transmit power is limited to 30 W ERP. 47 C.F.R. § 90.357(a).

published in 3GPP TR 37.857,[13] and positioning performance using PRS in 5G NR was published in 3GPP TR 38.855.[14]

NextNav simulated the proposed NR PRS system at 5-megahertz and 10-megahertz standard bandwidths with the features described in Section 1 above using the methodology, network configuration, path loss, and fading channel model as described in 3GPP TRs 37.857 and 38.855. In addition, the legacy TBS system at 5-megahertz bandwidth was simulated for comparison. The simulations were done across the indoor Urban and Rural Macro simulation models specified in TR 38.901[15] for both positioning and timing. A synchronization error of 10 ns RMS was assumed, consistent with the error spread that has been demonstrated for timing synchronization in the TBS leader-follower network.[16] The simulation framework introduces an indoor loss for the Urban Macro scenario ranging on an average from 20 to 32 dB, which includes indoor penetration loss of 20 dB and additional loss as a function of the simulated indoor distance of the UE up to a maximum of 12 dB. For the Rural Macro scenario, the simulation framework introduces an indoor average loss ranging from 10 to 15 dB, which includes indoor penetration loss of 10 dB and additional loss as a function of the simulated indoor distance of the UE up to a maximum of 5 dB. The simulation uses advanced signal processing using NextNav IP for ranging and multilateration.[17]

Figure 4 shows the Urban Macro indoor positioning performance, and Figure 5 shows the corresponding timing performance. One clear observation is that the 10-megahertz PRS provides far superior performance in both positioning and timing when compared with the 5-megahertz PRS and 5-megahertz TBS system. In fact, the PRS positioning error is reduced from 11.5 m to 6.2 m at the 95% confidence level, resulting in an improvement of 46.1%. Similarly, the timing errors improve from 28.8 ns to 11.1 ns at a 95% confidence level, a 61.5% improvement. A wider signal bandwidth can separate more tightly spaced multipath since a larger bandwidth in the frequency domain enables a finer time domain. Multipath is a major source of error in cluttered environments, and better resolvability from the wider bandwidth yields better range accuracy performance, which translates to better position and time estimation accuracy. The results clearly

[13] TR 37.857, *Study on indoor positioning enhancements for UTRA and LTE (Release 13)*, 3GPP (2015), https://tinyurl.com/4tbduh5p.

[14] TR 38.855, *Study on NR positioning support (Release 16)*, 3GPP (2019), https://tinyurl.com/4cb255e8.

[15] TR 38.901, *Study on channel model for frequencies from 0.5 to 100 GHz (Release 14)*, 3GPP (2017), https://tinyurl.com/czx4b9jz.

[16] *A Novel Method to Transfer Time Using the Terrestrial Timing System*, Institute of Navigation (2023).

[17] The ranging and trilateration for TBS are based on techniques used to obtain results shown in *Complementary PNT and GPS Backup Technologies Demonstration Report*. *See supra* note 5. For PRS, ranging and trilateration are based on techniques used in *Resilient 3D Navigation and Timing System using Terrestrial Beacons and Cellular Signals*. *See supra* note 6.

show that the 10-megahertz PRS configuration provides superior positioning and timing performance over the 5-megahertz configurations.

Figure 4: PRS OTDOA 5 Megahertz & 10 Megahertz vs Legacy TBS 5 Megahertz Positioning Performance – Urban, Macro Indoor

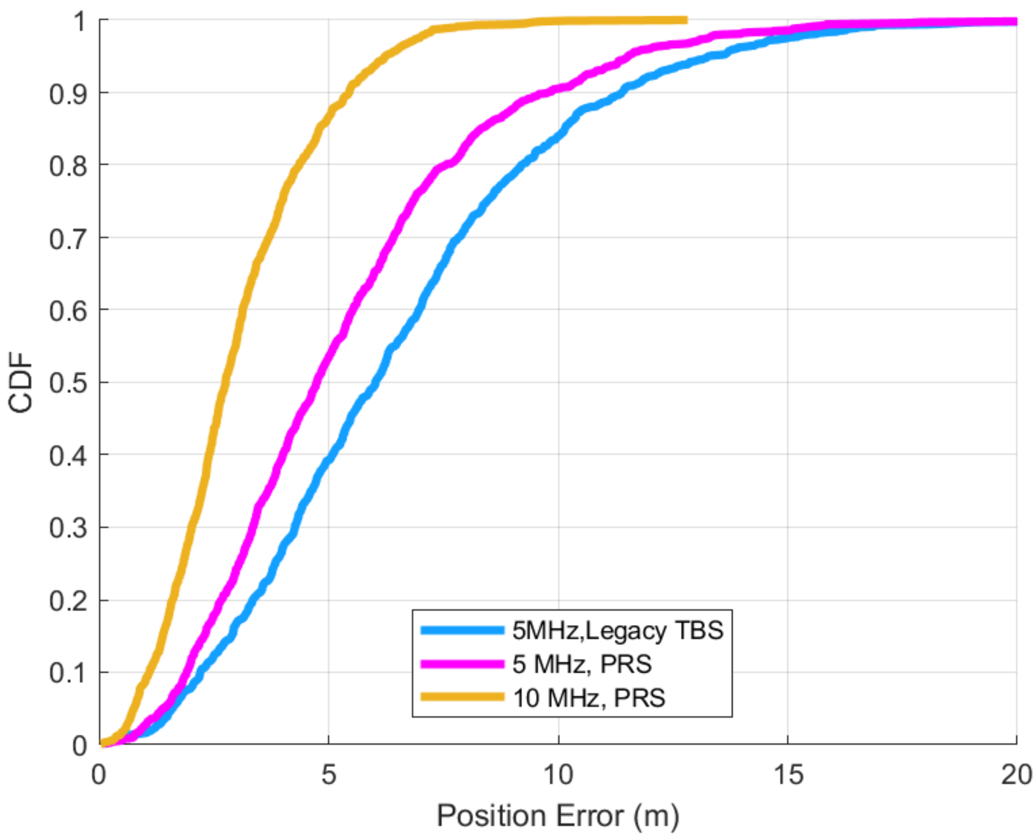

Figure 5: PRS OTDOA 5 Megahertz & 10 Megahertz vs Legacy TBS 5 Megahertz Timing Performance – Urban, Macro Indoor

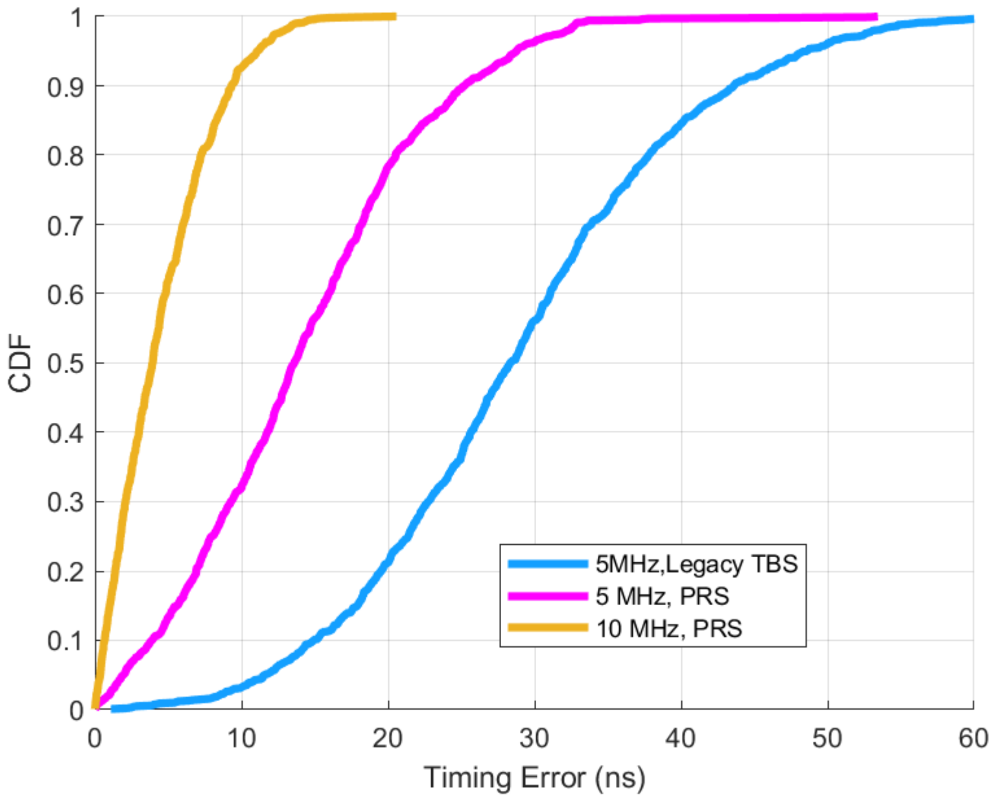

Table 1 summarizes the simulated positioning and timing results for the urban and rural[18] macro indoor scenarios at a 95% confidence level. The 10-megahertz configuration is the only option that can provide single-digit-meter positioning and sub-20-nanosecond timing accuracy.

Table 1. Simulated Positioning and Timing Accuracy Performance Comparison at 95% Confidence Level

System		Positioning Error @ 95% Confidence	Timing Error @ 95% Confidence
Urban Indoor	Legacy TBS	13.3 m	48.6 ns
	NextGen, 5 MHz	11.5 m	28.8 ns
	NextGen, 10 MHz	6.2 m	11.1 ns
Rural Indoor	Legacy TBS	7.8 m	34.0 ns
	NextGen, 5 MHz	6.7 m	23.2 ns
	NextGen, 10 MHz	5.0 m	12.1 ns

[18] An inter-site distance of 5,000 m is used for the rural scenarios.

EXHIBIT B – ADDITIONAL BACKGROUND

1996. The 1996 U.S. Global Positioning System ("GPS") Policy called for the Department of Defense ("DOD") and multiple agency counterparts to (1) support and enhance the country's economic competitiveness and productivity and protect U.S. national security and foreign policy interests while managing GPS, (2) investigate national security implications for GPS, and (3) develop "measures to prevent the hostile use of GPS and its augmentations to ensure that the United States retains a military advantage without unduly disrupting or degrading civilian uses."[1]

2004. President Bush's National Security Presidential Directive mandated the United States to develop, maintain, and modernize GPS, including providing a GPS backup capability in the event of GPS disruption "to meet growing national, homeland, and economic security requirements, for civil requirements, and to meet commercial and scientific demands."[2]

2008. A National Security Telecommunications Advisory Committee report found "that short-term loss or disruption of GPS signals will affect the ability to determine accurate location information for wireless E911 purposes" and "direct[ed] the [Department of Homeland Security ("DHS")] and [DOD] to include various GPS outage scenarios in future planned disaster recovery exercises in coordination with the commercial communications industry."[3]

2010. President Obama's National Space Policy sought "redundant and back-up systems or approaches for critical infrastructure, key resources, and mission-essential functions" given the harmful interference risk for GPS.[4]

2013. Critical infrastructure security and resilience were emphasized in a separate presidential policy directive and executive order "that are vital to public confidence and the Nation's safety, prosperity, and well-being."[5]

2014. The DHS Infrastructure Protection Plan urged "pursu[it] [of] self-healing [positioning, navigation, and timing ("PNT")] architectures and infrastructures (system-of-systems) that bend,

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[1] Press Release, *Fact Sheet U.S. Global Positioning System Policy*, White House Off. Sci. & Tech. Pol'y and Nat'l Sec. Council (Mar. 29, 1996), https://tinyurl.com/4m767sy4.

[2] *NSPD-39: U.S. Space-Based Position, Navigation, and Timing Policy*, White House (Dec. 15, 2004), https://tinyurl.com/2cxov7ge.

[3] NSTAC Report to the President on Commercial Communications Reliance on the Global Positioning System (GPS) (Feb. 28, 2008), https://tinyurl.com/26832su3.

[4] National Space Policy of the United States of America, White House, at 5 (June 28, 2010), https://tinyurl.com/yfybvpkt.

[5] *Presidential Policy Directive 21: Critical Infrastructure Security and Resilience*, White House (Feb. 12, 2013), https://tinyurl.com/2s42s4us; *see also* Exec. Order 13636, 78 Fed. Reg. 11739 (Feb. 12, 2013).

rather than break, in the face of a disruption."[6] DHS also noted its consideration of nationwide timing backup alternatives, such as Enhanced Long-Range Navigation (eLORAN) and PNT cloud concept.[7]

2017. The FCC Public Safety & Homeland Security Bureau Chief David Simpson, Rear Admiral (ret.) U.S. Navy, published a whitepaper noting the agency's Communications Security, Reliability, and Interoperability Council was "continuing work to better understand and address a wide range of technology risk, over-reliance on GPS for network timing," "evaluat[ing] other Global Navigation Satellite Systems and terrestrial systems for [PNT], identifying alternate sources of network timing to help mitigate some of this risk," and recognizing "best practice implementation and any remaining barriers to this critical element of critical infrastructure robustness."[8] The Alliance for Telecommunications Solutions urged Congress to establish one or more GPS alternatives.[9]

2018. The National Timing Resilience and Security Act of 2018 required "'the establishment, sustainment, and operation of a land-based, resilient, and reliable alternative timing system' within two years, with a nominal 20-year operational life . . . to reduce critical dependency on, and provide a complement to GPS, and to ensure availability of uncorrupted and non-degraded timing signals."[10]

2020. President Trump issued Executive Order 13905 to protect the national and economic security of the United States arising from disruptions to PNT services by "strengthening national resilience through responsible use of [PNT] services in critical infrastructure" because "the disruption or manipulation of [PNT] services has the potential to adversely affect the national and economic security of the United States."[11] Further, the Cybersecurity and Infrastructure Security Agency ("CISA") encouraged the federal government to adopt multiple PNT sources and expand

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[6] *Critical Infrastructure Security and Resilience*, DHS & Nat'l Coordination Off. for Space-Based Positioning Navigation & Timing, at 12 (Nov. 2014), https://tinyurl.com/2au3cgyw.

[7] *See* Sarah Mahmood, *Critical Infrastructure Vulnerabilities to GPS Disruptions*, DHS (June 4, 2014), https://tinyurl.com/yrwvrr42.

[8] David Simpson, *Cybersecurity Risk Reduction*, FCC White Paper, at 12 (2017), https://tinyurl.com/3zsm4aaj.

[9] *See* Letter from Thomas Goode, ATIS General Counsel, to Honorable Ed Markey et al., U.S. Senate (May 3, 2017), https://bit.ly/3JcBXdQ; Letter from Thomas Goode, ATIS General Counsel, to Honorable Jack Reed et al., U.S. Senate (May 7, 2021), https://bit.ly/3CtjkOT.

[10] *National Timing Resilience and Security Act Roadmap to Implementation*: *United States Department of Transportation Report to Congress*, DOT (2021), https://tinyurl.com/3z6688tp (quoting National Timing Resilience and Security Act of 2018, Pub. L. No. 115-282, 132 Stat. 4192 § 514).

[11] Exec. Order No. 13905, 85 Fed. Reg. 9359, 9359 (Feb. 12, 2020).

PNT services' availability based on market drivers to "diffuse the risk currently concentrated in wide-area PNT services such as GPS."[12]

2021. The Trump Administration issued "Space Policy Directive 7," which states, "Use of multiple, varied PNT services can result in better performance in terms of user accuracy, availability, and resilience. However, the United States Government does not assure the reliability or authenticity of foreign PNT services."[13] The Directive also states, "The United States is also encouraging the development of alternative approaches to PNT services and security that can incorporate new technologies and services as they are developed, such as quantum sensing, relative navigation and private or publicly owned and operated alternative PNT services."[14] The National Defense Authorization Act (fiscal year 2022) directed the Secretary of Defense to prioritize the most critical mission elements and systems for combatant commands' operational plans and produce sufficient equipment "to generate resilient and survivable alternative positioning, navigation, and timing signals."[15] The Department of Transportation ("DOT") explained that the promotion of "critical infrastructure owner/operator use of those technologies that show strong performance, operational diversity, operational readiness, and cost-effectiveness is worthwhile."[16] The White House Office of Science and Technology Policy concluded, "Improvements to resilience that address both GPS and other PNT sources will be most effective in satisfying the larger strategic objectives of preserving national, homeland, and economic security."[17] DOT issued the 2021 Federal Radionavigation Plan, which states, "Increased investment in non-GPS PNT services by the owners and operators of critical infrastructure is necessary to continue to provide a robust and resilient National PNT Architecture."[18]

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[12] *Report on Positioning, Navigation, and Timing (PNT) Backup and Complementary Capabilities to the Global Positioning System (GPS)*, DHS, at vi (2020), https://tinyurl.com/25c54ue2; *Resilient PNT for Critical Infrastructure*, DHS (Mar. 2020), https://tinyurl.com/26md7g8w ("Alternative timing technologies will not only provide new sources of robust timing data, but they will also hamper jamming and spoofing attempts, as having complementary timing sources enables comparison and validation of timing data.").

[13] *Memorandum on Space Policy Directive 7*, White House (Jan. 15, 2021), https://tinyurl.com/y87yorxh.

[14] *Id.*

[15] National Defense Authorization Act for Fiscal Year 2022, Pub. L. No. 117-81, 135 Stat. 1541.

[16] Andrew Hansen et al., *Complementary PNT and GPS Backup Technologies Demonstration Report: Sections 1 through 10*, DOT, DOT-VNTSC-20-07, at 195 (2021), https://tinyurl.com/2b35j86k.

[17] *National Research and Development Plan for Positioning, Navigation, and Timing Resilience*, White House Nat'l Sci. & Tech. Council, at 4 (Aug. 2021), https://tinyurl.com/4seaakjf.

[18] *2021 Federal Radionavigation Plan*, DOT, DOT-VNTSC-OST-R-15-01, at x (2021), https://tinyurl.com/27e5n72e.

2022. DHS established that "system designers can use a holistic approach to develop combinations of techniques which can be integrated into architectures to execute the objectives of the PNT [user equipment subsystems] and generate overall resilient outcomes."[19]

2023. DOT developed a Complementary PNT ("CPNT") Action Plan to "drive CPNT adoption across the Nation's transportation system and within other critical infrastructure sectors"; engage PNT stakeholders; monitor and support CPNT specifications and standards development; establish resources and procedures for CPNT testing and evaluation; and create a Federal PNT Services Clearinghouse for The Complementary PNT Action Plan establishes a designated "clearinghouse" for vetting and qualifying complementary PNT providers to help advance resilient PNT needs and procure service beginning in 2025.[20] Also, NIST issued cybersecurity PNT profile guidelines to help organizations identify systems that use PNT services and known and anticipated associated threats, protect systems that depend on PNT services, detect PNT disruptions and manipulation, and address PNT management and use risk "in a timely, effective, and resilient manner."[21] Increasing the security and resiliency of PNT is also a future U.S. Space Force initiative.[22]

2024. CISA issued the first version of its guidance for the procurement of PNT services.[23] U.S. DOT Volpe Center sought proposals by March 25, 2024, on the deployment of very high (≥8) Technology Readiness Level PNT services at operational or operationally equivalent field ranges.[24]

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[19] *Resilient Positioning, Navigation, and Timing (PNT) Reference Architecture*, DHS Sci. & Tech. Directorate, at 42 (June 2022), https://tinyurl.com/284t2653.

[20] *Complementary PNT Action Plan DOT Actions to Drive CPNT Adoption*, Department of Transportation, at 4 (Sept. 2023), https://tinyurl.com/22dbprhy.

[21] *See* Michael Bartock et al., *Foundational PNT Profile: Applying the Cybersecurity Framework for the Responsible Use of Positioning, Navigation, and Timing (PNT) Services*, NIST, NIST IR 8323r1, at 2, https://tinyurl.com/22rw5nmp; *see also Positioning, Navigation, and Timing*, CISA, https://tinyl.io/ARjO (last visited Mar. 4, 2024).

[22] *See Military Communications & Positioning, Navigation, and Timing*, Presentation by Cordell DeLaPena, Jr., Program Executive Officer for Military Communications and Positioning, Navigation, and Timing, Space Systems Command, U.S. Space Force, at 15 (June 2023), https://tinyurl.com/26lu2dxx.

[23] *Federal Positioning, Navigation, and Timing (PNT) Services Acquisitions Guidance*, CISA (Feb. 2024), https://tinyurl.com/22d43vkv.

[24] *See* Call for Proposals Operationally Ready Complementary PNT Services, DOT, https://tinyurl.com/266688my (last updated Mar. 21, 2024).