Before the
NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION
Washington, DC 20230

In the Matter of	)	
	)	
Developing a Sustainable Spectrum	)	Docket No. 181130999-8999-01
Strategy for America's Future	)	RIN 0660-XC044

COMMENTS OF THE GPS INNOVATION ALLIANCE

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TABLE OF CONTENTS

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	)	
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The GPS Innovation Alliance ("GPSIA")[1/] submits these comments in response to the Notice and Request for Comments issued by the National Telecommunications and Information Administration ("NTIA") in the above-referenced proceeding.[2/] GPSIA supports NTIA's efforts to develop a comprehensive, long-term national spectrum strategy and applauds its efforts to increase the efficiency of spectrum uses. Doing so will advance the deployment of wireless broadband services, including 5G, a goal which GPSIA fully embraces. However, GPSIA cautions that decisions regarding spectrum management must consider the many factors that are implicated by the provision of diverse services in adjacent spectrum bands – in particular the unique characteristics of Global Navigation Satellite System ("GNSS") services and the U.S. GNSS, the Global Positioning System ("GPS"). Any spectrum management strategy must recognize and establish means by which those systems – which have become integral to our national infrastructure – will be protected from harmful interference.

[1/] GPSIA was formed in February 2013 to protect, promote, and enhance the use of Global Positioning System ("GPS") and Global Navigation Satellite System ("GNSS") technologies. Members and affiliates of GPSIA come from a wide variety of fields and businesses reliant on GPS, including manufacturing, aviation, agriculture, construction, transportation, first responders, surveying, and mapping. GPSIA also includes organizations representing consumers who depend on GPS for boating and other outdoor activities and in their automobiles, smartphones, and tablets.

[2/] *See Developing a Sustainable Spectrum Strategy for America's Future*, 83 Fed. Reg. 65,640 (Dec. 21, 2018).

I. INTRODUCTION AND SUMMARY

Over the last 30 years, GPS-enabled technology has become a critical and irreplaceable part of our national infrastructure, and it becomes more deeply ingrained every year. The tremendous penetration of GPS and GPS-based technologies across diverse industries has created tangible, widespread economic benefits.[3/] In addition, GPS is essential in numerous applications that ensure safety-of-life, such as aviation navigation and 9-1-1 response. The importance of GPS and GNSS to safety of life, the domestic and global economies, and the daily activities of individuals and businesses worldwide make it critical that these systems be protected from harmful interference in a manner that is universal, predictable, and quantifiable.

GPSIA therefore urges NTIA, in considering spectrum management principles, to recognize the importance of GNSS in general and GPS specifically and the fundamental differences between these services and communications systems. In particular, spectrum management must consider that systems that support *navigation* functions are sensitive to adjacent-band operations in different ways than systems that operate *communications* services – particularly when services in adjacent spectrum bands operate with very different power levels. A "zoning" approach to spectrum management that groups similar services together can generally protect navigation services by ensuring that high-powered communications services are separated from services like GPS that require a "quiet neighborhood." That approach allows a

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[3/] The value of Radionavigation-Satellite Service ("RNSS"), in particular GPS, to the U.S. is well established. In addition to its military use, it is considered an "enabling technology" by the Department of Homeland Security because of its crucial role in 14 of the 16 industries the Department classifies as part of the country's critical infrastructure. It is similarly crucial in a variety of civilian industries, including agriculture, transportation (land, sea, and air), timing, construction, and mining. It is also utilized in personal civilian use and in a number of public safety applications. One estimate found that GPS provided between $37 and $75 billion dollars in value to the U.S. economy 2013. *See* Irv Leveson, *GPS Civilian Economic Value to the U.S.*, Interim Report (v.3), ASRC Federal Research and Technology Solutions, Inc., Aug. 31, 2015.

broad range of spectrum-based services to co-exist in adjacent bands while ensuring that devices that are vulnerable to interference, such as GPS and GNSS receivers, can still function in other bands. GPSIA and its members also continue to believe that spectrum management should employ the internationally established criteria of a 1 decibel ("dB") decrease in Carrier-to-Noise Ratio ("C/N_0") as an interference protection criterion. A "zoning" approach will generally create that protection, but the 1 dB standard should remain the basis of any technical assessment of spectrum compatibility. The 1 dB standard provides the most readily identifiable and predictable metric that will ensure a harmful interference level is prevented in the first place, so that systems operating in the same or adjacent bands do not interfere with one another. This will allow GPS to thrive and all GNSS systems to serve the critical role in ensuring safety-of-life services and propelling economic growth.

NTIA's role in protecting GPS is critical and unique. The satellites that transmit GPS signals are owned by the United States and operated by the United States Air Force. Because NTIA has spectrum management responsibilities for federal agencies – including the Air Force – it bears the primary obligation to ensure that the spectrum management practices summarized above and discussed in greater detail below are observed by both government and non-government entities. GPSIA applauds NTIA's work to date, which has helped GPS maintain its central relationship to the Nation's economy and infrastructure, and looks forward to NTIA's continued efforts to preserve and promote GPS.

II. COMMENTS

A. A Sound Spectrum Management Paradigm Must Consider Distinctions Between Different Spectrum Uses.

1. Navigation Systems Operate Differently from Communication Systems.

As GPSIA and its members have explained to the Federal Communications Commission ("FCC"),[4/] GPS and GNSS, as navigation systems, have inherently different functionality and technical attributes from communications systems. GPS satellites, which orbit more than 12,000 miles above the earth, rely on solar panels to generate the power needed to send GPS signals back to the ground. As a result, GPS satellites transmit with no more power than a 50-watt light bulb, and signals that are received by GPS devices are at a power level that is less than a millionth of a billionth of a watt.[5/] Terrestrial-based communications networks, on the other hand, transmit signals that can literally be billions of times stronger than GPS signals.

In addition, the primary measurement in GNSS is the precise timing of bit transitions in the navigation signal.[6/] Precise timing and positioning requires sub-nanosecond measurement of

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4/ *See, e.g.*, Comments of the GPS Innovation Alliance, ET Docket No. 17-340, at 5 (filed Jan. 31, 2018) ("GPSIA 2018 TAC Comments"); Comments of Trimble Inc., IB Docket No. 12-340; IB Docket No. 11-109; IBFS File Nos. SAT-MOD-20151231-00090; SAT-MOD-20151231-00091; SES-MOD-20151231-00981; SAT-AMD-20180531-00044; SAT-AMD-20180531-00045, at 7 (filed July 9, 2018) ("Trimble 2018 Comments"); Letter from F. Michael Swiek, Executive Director, GPSIA, to Marlene H. Dortch, Secretary, FCC, IB Docket No. 12-340; IB Docket No. 11-109; IBFS File Nos. SAT-MOD-20120928-00160; SAT-MOD-20120928-00161; SAT-MOD 20101118-00239; SES-MOD-20121001-00872, at 5 (filed July 13, 2017) ("GPSIA July 2017 *Ex Parte*"); Comments of the GPS Innovation Alliance, ET Docket No. 16-191, at 2 (filed Aug. 11, 2016).

5/ *See, e.g.*, Tim Bartlett, *Threats to GPS from Land-Based Signal Boosters*, POWER AND MOTORYACHT, May 7, 2012, https://www.powerandmotoryacht.com/electronics/understanding-impact-threats-gps-land-based-signal-boosters ("GPS signals come from solar-powered 50-Watt transmitters 12,000 miles out in space."); *see also* Sebastian Anthony, *Think GPS is Cool? IPS Will Blow Your Mind*, EXTREMETECH, Apr., 24, 2012, http://www.extremetech.com/extreme/126843-think-gps-is-cool-ips-will-blow-your-mind ("Detecting a GPS signal on Earth is comparable to detecting the light from a 25-watt bulb from 10,000 miles.").

6/ *See* GPSIA 2018 TAC Comments at 5; Trimble 2018 Comments at 7; GPSIA July 2017 *Ex Parte* at 5; *Improving Federal Spectrum Systems*, 114th Cong. 1, at 4 (Oct. 16, 2015) (written testimony of bit edges and effective multipath rejection. Both, in turn, require wide receiver bandwidth. Unlike communications systems, which operate above the noise floor, these wide bandwidth, spread spectrum GPS signals are below the thermal noise floor when they are received.[7/] GPS receivers must therefore perform an extraordinary engineering feat by extracting these faint signals and delivering a signal to the end user that is accurate, has integrity, and is available and continuous in nature.[8/] Even minor increases in the effective noise floor may impede the ability of GNSS receivers to extract signals from the noise, thereby degrading performance in unexpected or dramatic ways.

2. Differences Between Navigation and Communications Systems Impact Coordination and Potential Spectrum Sharing.

As GPSIA and others have noted,[9/] whether or not interference between divergent spectrum uses can be managed depends on a few general parameters: namely, the relative technical characteristics of the uses (*e.g*., similarity or dissimilarity of transmitter power and receiver sensitivity between the systems) and the proximity of the uses in space (or geography) and frequency. Similar uses are easier to coordinate, while dissimilar uses are more difficult to coordinate to the extent that they are in adjacent or nearby frequency bands, particularly where transmitters and receivers are operated in close spatial or geographic proximity.[10/]

GPSIA), https://docs.wixstatic.com/ugd/a5ea08_187ad436a8ce470991a8389a9fa189c3.pdf ("GPSIA 2015 Testimony").

7/ *See* GPSIA 2018 TAC Comments at 5; Trimble 2018 Comments at 7; GPSIA July 2017 *Ex Parte* at 5; GPSIA 2015 Testimony at 2, 4.

8/ *See* GPSIA 2018 TAC Comments at 8-9 (explaining that the accuracy, integrity, availability, and continuity requirements of space-based navigation services and safety-of-life systems differ greatly from those of terrestrial high-power communications systems); GPSIA July 2017 *Ex Parte* at 4.

9/ *See* GPSIA 2018 TAC Comments at 5; Trimble 2018 Comments at 7; GPSIA July 2017 *Ex Parte* at 5; GPSIA 2015 Testimony at 4.

10/ *See* GPSIA 2015 Testimony at 2.

For example, as GPSIA has previously observed, mobile carrier base station downlink transmissions can be proximate to each other in frequency and space because they have similar technical characteristics (*e.g.*, power levels, common timing, and signal characteristics) and because there are longstanding engineering techniques for coordinated operation of such fixed facilities.[11/] High-powered television or radio stations can likewise operate on the same frequencies, if they have sufficient geographic separation.

In contrast, coordination and management of potential interference between dissimilar uses, such as carrier-based mobile broadband operations and the reception of low-power satellite-to-earth transmissions like GPS signals, present a far more challenging scenario.[12/] *First*, the relative technical characteristics of the uses are substantially different. Mobile broadband base station (downlink) transmissions are very high powered relative to the satellite signals as received on earth – literally billions of times stronger. Even mobile broadband handset (uplink) transmissions can be billions of times stronger than GPS satellite signals as received on earth when a mobile handset is transmitting in close proximity to a GPS receiver (for example, when the passenger in the front seat of a car with a GPS navigation system is using his or her cell phone).

Second, there are challenging proximity variables involved in avoiding interference between terrestrial and satellite services.[13/] Both are nearly ubiquitous, allowing no geographic separation. Spatially, mobile broadband networks must be effectively ubiquitous from a user standpoint – users will take mobile handsets everywhere, so uplink transmissions are ubiquitous,

11/ *See id.*

12/ *See id.*

13/ *See id.*

and carriers design their networks to have downlink cell coverage that is as broad as possible. GPS has an even more ubiquitous footprint. GPS satellite signals are available nearly everywhere and, with over a half a billion GPS devices in everyday use in the U.S., including GPS receivers in nearly every cell phone, GPS receivers are in close proximity to fixed or mobile broadband transmitters the vast majority of the time.

Given the challenges described above, the performance of GPS devices, which are designed to withstand adjacent-band transmissions hundreds of millions of times stronger than GPS signals, can easily be degraded by in-band or out-of-band transmissions.[14/] As the FCC has long recognized,[15/] GPS receivers, which are designed to receive one set of "desired" frequencies below the noise floor, can be "overloaded" by "undesired" (potentially interfering) mobile broadband transmissions in adjacent frequencies. The issue of overload interference is not unique to GPS, particularly when the differences in power levels are great and the adjacent-band signals are closer in frequency to the desired signal. In fact, virtually any radio receiver can be overloaded if the adjacent frequency signals are in close enough spatial and spectral proximity and the disparity in power is sufficiently great.

3. Variations in Service Degradation and Interruption Further Complicate Spectrum Coordination and Sharing.

GPSIA has previously explained to Congress and the FCC that, unlike users of GPS devices, users of mobile communications networks can often observe, and take into account, the results of interference such as a brief loss of reception or poor call quality.[16/] During non-emergency situations, the brief loss of television reception, cellular wireless service, or access to

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14/ *See id.*

15/ *See id.* at 3.

16/ *See* GPSIA 2018 TAC Comments at 10; GPSIA 2015 Testimony at 4-5.

an unlicensed hotspot (*e.g.*, Wi-Fi) may be inconsequential. On the other hand, the positional accuracy of a GPS device can be degraded by interfering noise in a way that is not detectable. This can mislead users about their location and, in the case of automated guidance applications, cause poor performance or outright malfunctions. In extreme cases of interference, a GPS receiver can "lose lock" on available GPS satellites altogether, leaving the user with no means of determining location until the interference is abated. Losing services that rely on GNSS reception for navigation, collision avoidance, and route optimization – even momentarily – could prove catastrophic.

B. A "Zoning" Approach Previously Proposed by GPSIA Can Be Effective in Providing Interference Protection.

A "zoning" approach to spectrum management can generally take into consideration the distinctions highlighted above between communications and navigation systems. As GPSIA previously proposed to Congress,[17/] a "zoning" approach would group similar services together to the greatest extent possible to minimize the number of band edges or "border areas" where dissimilar uses in close proximity create serious interference challenges. This would ensure that high-powered spectrum users are separated, now and in the future, from dissimilar services like GPS that require a "quiet neighborhood."

Both the FCC and the International Telecommunication Union ("ITU") have historically maintained a quiet radio frequency spectrum neighborhood for GNSS receivers, along with other technologies that utilize faint radio signals and sensitive receivers.[18/] As GPSIA noted to the

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17/ *See* GPSIA 2015 Testimony at 6.

18/ *See* GPSIA 2018 TAC Comments at 11.

FCC,[19/] studies have found that regulation must be very sensitive to the function of a band because the rules determine the radio environment for that band. The need to provide spectral separation is also routinely taken into account in other spectrum planning contexts, including for mobile services.[20/] For example, downlink and uplink frequencies in paired mobile spectrum blocks used for frequency division duplex mobile technologies, which are by far the most common form of mobile technology, have significant separation (although, as noted above, uplink and downlink bands for different terrestrial communications may be grouped together because of common characteristics). Because the power differential between GPS and mobile operations is even higher, even greater levels of separation are required than those required to protect mobile receivers under normal operating conditions.

Not only is a "zoning" approach a long-recognized and effective means of managing spectrum, it would also avoid the use of technological standards or mandates to manage interference that could stifle innovation. As a general matter, and as GPSIA has previously explained,[21/] the government's ability to make predictive judgments about future technological developments is limited. That is why the FCC is generally reluctant to make technological mandates.[22/] NTIA should follow the same spectrum management approach here.

19/ *See* GPSIA 2018 TAC Comments at 11 (discussing a report from IEEE which recognized that open bands, like the ISM band, become populated with man-made signals, which may result in many terrestrial users and great utility, but also renders the band useless for space-based applications).

20/ *See* GPSIA 2015 Testimony at 3-4.

21/ *See id.* at 6.

22/ *See id.* (noting, among other things, that the FCC has recognized mandating a particular industry standard such as LTE would hamstring innovation and development as well as be contrary to the FCC's policy to preserve technical flexibility and refrain from imposing unnecessary technical standards).

C. The "1 Decibel (Db) Standard" Supported by GPSIA and Its Members Should Be Used to Assess Potential Spectrum Access.

While a "zoning" approach will generally create the protection necessary for GPS/GNSS, regardless of spectrum separation, the "1 decibel (dB) standard" should be the basis of any technical assessment of spectrum compatibility.[23/] As the FCC is aware, the 1 dB standard measures whether a new service causes a 1 dB degradation in a receiver's C/N_0, or a 25 percent increase in the noise floor. A 1 dB standard is appropriate because it is based upon well understood GNSS engineering considerations and is associated with quantifiable changes in the overall noise to which GNSS receivers are subject, with equally well understood effects on receiver operation.[24/] Use of C/N_0 as an interference metric also allows system designers and spectrum regulators to carefully allocate interference to various sources as the net effect of interference is the sum of the individual interference sources, each of which has been expressed in dB, permitting both aggregation of interference and the apportionment of interference among multiple sources.[25/]

Further, as GPSIA and its members have explained to the FCC, the 1 dB standard has had a long and well-established history in both international and domestic regulatory proceedings of protecting GPS operations from harmful interference.[26/] For example, the ITU has consistently

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[23/] *See, e.g.*, Trimble 2018 Comments at 1-2; GPSIA July 2017 *Ex Parte* at 3; GPSIA 2015 Testimony at 5.

[24/] *See* Trimble 2018 Comments at 8; GPSIA July 2017 *Ex Parte* at 3, 6. As explained by GPSIA and its members, C/N_0 is directly related to signal-to-noise ratio ("SNR") and bit error rate ("BER") and is the actual measure of noise and stress in tracking loops. So like BER and SNR, C/N_0 is a direct measurement of receiver performance, rather than a downstream measurement of use-case dependent parameters (such as position error) and is therefore the most appropriate parameter for consideration in an interference analysis. *See* Trimble 2018 Comments at 7-8; GPSIA July 2017 *Ex Parte* at 6.

[25/] *See* Trimble 2018 Comments at 7-8; GPSIA July 2017 *Ex Parte* at 6.

[26/] *See* GPSIA 2018 TAC Comments at 5-6; GPSIA 2015 Testimony at 5; *see also* Trimble 2018 Comments at 2-3.

applied an interference-to-noise ratio of -6 dB (equivalent to a 1 dB rise in the noise floor) in proceedings related to GNSS, other non-communications services, and some radiolocation services. U.S. governmental agencies agree, recognizing that the 1 dB standard is necessary to protect GPS operations from harmful interference.[27/] Indeed, the GNSS industry, the FCC, and NTIA have all used this metric in various contexts for many years.[28/]

Use of the 1 dB standard is particularly necessary to accommodate the technical characteristics of navigation receivers and to ensure the accuracy, integrity, continuity, and availability of the GNSS signal.[29/] *First*, GPSIA and its members have explained that a 1 dB decrease in C/N_0 within the RNSS band would cause a tenfold decrease in the mean time between cycle slips in a GNSS receiver tracking loop as shown in Figure 1 below.[30/] Most GNSS systems rely on continuous tracking of the signal carrier of each satellite being tracked in order to attain maximum accuracy. By continuously tracking the carrier and measuring its phase at the time of measurement (the "carrier phase"), relative motion with respect to the satellites can be ascertained at sub-centimeter levels. A cycle slip interrupts this continuous carrier phase, forcing the tracking loop to reacquire the carrier and then re-initiate the carrier phase

27/ *See Background Paper on Use of a 1-dB Decrease in C/N_0 as GPS Interference Protection Criterion*, UNITED STATES AIR FORCE, at Section 8(a) (2017), https://www.gps.gov/spectrum/ABC/1dB-background-paper.pdf ("The 1 dB interference protection criterion is the only appropriate IPC for protecting GPS and other GNSS receivers."); STEPHEN MACKEY, HADI WASSAF, & KAREN VAN DYKE, DOT GPS ADJACENT BAND COMPATIBILITY ASSESSMENT TEST RESULTS (2017), https://pdfs.semanticscholar.org/7468/1f17152e5953cfeeb54ff7def4e8496e897a.pdf.

28/ *See* Trimble 2018 Comments at 3; Comments of the GPS Innovation Alliance, ET Docket No. 17-215, at 9 (filed Oct. 30, 2017) ("GPSIA 2017 TAC Comments"); GPSIA July 2017 *Ex Parte* at 3.

29/ *See* GPSIA 2018 TAC Comments at 6; Trimble 2018 Comments at 4-5, 7-8; GPSIA July 2017 *Ex Parte* at 3, 6; GPSIA 2017 TAC Comments at 9.

30/ *See, e.g.*, GPSIA 2018 TAC Comments at 6; Trimble 2018 Comments at 9; GPSIA July 2017 *Ex Parte* at 6-7.

measurement. Lack of continuous carrier phase renders many high precision applications unavailable.

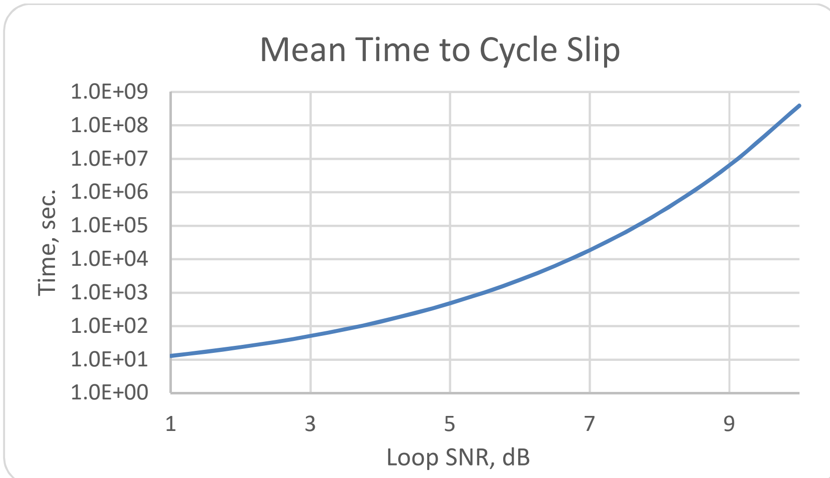

Figure 1: Mean Time to Cycle Slip

Increases in the noise floor would also make it difficult for GNSS applications to track the pseudo random noise code ("PRN code"). As GPSIA and its members have explained,[31/] all GNSS applications track the PRN code from selected satellites in view – this is accomplished in the code tracking loop. The code tracking loop synchronizes a locally generated replica PRN code with the PRN code broadcast from the satellite. This synchronization allows the receiver to make a precise measurement of the starting edge of the first bit of the PRN sequence as it repeats. With this code phase information, the receiver can determine how long it took the satellite signal to reach the receiver and consequently the distance to the satellite. However, as the noise floor rises, the increased noise makes it more difficult to precisely synchronize the replica PRN code to the broadcast signal, resulting in increased error in the measured distance to the satellite. In dynamic applications with wider tracking loop bandwidths, small increases in the

[31/] *See, e.g.*, GPSIA 2018 TAC Comments at 7; Trimble 2018 Comments at 10; GPSIA July 2017 *Ex Parte* at 7.

noise floor yield substantial changes in Coarse Acquisition code tracking error, especially in reduced signal scenarios in which the receiver is operating close to its acquisition sensitivity threshold.

GPSIA and its members have also noted that degradation may occur before the point at which there has been a 1 dB decrease in C/N_0, or before the point at which the noise due to interference has increased by 25 percent.[32/] This is particularly true in challenging use cases in which signal levels may be attenuated by foliage or structures (for example, suburban streets or "urban canyons," respectively) or in which signal reception is changing due to dynamic effects, such as large trucks passing on the highway or aircraft "pitch and roll" during normal maneuvering at takeoff, landing, or en route. It is critical that the margin established in the design of the GPS system for effects such as these not be eroded as spectrum use evolves.

Recent test results published by the National Advanced Spectrum and Communications Test Network ("NASCTN") confirm what GPSIA has said all along: the 1 dB standard continues to be the most appropriate metric for assessing the impact of harmful interference to GPS.[33/] As GPSIA detailed to the FCC, the NASCTN test data show a clear correlation between C/N_0 degradation and multiple user metrics, including a correlation between degradation in C/N_0 and the positional accuracy of general location/navigation receivers tested.[34/] The test results also show increased effects of changes in C/N_0 in "stressed" test conditions, which are more likely to represent real world conditions in many cases.

32/ *See, e.g.*, GPSIA 2018 TAC Comments at 7; Trimble 2018 Comments at 1; GPSIA July 2017 *Ex Parte* at 7-8.

33/ *See* GPSIA July 2017 *Ex Parte* at 1-2 (observing that the NASCTN test results provide both direct and indirect support for the use of the 1 dB standard for determining harmful interference).

34/ *See id.* at 9.

Other interference metrics, such as those that attempt to assess whether there is "actual" harm to an incumbent service, would not be as effective as a 1 dB approach. GPSIA has previously reported to Congress that an assessment of whether there is "actual" harm to an incumbent service wrongly assumes that you can accurately predict the impact of a new service across a heterogeneous series of devices in adjacent spectrum.[35/] Defining harmful interference by reference to a level of degradation to a particular key performance indicator among a limited universe of devices and applications would also undermine technological innovation by subjecting the design and development of future equipment to tremendous uncertainties about the amount of "noise" present in the radiofrequency environment. Use of a defined change in the noise floor, on the other hand, provides a readily identifiable and predictable metric that all interested parties can take into account now and in the future.

Nor is managing receiver characteristics an effective spectrum management tool. While GPSIA has recognized that the input of third-party groups and standards setting organizations may be useful,[36/] focusing myopically on receiver characteristics cannot solve interference caused to existing receivers. *First*, multiple factors – both internal and external to receiver design – affect the likelihood of interference, particularly between highly dissimilar spectrum uses.[37/] In some cases, differences between types of services and the physical proximity of their devices negate any possibility of coexistence. For example, receiver sensitivity and dynamic range coupled with the power delta between transmitter and receiver impose laws-of-physics restrictions on receiver blocking.

35/ *See* GPSIA 2015 Testimony at 5.

36/ *See, e.g.*, GPSIA 2018 TAC Comments at 20; GPSIA 2017 TAC Comments at 2.

37/ *See* GPSIA 2018 TAC Comments at 12; GPSIA 2015 Testimony at 5.

Second, as GPSIA has pointed out to the FCC, a focus on receivers as being responsible for mitigating interference – particularly GNSS receivers – ignores the fact that only transmitters cause a decrease in the carrier-to-noise ratio.[38/] Navigation devices are not capable of controlling that key parameter in the radiofrequency ecosystem. Although receivers can be designed to block some signals, no receiver can block *all* signals outside its band.

Third, because devices that use GPS for location-based applications come in a great variety of form factors and support an immense range of hardware devices and software applications, the ability of a receiver to implement mitigation strategies, such as including more elaborate filtering, may be impractical.[39/] And, in some receivers, improvements in receiver blocking come at the expense of receiver performance. While receiver manufacturers should follow responsible system design practices, they should not be required to use all possible techniques to accommodate any and every adjacent service, especially those techniques that will adversely affect the performance, cost, or availability of the established service.

Finally, any mandated transition to upgraded receivers would impede innovation and be difficult to enforce.[40/] Forcing a major redesign of GPS products is particularly impractical for the hundreds of thousands, if not millions, of GPS devices already in the market, many of which have long life-cycles.[41/] As GPSIA and its members have previously explained to the FCC, a fifteen-year period would be required to complete a normal replacement cycle of high precision

38/ *See* GPSIA 2018 TAC Comments at 11.

39/ *See id.* at 12-13; GPSIA 2015 Testimony at 5.

40/ *See* GPSIA 2015 Testimony at 5-6; GPSIA 2018 TAC Comments at 12-13.

41/ *See* Comments of the GPS Innovation Alliance, ET Docket No. 13-101, at 9 (filed July 22, 2013) ("GPSIA 2013 TAC Comments") ("The costs of hardening existing equipment to tolerate stronger signals in adjacent bands may be prohibitive."); Comments of Trimble Navigation Limited, IB Docket No. 11-109, IBFS File No. SAT-MOD-20101118-00239, at 60 (filed Aug. 1, 2011) ("Trimble 2011 Comments").

systems because they are routinely deployed for a useful life of ten to fifteen years.[42/] Accordingly, over the long term, the public will be best served by allowing companies to innovate with a wide variety of form factors, rather than implicitly or explicitly requiring engineering changes which effectively limit when and how GPS receivers can be used.

D. NTIA Must Protect Existing Users When Considering Future Spectrum Needs.

NTIA has requested comments in this proceeding pursuant to the recent Presidential Memorandum calling for the development of a sustainable spectrum strategy.[43/] As that memorandum explains, in looking for additional opportunities to share spectrum among federal and non-federal entities and encouraging investment and adoption by federal agencies of commercial, dual-use, or other advanced technologies that meet mission requirements, the U.S. government will "take appropriate measures to sustain the radiofrequency environment in which critical United States infrastructure and space systems operate."[44/]

GPSIA fully supports this policy. When evaluating the potential benefits of a new service against existing services such as GPS that are integral to economic growth, transportation, safety, and national security, NTIA must base its spectrum management plans on the two approaches discussed above: spectrum zoning and a 1 dB protection criterion. Identifying and establishing the protections described above will not only sustain the

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[42/] *See, e.g.*, Trimble 2011 Comments at 60 (adding that anything less "would render worthless a settled capital equipment investment in high precision GPS users systems across the public and private sectors . . . amounting to between $5 billion and $10 billion dollars, in addition to the costs associated with replacing embedded systems and the lost production costs and social costs of disruption, including potentially safety of life and property"); GPSIA 2013 TAC Comments at 9 ("In some instances, it may be impossible or impractical to retrofit hardware, which may need to be retired and replaced well before the end of the equipment's useful life.").

[43/] *See Developing a Sustainable Spectrum Strategy for America's Future; Memorandum for the Heads of Executive Departments and Agencies*, 83 Fed. Reg. 54,513 (Oct. 30, 2018).

[44/] *See id.* at 54,514.

radiofrequency environment, but will also help address the likely future needs of spectrum users, including for next generation services like 5G and for space-based applications.

Contrary to the views of some,[45/] frequencies useable for 5G are not reflexively being held "hostage" by the GPS industry. The GPS industry only seeks protection based on reasonable and identifiable criteria so that it can continue to provide critical services and remain the economic driver it is today. When those criteria are satisfied, the GPS industry is pleased to support new technologies.

III. CONCLUSION

GPSIA appreciates the efforts that NTIA has taken and will take to develop a sustainable spectrum strategy. NTIA must include in these efforts the recognition of the critical difference between communications and navigation systems and the need to protect the latter using internationally established criteria such as a "zoning" approach and, ultimately, the prevention of a 1 dB decrease in C/N_0. When weighing the economic and human costs to incumbent services against the potential benefit from new services, it is essential that NTIA give priority to critical services like GPS.

[45/] *See, e.g.*, Holman W. Jenkins, Jr., *Is Airwave Nimbyism Holding Back 5G?*, WALL STREET JOURNAL (Dec. 7, 2018), https://www.wsj.com/articles/is-airwave-nimbyism-holding-back-5g-1544227402.

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