Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of
Use of the 5.850-5.925 GHz Band

ET Docket No. 19-138

REPLY COMMENTS OF
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EXHIBIT B: Coleman Bazelon & Paroma Sanyal, The Economics of Unlicensed and Dedicated Use Spectrum in the 5.9 GHz Band (Apr. 27, 2020)
I. Introduction and Summary

The importance of and demand for Wi-Fi are the highest they have ever been. Over 72 million homes and businesses across the country subscribe to broadband delivered by cable providers, with Wi-Fi delivering a majority of this traffic to laptops, phones, tablets, televisions, and other devices. Millions of other broadband users rely on Wi-Fi to connect to the internet across the country, and a large and growing percentage of cellular traffic is offloaded to Wi-Fi as well. Critical industries like healthcare, education, transportation, finance, and agriculture rely on Wi-Fi to manage connected devices, monitor worker and consumer safety, provide educational resources, make secure transactions, and enable cost-effective connectivity. These dynamics are even more pronounced in the current moment, as millions of Americans rely on Wi-Fi to remain connected and productive while practicing social distancing.

It is clear that Wi-Fi is the single most important wireless technology for American consumers and businesses. But, as the Commission understands, unlicensed spectrum resources and channel sizes must keep pace with demand and technological advances in the Wi-Fi standard. The Commission’s proposal to open the lower 45 megahertz of the 5.9 GHz band is central to achieving this goal. Opening the band will create an essential bridge to next-generation Wi-Fi, as it will take advantage of existing equipment in consumers’ homes and businesses to quickly enable gigabit Wi-Fi speeds. As the economist Dr. Raul Katz has recently demonstrated, this will create enormous economic benefits—approximately $30 billion from the 5.9 GHz band alone—for the United States by 2025.
The record in response to the Commission’s 5.9 GHz Notice of Proposed Rulemaking\(^1\) (NPRM) strongly supports the FCC’s proposal to open the band to Wi-Fi while modernizing the Intelligent Transportation Systems (ITS) radio service. A diverse group of commenters agree with the Commission that it is important to open more spectrum for unlicensed use and that the 5.9 GHz band is uniquely suited to make a significant contribution to meeting Wi-Fi needs quickly. In particular, with the right technical rules in place, many existing Wi-Fi access points could be upgraded to use spectrum in the lower 45 megahertz of the band, including the contiguous 160-megahertz Wi-Fi channel made possible by the Commission’s extension of U-NII-3. Service providers, equipment companies, rural wireless internet service providers (WISPs), and public interest groups agree that the Commission’s compromise proposal would open this channel while also preserving sufficient spectrum for vehicle-to-everything (V2X) technologies to offer crash-avoidance services.

Automotive interests oppose the Commission’s efforts to improve the 5.9 GHz band’s performance. They argue that the Commission is wrong to conclude that the band is needed for Wi-Fi, hoping to preserve their exclusive access to the full band for non-safety uses, potential future commercial deployments, and safety uses that they keep promising are just over the horizon. Some ITS supporters argue that the Commission should delay its proceeding until the government or industry decides whether the automotive sector will embrace DSRC or C-V2X, despite the adoption of vehicle safety features that do not need the 5.9 GHz band. But while DSRC has stalled, innovators have developed other automotive-safety technologies that offer many of the benefits DSRC was slated to provide, such as blind-spot detection, lane-keep assist,

and other features that use non-5.9 GHz radar, lidar, sensors and other cellular technologies. Indeed, only a few years ago the FCC opened 5 gigahertz of spectrum for vehicular radar to facilitate these kinds of advancements. To further slow the Commission’s efforts, some automotive interests argue that the FCC lacks legal authority to act, while others suggest that unlicensed operations could not operate next door to DSRC or C-V2X without causing harmful interference—in spite of the fact that millions of Wi-Fi devices operate adjacent to ITS today.

As we discuss here, the materials in the record—and in many cases, V2X proponents’ own submissions—refute the automotive interests’ arguments for preserving the free, exclusive spectrum subsidy they have enjoyed, but allowed to lay fallow, for twenty years. Their comments fail to establish why the Commission should deviate from core principles of modern spectrum management and reserve exclusive spectrum for these companies to provide services other than safety-of-life applications, which require at most 30 megahertz of spectrum. To the contrary, the extensive record before the Commission confirms that it should move forward with the NPRM’s proposal. The Commission’s proposal finds a middle ground that preserves a band for automotive safety while also making important new spectrum available for unlicensed use.

The time to act is now. Our nation’s public health challenge reveals how critical Wi-Fi has become to our economy, education, and families. Americans are working and learning from home, seeing doctors remotely on their wireless devices, staying current on the latest news and health recommendations, and connecting with loved ones—and most of this activity relies on Wi-Fi networks. The Commission’s hard work to open additional unlicensed bands will transform the Wi-Fi experience for consumers by equipping service providers and equipment

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2 See Amendment of Parts 1, 2, 15, 90 and 95 of the Commission’s Rules to Permit Radar Services in the 76-81 GHz Band, Report and Order, 32 FCC Rcd. 8,822 (2017) (Vehicular Radar Order).
makers with the spectrum they need to ensure this ubiquitous connectivity is strong and grows even stronger in the future.

II. The 5.9 GHz Band Is Critical for Meeting Current and Near-Term Wi-Fi Needs.

A. The Record Strongly Supports the Commission’s Findings that the Country Needs Additional Mid-Band Unlicensed Spectrum and that the 5.9 GHz Band Is Uniquely Positioned to Address that Need.

The record provides overwhelming support for the Commission’s finding that Wi-Fi and other unlicensed technologies contribute greatly to innovation and the national economy. Numerous and varied commenters agree with the Commission that more mid-band unlicensed spectrum is needed to keep pace with demand. They further agree with the Commission that the 5.9 GHz band has a critical and unique role in meeting that need in the near term.

Numerous commenters agree with the Commission’s assessment of the importance of unlicensed spectrum and Wi-Fi in particular. Citizens Against Government Waste supports the Commission’s finding that Wi-Fi is important to American consumers and explains that unlicensed spectrum is a key component of “deploying 5G networks.” The Free State Foundation explains that Wi-Fi networks are “an integral component of the broadband ecosystem.” Similarly, the Taxpayers Protection Alliance agrees that unlicensed spectrum generates “great benefits” and “substantial economic value.” TechFreedom similarly argues

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5 Comments of David Williams, President of Taxpayers Protection Alliance at 2, ET Docket No. 19-138 (filed Mar. 6, 2020) (Taxpayers Protection Alliance Comments).
that “[a]ccess to Wi-Fi has become a staple of modern American life, empowering industry and individuals to connect and collaborate in ways that were hitherto unknowable.”

New America’s Open Technology Institute (OTI) and Public Knowledge discuss Wi-Fi’s many important use cases, including (1) meeting “the critical needs of community anchor institutions and businesses of all types,” like “schools and other educational institutions,” (2) helping bridge the Homework Gap by providing connectivity in libraries, retail establishments, and public spaces, (3) supporting “smart agriculture,” (4) increasing productivity in factories and other industrial settings, and (5) connecting “hospitals” and other medical institutions. They agree that Wi-Fi also plays an important role in supporting licensed spectrum users by offloading enormous amounts of mobile data traffic, a relationship that “will only deepen as 5G networks spawn very high-bandwidth applications and services.” And, critically, they explain Wi-Fi’s importance in businesses and the home to connect computers and other devices to the public internet—as well as the need for additional Wi-Fi bandwidth to ensure that the high speeds providers deliver to the home continue over the last few feet to end-user devices.

Commenters also agree with the Commission that the United States needs more mid-band Wi-Fi spectrum. The Dynamic Spectrum Alliance emphasizes that “the country needs a significant expansion in the amount of available unlicensed spectrum just to keep pace with existing technologies, and will need even more” to support the “new and innovative uses that

8 Id. at 8-9.
9 Id. at 16-17.
will maintain U.S. technological leadership.”10 Wi-Fi Alliance “applauds the Commission’s
efforts” in this proceeding “to address the urgent need for additional unlicensed spectrum which
is required to support the explosive growth of connected devices, mobile data off-loading, and
next generation Wi-Fi technology.”11 OTI and Public Knowledge explain that “additional
capacity for Wi-Fi is necessary . . . to help relieve the congestion current Wi-Fi bands are
experiencing due to the dependence of mobile device users [and] carriers for cellular offload.”12

The Competitive Enterprise Institute concurs, explaining that for Wi-Fi to maintain its
usefulness, particularly in supporting licensed services, “it cannot be congested itself,” and
“[a]dditional unlicensed capacity is . . . necessary,” particularly given new IOT applications and
5G.13 The Free State Foundation agrees that given continuous increases in demand, “[a]dditional
unlicensed wireless capacity . . . is needed.”14 While addressing today’s existing congestion is
necessary, it is not sufficient. Comcast explains that “[a]s the speed of our broadband networks
increase” to gigabit speeds and even 10 gigabits per second or 10G, “the speed of the Wi-Fi
networks that deliver the last hundred feet of broadband must keep pace.”15 Broadcom and

10 Comments of Dynamic Spectrum Alliance at 2, ET Docket No. 19-138 (filed Mar. 9, 2020)
(DSA Comments).
11 Comments of Wi-Fi Alliance at 1, ET Docket No. 19-138 (filed Mar. 9, 2020) (Wi-Fi
Alliance Comments).
12 OTI/PK Comments at 8.
13 Comments of Competitive Enterprise Institute at 8, ET Docket No. 19-138 (filed Mar. 9,
2020) (CEI Comments).
14 Free State Foundation Comments at 7-8.
15 Comments of Comcast Corporation at 3, ET Docket No. 19-138 (filed Mar. 9, 2020)
(Comcast Comments).
Facebook agree that, even putting aside congestion, “the U-NII-4 band is also important as it can enhance the existing 5 GHz U-NII ecosystem.”

Numerous commenters also recognize that the 5.9 GHz band is uniquely positioned compared to all other bands to substantially improve Wi-Fi for the country. They recognize that opening the lower 45 megahertz of the band would build on the success of the U-NII-3 band to create the “first and only gigabit-capable Wi-Fi channel” spanning 160 megahertz and not subject to restrictive “detect-and-avoid requirements.” Microsoft, for example, explains that wider channels would “support higher data rates and Gigabit Wi-Fi.” Broadcom and Facebook agree that U-NII-4 will “support next generation Wi-Fi, such as Wi-Fi 6, which operates on wider channels allowing gigabit connectivity with lower latency, improved coverage and power efficiency.” Wi-Fi Alliance cites the same benefits. Comcast agrees that U-NII-4 can help “provide the Nation’s first contiguous 160-megahertz channel not burdened by dynamic frequency selection.” A number of other commenters representing the interests of consumers and taxpayers cite these benefits in support of the Commission’s proposal.

16 Joint Comments of Broadcom Inc. and Facebook, Inc. at 2, ET Docket No. 19-138 (filed Mar. 9, 2020) (Broadcom/Facebook Comments).
17 OTI/PK Comments at 7-8.
18 Comments of Microsoft Corporation at 3, ET Docket No. 19-138 (filed Mar. 9, 2020) (Microsoft Comments).
19 Broadcom/Facebook Comments at 1; see also id. at 2 (opening U-NII-4 alongside U-NII-3 will “maximize the utility of both bands”).
20 Wi-Fi Alliance Comments at 4.
21 Comcast Comments at 7; see also DSA Comments at 2-3.
22 See Comments of Center for Growth and Opportunity at Utah State University at 4, ET Docket No. 19-138 (filed Mar. 9, 2020) (Center for Growth Comments); CAGW Comments at 3-4; Free State Foundation Comments at 3; Comments of R Street Institute at 8, ET Docket No. 19-138 (filed Mar. 9, 2020) (R Street Comments); TechFreedom Comments at 5-6.
The expanded capacity unlocked by next-generation Wi-Fi could support new services that require greater throughput and lower latency, and support “an enormous increase in the number of devices on a Wi-Fi network without a deterioration in performance.” And while these wide channels will unlock new possibilities for consumers, Microsoft explains that 45 megahertz of U-NII-4 spectrum would also “support[] multiple new 20 MHz and 40 MHz channels, some contained entirely within the U-NII-4 band and some that span the U-NII-3 and U-NII-4 bands,” offering important connectivity gains for “enterprise Wi-Fi deployments” that typically use these smaller channels with numerous devices.

Commenters also recognize that U-NII-4 spectrum is uniquely positioned to meet Wi-Fi needs now because its location adjacent to U-NII-3 would allow some existing equipment to use the spectrum very quickly through firmware/software upgrades, and allow new equipment to access U-NII-4 spectrum with minimal additional expense. TechFreedom explains that these similarities to U-NII-3 will “reduc[e] the user-side expense associated with increasing their Wi-Fi-enabled capabilities.” Comcast, for example, describes how “[m]uch of the Wi-Fi equipment deployed today” and operating in U-NII-3 “could bring consumers access to the 5.9 GHz spectrum with only software or firmware updates, a benefit that would not be possible in any other band.” Comcast also explains that, because of U-NII-4’s similar properties to U-NII-3, manufacturers of new equipment will be able to “repurpose their current baseband chip designs and to utilize existing or similar antennas and filters in creating products that” use

23 OTI/PK Comments at 8.
24 Microsoft Comments at 3; see also Wi-Fi Alliance Comments at 4 (describing the smaller channels also possible with U-NII-3 and U-NII-4 working in tandem).
26 Comcast Comments at 8.
U-NII-3 and U-NII-4, resulting in “efficiencies [that] will allow lower-cost devices for consumers, economize power consumption, and require less space in devices where space constraints are becoming acute.”

Microsoft agrees, noting that “deployed U-NII-3 devices that could operate in the U-NII-4 band in short order” through these methods would help “put the U-NII-4 band into productive use as soon as practicable.”

OTI and Public Knowledge likewise point out U-NII-4’s ability to “ensure the rapid availability of Wi-Fi 6’s capabilities without undue delay or reduced performance.”

WISPA agrees that Commission action will produce substantial gains in the near term, as do the Free State Foundation and the Center for Growth and Opportunity.

B. Automotive Interests Unjustifiably Reject the Commission’s Finding that the 5.9 GHz Band Is Important to the National Effort to Improve Broadband.

Some ITS proponents argue that the Commission should not pursue its effort to improve Wi-Fi and broadband performance by opening the 5.9 GHz band to unlicensed operations. They argue that the Commission has made other spectrum available for unlicensed use in recent years, that non-contiguous spectrum can be lumped together to assemble a 160-megahertz channel, and that the Commission’s actions in the 6 GHz band make action in the 5.9 GHz band unnecessary. They are wrong.

27 Id. at 9.
28 Microsoft Comments at 6.
29 OTI/PK Comments at 8.
31 Free State Foundation Comments at 9.
32 Center for Growth Comments at 4.
First, commenters like AT&T, 5G Automotive Association (5GAA), and the Alliance for Automotive Innovation argue that the Commission has “allocated substantial swaths of spectrum for unlicensed use over the last few years,” making action in the 5.9 GHz band an “incremental public benefit.” AT&T includes in those “last few years” the Commission’s decisions making available spectrum in the “U-NII-1-3 bands,” even though the Commission opened most of those bands twenty years ago. Indeed, Microsoft correctly notes that U-NII-4 “will be the first new authorization of unlicensed mid-band spectrum that can be used by Wi-Fi devices in over two decades.” Nonetheless, several ITS commenters cite spectrum far from the mid band, in extremely high frequency bands such as 37 GHz, bands in the 60 GHz range, and bands above 95 GHz. While these bands are valuable for a subset of emerging uses, they are not physically suited to meet Wi-Fi needs today or in the near future. Opponents of the Commission’s proposal also cite recent actions in the CBRS band as somehow rendering access to additional Wi-Fi spectrum unnecessary. But even the General Authorized Access portions of that band are unsuited for Wi-Fi and, while important and valuable for other uses, cannot substitute for U-NII-4 spectrum in addressing America’s Wi-Fi needs and offering the country a contiguous, widely usable 160-megahertz Wi-Fi channel that can quickly be brought online.

34 AT&T Comments at 15.
35 Microsoft Comments at 3.
36 See 5GAA Comments at 36-37; Auto Alliance Comments at 31; AT&T Comments at 15.
37 See 5GAA Comments at 36-37; Auto Alliance Comments at 31-32, AT&T Comments at 15.
Second, some commenters argue that “Wi-Fi . . . has other options for creating 160 MHz channels,” such as by “combining two non-adjacent 80 MHz channels” to “enable the same benefits as use of a single 160 MHz channel.” But two 80-megahertz channels do not equal one 160-megahertz channel in any meaningful sense. Broadcom has explained that “[a]t the chip level,” bonding two 80-megahertz channels “requires a device to operate on two channels simultaneously,” requiring “duplication of subsystems to support the second discontiguous channel, making integrated circuits much larger.” This requires device manufacturers to “scal[e] back other technical upgrades . . . in order to make room for larger Wi-Fi chips,” “reduc[ing] energy efficiency,” and “drain[ing]” device batteries faster, reducing device operating time between charges and potentially adding costs for consumers. Americans increasingly rely on “mobile devices,” for which “battery life is paramount,” and the “key performance indicators of the discontiguous approach will not meet the market needs.” Relying on existing 80-megahertz channels simply will not address the need for a 160-megahertz channel with the throughput to scale broadband capacity needed today and to support future high-bandwidth applications like AR/VR, immersive education, telehealth, gaming, and more. The next generation standard of Wi-Fi—Wi-Fi 6—enables 160-megahertz channels to more efficiently use shared unlicensed spectrum to deliver up to 10-gigabit speeds and to create more capacity for those high-bandwidth applications, but requires contiguous spectrum channels to do so.

38 Auto Alliance Comments at 32-33.
40 Id.
41 Id.
Third, some commenters argue that no action is needed to open Wi-Fi spectrum in the 5.9 GHz band given that the Commission has recently made additional unlicensed spectrum available in the 6 GHz band.\textsuperscript{42} While the 6 GHz band is critical to the future of unlicensed technologies, Commission action in the 6 GHz band does not reduce the importance of the Commission’s actions here. First, unlicensed access to 5.9 GHz will create an important bridge to the next generation of Wi-Fi, as some Wi-Fi devices are already equipped to use 5.9 GHz with software or firmware upgrades, whereas 6 GHz devices still require equipment certification under the Commission’s new rules, and must then be deployed. Second, although the Commission’s 6 GHz rules will open significant bandwidth to enable next-generation Wi-Fi, consumer-grade equipment is effectively limited to low-power and indoor use. Opening 5.9 GHz spectrum for standard-power indoor and outdoor Wi-Fi use under more flexible technical rules, on the other hand, will in the near term allow a variety of different use cases that may not be possible with those device classes in 6 GHz spectrum, such as smart farming, smart city applications, outdoor Wi-Fi hotspots, outdoor industrial uses, and more. Additionally, unlocking the potential of the 6 GHz band for devices operating at the standard Wi-Fi power levels that consumers use today will take significant time because those devices are required to be controlled by an Automated Frequency Coordination (AFC) mechanism to avoid interference with incumbent operations in the band. The Commission has established rules for the use of a

\textsuperscript{42} See 5GAA Comments at 37-39; Auto Alliance Comments at 32; AT&T Comments at 15; Comments of General Motors LLC at 12-13, ET Docket No. 19-138 (filed Mar. 9, 2020) (General Motors Comments); Comments of T-Mobile USA, Inc. at 4-5, ET Docket No. 19-138 (filed Mar. 9, 2020) (T-Mobile Comments); Comments of Consumer Reports at 9, ET Docket No. 19-138 (filed Mar. 9, 2020).
new AFC mechanism for such standard power access points. But companies must build this mechanism and seek Commission approval of individual AFCs. Only then can manufacturers design, build, certify, and operate standard-power 6 GHz access points.

Moreover, even once the 6 GHz band is up and running, the environment in this band will be significantly different from the 5.9 GHz band. Most importantly, the 6 GHz band has established, fully operational incumbents that Commission rules will protect, unlike in the lower 45 megahertz of the 5.9 GHz band. As a result, the AFC mechanism will block standard-power access points from operating at all in many areas, and the Commission’s AFC rules block all mobile access points. Furthermore, Low-Power Indoor (LPI) access points, which are very important for the future of Wi-Fi, will be substantially different from the access points found in U-NII-3 today. LPI access points will have a far lower power maximum than today’s Wi-Fi, and will operate only indoors. In addition, 6 GHz spectrum cannot substitute for U-NII-4’s ability to maximize the utility of U-NII-3 by providing a contiguous, widely usable 160-megahertz channel spanning both bands, which will make the U-NII-3 band far more productive.

In sum, the 5.9 GHz and 6 GHz bands are complementary, and the Commission’s 5.9 GHz NPRM rightly reflects that “[b]oth actions—making the 6 GHz band available and providing access to the U-NII-4 band—are important.”


44 See Broadcom/Facebook Comments at 2 (“Although access to the 6 GHz band will be critical to relieving spectrum congestion, the U-NII-4 band is also important as it can enhance the existing 5 GHz U-NII ecosystem.”); Wi-Fi Alliance Comments at 3-4 (“Although the 6 GHz band will ultimately provide relief from spectrum congestion and enable Wi-Fi innovation, the U-NII-4 band can enhance the ability of the existing 5 GHz U-NII ecosystem to timely deliver much needed broadband connectivity to all Americans.”).

45 Wi-Fi Alliance Comments at 4.
III. THE RECORD SUPPORTS THE COMMISSION’S PROPOSAL TO PERMIT WI-FI IN THE LOWER 45 MEGAHERTZ OF THE BAND.

In the NPRM, the Commission explained that “[t]he band plan we propose promises to transform the use of [the 5.9 GHz band] to more fully and effectively serve the American people.”\textsuperscript{46} Opening a portion of the band for unlicensed shared use, and preserving the remainder for automotive uses, will “optimize the use of spectrum resources . . . by enabling valuable additions and enhancements to the unlicensed ecosystem and by continuing to dedicate sufficient spectrum to meet current and future ITS needs within the vehicular-related ecosystem.”\textsuperscript{47}

NCTA continues to believe that the optimal use of this valuable spectrum would be to permit unlicensed operations throughout the 5.9 GHz band, but we nonetheless strongly support the Commission’s proposal. Many other commenters do as well. Conversely, many of the same automotive interests that secured the original, failed DSRC allocation twenty years ago urge the Commission to maintain the unacceptable status quo, raising a series of unpersuasive arguments on why they should continue to have exclusive access to this mid-band spectrum without paying for it or satisfying other conditions the Commission ordinarily requires. But their arguments fail to justify their extraordinary request. A huge subsidy of free spectrum could only possibly be warranted for safety-of-life services, and the record demonstrates that the 30 megahertz the Commission proposes to reserve for ITS is sufficient for that purpose. Non-safety applications can use other licensed spectrum, or unlicensed spectrum (including in the lower 45 megahertz of the 5.9 GHz band).

\textsuperscript{46} NPRM ¶ 9.

\textsuperscript{47} Id. ¶ 11.
A. A Broad Range of Commenters Support the Commission’s Proposal.

A diverse set of commenters have, like NCTA, filed comments urging the Commission to adopt its proposal. As Comcast notes, the NPRM proposal “has broad support from industry, public advocacy groups, economists, and lawmakers.” Commenters that deliver Wi-Fi equipment, connectivity, and the services that rely on it, like Broadcom, Facebook, and Microsoft, support the Commission’s proposal to make at least 45 megahertz available for unlicensed use. Comcast “urge[s] the Commission to move forward with its proposal” so that “Americans receive the full potential of this valuable resource.” WISPA likewise “strongly supports the Commission’s . . . proposal to designate 45 megahertz of spectrum in the lower portion of the band for unlicensed use.” Wi-Fi Alliance, too, “strongly supports the Commission’s proposed designation of spectrum for unlicensed devices.” Dynamic Spectrum Alliance is “supportive of the Commission’s band segmentation proposal.”

A long list of public advocacy groups submitted comments supporting the proposal, many of which noted that the Commission’s proposal sensibly balanced the need for additional Wi-Fi spectrum and the important interest in automotive safety. TechFreedom, for example, calls the proposal an “eminently sensible compromise” that “protects incumbent uses and policy objectives while simultaneously accommodating prospective developments of new transportation safety and Wi-Fi technology.” Free State Foundation calls this proceeding a “prime

48 Comcast Comments at 2.
49 See Broadcom/Facebook Comments at 1; Microsoft Comments at 2.
50 Comcast Comments at 14.
51 WISPA Comments at 1.
52 Wi-Fi Alliance Comments at 2.
53 DSA Comments at 4.
54 TechFreedom Comments at 7.
opportunity to reallocate what essentially is greenfield spectrum, quickly and with relative ease, to what is its best and highest use: unlicensed operations, in particular Wi-Fi.” 55 The Taxpayers Protection Alliance urges the Commission to “move forward with its plan to reallocate” 45 megahertz of spectrum “because it will be a win-win for taxpayers and consumers.” 56 Consumer Action for a Strong Economy “enthusiastically supports” the NPRM proposal, 57 and Citizens Against Government Waste similarly endorses the NPRM proposal as “critical and in the public interest.” 58 R Street Institute, 59 the Institute for Policy Innovation, 60 and the Competitive Enterprise Institute 61 similarly urge adoption of the proposal. OTI and Public Knowledge also support reallocating “at least 45 megahertz,” while also “urg[ing] the Commission to consider moving ITS operations to another band” so Wi-Fi can operate in all 75 megahertz. 62 The Center for Growth and Opportunity likewise calls the NPRM proposal a “step in the right direction,” while arguing the Commission “should go further and designate[] the entire band as unlicensed.” 63

55 Free State Foundation Comments at 3.
56 Taxpayers Protection Alliance Comments at 3.
58 CAGW Comments at 4.
59 R Street Comments at 3.
60 Comments of Institute for Policy Innovation at 1, ET Docket No. 19-138 (filed Mar. 9, 2020).
61 CEI Comments at 8.
62 OTI/PK Comments at 2, 4.
63 Center for Growth Comments at 2.

Comments from ITS advocates repeatedly argue that the Commission should “preserve the entire 75 MHz of the 5.9 GHz band for V2X,” but they offer no support for the proposition that the Commission must do so in order for V2X technologies to offer safety-of-life services. To the contrary, the record demonstrates that no more than 30 megahertz (if that) are needed for DSRC and/or C-V2X to transmit the Basic Safety Message or similar messages meant to aid in crash avoidance and other safety-of-life uses.

The Commission requested that automotive interests articulate which “specific” functions should remain in the band, “how much bandwidth in this particular band is necessary” for those capabilities, whether “all of these applications [are] equally critical to ensure automotive safety,” and “how the Commission can ensure that ITS is used for safety of life applications.” It is revealing that, rather than answer these questions, ITS advocates chose instead to lump all their desired services together, arguing that the Commission nonetheless ought to give them exclusive access, without an auction, to valuable mid-band spectrum so they can deliver “lifestyle benefits” and other services that, while perhaps useful, are not necessary to improve highway safety and can use other, non-exclusive spectrum. Despite these rhetorical maneuvers, the record demonstrates that the NPRM’s proposal reserves sufficient spectrum for V2X technologies to deliver safety-of-life services.

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64 See, e.g., Auto Alliance Comments at 1.
65 NPRM ¶ 61.
66 Auto Alliance Comments at 1.
1. If the Commission Takes the Extraordinary Step of Reserving a Band for a Government-Selected Use, It Should Do So Only for True Safety-of-Life Applications.

NCTA believes that V2X functions other than safety-of-life do not need or warrant an exclusive spectrum allocation.67 Other commenters agree. OTI and Public Knowledge, for example, explain that the Commission has “moved decisively away” from the mode of spectrum allocation that produced the 1999 ITS rules, and now emphasizes flexible licensed uses and unlicensed spectrum, and “limiting exceptions for special purpose needs like public safety to no more than what is necessary to satisfy a compelling public purpose.”68 R Street Institute agrees that “vehicle safety should be the FCC’s only concern” in allocating ITS spectrum in the 5.9 GHz band, and “calls for additional spectrum” for other purposes “should be rejected.”69

Comments filed by DSRC and C-V2X proponents in response to the NPRM do not appear to object to restricting the band to safety-critical uses. The U.S. Department of Transportation (DOT), 5GAA, ITS America, and the American Association of State Highway and Transportation Officials (AASHTO) (who collectively through their various memberships, funding, and incarnations also represent a sizeable number of the other parties filing comments) do not oppose restricting the band only to safety use in their comments, for example. “Given all the safety rhetoric expended on this issue,” as Commissioner O’Rielly has noted, it would be


68 OTI/PK Comments at 18; see also Michael Calabrese & Amir Nasr, The 5.9 GHz Band: Removing the Roadblock to Gigabit Wi-Fi 6-12 (Mar. 2020), attached to Letter from Michael Calabrese & Amir Nasr, Open Technology Institute at New America, to Marlene H. Dortch, Secretary, FCC, ET Docket No. 19-138 (filed Mar. 9, 2020) (OTI Issue Brief) (discussing in greater detail the incompatibility of the DSRC allocation with the Commission’s modern spectrum-allocation approach).

69 R Street Comments at 5.
quite hypocritical “to claim that this 30-megahertz block should be used for anything other than safety of life.”\textsuperscript{70} Yet while these commenters did not oppose a safety-only rule, they continue to resist enumerating the “specific” functions that provide safety-of-life protection, or which uses are “equally critical” for that purpose, or which need dedicated spectrum “in this particular band” to do so.\textsuperscript{71}

The Commission should restrict automotive access to the 5.9 GHz band only to safety operations and should find that the relevant safety-of-life applications (1) are only those that are supported by V2X and cannot be supported by other technologies, and (2) require far less exclusive spectrum than ITS advocates seek to keep for themselves. As Professor Jon M. Peha explains, “a lot of V2X traffic is not safety-critical, or can tolerate latency and loss, or both.”\textsuperscript{72} Much of that traffic could even “operate outside the ITS band in unlicensed spectrum,” particularly if the Commission adopts the NPRM proposal and reduces the ITS spectrum allocation “from 75 to 30 MHz.”\textsuperscript{73} The IEEE 802 LAN/MAN Standards Committee (IEEE 802) comments that “non-safety critical messages may constitute the major economic driver for market adoption of V2X,” even as it says those ITS messages may “creat[e] frequent potential interference” to Basic Safety Messages or BSMs.\textsuperscript{74} IEEE 802 concludes from that premise that these “non-safety critical messages must not be allowed to transmit on the same channel as BSMs.”\textsuperscript{75} But the more obvious conclusion is that these messages should not travel over

\textsuperscript{70} NPRM, Statement of Commissioner Michael O’Rielly.
\textsuperscript{71} Id. ¶ 61.
\textsuperscript{72} Comments of Jon M. Peha at 4, ET Docket No. 19-138 (filed Mar. 9, 2020).
\textsuperscript{73} Id.
\textsuperscript{74} Comments of IEEE 802 LAN/MAN Standards Committee at 7, ET Docket No. 19-138 (filed Mar. 3, 2020).
\textsuperscript{75} Id.
dedicated 5.9 GHz spectrum in the first place, particularly as they can be delivered over other spectrum, including, in some cases, unlicensed spectrum. The Commission no longer routinely reserves spectrum for specific industries or “beauty contest” winners—and consistent with that modern approach, it should not reserve exclusive, no-auction, mid-band spectrum for non-safety-critical messages to subsidize private enterprise’s deployment of these technologies, but instead should allow the industry and marketplace to determine the best use of the band by creating access on a technology-neutral and unlicensed basis.

2. The Record Confirms the Commission’s Determination that 30 Megahertz Is Adequate for Safety-of-Life Services.

Assuming that the Commission is persuaded that it should reserve spectrum in the 5.9 GHz band for DSRC or C-V2X at all for safety-of-life services, 30 megahertz is sufficient. The record confirms that many of the automotive-safety functions originally contemplated for V2X, like alerting drivers to vehicles or other objects, lane-merging alerts, and emergency braking, are already met now through other technologies like radar, lidar, cameras, and sensors.76 The Commission recently made available several gigahertz of spectrum for long-range vehicular radar to support some of these use cases.77 Even critics of the NPRM’s proposal, including DOT, agree that these technologies “play an important role in crash avoidance and vehicle safety.” 78 Panasonic, for example, agrees that these technologies “can support advanced driver

76 See NCTA Comments at 17-19.
77 See Vehicular Radar Order ¶ 25.
assistance systems." To be sure, DSRC and C-V2X proponents argue that these technologies have limits, even as many of them are far more optimistic about these technologies when marketing vehicles and equipment than they are in their advocacy in this proceeding. Their main argument is that these technologies are less effective in “instances where the vehicles involved do not have a direct line-of-sight relationship with each other.”

But if that is the safety-critical advantage DSRC or C-V2X offer over the numerous other technologies that have developed since the initial DSRC allocation, the Commission should allocate no more spectrum than is needed to realize that advantage.

The Basic Safety Message or BSM is the core message that delivers crash-avoidance information in DSRC and C-V2X. And DSRC and C-V2X require no more than 30 megahertz,

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79 Comments of Panasonic Corporation of North America at 14, ET Docket No. 19-138 (filed Mar. 9, 2020) (Panasonic Comments)

80 See, e.g., Continental, Press Release, High-tech Solution for Anticipatory Driving: 20 Years of Continental Long-Range Radar in Series Production (Nov. 7, 2019) (“long-range radar” is a “driving force towards new, future-oriented and safer mobility”); General Motors, Press Release, GM Advances Self-Driving Vehicle Deployment With Acquisition of LIDAR Developer (Oct. 9, 2017) (“As self-driving technology continues to evolve, LIDAR’s accuracy will play a critical role in its deployment.”).

81 DOT Comments at 16; see also, e.g., 5GAA Comments at 11 (“current vehicle-resident technologies . . . experience limitations in non-line-of-sight conditions”); Auto Alliance Comments at 11-12 (“sensors and cameras require direct line-of-sight”); Comments of DSRC Auto Safety Coalition at 3, ET Docket No. 19-138 (filed Mar. 9, 2020) (DSRC Auto Safety Coalition Comments) (“resident driver assistance technologies . . . cannot see beyond line-of-sight”).

82 See, e.g., Letter from Scott Delacourt, Counsel, Association of Global Automakers, to Marlene H. Dortch, Secretary, Federal Communications Commission, ET Docket No. 13-49, GN Docket No. 18-357, at 4 (filed May 17, 2019) (AGA May 2019 Ex Parte) (“V2X technology is built around the ability to transmit and receive the Basic Safety Message . . . which provides key information about moving vehicles including size, position, speed, and heading”); Letter from Scott Delacourt, Counsel, Association of Global Automakers, Inc., to Marlene H. Dortch, Secretary, FCC, ET Docket Nos. 19-138 and 13-49, GN Docket No. 18-357, at 4 (filed Nov. 27, 2019) (criticizing the draft of this NPRM for supposedly not “acknowledging the importance of the basic safety message”); DOT Comments at 11
if that, to securely transmit BSMs. Qualcomm explains that even if C-V2X receives all the spectrum its advocates ask for, “the basic safety messages will continue to be carried over 4G LTE in a 20 MHz channel”—the same 20-megahertz channel 5GAA and other C-V2X advocates asked the Commission to provide in their 2018 petition. In requesting that the Commission immediately permit C-V2X operations in the upper 20 megahertz of the band, 5GAA agrees that the “C-V2X Direct” service is capable of operating in that spectrum, consistent with 5GAA’s petition for waiver asking for the same relief and explaining that the “requested waiver” would “support V2V and V2I messages such as the Basic Safety Message” and a long list of other messages “encompassed by the Road Safety Message.” Other commenters—even those that advocate for additional V2X spectrum—agree. Cisco, for example, says that from its perspective, “it appears that V2V crash avoidance can be supported, and possibly other applications,” in 30 megahertz. Even a “recipient of Federal funds” to


84 5GAA Comments at 22-27.

85 5GAA Petition for Waiver at 22 n.50, GN Docket No. 18-357 (filed Nov. 21, 2018) (5GAA Waiver Petition); see also id. at 30.

deploy DSRC, Tampa Hillsborough Expressway Authority, agrees that “30 MHz is sufficient to support existing [connected vehicle] applications for basic driver warnings.”

While many commenters, including DOT and state transportation officials, attempt to show that existing pilots “are currently deploying V2X applications” across the DSRC channels available today, that does not demonstrate that DSRC or C-V2X need that much spectrum for the existing uses, particularly for safety-critical messages. There is no evidence on the record that these pilots are spectrally efficient, heavily used, or even successful. DSRC and C-V2X proponents argue for “all seven channels” not because existing safety uses require them, but because they seek to “accommodate new technologies.”


In arguing for additional V2X spectrum, commenters repeatedly cite a handful of position papers from their allies suggesting that V2X requires approximately 75 megahertz of dedicated spectrum. These papers, however, do not address the spectrum required for safety-critical uses like transmitting the BSM to address non-line-of-sight crash-avoidance—instead, their totals (like ITS proponents’ comments in this proceeding) reflect the spectrum that could support other, non-safety-critical applications.

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87 Letter from Joe Waggoner, Executive Director, Tampa-Hillsborough County Expressway Authority, to Marlene H. Dortch, Secretary, FCC, ET Docket No. 19-138, at 3 (filed Mar. 5, 2020).

88 DOT Comments at 15-16; see also, e.g., Comments of American Association of State Highway and Transportation Officials (AASHTO) at 13-14, ET Docket No. 19-138 (filed Mar. 2, 2020) (AASHTO Comments); Auto Alliance Comments at 10-11; DSRC Auto Safety Coalition at 8-9.

89 Comments of American Honda Motor Co., Inc. at 5, ET Docket No. 19-138 (filed Mar. 9, 2020) (Honda Comments); see also AASHTO Comments at 12 (calling for “more than 30 MHz” for “deployed and developing ITS applications”).
A number of commenters cite, for example, a position paper from the “CAR 2 CAR Communication Consortium,” a group founded by “vehicle manufacturers” and joined by their “equipment suppliers” and allies.\(^9\) But as AASHTO notes, that position paper assesses the spectrum that ITS technologies could use not only for applications “currently deployed,” but for applications “under development.”\(^9\) The position paper itself recognizes that in the United States, the Basic Safety Message is the message that supports “dangerous situation warning[s],” “intersection collision warning[s],” “pre-/postcrash warning[s],” and the like.\(^9\) But according to the position paper, no more than one 10-megahertz channel is needed for the Basic Safety Message.\(^9\) Even adding in capacity for “signal phase and timing,” “road/lane topology and traffic maneuver,” “in-vehicle information and other I2V messages,” and the “personal safety message,” only twenty megahertz are needed.\(^9\) The remaining spectrum that CAR 2 CAR advocates for in its position paper is for the “platooning control message” (one 10-megahertz channel), and two other messages for potential “sensor sharing” and “cooperative automated driving” use cases.\(^9\) Even assuming for the sake of argument that the underlying methodology of the position paper’s calculations of spectrum needs for all these message types is sound, the

\(^9\) CAR 2 CAR Communication Consortium, Position Paper on Road Safety and Road Efficiency Spectrum Needs in the 5.9 GHz for C-ITS and Cooperative Automated Driving (Feb. 28, 2020) (CAR 2 CAR Position Paper); see, e.g., Auto Alliance Comments at 8-9; DSRC Auto Safety Coalition Comments at 10; General Motors Comments at 6-7 & n.6; Honda Comments at 9 & n.15; Comments of Toyota Motor Corporation at 7-8, ET Docket No. 19-138 (filed Mar. 9, 2020) (Toyota Comments); AASHTO Comments at 11.

\(^9\) AASHTO Comments at 11.

\(^9\) CAR 2 CAR Position Paper at 5 tbl. 1 (capitalization altered).

\(^9\) Id. at 7 tbl. 3.

\(^9\) Id.

\(^9\) Id. at 5 tbl. 1, 7 tbl. 3; see, e.g., Honda Comments at 9-10 (recognizing that these messages described in the study go beyond the Basic Safety Message and similar messages to “advanced” features that may “evol[ve]” in the future).
paper does not establish spectrum needs for crash-avoidance. Instead, the paper concerns spectrum these advocates desire for speculative use cases like “cooperative automated driving”\textsuperscript{96} that may or may not develop and do not justify dedicated auction-exempt spectrum, let alone in the 5.9 GHz band.

DSRC and C-V2X advocates also cite a paper from the ACEA (the European Automobile Manufacturers’ Association) and CLEPA (the European Association of Automotive Suppliers), two advocacy groups whose members include (in the case of ACEA) “Ford of Europe,” “Honda Motor Europe,” “Toyota Motor Europe,” and others.\textsuperscript{97} Commenters like the Auto Alliance, General Motors, Hyundai, and Continental cite this position paper as research demonstrating how much spectrum is needed for “safety critical communications.”\textsuperscript{98} But the paper does not present any empirical research—it simply recycles and cites generally the CAR 2 CAR Position Paper on that point.\textsuperscript{99} Indeed, consistent with the CAR 2 CAR Position Paper, and the comments discussed above, the ACEA/CLEPA paper admits that the “cooperative awareness” messages (the European equivalent of the Basic Safety Message) and others “can be achieved within the existing EU C-ITS spectrum.”\textsuperscript{100} The remainder of the paper describes new and speculative services that “are being elaborated” or “currently being researched and developed,” including

\textsuperscript{96} CAR 2 CAR Position Paper at 20.


\textsuperscript{98} Comments of Hyundai America Technical Center, Inc. at 4, ET Docket No. 19-138 (filed Mar. 9, 2020) (Hyundai Comments); see Auto Alliance Comments at 9; General Motors Comments at 8; Comments of Continental Automotive Systems at 2, ET Docket No. 19-138 (filed Dec. 5, 2019) (Continental Comments).

\textsuperscript{99} ACEA/CLEPA Position Paper at 3 & n.2.

\textsuperscript{100} Id. at 2.
uses that go beyond safety to make “road transport more efficient and environmentally-friendly overall.”

Neither of these papers therefore provides adequate support for the proposition that more than 30 megahertz of spectrum is required for V2X safety services.


The best argument V2X proponents have for the Commission’s allocating more spectrum than is needed for safety-critical transmission of the BSM and similar crash-avoidance messages is that the Commission should “consider the potential spectrum needs of” future versions of their technologies. 5GAA, for example, argues that the Commission should block off spectrum for “advanced applications [that] will evolve as the technology changes.” The Auto Alliance similarly wants reserved spectrum for “the evolution of V2X technologies.” The DSRC Auto Safety Coalition wants a “home for the more advanced suite of V2X solutions of tomorrow.”

Given the twenty-year history of this band—and the fact that commercially marketed vehicles do not have DSRC radios to provide even the “basic” versions of these services despite twenty years of government subsidies—the Commission has rightly proposed that it should not block off 45 megahertz of important mid-band spectrum to subsidize another round of future, speculative developments in these technologies. V2X proponents’ request is an invitation to repeat the error of 1999, with even greater opportunity cost given the potential of U-NII-4 spectrum to quickly provide much-needed bandwidth to American consumers and businesses.

101 Id. at 1, 3.
102 DOT Comments at 32.
103 5GAA Comments at 29.
104 Auto Alliance Comments at 15.
105 DSRC Auto Safety Coalition Comments at 10.
106 See NPRM ¶ 21.
As discussed in greater detail below, the automotive industry remains torn even on the starting-gate question whether DSRC or C-V2X should be the technology used to transmit the Basic Safety Message. It could take decades for the industry to research, develop, agree upon, and implement “advanced” use cases of either of these technologies. By that point, vehicle-resident technologies like cameras and sensors—or other, unforeseen technological advances—could meet the same needs, without requiring this massive spectrum subsidy. A key lesson of the failed DSRC experiment is that allocating important spectrum based on vague predictions and promises of future technologies that will use the spectrum is inefficient and wasteful. The Commission should not repeat that mistake in the 5.9 GHz band, particularly for technologies that have not even widely deployed in their current states.

5. No Other Country Has Reserved the Full 75 Megahertz of the 5.9 GHz Band for Safety-of-Life Uses.

Automotive manufacturers and their supporters also argue that the Commission should reserve the entire 5.9 GHz band for V2X technologies in the interest of international harmonization or global competitiveness. These claims are overstated for a number of reasons, and most importantly, they fail to demonstrate why the Commission should reserve more spectrum for either V2X technology than is necessary to deliver safety-of-life services.

First, putting aside the specifics of the spectrum-allocation decisions under consideration in any particular region or country, the international V2X stage is far from “harmonized.” Just as DSRC and C-V2X advocates battle for spectrum in the 5.9 GHz band here, they fight on other fronts as well. China has permitted C-V2X to operate in twenty megahertz of the 5.9 GHz band (from 5905-5925 MHz),\(^{107}\) with no other 5.9 GHz spectrum for V2X, while Europe, for example,

\(^{107}\) See, e.g., Xinhua Silk Road Information Service, *China’s MIIT publishes regulations for direct communication of Internet of Vehicles* (Nov. 16, 2018), https://en.imsilkroad.com/p/
has not chosen either DSRC or C-V2X. Japan, meanwhile, currently uses only 10 megahertz for “transportation safety communications, including V2V,” in an entirely different band in 700 MHz, and allows only “infrastructure-to-vehicle communications,” including “electronic toll collection,” in 5 GHz spectrum below 5.9 GHz.\textsuperscript{108} But V2X proponents disagree sharply on what developments like those in China mean: 5GAA views the developments in China as reflecting movement “forward with C-V2X Direct implementation in the 5.9 GHz band,”\textsuperscript{109} while DSRC proponent Toyota describes China only as having made a 20-megahertz allocation for an unnamed “basic ITS technology”\textsuperscript{110} and the DSRC Auto Safety Coalition suggests that China is backsliding on its commitment to C-V2X and opening the door for the United States to shift global consensus to “superior DSRC technology.”\textsuperscript{111} DSRC and C-V2X proponents continue to battle one another for spectrum around the globe in a manner that is flatly inconsistent with their arguments about harmonization before the Commission.

Second, adopting the NPRM proposal would actually bring the U.S. closer to the ITS spectrum allocations found in other countries. China, for example, has permitted C-V2X in 5905-5925 MHz, the same 20 megahertz the Commission proposes to allocate for C-V2X. If, as 5GAA argues, it is critical to open up those 20 megahertz as soon as possible to “maintain global

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\textsuperscript{108} ITS America Comments at 27; see also 5GAA Comments at 34.
\textsuperscript{109} 5GAA Comments at 16.
\textsuperscript{110} Toyota Comments at 13.
\textsuperscript{111} DSRC Auto Safety Coalition Comments at 7 n.21.
\end{flushright}
competitiveness” by facilitating “near term deployment,” C-V2X proponents must be willing to start deploying radios that operate in that channel (and presumably can design radios that will use that spectrum both here and in China). If the economies of scale that V2X proponents argue for are real, they must be capable of realization where spectrum allocations overlap—for example, in China and in the United States if the Commission adopts the NPRM proposal—even if some countries have dedicated more or less spectrum than others.

Third, the Commission’s NPRM correctly proposes that no more than 30 megahertz of spectrum is needed for safety-of-life use cases. Absent compelling evidence that automakers require additional spectrum for crash avoidance, the fact that some other countries are considering allocating more ITS spectrum for non-safety purposes is not a reason to follow suit. The U.S. has consistently resisted the more regulatory industrial policies of other countries when making spectrum policy—especially when this involves a foreign government selecting a particular technology, mandating particular uses of business plans, or distorting market forces. V2X proponents’ arguments that the Commission must allocate unnecessary spectrum to maintain the “competitiveness in connected and automated vehicle technology” of individual corporations are based on rhetoric, not substance and are inconsistent with the Commission’s approach to spectrum policy.

Although Europe—one of the V2X proponents’ favorite examples—is considering adding some additional spectrum for ITS, this is not to enable the Basic Safety Message to address non-line-of-sight crash avoidance, but for other, speculative features. The Commission

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112 5GAA Comments at 23-24.
113 *NPRM* ¶ 21.
114 5GAA Comments at 35; see also, e.g., Auto Alliance Comments at 19-20.
should not follow suit. It can proceed with the NPRM proposal and allow V2X technologies to deploy widely in vehicles today with room to explore how V2X can support automation, without blocking off an enormous swath of additional spectrum for speculative future developments.

Fourth, the examples that V2X proponents cite do not establish that the spectrum other countries or regions are considering for V2X will unfold as automakers imply. As discussed above, China has recently allocated only 20 megahertz, and it does not appear that any additional allocation in 5.9 GHz is imminent. In Europe, C-V2X and DSRC proponents cite recent developments in the Electronic Communications Committee (ECC), but the ECC has proposed adding 20 megahertz of spectrum for use by both “Urban Rail” ITS and “Road” ITS, the former of which does not exist in the U.S.\footnote{See Electronic Communications Committee, ECC Decision (08)01, The harmonized use of Safety-Related Intelligent Transport Systems (ITS) in the 5875-5935 MHz frequency band (approved Mar. 14, 2008, last amended Mar. 6, 2020) (ECC (08)01).} This means that ECC (08)01, which is not legally binding and instead is only a proposal that individual nations in the European Union may choose to implement or not,\footnote{See id. at 4.} is not evidence that additional spectrum is needed in the United States for automotive crash avoidance. Furthermore, the ECC issued ECC (08)01 based on its analysis in a report issued in March 2019, in which it noted previous conclusions that there was “no evidence that spectrum availability is currently a constraint on the development of ITS.”\footnote{CEPT, CEPT Report 71, Report from CEPT to the European Commission in response to the Mandate to study the extension of the Intelligent Transport Systems (ITS) safety-related band at 5.9 GHz, at 7 (Mar. 8, 2019) (internal quotation omitted).} Importantly, ECC (08)01 does not suggest that basic fact has changed, and the CAR 2 CAR Position Paper confirms that existing spectrum in Europe is more than sufficient for safety-critical applications, as discussed above. The fact that the spectrum the ECC suggests should be allocated for ITS

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116 See id. at 4.

would be used for both “Road ITS” (“any kind of ground-based transportation systems”) and “Urban Rail ITS” (“urban or suburban railway lines”) is therefore a key difference between the U.S. and European situations. Facilitating both technologies in Europe may call for more spectrum than vehicle applications alone would require in the U.S.,\textsuperscript{118} which does not have an “urban rail ITS” system to accommodate in the same spectrum.

In addition, Europe faces a fundamentally different Wi-Fi environment in these frequencies compared to the U.S. In the U.S., U-NII-3 is the workhorse Wi-Fi band, and U-NII-4 spectrum in the 5.9 GHz band would thus extend the country’s most successful Wi-Fi band in all the important ways discussed above and in NCTA’s opening comments. In Europe, on the other hand, channels in U-NII-3 spectrum are “not used for Wi-Fi in practice” because the “power level is too low”—Europe permits only 25 mW maximum radiated power\textsuperscript{119} versus approximately 4,000 mW in the United States. The fact that devices in those channels may operate at only 1/160 the power of U-NII-3 devices in the U.S. means that the band is lightly used. The value in Europe of extending the equivalent of the U-NII-3 band is therefore far lower than it is in the U.S. The U.S.’s leadership in unlicensed spectrum policy, as illustrated by U-NII-3, has led to much more efficient and expansive use of Wi-Fi. Over 72 million American homes and businesses subscribe to cable broadband and rely on it—and the Wi-Fi connection it enables—to power factories, hospitals, sea ports, railways, airports, cities, and more.

This lower value, the fact that Europe is considering the additional spectrum for government-selected services that are not limited to safety of life, and urban rail ITS service that

\textsuperscript{118} ECC (08)01 at 2.
is not present here, together render any European decisions on these frequencies inapplicable to the U.S. and unhelpful for guiding U.S. regulatory decisions.

C. If ITS Technologies Require Additional Spectrum, Especially for Non-Safety Applications, Automakers Should Look to Other Bands.

The comments of ITS interests appear to assume that if they can conceive of a use case for dedicated, exclusive 5.9 GHz spectrum, they are entitled to that spectrum for all such use cases so long as they rely on DSRC or C-V2X technology. The Commission’s proposal, on the other hand, correctly recognizes that the 1999 ITS spectrum designation was an anomaly and is inconsistent with the Commission’s modern approach to spectrum allocation. The Commission no longer holds comparative hearings to determine which of several applicants receives a license—today companies seeking the benefits of licensed access pay for those rights in auctions, and users willing to share spectrum with other technologies and users without interference protection operate in shared unlicensed bands.

If automotive interests require dedicated, exclusive spectrum for any purposes other than clear safety-of-life uses, the Commission should expect these companies to acquire these spectrum rights in the same way that companies in other industries do. They can secure spectrum at auction or through another FCC licensing process, lease spectrum from an auction winner, or determine that they can use shared unlicensed bands as do many technologies, from Wi-Fi to Bluetooth to fixed wireless broadband connections in rural communities. Particularly given the breadth of non-safety use cases DSRC and C-V2X companies have suggested over the years,\(^{120}\) including infotainment and other commercial ventures, the Commission should not accept at face value these parties’ assertions that they need the Commission to undertake the

\(^{120}\) See NCTA Comments at 22-23 (collecting examples).
extraordinary step of granting auction-exempt dedicated spectrum rights to the 5.9 GHz band for all the services they contemplate.

Indeed, C-V2X advocates like AT&T admit that “licensed spectrum is vital” for C-V2X—it could, for example, serve as a “complement” to the 20 or 30 megahertz of dedicated spectrum that houses the safety functions C-V2X proponents wish to offer. AT&T agrees that messages like “security related communications” can use licensed spectrum outside the 5.9 GHz band, as can applications with “less stringent performance requirements” than basic crash avoidance, and C-V2X could even use licensed spectrum to “extend the range of some V2V enabled applications,” including to “vehicles or other end points” without V2X radios. Licensed spectrum will offer “both safety and traffic efficiency benefits,” such as by redirecting vehicles “away from crash-induced traffic congestion” and by “rout[ing]” the same information to “transportation system operators and public safety users to facilitate better traffic management and public safety emergency response.” 5GAA agrees that C-V2X messages can “rid[e] over existing commercial mobile infrastructure,” especially “with the deployment of 5G networks.”

Even assuming that licensed spectrum cannot offer the “ubiquitous availability” or “degree of reliability” that crash-avoidance services require, that subset of latency-sensitive, safety-critical messages does not require significant amounts of spectrum in the 5.9 GHz band.

NCTA recommends that the Commission should not reserve any additional exclusive V2X spectrum beyond what is needed for safety-critical applications, particularly given C-V2X

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121 AT&T Comments at 14.
122 Id. at 14-15.
123 Id. at 15.
124 5GAA Comments at 15-16.
125 AT&T Comments at 15.
advocates’ admissions that many functions contemplated for the technology can use licensed spectrum. If the Commission decides to do so, however, it should look outside the 5.9 GHz band and, in particular, at the 4.9 GHz band, for the reasons discussed in our opening comments.126 Dynamic Spectrum Alliance agrees that the 4.9 GHz band could be allocated to permit C-V2X to “evolve toward 5G.”127 And OTI and Public Knowledge explain that the band has “50 megahertz of extremely underutilized spectrum” and the “Commission has lamented” the “light usage” of the band to date.128 At least one major V2X proponent, 5GAA, is open to the possibility of the Commission’s “identify[ing] . . . dedicated, mid-band spectrum” outside the 5.9 GHz band for C-V2X’s “evolution to 5G,” though its demand that the Commission do so “simultaneously” with opening the lower 45 megahertz of the 5.9 GHz band for unlicensed is clearly unnecessary given the undeveloped state of V2X technology.129

IV. THE COMMISSION SHOULD NOT ADOPT ANY OF THE VARIOUS PROPOSALS TO FURTHER DELAY PROGRESS IN THE 5.9 GHZ BAND.

Many ITS advocates opposing the Commission’s proposal suggest alternative approaches, all of which appear calculated either to unjustifiably tie the Commission’s hands before it adopts final rules for the full band, or to mire this proceeding in even more delay. The Commission should reject them.

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126 See NCTA Comments at 19.
127 DSA Comments at 6.
128 OTI/PK Comments at 4-5; see also R Street Comments at 10 (“there is nothing stopping the Commission from finding alternative spectrum bands” for V2X).
129 5GAA Comments at 41.
A. The Commission Should Not Delay Its Proceeding to Wait for the Automotive Industry to Decide on a Preferred ITS Technology.

Several commenters ask the Commission either to decide this proceeding prematurely in their favor, or not decide it at all. 5GAA, consistent with its earlier efforts to secure a waiver to operate in the upper 20 megahertz of the 5.9 GHz band, asks the Commission to grant that waiver now, or simply to issue final rules now permitting C-V2X operations in that area of the band. The Commission has not granted that waiver request, and it should not do so now, for the same reasons NCTA explained when 5GAA first filed the petition—the waiver itself seeks inappropriate relief and would interfere with the Commission’s decision-making in this proceeding. Nor should the Commission grant the same relief here by adopting final rules for only part of the band and “resolving the broader questions about the remainder of the band” sometime in the future. We agree with 5GAA that the Commission should act expeditiously in the band, but the proposal to act now on 5GAA’s request for 20 megahertz would prematurely determine the future of the band.

General Motors and Toyota, on the other hand, effectively ask the Commission not to make any decision at all regarding the future of the 5.9 GHz band. General Motors asks the Commission simply to wait until “the transportation community (vehicle manufacturers and infrastructure owner/operators)” are able to “define an industry-wide V2X deployment plan” that “contemplates the necessary items for deployment to be realized.” General Motors assures the

130 See 5GAA Waiver Petition.
131 5GAA Comments at 22-26.
133 5GAA Comments at 22.
134 General Motors Comments at 3-4.
Commission that “a timely plan is possible” to that end, but provides no details on how such a consensus would emerge in the “brief period” it proposes.  

Toya, unlike General Motors, recognizes that “considerable disagreement remains among stakeholders about which communication protocol is preferable” and that industry consensus is unlikely to emerge any time soon.  

Rather than feign General Motors’s optimism, Toyota asks the Commission to do nothing for “perhaps 12-18 months” in hopes that DOT will “identify[] to the Commission” which technology it prefers, at which point the Commission would “incorporate the identified protocol into its rules.”  

As with General Motors, Toyota asks that the Commission take this approach, and further prolong the under-utilization of this valuable spectrum, “with respect to the entire 75 MHz band of spectrum” so that the Commission cannot proceed with its unanimous proposal to permit Wi-Fi in the lower 45 megahertz of the band.

AT&T, meanwhile, offers a hybrid of these other tactics: the Commission should (1) “during the pendency of this rulemaking,” prematurely grant new DSRC licenses in the lower 30 megahertz of the band and “permit the operation of C-V2X” in the upper 30 megahertz; (2) adopt a “transition band plan” to facilitate “continued development for both DSRC and C-V2X,” and (3) “refresh[] the record in this docket after the DOT resolves the technology choice for the band, but no later than in three years.”  

AT&T also suggests—in tension with its preference for DOT to “resolve[] the technology choice for the band”—that the Commission “develop technology neutral service rules for the band that can be used for DSRC and

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135 Id.  
136 Toyota Comments at 27.  
137 Id.  
138 Id. at 28.  
139 AT&T Comments at 5, 24.
C-V2X.” This proposal combines the detriments of the other suggestions—namely, years-long delay—with few virtues. It assumes, for example, that industry will “reconcile issues of interoperability” at some point in the future without any indication how the well-known interoperability hurdles would be overcome. The purpose of these proposals seems to be to ensure that, even though 30 megahertz apparently is enough for either DSRC or C-V2X to develop and deploy, the Commission does not permit unlicensed use of the 5.9 GHz band any time soon.

These requests for delay and for further government mandates have common failings: They do not appreciate the mistakes of the FCC’s 1999 ITS approach, they ask the Commission to repeat those mistakes now, and they do not explain how doing so is consistent with “modern spectrum management best practices.” They also effectively reveal that a divided automotive industry is not close to resolving the conflict between DSRC and C-V2X that stands in the way of V2X deploying in the 5.9 GHz band in a robust way.


Automotive interests also suggest the possibility that the Commission could justify continuing the ITS spectrum reservation by adopting build-out requirements, asserting that these rules would improve the utility of the band. Panasonic, for example, says the Commission “could consider creating build-out requirements for infrastructure and vehicular deployments, where failure to meet such benchmarks would result in a forfeiture of the spectrum,” though it

140 Id. at 24-25.
141 Id. at 25.
142 See, e.g., AGA May 2019 Ex Parte at 7.
does not offer any detail how that forfeiture would function. Toyota suggests that the
Commission consider the “buildout requirements and incentives proposed by the Association of
Global Automakers” in May 2019.144

But Toyota’s proposal would be ineffective, and even if fulfilled would mean it is “very
unlikely that any two vehicles that might be involved in a collision will both be equipped with
vehicle-to-vehicle radios that could prevent it.”145 This is because the Association of Global
Automakers proposal was not a true build-out requirement and lacked a serious enforcement
mechanism. The proposed “interim” requirement was deployment of two million V2X radios
within five years, including aftermarket devices and devices on roadway infrastructure, and the
“final” requirement was deployment of “V2X radios in an amount equivalent to 75% of new
light vehicles sold in the U.S. in the calendar year of the final build-out deadline.”146 The “final”
requirement is not written as an annual deployment commitment, seeming to allow the
“equivalent to 75%” of new vehicles from one calendar year to be spread over the ten-year period. Worse, the penalty for failing to meet the “interim” requirement was simply the
acceleration of the “final” requirement by two years, and the penalty for failing to meet the
“final” requirement was simply that the Commission—in eight or ten years—would “revisit
alternative uses of the 5.9 GHz band.”147 These “requirements” were not even to be imposed on
individual licenses—they were to be imposed “on a collective basis” across the industry,148 a

143 Panasonic Comments at 14-15.
144 Toyota Comments at 28; see AGA May 2019 Ex Parte at 7.
145 Center for Growth Comments at 2.
146 AGA May 2019 Ex Parte at 7.
147 Id.
148 Id.
structure that is inconsistent with Commission practice, would make accountability and enforcement completely unworkable, and would not give any individual company the incentive to make the investments they have so far failed to make but are necessary for full-scale deployment. Adopting the proposal would needlessly add another decade or more of delay to productive use of this spectrum.

Even if V2X licensees collectively complied with the proposed requirements, an insufficient number of vehicles would be equipped with V2X radios to achieve the “critical mass of communicating vehicles” that DOT has said is necessary to “achieve” the technology’s “crash avoidance benefits.” Assuming for purposes of illustration that there are 10 million new car sales by 10 years after the imposition of the proposed requirements, the proposal would amount to only a small fraction of the more than 272 million registered highway vehicles in the United States in 2017. It would be decades at that rate for a critical mass of highway vehicles to have V2X radios, during which time other technological advancements likely will have improved highway safety. Such weak build-out requirements are essentially meaningless and certainly do not inspire confidence that the proposed years of delay would actually lead to widespread V2X deployment. More fundamentally, because V2X technologies do not need 75 megahertz of spectrum to deliver Basic Safety Messages, even if widespread deployment of the technologies in the full band occurred, this would still result in under-utilization of valuable mid-band

149 See U.S. Gov’t Accountability Off., GAO-14-236, Spectrum Management: FCC’s Use and Enforcement of Buildout Requirements, 18 (2014) (describing license termination and other outcomes for licensees that failed to meet build-out requirements).


spectrum. At a time when Americans are relying on online connectivity more than ever, and as we race against the rest of the world to deploy next-generation wireless services, the U.S. cannot afford to risk making the same mistake on this band twice.

Days before the deadline for reply comments, the Auto Alliance filed a letter with a conditional “commitment” that if the “FCC assures” its members that they will have access to the full 75 megahertz of the 5.9 GHz band for both DSRC and C-V2X, they “will commit” to reaching “a total of at least 5 million radios on vehicles and roadway infrastructure . . . including any previous V2X deployments” “[w]ithin 5 years.” 152 This non-binding “collective, industry-wide commitment”153 is no better than the promises of the past addressed above. There is no penalty for companies that fail to meet the requirement. There is no explanation how an industry that cannot even choose between DSRC and C-V2X will collectively ensure individual members follow through with their amorphous obligations. This is public relations, not a build-out requirement or a meaningful commitment.

Most importantly, even if Auto Alliance members did follow through, it would be ineffective. The commitment would result in only a tiny fraction of vehicles on the road even five years from now having either DSRC or C-V2X radios, and these two standards do not interoperate. The chance that two vehicles would both be equipped with a V2X device, and that they would be compatible, would be too low to produce a reliable safety service. The bottom line is that the auto industry’s demand that the Commission grant them the full band, couched as


153 Id.
a weak “commitment,” only reinforces the need for the Commission to move forward with the NPRM proposal as soon as possible.


Many of the V2X proponents oppose the Commission’s proposal to split the band and instead ask that the Commission reconsider detect-and-vacate testing.154 But the years-long record the Commission considered in adopting its proposal is clear that detect-and-vacate is impractical, more complex and expensive, and would drive investment away from the band. In fact, when the Commission released results from Phase I of the testing process, even ITS proponents attacked the detect-and-vacate approach and argued that the laboratory testing showed it was unworkable.155 The argument for further testing of that approach now is therefore curious—it appears unlikely that the commenters asking for the Commission to reconsider detect-and-vacate now would ever be satisfied based on some future testing that unlicensed operations and V2X could share the same spectrum effectively. The bottom line is that co-channel operation of Wi-Fi and safety-of-life V2X would be unnecessarily complex, costly, burdensome, and require heavy-handed regulation that would eviscerate the benefits of opening this important band for Wi-Fi in the first place.156 The Commission should adopt its realistic and workable proposal, and should not further consider the detect-and-vacate approach or support associated testing that would merely waste taxpayer dollars.

154 See, e.g., Auto Alliance Comments at 42-45; General Motors Comments at 15; Toyota Comments at 3-4; ITS America Comments at 10.


156 Id. at 8.
V. THE COMMISSION SHOULD MOVE FORWARD EXPEDITIOUSLY WITH REASONABLE OPERATING RULES FOR THE U-NII-4 BAND.

The record in this proceeding confirms that the Commission should implement in-band technical rules for U-NII-4 that will build on the enormous success of the U-NII-3 band. The Commission should also set reasonable U-NII-4 out-of-band-emission (OOBE) limits that reflect real-world operating environments, and categorically reject ITS proponents’ unsubstantiated OOBE interference claims.


1. The Record Demonstrates that Harmonizing In-Band Rules Will Result in Substantial Benefits.

As described above, the record confirms that the 5.9 GHz band is uniquely positioned to substantially improve Wi-Fi and other unlicensed broadband operations in the near term. Importantly, the record also demonstrates that this will happen if the Commission adopts its proposal to implement in-band rules that align with the long-established technical rules for operations in the 5725-5850 MHz U-NII-3 band.

For example, Broadcom and Facebook explain that “next generation Wi-Fi standards . . . such as Wi-Fi 6” can enable the combined U-NII-3 and U-NII-4 spectrum to significantly “enhance the existing 5 GHz U-NII ecosystem,” provided the new contiguous 160-megahertz channel is not subject to operating constraints. As these companies emphasize, however, the Commission will need to adopt its proposal to implement “consistent technical rules across the U-NII-4 and U-NII-3 bands” in order to “build on the success” of unlicensed operations in

\[157\] See generally Section II.A, supra.

\[158\] Broadcom/Facebook Comments at 2.
U-NII-3 and take full advantage of features including “gigabit connectivity, lower latency, improved coverage and power efficiency.”\textsuperscript{159}

Similarly, Microsoft explains that “extend[ing] the U-NII-3 band technical rules to the U-NII-4 band, except for the existing [OOBE limits],” will enable the public “to realize the maximum benefit” from the U-NII-4 band, including “accelerat[ing] the timeline for initial deployments” using this 45 megahertz of spectrum.\textsuperscript{160} Indeed, establishing “the same power levels in the U-NII-4 band as the U-NII-3 band is essential for . . . larger [high bandwidth Wi-Fi] channels to be highly utilized.”\textsuperscript{161}

Other commenters agree. For example, the Wi-Fi Alliance notes that, to “expand[] operations of existing U-NII devices, the technical rules governing the [U-NII-4] band must be aligned with the rules covering the U-NII-3 band.”\textsuperscript{162} As the Wi-Fi Alliance cautions, “[i]f different power levels or other [in-band] technical rules for the two bands are adopted, U-NII devices will not be able to operate across both the U-NII-3 and U-NII-4 bands, eliminating the potential use of wider channels, equipment commonality, reduced cost and complexity, superior performance and other benefits that may be realized by the Commission’s proposal.”\textsuperscript{163} And the Dynamic Spectrum Alliance likewise notes that “[h]aving the same [in-band] EIRP limits and power spectral density limits” is needed to “simplify the design of Wi-Fi devices operating on

\textsuperscript{159} Id.
\textsuperscript{160} Microsoft Comments at 4, 7.
\textsuperscript{161} Id. at 7.
\textsuperscript{162} Wi-Fi Alliance Comments at 6.
\textsuperscript{163} Id.
the new 20, 40, 80, and 160 MHz channels that span the U-NII-3 and U-NII-4 bands to operate under a single set of technical rules.”164

Finally, WISPA observes that harmonizing the in-band rules is also a “sensible and efficient approach” because the advantages of doing so “apply not just to Wi-Fi equipment designed for short-range transmission, but also to existing equipment authorized in the U-NII bands” that is used to “provid[e] fixed wireless broadband service.”165 Indeed, the Wireless Telecommunications Bureau recently granted a 60-day special temporary authorization for 33 WISPs in rural areas to use the lower 45 megahertz of the 5.9 GHz band.166 As the Bureau’s grant recognizes, this spectrum can be used in the very near term to help address the significant increase in demand for connectivity during the COVID-19 health crisis.167

Thus, for a wide range of unlicensed broadband uses, harmonizing the U-NII-3 and U-NII-4 in-band rules will enable “operation on these frequencies in the newly allocated band [to] be available more quickly and easily.”168

2. No Special Restrictions Are Necessary to Protect Incumbent Satellite Operations.

Incumbent fixed satellite service (FSS) operations in the 5.9 GHz band are “limited to international inter-continental systems . . . subject to case-by-case electromagnetic compatibility

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164 DSA Comments at 4.
165 WISPA Comments at 5-6.
167 Id. at 1.
168 WISPA Comments at 5.
analysis.” As the Commission has explained, moreover, the satellite components of these inter-continental systems necessarily must be “located at longitudes that are not located over the U.S.” Nevertheless, SES and Intelsat argue that the Commission should impose an aggregate emissions limit for ITS and unlicensed operations throughout the U.S. to accommodate these limited uses, and require unlicensed operations to connect to databases to enforce this limit.

The Commission should reject this proposal, as it recently did in the 6 GHz Report and Order, as unnecessary, costly, and detrimental to establishing harmonized operating rules for U-NII-3 and U-NII-4.

As the Commission has recognized, U-NII-4 operations are very unlikely to result in harmful interference to extended C-band FSS operations due to (1) the expected unlicensed use cases, such as terrestrial Wi-Fi, and (2) the significant distance between those operations and FSS satellite receivers, which are located in a geostationary orbit. SES and Intelsat cite a 2018 “Petition for Notice of Inquiry” filed by Globalstar regarding an alleged 2 dB noise rise Globalstar attributes to U-NII-1 devices as evidence that the Commission should treat aggregate interference from terrestrial operations as a “valid[] and serious[]” concern. But as several

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169 NPRM ¶ 49.
170 Id.
172 6 GHz Report and Order ¶¶ 89-92.
173 NPRM ¶ 58.
174 SES/Intelsat Comments at 7.
parties have pointed out in that proceeding, there are many reasons for the Commission to be skeptical of Globalstar’s claims.\textsuperscript{175}

Moreover, while there is no reliable evidence to substantiate Globalstar’s harmful-interference arguments, there is even less reason to believe that Wi-Fi would cause harmful interference to FSS in U-NII-4. Unlike Globalstar’s system, SES and Intelsat’s satellites orbit at over 35,000 kilometers above the Earth.\textsuperscript{176} This is a far greater height than mobile satellites in U-NII-1, which are 1,400 kilometers from the Earth at their closest orbital point.\textsuperscript{177} This distance differential entails significant additional signal spreading loss, such that Wi-Fi signals will be approximately 640 times weaker at the SES and Intelsat satellite receivers compared to even Globalstar’s satellite receivers, where there is no reasonable evidence of harmful interference.\textsuperscript{178}

As set forth in greater detail by a CableLabs/University of Colorado paper previously submitted to the Commission, this distance is one reason why the potential for aggregate interference from unlicensed operations is very low.\textsuperscript{179}

Finally, the Commission should reasonably expect licensees to design their systems to coexist with another co-primary service that has been allocated for more than two decades. SES and Intelsat have had to design systems cognizant of the presence of ITS operations in the band.

\textsuperscript{175} See, e.g., NCTA – The Internet & Television Association Replies to Comments on Petition for Notice of Inquiry, RM-11808 (filed July 23, 2018) (summarizing oppositions to Globalstar’s request).


\textsuperscript{177} Id.

\textsuperscript{178} Id.

\textsuperscript{179} See id.; Rob Alderfer, CableLabs, and Dirk Grunwald and Kenneth Baker, University of Colorado, Toward Expanded Wi-Fi Access in the 5 GHz Band at 56-57, as attached to 2013 NCTA Reply Comments.
Their proposed remedy with respect to ITS—that the Commission “simply decline to authorize additional systems” that transmit basic safety messages once SES and Intelsat’s satellites allegedly experience harmful interference—underscores the unreasonableness of the FSS interests’ position with respect to both ITS and Wi-Fi. The truth is that neither ITS nor Wi-Fi pose a threat of harmful interference to geostationary satellites.


When establishing U-NII-4 OOB-limit rules that provide reasonable protection for incumbents, the Commission should take into account several factors, including the actual likelihood of harmful interference based on the environment in which devices will operate. In addition, it should reject ITS proponents’ unsubstantiated OOB arguments—including those that, if true, would mean that ITS devices could not operate in today’s spectrum environment. Finally, while the Commission should set reasonable baseline OOB limits for all U-NII-4 devices, it should also establish less restrictive limits for indoor operations.

1. CableLabs Analysis Confirms that Adjacent U-NII-4 Devices Operating Under Reasonable Rules Will Not Cause Harmful Interference to 5.9 GHz ITS Services.

In order to accurately assess coexistence feasibility between U-NII-4 and adjacent ITS band operations, the Commission should account for important factors that reflect how devices will operate in real-world conditions. As set forth in the attached technical report, CableLabs has

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180 SES/Intelsat Comments at 8.
conducted detailed analyses of adjacent-band coexistence based on lab testing and city-scale simulations.\textsuperscript{181} This analysis offers several important insights.

\textit{Measuring packet loss is not the same as measuring harmful interference.} While ITS proponents often describe their system performance in terms of packet error rate (PER), PER is at best an imperfect and uncertain proxy for predicting the marginal increase in likelihood of harmful interference attributable to adjacent wireless broadband operations.\textsuperscript{182} This is because the very nature of V2X operations results in increased PER—sometimes quite substantially—when there is vehicular traffic. Robust “city-scale” simulations performed by CableLabs involving more than 22,000 vehicles empirically observed in a typical morning rush hour environment demonstrated that “DSRC average PER can be significant in dense vehicular traffic scenarios” even when no adjacent channel unlicensed operations are present.\textsuperscript{183} Indeed, in real-world scenarios, with many vehicles transmitting and receiving ITS signals on roadways, moving both toward and away from each other, PER will naturally fluctuate. CableLabs’ analysis demonstrates that these PER fluctuations are not, in and of themselves, safety-impacting.

In fact, DSRC—and presumably C-V2X—are specifically designed with the expectation that systems will experience packet loss, and include mechanisms to meet performance expectations under those conditions.\textsuperscript{184} For example, although DSRC is designed to transmit

\textsuperscript{181} See CableLabs Technical Report, Adjacent-Band Coexistence Between Wi-Fi and Intelligent Transportation Systems (ITS) in 5.9 GHz Spectrum (April 2020) (CableLabs Report) (attached as Exhibit A).

\textsuperscript{182} See id. § 6.2.1.

\textsuperscript{183} See id. §§ 7.1-7.3.1.

Basic Safety Messages at a rate of 10 Hz (i.e., ten messages per second), “safety applications have been successfully tested” at 5 Hz—i.e., 50% PER. As CableLabs explains, while some sources indicate that 10% PER is acceptable, others sources, such as a study commissioned for the National Highway Traffic Safety Administration, use a 20% packet loss threshold to define whether an “error” has occurred.

CableLabs’ assessment of DSRC interference risk demonstrates that several real-world factors—each with a very low individual likelihood—must occur simultaneously in order for adjacent channel Wi-Fi operations to result in DSRC PER for a Basic Safety Message that exceeds even the conservative PER 10% threshold. These include a very weak DSRC signal, an extremely strong Wi-Fi signal received at the DSRC device, and very high Wi-Fi channel utilization operating directly adjacent in frequency. The probability of satisfying all of these conditions is approximately 0.0000099% - 0.0001056%. Moreover, should this highly unlikely scenario occur, it would do so when the communicating vehicles are very far apart in physical distance, not in a crash-imminent scenario when low PER is most important.

*Interference analysis should account for real-world factors such as the presence of other traffic.* CableLabs’ analysis included a detailed simulation of traffic behavior and radio propagation between vehicles on roadways to assess performance “in critical vehicular scenarios when collisions are possible.” In addition, CableLabs measured multiple metrics to evaluate

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186 *See* CableLabs Report § 6.2.1 (citing Booz Allen Study at 52).
187 *Id.* § 6.3.3.
188 *Id.*
189 *See id.* § 7.
potential performance impacts, culminating in an aggregate Safety Alert Failure Rate (SAFR) that takes into account transmission, reception, and error probabilities in critical Basic Safety Message transmission situations.\textsuperscript{190} This metric directly captures communications performance when vehicular safety is at risk. Thus, SAFR represents an appropriate metric for assessing ITS safety system performance. In contrast, PER provides little safety-relevant information.

CableLabs simulations concluded that “the existence of Wi-Fi on an adjacent channel . . . does not increase the SAFR.”\textsuperscript{191} This is likely attributable to the fact that emissions from adjacent channel Wi-Fi “appear[] very similar to high density DSRC traffic.”\textsuperscript{192} Moreover, as CableLabs explains, “in critical PER scenarios, vehicles at risk of collision are near one another,” resulting in high signal to noise ratios even in the presence of energy from other sources.\textsuperscript{193}

Importantly, while traffic density had a material impact on the SAFR, the rate at which the adjacent Wi-Fi channel was used did not.\textsuperscript{194} Indeed, CableLabs simulations showed the critical BSM packet reception rate and packet error rate to be “independent of [adjacent] Wi-Fi channel utilization.”\textsuperscript{195} This finding underscores a significant shortcoming of technical analyses submitted by ITS proponents in this proceeding, which generally do not examine

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\item[\textsuperscript{190}] Id. § 7.2.
\item[\textsuperscript{191}] Id. § 7.4.
\item[\textsuperscript{192}] Id.
\item[\textsuperscript{193}] Id.
\item[\textsuperscript{194}] See id.
\item[\textsuperscript{195}] See id. While there was some correlation between adjacent channel Wi-Fi utilization and media access delay for DSRC transmitters, “the maximum observed media access delay is well below the threshold (100ms) at which it may impact DSRC” critical packet transmission rates. Id. at fig. 12.
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communications performance in an operational environment with many vehicular interactions, much less address the operational scenarios that entail collision risk.

*C-V2X, a more modern ITS technology, exhibits better OOBE resilience than DSRC.* CableLabs’ assessment of C-V2X technologies indicates that “C-V2X employs superior signal processing and congestion control that makes it more resilient to OOBE.”196 In particular, C-V2X will “require[] approximately 11 dB less signal-to-noise-ratio (SNR) to maintain PER below 10%,” compared to DSRC.197 Accordingly, as the CableLabs Report explains, because there is “no plausible real-world interference risk to DSRC from adjacent-channel Wi-Fi,” it is reasonable to assume that “C-V2X will remain even more robust to OOBE from adjacent-channel Wi-Fi.”198

2. The Commission Should Not Set OOBE Limits Based on ITS Services that Could Not Even Operate in Today’s Spectrum Environment.

As a result of Commission policies first put in place over two decades ago, Americans use the U-NII-3 band extensively for a wide range of wireless broadband applications—including 5 GHz Wi-Fi, which was standardized in 1999. Indeed, the Commission initiated this proceeding precisely because 5 GHz operations are already “a vital component of the communications landscape”—and will only continue to increase.199 Nevertheless, OOBE arguments from several ITS proponents suggest that the Commission should base its technical rules on the possibility that ITS engineers might design systems that would not be able to operate in today’s spectrum environment. The Commission should disregard any technical assertions

196 Id. § 8.1.
197 Id.
198 Id. § 8.3.
199 NPRM ¶ 6.
made by ITS proponents that—if true—would also mean that the ITS services they are contemplating for use in the 5.9 GHz band would not function regardless of any action the Commission takes in this proceeding.

DOT’s comments include several statements along these lines. For example, DOT claims that “while the increase in OOBE identified in Part 15.407 (issued March 1, 2016) represents an improvement over the OOBE limits allowed for digitally modulated devices in Part 15.247, the new OOBE limits described in Part 15.407 are above the previous levels allowed for U-NII devices, and the level of potential interference has significant potential to disrupt 5.9 GHz band device access to the safety-of-life channel.”

Similarly, DOT argues that the “FCC’s proposed band plan in Appendix B,” which references the existing U-NII-3 OOBE limit at 5925 MHz, should not be adopted because “[t]he FCC’s 2016 changes in the OOBE [rules] result in the high probability of problematic or harmful interference.” The FCC should decline to relitigate its 2016 OOBE decision here.

To be clear: before the FCC harmonized Sections 15.247 and 15.407 of its rules, 5 GHz digitally modulated devices (such as Wi-Fi) using U-NII-3 spectrum could be certified under either section. The longstanding Section 15.247 OOBE limits were higher than the current, harmonized Section 15.407 OOBE limit that DOT continues to argue has the “significant potential to disrupt” ITS.

Indeed, the FCC’s existing U-NII rules have continued to allow many Wi-Fi devices originally certified prior to 2018 using the higher Section 15.247 limits to be manufactured until March 2, 2020.

200 DOT Comments at 54.
201 Id. at 52.
202 Id. at 54.
To the extent there was any ambiguity about the impact of the March 2016 order DOT cites, the Commission reiterated in that same order that “DSRC systems will receive greater interference protection” under the current emissions mask that DOT is objecting to in this proceeding “than was provided under the old rules.”  

It is simply inconceivable that ITS interests have been designing systems that are incompatible with the longstanding Section 15.247 OOBE limits that applied to millions of already-deployed unlicensed broadband devices that could be manufactured up until March of this year, let alone the more protective limit the Commission put in place in 2016, and that applies to all newly manufactured devices as of March 3. Nevertheless, several ITS proponents have proposed OOBE limits for U-NII-4 devices that, if actually necessary, would mean exactly that.

For example, General Motors maintains that the OOBE limit for U-NII-4 devices should be -17 dBm/MHz for the first 10 MHz above the band edge, and -27 dBm/MHz thereafter.  In other words, according to GM, maximum allowed energy from a U-NII-4 device would need to be approximately 15 dB lower at 5905 MHz than the energy emitted from a U-NII-3 device at that very same frequency. IEEE 1609 WAVE and Volkswagen go even further, suggesting that U-NII-4 devices comply with a -40 dBm/MHz limit at 10 MHz above the band edge. This would mean that a U-NII-4 device’s OOBE limit at 5905 MHz would need to be approximately

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205 General Motors Comments at 11.

28 dB lower than the existing limit that applies to millions of Wi-Fi devices today at that very same frequency. Most egregiously, however, 5GAA claims that “allowing noise above -27 dBm/MHz into the ITS band from unrestricted unlicensed uses outdoors”—which the FCC’s existing rules have expressly permitted for years—“will cause harmful interference to C-V2X.”\textsuperscript{207} Although 5GAA has proposed a more relaxed mask for indoor-only U-NII-4 operations, 5GAA argues that devices such as mobile hotspots that operate adjacent to C-V2X would need to meet an OOBE limit of -60 dBm/MHz—at least 33 dB lower than the limit that currently applies to millions of U-NII-3 devices for unwanted emissions into any portion of the ITS band.\textsuperscript{208}

In other words, ITS interests have called for unlicensed device emissions limits for U-NII-4 that are many, many times lower than the limits that have applied for years to millions of existing U-NII-3 devices at those very same frequencies. Either these limits are unnecessary to protect ITS services, or the longstanding spectrum environment in the 5.8 GHz and 5.9 GHz bands will disrupt the planned ITS services regardless of any action the Commission takes in this proceeding. If the latter is true, the Commission should reconsider whether it is even possible for ITS services to fulfill the safety functions that they plan. If these systems cannot operate reliably even in today’s wireless environment, the Commission should conclude that ITS safety services should not exist in any part of the 5.9 GHz band, and move the service to other frequencies.

\textsuperscript{207} 5GAA Comments at 44 n.129.

\textsuperscript{208} See 5GAA Comments at 43 n.126 (citing Letter from 5G Automotive Association to Marlene H. Dortch, Secretary, FCC, ET Docket No. 18-295, GN Docket No. 17-183 (filed Jan. 24, 2020)).
3. ITS Proponents’ Technical Analyses Are Flawed.

Many U-NII-4 opponents cite a December 2019 “Pre-Final” National Highway Traffic Safety Administration Report for the proposition that unlicensed Wi-Fi operations cannot co-exist adjacent to ITS operations in the 5.9 GHz band.\(^{209}\) But as NCTA explained in detail in its opening comments, this report contains numerous and substantial flaws.\(^{210}\) For similar reasons, the Commission should not rely on other new analyses offered by ITS interests when establishing OOBÉ limits for U-NII-4 devices.

First, DOT, state transportation officials, and several other commenters cite a December 2019 DOT “preliminary technical assessment” of OOBÉ.\(^{211}\) This four-page document, which DOT characterizes as a “white paper,”\(^{212}\) consists primarily of screenshots of plots from a spectrum analyzer depicting emissions from Wi-Fi, DSRC, and C-V2X devices. Based on these plots, DOT asserts that “the three devices cannot co-exist in the same band.”\(^{213}\) But screenshots of spectrum plots are not harmful interference analyses. DOT’s assessment does not even attempt to account for adjacent channel emissions rejection performance from these devices, let

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\(^{209}\) See, e.g., DOT Comments at 47; Comments of the National Transportation Safety Board (NTSB) at 4, ET Docket No. 19-138 (filed Mar. 4, 2020); Comments of Continental AG at 7, ET Docket No. 19-138 (filed Mar. 9, 2020); General Motors Comments at 11; Comments of the Intelligent Transportation Society of Michigan at 3-4, ET Docket No. 19-138 (filed Mar. 9, 2020); Comments of the American Trucking Ass’n at 4-5, ET Docket No. 19-138 (filed Mar. 9, 2020).

\(^{210}\) See NCTA Comments Section VI.C. and Exhibit A.


\(^{212}\) DOT Comments at 49.

\(^{213}\) Id. at 49.
alone evaluate ITS safety message transmission, reception, and error probabilities in real-world environments.

DOT also cites “version 0.5” of a recent draft report regarding the effects of U-NII-3 devices on DSRC. This draft report focuses primarily on co-channel DSRC operations with Wi-Fi, which are not contemplated by the Commission’s proposal and not at issue in this proceeding. Nevertheless, DOT argues that its draft, which includes “some preliminary findings on adjacent channel interference,” also “[e]stablishes a foundation” for future testing. This is not the case.

DOT’s field measurements involved Roadside Unit (RSU) transmissions to DSRC on-board units. However, RSUs do not transmit basic safety messages, and the communications DOT evaluated were not safety critical. Even then, DOT’s findings do not represent real-world operating environments. For example, DOT set the Wi-Fi device radiated transmit power at 35 dBm—near the radiated maximum specified by the current U-NII-3 rules. But as NCTA has previously explained, the rules allow this power only when using antennas with directional gain. This means that peak power levels can occur only at a fraction of the elevation angles of

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215 See NPRM ¶ 10 (“Given the limited scope of DSRC deployment within the U.S. to date and the complexities that sharing entails, we are skeptical that delays to accommodate further testing are warranted—despite the fact that ongoing testing has shown promising results.”).

216 DOT Comments at 48.


218 See id. at 240.

219 NCTA Comments at 53.
the Wi-Fi access point, and in many other directions gain will be less. DOT did not account for this in its analysis. In addition, DOT assumed a constant Wi-Fi load of 15%, far higher than the average activity determined by empirical real-world measurements. Further, with respect to DSRC devices, DOT appears to be testing receivers that are several dB more sensitive than the -92 dBm value specified in the SAE J2945/1 standard. Moreover, DOT’s field test involved only two DSRC transceivers (the roadside unit and the automobile on-board unit). Thus, DOT failed to account for the presence of traffic, even though intra-system DSRC signals themselves are likely to be the cause of measurable packet error rate increases when many vehicles are present.

DOT’s repeated offerings of incomplete and otherwise deficient “draft,” “preliminary,” and “pre-final” analyses do not mean that the Commission should defer acting on U-NII-4. As the FCC has recognized, after two decades, it is now time “[t]o ensure that the American public can reap the utmost utility from the 5.9 GHz band with minimal further delay.”

Finally, Ford Motor Company submits a new report that it claims shows that U-NII-4 Wi-Fi operations will “render the ITS channels unusable for safety applications.” In reality, Ford tested only a signal generator—i.e., not even an actual Wi-Fi access point—located inside

220 See CableLabs Report § 6.2.4.2 (“Empirical 5 GHz Wi-Fi activity data from 500,000 APs measured over ten days reveals that the 99th percentile peak Wi-Fi activity level is in fact 7%, and the weighted average activity factor is 0.4%.”); see also Letter from Rob Alderfer, Vice President, Technology Policy, CableLabs to Marlene H. Dortch, Secretary, FCC, ET Docket No. 18-295, GN Docket No. 17-183 (filed Dec. 20, 2019).

221 See 2020 U-NII-3 Draft Report at 235, Figure 9-83.

222 See Section V.B.1., supra; CableLabs Report § 7.

223 NPRM ¶ 10.

an automobile.\textsuperscript{225} This is of limited value for several reasons. First, Ford assumes that the interference received at the C-V2X antenna is -38 dBm, and extrapolates packet error rates at several distances based on this value.\textsuperscript{226} But -38 dBm is a substantially higher received power level than could reasonably be expected from outdoor/roadside Wi-Fi access points.

Indeed, CableLabs’ measurements of 50,000 Wi-Fi access point downlink sessions set forth in the attached report revealed that worst-case outdoor Wi-Fi received signal strengths at an ITS receiver are very likely to be at least 15-30 dB lower.\textsuperscript{227} As CableLabs explains, “-53 dBm represents the strongest 1.5% of these measurements, and -68 dBm represents the strongest 16% of measurements.”\textsuperscript{228} And, of course, signals received from indoor Wi-Fi operations would be even more attenuated.

In addition, Ford’s use of a signal generator means that the transmissions it tested might bear little resemblance to real-world Wi-Fi radios. For example, Ford does not even discuss the assumptions that it made about Wi-Fi duty cycle. But 90% of the time, Wi-Fi duty cycles will be 1% or less.\textsuperscript{229} This is an especially important consideration for the in-vehicle Wi-Fi use case. Because in-vehicle Wi-Fi systems are backhauled by cellular networks, the likelihood that the end-to-end system could support the substantial data transfers needed to produce a high duty cycle on the in-vehicle Wi-Fi link is very low.

\textsuperscript{225} See Impact of U-NII-4 Band Wi-Fi Adjacent Channel Interference on 5.9 GHz V2X Safety Systems at 15-16 (Ford Report), as attached to Ford Comments.

\textsuperscript{226} Id. at 27-28.

\textsuperscript{227} CableLabs Report § 6.2.4.3.

\textsuperscript{228} Id.

\textsuperscript{229} Declaration of Joseph Padden ¶ 8, as attached to NCTA Comments.
Finally, Ford’s tests used an assumed OOBE limit of -27 dBm/MHz at 5925 MHz—\textsuperscript{230}the very same OOBE limit at 5925 MHz that applies to millions of U-NII-3 devices that Americans use every day. As noted above, if the existing OOBE limit at this frequency is truly a problem with respect to real-world Wi-Fi operations rather than a signal generator, it will be a problem regardless of any action the Commission takes in this proceeding. If Ford’s results suggest that future safety-of-life ITS operations will not be able to operate reliably even if the Commission does not open the 5.9 GHz band to unlicensed devices, then the Commission should consider moving the entire ITS service to other frequencies, as noted above.

4. **The Commission Should Establish Baseline OOBE Limits for All Devices, as Well as Less-Restrictive Limits for Indoor Operations.**

There is virtually unanimous agreement in this proceeding that signals from indoor operations in the 5850-5895 MHz band will be substantially attenuated.\textsuperscript{231} For example, Wi-Fi Alliance explains that the “signal energy and corresponding OOBE levels [of indoor U-NII-4 devices] will be largely contained within the building structure,” and “would be further attenuated by propagation, polarization-mismatch, clutter-effects and other losses.”\textsuperscript{232} Making conservative assumptions about these factors results in an “aggregate attenuation . . . exceed[ing] 20 dB.”\textsuperscript{233} Indeed, even ITS advocates such as 5GAA acknowledge that “indoor use potentially would allow the FCC to adopt a more relaxed mask for U-NII-4 operations than what is needed

\textsuperscript{230} See Ford Report at 16.

\textsuperscript{231} See, e.g., DSA Comments at 5 (“Taking building entry loss and the physical separation from ITS systems into account for indoor devices should allow for significant relaxation in the emissions mask while maintaining robust protection for ITS communications.”); Broadcom/Facebook Comments at 6; NCTA Comments at 49-50; Comcast Comments at 11.

\textsuperscript{232} Wi-Fi Alliance Comments at 7-8.

\textsuperscript{233} Id. at 8.
outdoors to protect C-V2X Direct because the unlicensed signals will be attenuated by Building Entry Loss (‘BEL’).”

This does not mean, however, that the Commission should impose an indoor use restriction on all devices. Rather, as multiple comments have suggested, the Commission can most effectively account for the substantial building entry loss and other indoor operation factors by establishing baseline OOBE limits for U-NII-4 devices, as well as less-stringent limits for devices that operate exclusively indoors. For example, Wi-Fi Alliance proposes that, for “an indoor device, all emissions at or above 5.925 GHz shall not exceed an EIRP of -7 dBm/MHz increasing linearly to 15 dBm/MHz at 5.895 GHz.”

Opponents of outdoor operations argue that an indoor use restriction is appropriate, in part, because most Wi-Fi use occurs indoors today. There is no question that indoor use—including consumer devices in residences and businesses—represents an important use case for unlicensed broadband. But as the Commission has recognized in the U-NII-1 context, providing additional flexibility for outdoor unlicensed operations—even if this means adopting separate rules for indoor use—also leads to substantial benefits, because “[u]nlicensed communication links are included in a wide variety of devices which are increasingly mobile or portable in

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234 5GAA Comments at 47.
235 Cf., e.g., 5GAA Comments at 41; Cisco Comments at 16; Qualcomm Comments at 19.
236 See, e.g., Wi-Fi Alliance Comments at 8; DSA Comments at 5; Broadcom/Facebook Comments at 6; see also Comcast Comments at 11. Moreover, as the Commission recognized in the 6 GHz proceeding, these limits “should be verified using an RMS detector or other appropriate techniques for measuring average power” with respect to emissions into the ITS band, because 5 GHz measurement guidance specifying peak power “was instituted to mitigate a known interference issue with federal radars” that are not present in the 5.9 GHz band. 6 GHz Report and Order ¶ 198.
237 Wi-Fi Alliance Comments at 8.
238 See, e.g., 5GAA Comments at 42.
nature.” As others have explained, moreover, outdoor uses that would benefit from unlicensed gigabit broadband in the near term also include fixed wireless broadband as well as industrial uses such as smart city, smart agriculture and precision farming. Smart city applications like security, metering, utility and infrastructure monitoring, and others will improve energy and cost efficiency for cities and their residents. Enhancements to precision agriculture will benefit the entire industry, and small farms in particular. The Commission’s technical rules should accommodate these important uses.

VI. **ADOPTING THE NPRM PROPOSAL WILL RESULT IN SIGNIFICANT ECONOMIC BENEFITS.**

A. **Recent Empirical Research Confirms that Permitting Unlicensed Operations in the Lower 45 Megahertz of the 5.9 GHz Band Will Create Tens of Billions of Dollars in Economic Benefits in the Near Term.**

NCTA’s opening comments summarize existing research demonstrating that Wi-Fi and other unlicensed technologies contribute hundreds of billions of dollars in economic value, including widely cited research from Dr. Raul Katz. Dr. Katz has now completed a new quantification of a subset of the diverse economic benefits of unlicensed use of the 5.9 GHz band.

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241 *See, e.g., WISPA Comments at 1-6; OTI Issue Brief at 20-22.*

242 OTI Issue Brief at 22.

243 *See NCTA Comments at 27-29.*
band, in order to provide a partial, but more specific, valuation of this band.\textsuperscript{244} Dr. Katz estimates that permitting unlicensed use even in only the lower 45 megahertz of the band will generate approximately $30 billion in economic benefits between 2020 and 2025, relying on several conservative assumptions.\textsuperscript{245}

Dr. Katz estimates those benefits by analyzing three sources of economic value: (1) the “impact on GDP yielded by an increase in average broadband speed” enabled by next-generation, wide-bandwidth Wi-Fi that could operate on the new 160-megahertz channel spanning U-NII-3 and U-NII-4, (2) the “consumer surplus derived from faster average broadband speed,” and (3) the “producer surplus generated by the sale of new Wi-Fi equipment enabled by the additional unlicensed channels.”\textsuperscript{246} Dr. Katz explains that the equipment-sales component of his total will stem from both the Commission’s proposed actions in this proceeding and the Commission’s actions in the 6 GHz proceeding, making it difficult to apportion precisely that value between this proceeding and the 6 GHz proceeding.\textsuperscript{247} Thus, of the approximately $30 billion contribution Dr. Katz estimates, the roughly $1.5 billion attributable to that component “results from the combined effect of” the 5.9 GHz and 6 GHz spectrum proposals.\textsuperscript{248}

With respect to GDP contribution, Dr. Katz explains how existing research “uniformly concludes that faster Internet access has a positive impact on GDP growth,”\textsuperscript{249} making it an


\textsuperscript{245} \textit{See id.} at 4-5, 40.

\textsuperscript{246} \textit{Id.} at 11.

\textsuperscript{247} \textit{See id.} at 7; \textit{see also id.} at 11-14 (explaining methodology).

\textsuperscript{248} \textit{Id.} at 12.

\textsuperscript{249} \textit{Id.} at 15.
“appropriate way to measure” at least some of “the benefits of introducing unlicensed operations in the 5.9 GHz band.” Wireline broadband providers have invested heavily in delivering gigabit speeds to homes and businesses, and are deploying 10G over DOCSIS as they continue to push fiber to the home, which will enable 10-gigabit speeds for consumers. But as fewer and fewer devices are even capable of connecting via an Ethernet cord to the internet, Wi-Fi must be able to pass through that capacity and speed to users. And unless the Commission makes additional unlicensed spectrum available, spectrum limitation will result in a “network bottleneck” that prevents the delivery of those multi-gigabit speeds. Because U-NII-4 spectrum will help relieve that bottleneck (largely through the availability of a new 160-megahertz channel that enables gigabit to multi-gigabit Wi-Fi speeds), it will lead to “higher adoption of ultra-fast broadband” and substantial economic benefits. Using this methodology, Dr. Katz estimates a likely GDP contribution of approximately $7.2 billion (and up to $14 billion) in 2022 alone, with a total likely GDP contribution of more than $23 billion between 2022 and 2025 based on the lower baseline assumption.

With respect to consumer surplus, Dr. Katz explains how, even accounting for the “highly concave” curve describing consumer valuations of broadband speeds above 100 Mbps (i.e., as bandwidth increases, willingness to pay for even more bandwidth decreases), consumer surplus of approximately $1.6 billion (and “likely” up to $3.2 billion) in 2022 is expected as

\[ \text{250} \] NPRM ¶ 65.
\[ \text{251} \] See Assessing Value of 5.9 at 17-18.
\[ \text{252} \] Id. at 19.
\[ \text{253} \] Id. at 28-30. Dr. Katz separately analyzes the savings in capital expenditures cellular carriers will realize from offloading of traffic to Wi-Fi, but does not include them in the total economic benefits to avoid double-counting to the extent that saving is realized in contribution to GDP. See id. at 40, 58 tbl. 5-1.
consumers receive increased broadband speeds simply through “increased router throughput.”254

The total consumer surplus between 2022 and 2025 based on the baseline assumption would likely reach approximately $5.1 billion.255

Dr. Katz estimates that U.S. manufacturers of equipment will also benefit from the ability to market “equipment enabled by the 45 MHz in 5.9 GHz” and spectrum opened up in the 6 GHz proceeding, with a total producer surplus between 2020 and 2025 of approximately $1.5 billion.256 Though this effect stems both from the Commission’s 5.9 GHz proposal here and from the 6 GHz Report and Order, its impact here is significant.

These findings—a conservative estimate of approximately $30 billion in economic benefits between 2022 and 2025—demonstrate several concrete ways in which the NPRM proposal will provide benefits to the U.S. economy.257 Using likely, real-world assumptions would increase the total by nearly $9 billion in 2022 alone, and likely tens of billions between 2022 and 2025.258 And the total economic contribution very likely reaches beyond these measurements: Dr. Katz mentions, but does not himself measure, for example, benefits from “the broadband speed impact on enterprise productivity.”259 This research confirms the great benefits to be realized when the Commission adopts its proposal.

254 Id. at 19, 30, 33.
255 Id. at 34.
256 Id. at 35-37.
257 As discussed above, a small percentage of this total is partially attributable to the Commission’s decision in 6 GHz.
258 See id. at 24, 29-30 & tbls. 3-5 & 3-8 (identifying likely scenarios from assumptions that are likely, but less conservative than the baseline assumptions).
259 Id. at 21.
B. Commenters Opposing the NPRM Proposal Improperly Assess Its Supposed Costs.

A number of V2X proponents argue that the benefits of unlicensed use in the 5.9 GHz band are outweighed by costs associated with adopting the NPRM proposal. These arguments are unpersuasive. Because V2X safety functions can be provided in the 30 megahertz the Commission proposes to set aside for ITS use, and because the use cases envisioned for non-safety ITS can be provided through other technologies or different licensed or unlicensed spectrum bands, the economic costs associated with the Commission’s proposal are limited to transition costs for the existing DSRC pilot projects. Furthermore, the one cost that these commenters are able to quantify—the small cost associated with transitioning current DSRC deployments by state departments of transportation and DOT in the band to more productive use—reinforces how little DSRC has progressed in the 20 years since the Commission provided dedicated spectrum for its use. As the attached analysis from Coleman Bazelon and Paroma Sanyal illustrates, the benefits of adopting the NPRM proposal far outweigh the minimal actual costs associated with doing so.

The Auto Alliance and Panasonic argue that the Commission must consider the Value of a Statistical Life (VSL) and quantify safety benefits foregone by adopting the NPRM proposal. But this argument—that the Commission must consider foregone safety benefits—ignores that the NPRM proposal would reserve more than enough spectrum for actual safety-of-life messages to be transmitted. In other words, because the safety benefits associated with V2X can be

260 See Coleman Bazel & Paroma Sanyal, The Economics of Unlicensed and Dedicated Use Spectrum in the 5.9 GHz Band (Apr. 27, 2020) (Brattle 5.9 GHz Analysis) (attached as Exhibit B).

261 See Auto Alliance Comments at 36-40; Panasonic Comments at 10-11.

262 See Brattle 5.9 GHz Analysis at 5-7.
provided in 30 megahertz and any non-safety benefits that V2X might provide can be provided using other technologies or licensed spectrum bands, the only economic costs to opening 45 megahertz of the band for unlicensed use are transition costs.

Individual commenters also commit serious errors in reaching the various figures they attempt to categorize as “costs” of this kind. Auto Alliance, for example, argues that “V2X deployment could yield a recurring benefit of over $192 billion per year” based on assumptions that (1) vehicle deaths will remain constant despite the significant improvements in highway safety technologies, (2) V2X technologies will reach “full deployment” soon, and (3) those technologies will successfully “eliminat[e] . . . half of auto fatalities.” It does not justify any of those assumptions, and as Brattle’s economic analysis explains, the assumption regarding traffic fatalities is unfounded and there is no cost to safety in the NPRM proposal, given that reserving 30 megahertz for safety ITS is sufficient to preserve all safety benefits. DSRC Auto Safety Coalition commits a similar error in asserting a cost of “up to $836 billion in damages due to loss of life, lost economic activity, and decreased quality of life, including unrealized cost savings from ameliorating traffic congestion.” But the NPRM proposal reserves spectrum for crash-avoidance, meaning any safety benefits from V2X will still be realized, and DSRC Auto Safety Coalition supplies no evidence for the unlikely proposition that 5.9 GHz spectrum in particular is needed to ameliorate traffic congestion. Indeed, AT&T explains that the opposite is

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263 Auto Alliance Comments at 38-39.

264 For example, the National Safety Council, on which the Auto Alliance relies (see id. at 6, 38), shows that auto fatalities have fallen 30% since peaking in 1972. This suggests that fatalities would continue to fall even without these new DSRC measures, a fact that the Auto Alliance ignores in its analysis. See National Safety Council, Injury Facts: Overview https://injuryfacts.nsc.org/motor-vehicle/overview/introduction/ (last visited Apr. 26, 2020).

265 Brattle 5.9 GHz Analysis at 8-12.

true, as licensed spectrum is capable of addressing “traffic congestion” by redirecting cars around accident areas and “rout[ing]” information to “transportation system operators and public safety users.”\textsuperscript{267} Others like ITS America,\textsuperscript{268} Toyota,\textsuperscript{269} and Hyundai\textsuperscript{270} make similar arguments that fall prey to the same fallacies—AASHTO even asserts based on similar reasoning that the NPRM proposal “puts potential benefits of over $1 trillion annually in safety and an additional $140 billion in congestion costs at risk.”\textsuperscript{271} These inflated numbers are not serious economic analyses, as they do not consider what safety and other benefits will be realized from increasing the amount of V2X spectrum allocated for safety purposes to 30 megahertz or whether the non-safety benefits envisioned can be provided through other technologies or using licensed spectrum bands.

Some commenters, like DOT and the DSRC Auto Safety Coalition, also argue that the Commission should consider “sunk costs to research and implementation to date,” including the investments made by state highway and transportation departments.\textsuperscript{272} DOT includes in those “sunk costs” approximately $700 billion in funding directed at pilot projects that have not successfully led to adoption of DSRC. But as Brattle explains, “[p]ast investments are sunk and

\textsuperscript{267} AT&T Comments at 14-15.
\textsuperscript{268} ITS America Comments at 25-27 (asserting economic benefits of “safer transportation,” “enhance[d] mobility and alleviat[ing] congestion” and “reduc[ing] harmful emissions”) (cleaned up).
\textsuperscript{269} Toyota Comments at 19-20 (arguing that the Commission should consider costs to safety, fuel efficiency, and responses to public safety and emergency situations).
\textsuperscript{270} Hyundai Comments at 17-18 (arguing that the NPRM proposal would incur costs from losses including to transportation efficiency, environmental preservation, “decreasing automobile crashes”).
\textsuperscript{271} AASHTO Comments at 20-21.
\textsuperscript{272} DOT Comments at 17; see DSRC Auto Safety Coalition at 13.
should not be taken into account when comparing the costs and benefits of the reallocation.”273 Not only would those sunk costs also be attributable to replacing C-V2X with DSRC, regardless of whether unlicensed operations are permitted in the band, but these costs are associated with investment in research that likely could “still be used for the same purpose going forward” with C-V2X, making it “not a net cost” in the first place.274

Rather, as Brattle explains, “[t]he only relevant costs when measuring the tradeoff between benefits and costs of the NPRM’s proposed sharing of ITS spectrum are the costs of transitioning the ITS applications from a dedicated 75 megahertz to a dedicated 30 megahertz.”275 DOT argues that the costs of converting existing DSRC operations to be capable of using C-V2X technology are approximately $500 million, or up to $645 million.276 Brattle explains that this cost is “likely overestimated,” as DOT’s analysis does not account for factors like how far along various planned projects have progressed.277 But even if that estimate is correct, it is a powerful argument for just how little ITS interests, including state highway and transportation departments, have invested in the band despite twenty years of spectrum subsidy and government financial support. And for the Commission’s consideration of costs and benefits, it is clear that the tens of billions of dollars gained by permitting unlicensed operations in even the lower 45 megahertz of the 5.9 GHz band “would be expected to far outweigh the minimal . . . costs” of transitioning existing deployments.278

273 Brattle 5.9 GHz Analysis at 13.
274 Id.
275 Id.
276 DOT Comments at 17, 36-39.
277 Brattle 5.9 GHz Analysis at 14-15.
278 Id. at 21.
VII. THE COMMISSION HAS CLEAR LEGAL AUTHORITY TO UPDATE THE RULES FOR THE BAND AND MOVE FORWARD.

Some ITS proponents attempt to cast doubt on the Commission’s authority to move forward in this proceeding. None of their arguments are persuasive—the Commission has authority to adopt the NPRM proposal, and it should do so.

A. The Commission Has Authority to Modify Existing Road-Side Unit Licenses.

The Auto Alliance, ITS America, AASHTO, and several other commenters argue that the Commission cannot modify existing RSU licenses consistent with the NPRM proposal, arguing that it would be an impermissible “fundamental change” to those licenses.279 But these arguments either ignore or misunderstand the Commission’s precedent interpreting Section 316, for reasons already discussed at length in our opening comments.280

The Auto Alliance and some others argue that “DSRC licensees” such as state transportation departments would not be able to “provid[e] safety critical communications using V2X technologies,” in particular because they would not be able to serve all “use cases” contemplated in their plans.281 This is wrong for several reasons. As discussed above, existing RSU licensees—the only parties whose interests are relevant for purposes of Section 316—can deliver safety-of-life services in 30 megahertz of spectrum. It is irrelevant whether they could

279 See Auto Alliance Comments at 33-35; ITS America Comments at 13-15; AASHTO Comments at 15; General Motors Comments at 13 & n.25; Comments of the Pennsylvania Department of Transportation at 9, ET Docket No. 19-138 (filed Mar. 9, 2020); Comments of the Utah Department of Transportation at 9-10, ET Docket No. 19-138 (filed Mar. 9, 2020) (Utah DOT Comments).

280 See NCTA Comments at 30-43.

281 Auto Alliance Comments at 34-35; see AASHTO Comments at 15 (arguing 30 megahertz would be insufficient for “effective deployment of the planned safety applications”) (emphasis added); General Motors Comments at 13 n.25 (arguing 30 megahertz would not be sufficient for “innovative” new applications or “V2X technologies” in general).
hypothetically provide other services in that spectrum, whether they be entertainment or more advanced driving features that might develop in the future. The Commission has already explained that the question for Section 316 purposes is whether they can deliver their current services. Moreover, because Section 316 applies only to licensees—not users of devices permitted under Part 90 like on-board units—the question for Section 316 purposes (distinct from the policy questions in this proceeding) is not whether on-board units (OBUs) can exchange V2V communications in the 30 megahertz, but whether individual RSU licensees can deliver their existing messages (e.g., presumably, infrastructure-to-vehicle messages) in 30 megahertz. They clearly can, as existing RSU deployments are sparse and focused on delivery of a tiny percentage of V2X messages on which ITS proponents wish to focus.

ITS America argues that the NPRM proposal must be a fundamental change simply because of the percentage of the band that would remain available. The Commission has also recently rejected that mode of analysis, explaining that Section 316’s functional test is not based on an “arbitrary numerical limit.” That is enough for the Commission to reject this argument, but we note that ITS America’s premise—that the Commission would be reducing existing licensees’ spectrum “by 86 percent” (from 75 megahertz to 10 megahertz for DSRC)—is incorrect. If the Commission split the 30 megahertz of ITS spectrum between C-V2X and


283 See NCTA Comments at 35-37 (explaining that OBUs are not licensed and thus do not require any modifications under Section 316).

284 ITS America Comments at 14; see also Utah DOT Comments at 9-10.

285 C-Band Order ¶ 138.

286 ITS America Comments at 14; see also Utah DOT Comments at 9.
DSRC as described in the NPRM, existing ITS licensees would still have access to the
20 megahertz for C-V2X, as well as the bottom 45 megahertz of the band on an unlicensed basis
because unlicensed spectrum can be used by virtually any technology so long as it meets the
FCC’s flexible Part 15 requirements. Accordingly, the “reduction” in spectrum is far less drastic
than ITS America suggests.287

Finally, the Auto Alliance argues that the NPRM proposal will “result in pervasive,
harmful cross-channel interference,” which itself would effect a fundamental change to
licenses.288 This argument commits the same errors discussed previously in this section,
 focusing on general concerns regarding harmful interference (e.g., from one licensed-by-rule
OBU to another licensed-by-rule OBU) rather than harmful interference to transmissions from
RSUs. Moreover, it is simply incorrect on its own terms regarding the risk of harmful
interference, as discussed in Section V, supra.

B. No Statute Prevents the Commission from Proceeding or Requires It to Defer
to DOT.

A handful of commenters repeat arguments similar to those raised by the Amateur Radio
Emergency Data Network (AREDN)289 that the Transportation Equity Act for the 21st Century
requires the Commission to allocate a certain amount of spectrum for V2X or more generally to

287 See Auto Alliance Comments at 35 (agreeing that “updating the rules” in ITS spectrum to
“permit C-V2X” would not be a fundamental change, as it “would allow for provision of
substantially the same service, V2X, merely using a different technology”); NCTA
Comments at 43 (explaining that existing licenses “grant permission to operate in the
Intelligent Transportation Service,” not to use a particular technology).

288 Auto Alliance Comments at 35.

(filed Feb. 7, 2020).
defer to DOT in this area. Cisco, for example, argues that because Congress directed the Commission to “consider” allocating spectrum for ITS before January 1, 2000, the Commission “must explain” why adopting the NPRM proposal would “continue to foster the objectives identified by the US DoT in its implementation of this Congressional action.” That conclusion simply does not follow from the premise, as NCTA explained in its opening comments. The Transportation Equity Act did not revoke the Commission’s authority over spectrum allocation, mandate a particular result, require that the Commission continue down a particular path more than twenty years later, or require deference to DOT in this area.

ITS America argues that the NPRM proposal “would not satisfy the requirements of Section 1 of the Communications Act,” the statute enumerating the various purposes for which Congress created the FCC. ITS America appears not to go so far as asserting that Section 1 itself requires a particular spectrum allocation, but rather that it requires the Commission to defer to DOT. Section 1, of course, requires neither of those things. While the Commission must consider the purposes for which it was created, including public safety, the NPRM affirms the Commission’s commitment to “traffic safety.” And the record certainly supports the Commission’s conclusion that reserving 30 megahertz of spectrum for ITS serves the interests of public safety, as discussed above. ITS America cannot bootstrap Section 1 to argue that the

\[\text{See Cisco Comments at 5-6; Comments of the Georgia Department of Transportation at 11, ET Docket No. 19-138 (filed Mar. 9, 2020); ITS America Comments at 12-13.}\]

\[\text{Cisco Comments at 6.}\]

\[\text{See NCTA Comments at 33.}\]

\[\text{ITS America Comments at 12; see 47 U.S.C. § 151.}\]

\[\text{ITS America Comments at 12-13; see also IEEE 1609 Comments at 8, 10.}\]

\[\text{See, e.g., Mozilla Corp. v. FCC, 940 F.3d 1, 59-60 (D.C. Cir. 2019).}\]

\[\text{NPRM ¶ 18.}\]
Commission is forever barred from changing the allocation for spectrum that is—and has been for 20 years—vacant at practically all times and in practically all locations. As the Commission explains, its proposal in fact reserves more spectrum for ITS purposes (30 megahertz) than “the amount that was dedicated for public safety purposes on Channels 172 and 184 (20 megahertz).”297 That is on top of the Commission’s other recent actions to make large amounts—5 gigahertz—of spectrum available for vehicular radars and other features that, unlike DSRC to date, have “materially and significantly advanced overall automotive safety, generally surpassing many functions that were originally envisioned to be performed by DSRC.”298

C. The NPRM Proposal Is Not Arbitrary and Capricious, or an Unlawful Departure from Previous Policy.

Finally, some commenters threaten that adopting the NPRM proposal might be arbitrary and capricious or an unlawful departure from previous policy. The DSRC Auto Safety Coalition (some of whose members, like Honda and Toyota, are members of multiple other filers like ITS America and the Auto Alliance) rattles the saber of “litigation risk,” arguing that the Commission “fails to acknowledge” the potential for harmful-interference and “fails to seek comment on the broader risks its proposal will have on public safety.”299 It makes this assertion even though a substantial record has already developed on how the Commission can adopt technical rules that will prevent harmful interference to ITS. And the DSRC Auto Safety Coalition, in the same breath, argues that “DOT and other stakeholders” have commented on vehicular-safety issues pertinent to this proceeding.300 Even a cursory review of the large

297 Id. ¶ 31 n.66.
298 Id. ¶ 4.
299 DSRC Auto Safety Coalition Comments at 23, 24.
300 Id. at 23.
volume of comments from DSRC proponents, C-V2X proponents, and Wi-Fi advocates reveals that numerous commenters are providing the Commission their views, data, and analysis on out-of-band emissions, emissions limits, and how much reserved spectrum (if any) ITS technologies need to deliver safety-of-life benefits. DSRC Auto Safety Coalition also argues that the Commission “fails to consider the significant investments” that have been made in developing the limited DSRC deployments present today, but that is simply not the case. The Commission is proposing to continue to reserve a significant amount of spectrum for ITS technologies and actively seeking comment on how it can maximize the potential of that spectrum for safety-of-life uses. The fact that DSRC Auto Safety Coalition or its members do not agree with the Commission’s proposal does not mean that the Commission is veering outside the “heightened degree of deference” it is entitled to in “spectrum reallocation” decisions, an area within its unique “expertise.”

VIII. CONCLUSION

Today, Americans rely on Wi-Fi connections more than ever before. For millions of households, Wi-Fi is the essential connection to their broadband network. For business, it is critical to reaching customers, managing operations, and tracking inventories. Cellular networks will offload even more traffic to unlicensed networks as they transition to 5G. And the public health crisis has deepened our country’s reliance on Wi-Fi, as we all use Wi-Fi to stay connected to workplaces, schools, and doctors.

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301 Id. at 23-24.
303 Teledesic LLC v. FCC, 275 F.3d 75, 84 (D.C. Cir. 2001).
The Commission has correctly recognized that additional unlicensed spectrum is essential to meeting increasing traffic demands and bringing Wi-Fi 6 to the nation. The Commission’s proposal to permit unlicensed operations in the lower 45 megahertz of the 5.9 GHz band is therefore a wise compromise that will help address significant current and near-term Wi-Fi spectrum needs, while preserving the ability of V2X technologies to deliver crash-avoidance services in the future. While the Commission could realize even greater economic benefits by opening the entire 5.9 GHz band for unlicensed use, NCTA strongly supports the Commission’s moving forward with the NPRM proposal.

It is no surprise that the ITS interests who first secured the DSRC allocation 20 years ago continue to defend the exceptional spectrum subsidy the Commission gave them in 1999 (and the basis for continued direct financial subsidy from DOT). But the record makes clear that the 30 megahertz the Commission proposes to reserve for ITS is more than sufficient to enable ITS companies to deliver the crash-avoidance applications that they argue can only be realized in the 5.9 GHz band. The record confirms that the Commission should reject ITS delay tactics, adopt its proposal to open the lower 45 megahertz of the 5.9 GHz band to unlicensed services, establish reasonable technical rules, and proceed to a final order as soon as possible.

Respectfully submitted,

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EXHIBIT A
Technical Report

Adjacent-Band Coexistence Between Wi-Fi and Intelligent Transportation Systems (ITS) in 5.9 GHz Spectrum
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1. **INTRODUCTION**

This technical report examines adjacent-channel coexistence between Wi-Fi and Intelligent Transportation Systems (ITS) operating in the 5850 – 5925 MHz wireless frequency band (the 5.9 GHz band). This research is undertaken to determine the impact to ITS of expanding Wi-Fi access into this band, consistent with FCC proposals in both 2013 and 2019.¹ This report contributes unique technical insights into the potential for adjacent-channel spectrum sharing in 5.9 GHz based on comprehensive and novel research.

2. **SCOPE**

The benefits of expanding Wi-Fi access into 5.9 GHz are well-established and a primary driver of FCC action. In addition, a long-held spectrum allocation for ITS has been underdeveloped by Dedicated Short Range Communications (DSRC), the ITS technology developed within IEEE standards that has not been widely deployed into vehicular infrastructure as envisioned by its proponents. New ITS technologies from the 3GPP family of standards – primarily cellular vehicle-to-everything (C-V2X) – have been developed that are incompatible with current FCC regulations. Others have covered this regulatory history at length,² and we do not elaborate further in this technical report.

Instead, we contribute unique technical insights related to adjacent-channel spectrum sharing between Wi-Fi and ITS in 5.9 GHz. We study 5.9 GHz with Wi-Fi operating in the

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² See 5.9 GHz NPRM at paras. 3-8.
5850-5895 MHz sub-portion of 5.9 GHz, with ITS operating in 5895-5925 MHz, in accordance with FCC proposals. Within this frequency structure we analyze the potential for harmful interference from Wi-Fi to ITS, with a primary focus on the crash-avoidance vehicular safety systems that we assume will operate in the 5895-5925 MHz sub-band. CableLabs undertakes its studies through lab measurements, risk-informed analysis, and city-scale simulation. Together, these approaches provide a comprehensive view of real-world interference risk to ITS from adjacent-channel Wi-Fi.

3. REFERENCES

5GAA, “V2X Functional and Performance Test Report; Test Procedures and Results”, 5GAA P-190033, April 11, 2019


Letter from Rob Alderfer, Vice President, Technology Policy, CableLabs to Marlene H. Dortch, Secretary, Federal Communications Commission FCC, ET Docket No. 18-295, GN Docket No. 17-183, (Dec. 20, 2019)


Booz Allen Hamilton, Dev. of DSRC Device & Commc’n Sys. Performance Measures: Recommendations for DSRC OBE Performance & Sec. Requirements, Dep’t of Transp. FHWA-JPO-17-483


Ford Motor Company, “Impact of U-NII-4 Band Wi-Fi Adjacent Chanel Interference on 5.9 GHz V2X Safety Systems” (March 9, 2019)

G. Pei and T. R. Henderson, “Validation of ofdm error rate model in ns-3,” Boeing Research Technology

Pang, Yimin and Padden, Joey and Alderfer, Rob, Sophisticated Spectrum Sharing Analysis: The Case of the 5.9 GHz Band (March 14, 2018). TPRC 46: The 46th Research Conference on Communication, Information and Internet Policy 2018


“Tests Confirm That 5.9 GHz Rechannelization Protects Adjacent-Channel DSRC Safety Operations”, as attached to, Letter from Paul Margie, Counsel to NCTA, to Marlene H. Dortch, Secretary, FCC, ET Docket No. 13-295 (dated June 28, 2017)


3.1. STANDARDS

1609.4-2016 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE)

3GPP TS 22.185 version 14.3.0 Release 14

802.11ac-2013 - IEEE Standard for Information technology--Telecommunications and information exchange between systems

SAE-J2945 - Dedicated Short Range Communication (DSRC) Systems Engineering Process Guidance

SAE-J2735 - Dedicated Short Range Communications (DSRC) Message Set Dictionary

802.11p-2010 - IEEE Standard for Information technology-- Local and metropolitan area networks
## 4. **ACRONYMS**

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>3GPP</td>
<td>Third Generation Partnership Project</td>
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<tr>
<td>5GAA</td>
<td>5G Automotive Association</td>
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<tr>
<td>BSM</td>
<td>Basic Safety Message</td>
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<tr>
<td>C-V2X</td>
<td>Cellular Vehicle-to-Everything</td>
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<tr>
<td>dBm</td>
<td>Decibel milliwatts</td>
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<tr>
<td>DoT</td>
<td>Department of Transportation</td>
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<tr>
<td>DSRC</td>
<td>Dedicated Short Range Communications</td>
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<td>EDCA</td>
<td>Enhanced Distributed Channel Access</td>
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<td>FCC</td>
<td>Federal Communications Commission</td>
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<tr>
<td>GHz</td>
<td>Gigahertz</td>
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<td>HARQ</td>
<td>Hybrid Automatic Repeat Request</td>
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<tr>
<td>IEEE</td>
<td>Institute of Electrical and Electronics Engineers</td>
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<tr>
<td>INET</td>
<td>Internet Networking simulator</td>
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<tr>
<td>ITS</td>
<td>Intelligent Transportation Systems (including DSRC and C-V2X)</td>
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<tr>
<td>LOS</td>
<td>Line of Sight</td>
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<tr>
<td>MAC</td>
<td>Media Access Control</td>
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<tr>
<td>Mbps</td>
<td>Megabits per second</td>
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<td>MHz</td>
<td>Megahertz</td>
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<tr>
<td>ms</td>
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<td>NHTSA</td>
<td>National Highway Traffic Safety Administration</td>
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<td>NLOS</td>
<td>Non-Line of Sight</td>
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<td>OBU</td>
<td>On-board Unit</td>
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<tr>
<td>OMNeT++</td>
<td>Objective Modular Network Testbed in C++</td>
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<tr>
<td>OOBE</td>
<td>Out-Of-Band Emissions</td>
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<tr>
<td>PER</td>
<td>Packet Error Rate</td>
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<td>SIFS</td>
<td>Short Interframe Space</td>
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<td>SNR</td>
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<td>SUMO</td>
<td>Simulation of Urban Mobility</td>
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<td>UDP</td>
<td>User Datagram Protocol</td>
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<td>VEINS</td>
<td>Vehicles in Network Simulation</td>
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5. EXECUTIVE SUMMARY

The FCC has proposed to expand Wi-Fi access into the 5.9 GHz band, from 5850-5895 MHz, while maintaining a primary spectrum allocation for ITS in 5895-5925 MHz. This action would enable improved performance for existing and new Wi-Fi devices while authorizing new ITS technologies. An important consideration related to this action is the potential for harmful interference to ITS from adjacent-channel Wi-Fi operations. This potential is not new, since Wi-Fi currently operates up to 5850 MHz, the lower band-edge for ITS under existing FCC rules. Nevertheless, it is appropriate to examine adjacent-channel system interactions as the FCC considers a reconfiguration of the 5.9 GHz band.

CableLabs has comprehensively studied the potential for harmful interference to ITS through lab measurements, risk-informed interference analysis, and city-scale simulation.

Lab measurements used both prototype and commercially-available ITS (DSRC) products and prototype Wi-Fi equipment to determine the adjacent-channel system interactions that would yield DSRC packet error rate (PER) of at least 10%, a conservative threshold for ITS harmful interference suggested by DSRC advocates. Using these lab results, we then determine the real-world likelihood of these system interactions using relevant empirical data related to relative signal strength, spectrum availability, and Wi-Fi activity levels, consistent with recommendations by the FCC’s Technological Advisory

3 5.9 GHz NPRM (2019)

4 See, e.g., 82 FR 3854, Notice of Proposed Rulemaking, Federal Motor Vehicle Safety Standards; V2V Communications; Docket No. NHTSA–2016–0126, National Highway Traffic Safety Administration (NHTSA), Department of Transportation (DOT), at p.3884 (“The agency is proposing to require that a message packet error rate (PER) is less than 10%. We believe that 10% PER is an appropriate threshold and that vehicles will still be able to receive the basic safety messages so long as the PER is below 10%.”).
Council.\textsuperscript{5} This contextual data provides an accurate perspective of the likelihood of adjacent-channel interference to ITS.

We focus entirely on the impact of outdoor Wi-Fi deployments, which have zero building entry loss, and will be deployed closer to roadways than indoor Wi-Fi access points, thus representing a potentially challenging coexistence environment relative to indoor Wi-Fi. This focus on outdoor deployments is designed to address potential worst-case coexistence scenarios, even though many Wi-Fi deployments are indoors. Furthermore, this work utilizes out-of-band emissions (OOBE) that are equivalent to existing UNII-3 products and standards, which exceed the -27 dBm/MHz band-edge standard proposed in the 2019 NPRM.\textsuperscript{6} We nevertheless find that these outdoor Wi-Fi deployments entail a de minimis probability of DSRC PER exceeding 10%, which we find to be no greater than 0.0001%. This low level of risk is dwarfed by other sources of error within DSRC itself. For instance, GPS is required in ITS systems for vehicular location accuracy, however GPS receivers may be unavailable in urban canyons, with an average outage rate of 1.5% to 2%.\textsuperscript{7} This makes GPS availability 2 million times more likely to impact the DSRC safety efficacy relative to the potential for adjacent channel Wi-Fi interference.

We also study the potential for adjacent-channel interference in an actual field deployment scenario – again, focused exclusively on the challenging outdoor Wi-Fi

\textsuperscript{5} See, \textit{e.g.}, \textit{A Quick Introduction to Risk-Informed Interference Assessment}, The Spectrum and Receiver Performance Working Group of the Federal Communications Commission Technological Advisory Council, April 15, 2015.

\textsuperscript{6} The UNII-3 requirements in CFR 47 Part 15.407, require OOBE of -27 dBm/MHz beginning at 75 MHz above the band edge. In contrast, the NPRM proposal is for -27 dBm/MHz to start just 30 MHz away from the carrier edge. Our testing and simulation used a Wi-Fi signal that would comply with UNII-3 rules but would exceed the proposed level in the NPRM. However, despite using a more relaxed OOBE mask, our results show that the probability of interference is de minimis.

deployment case - by constructing a large-scale simulation of Wi-Fi and ITS (DSRC) interactions in a city, using actual roadway and vehicular traffic measurement data. In doing so, we can refine the relevant metric for harmful interference by focusing on vehicular interactions that entail a risk of collision. By examining wireless system interactions in these risky vehicular scenarios, we provide a novel and highly informative perspective on harmful interference to ITS in the context of its safety applications, which are of highest interest to policymakers. We define this risk-informed safety metric as the Safety Alert Failure Rate (SAFR), and through our city-scale simulation, we determine that Wi-Fi has no discernible impact on SAFR, which is instead heavily influenced by vehicular traffic loads and associated DSRC wireless transmissions.

We therefore determine that adjacent-channel Wi-Fi poses no meaningful risk of harmful interference to DSRC. We further observe that C-V2X technologies have been demonstrated to be more robust and resilient to adjacent-channel noise than DSRC. This report therefore concludes that there is no risk of harmful interference to any ITS technology from adjacent-channel Wi-Fi operations. We therefore recommend that the FCC expand Wi-Fi access into 5.9 GHz in accordance with its proposal.

Subsequent sections of this report detail these technical studies.

6. LAB TESTING AND RISK-INFORMED ANALYSIS

Lab testing of adjacent-channel coexistence was performed with Wi-Fi and DSRC products, in order to determine how Wi-Fi OOBE impacts DSRC transceiver performance,

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8 This section details analysis that was previously filed in the FCC record; See, “Tests Confirm That 5.9 GHz Rechannelization Protects Adjacent-Channel DSRC Safety Operations”, as attached to, Letter from Paul Margie, Counsel to NCTA, to Marlene H. Dortch, Secretary, FCC, ET Docket No. 13-295 (dated June 28, 2017) (“2017 Coexistence Analysis”).
specifically PER. These lab results were then anchored to real-world metrics to determine the likelihood of such results arising the real world. This provides a risk-informed perspective on interference, consistent with current best practice in spectrum policy.9

6.1. METHODOLOGY

Wi-Fi transmissions were measured to determine at which point DSRC PER exceeded 10% when configured with the Wi-Fi channel directly adjacent (lower adjacent in this case) to the DSRC channel. However, these lab results are not instructive on their own. Instead, lab measurements properly form the basis of risk-informed analysis, to obtain a probabilistic view of interference risk. That is, CableLabs used the lab measurements as an input to quantify the real-world likelihood of Wi-Fi / DSRC system interactions resulting in DSRC PER exceeding 10%. Lab measurements provide device performance information, which can then be considered alongside other system interaction parameters that influence real-world interference outcomes, including Wi-Fi and DSRC operational signal levels, likelihood of next-adjacent channel operation, and Wi-Fi activity levels.

6.2. LAB TESTING

CableLabs obtained the lowest operational signal level of DSRC in order to anchor its findings to the most sensitive operation of the system, and also examined stronger DSRC signals. Wi-Fi activity levels, signal strength, and spectral separation were varied to determine the configurations in which DSRC PER was 10% or higher.

6.2.1. PER as an Imperfect Key Performance Indicator

PER is often used by DSRC system architects as a proxy for system performance. We explain why that is in this section, and why it provides an overly simplified perspective on ITS safety system efficacy.

The IEEE 1609.4 standard divides DSRC transmissions into 100 millisecond intervals. V2V safety warning services are provided in a single dedicated 10 MHz channel in order to increase the reliability of transmissions. Use cases can involve communications between vehicles moving at high relative velocity, and safety warnings must be delivered in a timely fashion. The use of a single channel for this service ensures that all vehicles are tuned to the same frequency to exchange information. This V2V information exchange occurs through Basic Safety Messages (BSMs). BSMs contain all relevant information to provide safety warnings between vehicles, such as geographic coordinates, heading, acceleration, and other key information. This information is transmitted every 100 milliseconds, or 10 times every second. This transmission rate makes DSRC fault-tolerant; over several seconds a BSM can be transmitted dozens of times, greatly enhancing the probability of successful communication and the provision of safety warnings to drivers.

PER is expected and designed into the DSRC system. The appropriate PER level must be viewed in the context of V2V system circumstances. Vehicles that are farther from each other can tolerate higher PER in their DSRC communications because they are at lower risk of collision. The opposite is also true: Vehicles that are close in proximity are more at risk of collision and therefore require lower PER to ensure the successful provision of BSMs, leading to driver warnings as necessary. Furthermore, PER can be expected to increase during high vehicular traffic scenarios given the continuous retransmission protocol utilized; in that sense, PER is an anticipated feature of ITS.
Furthermore, PER in the DSRC context is often discussed in simple two-vehicle examples. However, in the real world, cars will be exchanging BSMs with many other cars simultaneously. In this scenario, PER is no longer single value, it becomes a unique value per vehicle pair. Further, it is clear that some PER values are then more consequential to safety than others; the PER between cars moving towards each other is likely more important than PER between cars moving away from one another.

PER, on its own, is therefore not a perfect indicator of DSRC system efficacy. The function of the DSRC safety system is to provide warnings to drivers to enable collision avoidance; PER provides an indication of communications performance, but no context on impact to the delivery of warnings to the driver (who must also take action, by braking, for instance, in response to a warning). Indeed, it is anticipated that the vast majority of DSRC transmissions will result in no driver warnings, and high PER in these circumstances will have no impact on safety outcomes.

Given these uncertainties about the utility of DSRC BSMs relative to vehicular context, there is some dispute on the proper PER threshold for evaluating acceptable radio performance. Some sources indicate that 10% PER is generally accepted, others use 20% or higher thresholds.10

Recognizing that PER is an imperfect and uncertain proxy for DSRC system efficacy, we nevertheless utilize 10% PER as our figure of merit in lab tests for our immediate purposes in this section. This provides a conservative perspective on coexistence,

maintaining DSRC communications efficacy even when it may not be required for safety purposes.

6.2.2. Devices Under Test

Wi-Fi (802.11ac) and DSRC products were used for testing; the Wi-Fi transmitter utilized specialized firmware in order to enable operation in the 5.9 GHz band.\textsuperscript{11}

6.2.3. Lab Equipment

Tests were conducted in a controlled environment using an anechoic chamber. CableLabs’ anechoic chamber is a Rhode & Schwarz (R&S) TS8991 OTA Performance Test System model WPTC-M certified for frequencies between 600MHz and 18 GHz. This chamber allows for very high isolation of the inside environment, enabling precise control of the interference environment created for our testing. Signals were fed into the anechoic chamber via an R&S Open Switch (OSP 130) system which allows for programmatic control of chamber RF inputs and outputs.

Signal levels at the DSRC receiver under test were measured and system settings were calibrated using a R&S FSV7 signal and spectrum analyzer. The FSV7 input was connected to the same RF cable used for testing to ensure calibration precision. RF signal levels were controlled with 1 dB precision via Keysight 8494B and 8495B step attenuators calibrated from DC to 18 GHz.

\textsuperscript{11} CableLabs is committed to vendor neutrality and as a matter of practice does not publicly attribute performance characteristics to specific devices or manufacturers.
6.2.4. Test Setup

Tests were structured to represent conservative system interactions from the perspective of interference to DSRC.

6.2.4.1. DSRC Signal Levels

DSRC is at highest risk of adjacent-channel interference when operating at its lowest signal levels, which can also be understood as its maximum effective range (physical distance). Vehicle-to-vehicle safety communications in the field will operate at this signal level only when they are relatively distant; that operational scenario also implies significant PER tolerance, such that levels exceeding 10% are unlikely to impact safety outcomes.\(^\text{12}\)

DSRC devices under test operated with less than 10% PER at a minimum signal level of -88 dBm RSSI.\(^\text{13}\) Testing was also conducted at DSRC RSSI up to -63 dBm. These signal levels are contextualized by a NHTSA pilot program that captured DSRC RSSI across a range of driving scenarios, including deep urban, major urban thruway, major roads, and local roads.\(^\text{14}\) The local road driving scenario was the most sensitive of these road scenarios, with a larger number of observations at lower RSSI levels. Measured RSSI levels are shown in Figure 1 below. -88 dBm test levels correspond to the weakest 2\% of signals in the NHTSA local road pilot, while -63 dBm captures all measured RSSI.

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\(^{12}\) Estimates of effective communications range at low signal levels vary between 300 meters and 900 meters. The former estimate is found in "NHTSA V2V Pilot". The latter estimate is found in the Booz Allen Report.

\(^{13}\) Note that while this is above the -92 dBm receiver sensitivity required by SAE J2945, this is the lowest the DSRC device could achieve in our calibrated test environment.

\(^{14}\) NHTSA V2V Pilot
6.2.4.2. Wi-Fi Activity Levels

Wi-Fi activity was varied from 10% to 30% to 100%; all values represent a very intensive usage environment, and one that is more aggressive than what we know to be the case in active Wi-Fi networks. Empirical 5 GHz Wi-Fi activity data from 500,000 APs measured over ten days reveals that the 99th percentile peak Wi-Fi activity level is in fact 7%, and the weighted average activity factor is 0.4%.\(^{15}\)

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\(^{15}\) Letter from Rob Alderfer, Vice President, Technology Policy, CableLabs to Marlene H. Dortch, Secretary, Federal Communications Commission FCC, ET Docket No. 18-295, GN Docket No. 17-183, (Dec. 20, 2019) (“2019 Wi-Fi Activity Data”). Note that this empirical Wi-Fi activity data was gathered after lab testing and after our 2017 Coexistence Analysis; therefore, that Analysis contains different Wi-Fi activity data assumptions. Our 2019 Wi-Fi Activity Data is an authoritative view sourced directly from active cable Wi-Fi networks, and is therefore used in this Technical Report.
6.2.4.3. Wi-Fi Signal Strength

Wi-Fi received signal strength was varied between -72 dBm and -53 dBm as measured at the DSRC receiver operating at its lowest RSSI (-88 dBm). Wi-Fi RSSI was also taken to -28 dBm when DSRC signals were tuned more strongly (-63 dBm). These represent very strong Wi-Fi signals, as judged by empirical RSSI measurements from Wi-Fi access points. 50,000 field measurements were taken on outdoor 5 GHz AP downlink sessions from the network of a cable operator. This dataset is represented in the cumulative distribution function depicted below. -28 dBm is stronger than any Wi-Fi signals observed in operational networks; -53 dBm represents the strongest 1.5% of these measurements, and -68 dBm represents the strongest 16% of measurements.
Figure 3 – Cumulative Distribution Function of Measured RSSI in Outdoor Wi-Fi Networks

Note that these Wi-Fi signal strength measurements are taken from outdoor Wi-Fi networks; indoor Wi-Fi networks will have lower RSSI at DSRC OBU's due to building entry loss.

6.2.4.4. Spectral Separation

DSRC experiences highest OOB E from adjacent-channel Wi-Fi operating in 20 MHz channelization.\textsuperscript{16} Testing was therefore conducted in this configuration. Wider Wi-Fi channels of 40, 80 or 160 MHz result in lower OOB E to the next adjacent channel. The plot below depicts this dynamic, and represents the masks defined by IEEE 802.11ac-2013; actual Wi-Fi products typically perform better than this standard.

\textsuperscript{16} Ford Motor Company, “Impact of U-NII-4 Band Wi-Fi Adjacent Channel Interference on 5.9 GHz V2X Safety Systems”, p.22, Figure IV-5, as attached to Comments of Ford Motor Company in ET Docket 19-138 (March 9, 2019).
6.2.5. Measurement Results

DSRC PER exceeded 10% only when operating at its lowest signal level of -88 dBm, and only when Wi-Fi was on the next adjacent channel in the following configurations:

- -68 dBm at full (100%) duty cycle
- -58 dBm at 30% duty cycle
- -53 dBm at 10% duty cycle

---

17 Relative channel power based on 100kHz resolution bandwidth calculations.
DSRC PER exceed 10% when operating at -63 dBm RSSI only when Wi-Fi RSSI was at least -35 dBm. Since this extremely strong Wi-Fi signal is not observed in real-world empirical data, we disregard this finding for any further analysis, and instead focus only on the lowest DSRC RSSI scenarios.

These measurement results represent a strong basis for optimism for DSRC system performance in the presence of adjacent-channel Wi-Fi. PER exceeded 10% only when DSRC was operating at its lowest signal level, or maximum range, and only when Wi-Fi signals were very strong and much more active than is typical. We analyze this more systematically in the next section.

6.3. RISK-INFORMED ANALYSIS

Lab measurements provide the first step in obtaining a realistic assessment of interference risk. We can characterize the likelihood of high PER (>10%) system interactions manifesting in the field by anchoring our results to relevant empirical observations. This approach enables the interpretation of lab measurements in a manner that is informative for assessing the true level of interference risk.

6.3.1. Overview

As noted by de Vries (2015) and other scholars, quantitative risk assessment provides an objective basis for decision making across many fields of study, from finance to food safety. Its application in spectrum policy is relatively new, and its importance has grown as the demand for spectrum across sectors and systems has also grown in recent years. Traditional methods of ‘worst-case’ analysis provide a simplified view that often leads to overly protective policies that reduce spectral utility. While it is useful to explore these worst-case scenarios, it is also important to assess their likelihood and impact in order to
come to appropriate policy conclusions. This section endeavors such an effort, using our conservative lab measurements as a basis.

6.3.2. Analytic Inputs

The following parameters are used in the risk-informed analysis:

- Lab Test Results
- Wi-Fi Activity Factor
- Wi-Fi Signal Levels
- DSRC Signal Levels
- Wi-Fi Spectrum Availability

We describe each of these factors and their influence on risk-informed interference conclusions in the following sub-sections.

6.3.2.1. Lab Test Results

Lab testing reveals system configurations that cause DSRC PER to exceed 10% - a conservative proxy of interference to DSRC systems, as described above. DSRC PER exceeded 10% only when operating at its lowest signal level of -88 dBm, and only when Wi-Fi was on the next adjacent channel in the following configurations:

- -68 dBm at full (100%) duty cycle
- -58 dBm at 30% duty cycle
- -53 dBm at 10% duty cycle

As the DSRC signal level increased in our testing, the Wi-Fi signal needed to produce 10% PER increased in matching (or greater) steps. This data is not presented here because the Wi-Fi signal levels in the data presented above already fall in the lower percentiles. Said differently, our results show the Wi-Fi signal level needed to produce
10% PER becomes less and less likely as DSRC signal strength increases. From a risk informed analysis perspective, 10% PER interference scenarios with elevated DSRC signal strength (and thus elevated Wi-Fi signal levels) are less likely than the scenario presented.

6.3.2.2. Wi-Fi Activity Factor

Wi-Fi activity was varied from 10% to 30% to 100% in lab measurements. Empirical observations of Wi-Fi activity factors shows that the 99th percentile peak is 7% activity; the weighted average in these actual networks is 0.4%. This empirical distribution represents real-world likelihood of different Wi-Fi activity levels. The cases tested here represent less than 1% likelihood.

6.3.2.3. Wi-Fi Signal Levels

Wi-Fi received signal strength was varied between -68 dBm and -53 dBm as measured at the DSRC receiver. As described above, -53 dBm represents the strongest 1.5% of these measurements, and -68 dBm represents the strongest 16% of measurements. These percentiles are used as probabilities in this analysis.

6.3.2.4. DSRC Signal Levels

DSRC devices under test operated with less than 10% PER at a minimum signal level of -88 dBm RSSI; lab measurement was also performed at -63 dBm RSSI. As described above, based on the NHTSA V2V Pilot program RSSI measurements, -88 dBm corresponds to 2% of field measurement points for DSRC operations, representing the real-world likelihood of this RSSI level. -63 dBm represents the entire distribution of field measurements, so this parameter can be conceived here as 100% likely. We incorporate these likelihood values into our view of interference risk in Section 6.3.3.
6.3.2.5. Wi-Fi Spectrum Availability

Lab tests were performed with no spectral separation on the immediately adjacent channel using 20 MHz Wi-Fi channelization. Wi-Fi also operates on up to twenty-eight 20 MHz channels across the 2.4 GHz and 5 GHz bands. Therefore, the likelihood of operation on the channel immediately adjacent to DSRC is approximately 3%. The availability of 6 GHz spectrum, recently designated by the FCC for shared unlicensed use, will more than double the amount of total spectrum available to Wi-Fi and therefore reduce risk by more than half of what we account for here.18

6.3.3. Probabilistic Interference Risk

These parameters can be combined to provide a holistic view of interference risk to DSRC from adjacent-channel Wi-Fi under conservative parameters.

18 The potential availability of 6 GHz for Wi-Fi does not negate the value of releasing the 5.9 GHz band, since 5.9 GHz can be adopted in a large embedded base of deployed Wi-Fi devices, subject to vendor support for software updates.
<table>
<thead>
<tr>
<th>Probability Factor</th>
<th>Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) -88 dBm (or less) DSRC RSSI</td>
<td>2.2%</td>
</tr>
<tr>
<td>(b) -53 dBm (or more) to -68 dBm Wi-Fi RSSI</td>
<td>1.5% - 16%</td>
</tr>
<tr>
<td>(c) Wi-Fi operating on adjacent channel</td>
<td>3%</td>
</tr>
<tr>
<td>(d) Wi-Fi operating at 10% or higher activity</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>COMBINED PROBABILITY (a<em>b</em>c*d)</td>
<td>0.0000099% - 0.0001056%</td>
</tr>
</tbody>
</table>

Table 1 - Probabilistic Interference Risk

The table above depicts the worst-case interactions based on our measurements and empirical anchors; other variations across analytic dimensions yield results that are similar or even less likely to occur.

We therefore observe that Wi-Fi / DSRC system interactions resulting in PER exceeding 10% are less than 0.0001% (one ten thousandth) likely, which corresponds to a one in a million chance.\(^{19}\) Note that this is very low likelihood is simply that of exceeding 10% PER, which we observed previously is an imperfect and conservative proxy for assessing DSRC system performance. In particular, we note that at the low DSRC RSSI levels implied in these probabilities, vehicles are likely to be very far apart in physical distance.

\(^{19}\) Note that our 2017 Coexistence Analysis had a slightly different quantitative conclusion due primarily to the use of different data pertaining to Wi-Fi activity. See FN 15 of this Technical Report.
and at no risk of collision. Also, other factors, such as GPS failure, are over a million times more likely to impact the safety efficacy of the DSRC system.²⁰

6.4. LAB TESTING AND RISK-INFORMED ANALYSIS

CONCLUSIONS

Lab measurements recorded Wi-Fi / DSRC system interactions where DSRC PER exceeded 10%, a conservative and imperfect proxy for DSRC system efficacy. Anchoring these results to empirical observations enables a realistic view of the likelihood of system interactions arising, consistent with spectrum policy best practice. In examining the real-world levels of DSRC and Wi-Fi RSSI, Wi-Fi activity levels and spectrum availability, we find that the likelihood of DSRC PER exceeding 10% is not higher than 0.0001%, or one in a million. We further observe that the impact of DSRC PER exceeding 10% is not necessarily indicative of system failure; the potential impact of Wi-Fi is in fact far lower than the impact of limited GPS availability on DSRC performance. Furthermore, the fault-tolerant nature of DSRC will enable timely provision of safety warnings to drivers in many cases when PER exceeds 10%.

We therefore conclude based on lab testing and risk-informed analysis that there is no material risk of adjacent-channel interference impacting DSRC.

²⁰ NHTSA V2V Pilot
7. CITY-SCALE SIMULATION21

The lab measurement and analysis we outline above provides a reliable indication that Wi-Fi will not cause harmful interference to DSRC. To bolster this finding, we also examine the real-world performance of DSRC and the effect of adjacent-channel Wi-Fi through a city-scale simulation. This approach enables a dynamic view of Wi-Fi and DSRC in an actual cityscape, taking lab measurement into the field virtually by observing the effect of Wi-Fi on DSRC-equipped vehicles as they drive around a city transmitting and receiving BSM signals. This approach not only enables observation of DSRC / Wi-Fi system interaction in an operational environment, but it also allows for observation of DSRC system performance in critical vehicular scenarios when collisions are possible.

7.1. OVERVIEW

We simulate Wi-Fi / DSRC adjacent-channel interaction in the Italian city of Bologna with real-world empirically measured traffic data, involving more than 22,000 vehicles in a typical morning rush hour, with Wi-Fi APs deployed around the city. We investigate the impact on DSRC safety alert efficacy under key performance metrics, including a novel metric that provides a quantitative assessment of DSRC performance in the presence of Wi-Fi when vehicular collisions are possible. We title this metric the Safety Alert Failure Rate (SAFR), and it enables an appropriate assessment of the potential interference to the system outcome of policy concern, in a more accurate and tailored fashion than existing metrics such as PER.

7.2. METHODOLOGY

As described further below, we first conducted device measurements in an anechoic chamber, examining DSRC system tolerance to adjacent-channel Wi-Fi transmissions. We then built a simulation of DSRC and Wi-Fi radio models and compare DSRC PER as simulated to those as measured to ensure our simulation is at least as sensitive to adjacent-channel interactions as are actual devices. Simulated radio interactions were then adopted at city-scale, with outdoor Wi-Fi APs scattered around the Italian city of Bologna, and we incorporated an empirical vehicular traffic dataset to determine radio interactions in a field environment. We record PTR, PRR, and PER, and observed those metrics in vehicular scenarios where there is a risk of collision; from this we derive a new performance metric aligned with risk-informed techno-policy analysis, which we call SAFR. SAFR captures DSRC BSM performance under risky traffic conditions, providing a metric aligned with real-world safety concern.

7.2.1. Lab Measurements

Before we perform our simulation at the city scale, we conducted a unit test in the lab to compare our simulator with real world devices. Testing described in Section 6.2 of this report was also used to anchor our simulation. We briefly restate the key elements of these tests in this section.

The Wi-Fi device operated on Ch177, with adjacent channel interference affecting DSRC on Ch 180. Wi-Fi traffic was varied from 0% to fully saturated, which at the upper end led to 74% channel utilization. The DSRC nodes transmit BSMs at 100ms intervals. We fixed the DSRC in-band reception power, and then raised the Wi-Fi transmit power until the DSRC PER (average PER) passed over 10%. We record this 10%-DSRC-PER-reaching Wi-Fi power as the corresponding in-band Wi-Fi reception power on Ch 177. This
measurement is based on the FCC test and measurement plan.\textsuperscript{22} We repeated this process for DSRC RSSI between -88 dBm and -63 dBm. These lab measurements enable accurate calibration of the simulation.

7.2.2. Simulation

We built an OMNeT++ based simulator to analyze the DSRC safety alert failure rate (SAFR), in the presence of adjacent channel outdoor Wi-Fi operation, driven by large scale, real-world observed vehicular traffic data.

We explain several key aspects of the simulator in this section. First, we present the Objective Modular Network Testbed in C++ (OMNeT++) simulator tools utilized to examine the adjacent-channel coexistence of Wi-Fi and DSRC systems. We also describe the radio and vehicular traffic models used in the simulation, and we outline the simulation scenario setup and parameters. Finally, we describe further and outline the impact to our SAFR key performance metric, using typical driver response times and safe vehicular distances.

To our knowledge, this simulation is the first to combine real world traffic movement, VEINS modeling of the DSRC system, and a realistic radio channel propagation model. We chose the VEINS simulation tool set because it is the de-facto standard for vehicular ad-hoc network (VANET) research, which has been used in almost 1000 published journal papers, technical reports, book chapters and research theses.\textsuperscript{23}

7.2.2.1. OMNeT++ Tools


\textsuperscript{23} https://veins.car2x.org/publications/
OMNeT++ is a widely used open source discrete event simulator for general purpose use. Two adaptations of the OMNeT++ framework are used in our simulation: Vehicles in Network Simulation (VEINS) is an open-source vehicular network simulation framework widely used by researchers in the vehicular communications field. VEINS also incorporates the Simulation of Urban Mobility (SUMO) road traffic simulator, providing a suite of models for vehicular simulation. We also utilize the INET Framework OMNeT++ model library to simulate communications networks, which contains support for 802.11 link layers as well as mobility. These tools were modified to have them share the same physical layer and join the radio and vehicular components in the simulation.

In this way, a BSM from a VEINS OBU instance is transmitted over the INET radio medium instance and a Wi-Fi frame is forwarded to the VEINS media access instance. The DSRC and Wi-Fi frames are recognizable by the reciprocal system, decoding intended frames at the MAC layer.

This merged simulator calculates the PER for a received radio frame according to the minimum SINR of the transmission time and frequency. The mapping from minimum SINR to PER is determined by reference to a NIST error model. Once a PER value is assigned to a radio frame, the PHY model makes a random decision, based on calculated PER, if the frame should be handed up to the media access layer. We thereby collect the average PER at DSRC receiver.

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24 SUMO is also integrated into the Federal Highway Administration (FHWA) Driver Model Platform v0.6, a tool created “so that planners and engineers could more accurately predict and assess the operational impacts of specialized events and technologies—such as … connected and automated vehicle applications.” https://www.fhwa.dot.gov/publications/research/operations/18014/index.cfm

7.2.2.2 Dimensional Radio Model

We incorporated in the simulation a 20 MHz-channelized 802.11ac Wi-Fi device operating directly adjacent to DSRC channel 180. As described previously [Section 6.2.4.4], this configuration represents the highest potential out-of-band noise into DSRC. We represent Wi-Fi noise according to the emission mask specified in the 802.11ac-2013 standard, as depicted below, though actual Wi-Fi products frequently exceed these requirements.

![Wi-Fi and DSRC Spectral Masks and Channelization](image)

**Figure 5 - Wi-Fi and DSRC Spectral Masks and Channelization**

Wi-Fi APs are assumed to be transmitting at 1W isotropic (in all directions), representing conducted power of 5 GHz APs. APs are also allowed +6 dBi of gain under Part 15 rules, however this directional energy comes at the expense of other angles of the antenna pattern, so 1 watt isotropic is a valid value for our simulation. DSRC transmits at 10
milliwatts in the simulation, consistent with standards and the capabilities of the product as tested.26

Wi-Fi data rates are set to 54 Mbps and DSRC data rates are set to 6 Mbps, consistent with typical performance. We simulate five levels of Wi-Fi activity: 0% (baseline DSRC performance), 10%, 20%, 30%, and 74% (saturated). As described previously, the non-zero activity levels used here exceed empirically observed levels in operational networks. We therefore over-estimate the impact of Wi-Fi in our simulation. Additional Wi-Fi and DSRC simulation parameters are outlined in the tables below.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>OMNeT++ version</td>
<td>5.0</td>
</tr>
<tr>
<td>INET version</td>
<td>3.4.0</td>
</tr>
<tr>
<td>UDP application message length</td>
<td>10240 bytes</td>
</tr>
<tr>
<td>UDP application message send interval for 5 channel utilizations</td>
<td>(\infty, 39.1\text{ms}, 19\text{ms}, 12.5\text{ms}, 1\text{ms} )</td>
</tr>
<tr>
<td>operation mode</td>
<td>802.11a</td>
</tr>
<tr>
<td>MAC payload length</td>
<td>1536 bytes</td>
</tr>
<tr>
<td>bitrate</td>
<td>54Mbps</td>
</tr>
<tr>
<td>energy detection</td>
<td>-62dBm</td>
</tr>
<tr>
<td>sensitivity</td>
<td>-82dBm</td>
</tr>
<tr>
<td>slot time</td>
<td>9us</td>
</tr>
<tr>
<td>SIFS</td>
<td>16us</td>
</tr>
<tr>
<td>transmit power</td>
<td>1000mW</td>
</tr>
<tr>
<td>data frame transmission duration</td>
<td>254us</td>
</tr>
<tr>
<td>beacon transmission duration</td>
<td>304us</td>
</tr>
<tr>
<td>antenna type</td>
<td>isotropic</td>
</tr>
</tbody>
</table>

26 SAE-J2945 states OBU power should be between 10 dBm and 20 dBm. The devices CableLabs obtained and tested were only capable of 10 dBm.
Table 2 - Simulation Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VEINS version</td>
<td>4.4</td>
</tr>
<tr>
<td>BSM length</td>
<td>300 bytes</td>
</tr>
<tr>
<td>BSM interval</td>
<td>100ms</td>
</tr>
<tr>
<td>energy detection</td>
<td>-65dBm</td>
</tr>
<tr>
<td>sensitivity</td>
<td>-92dBm</td>
</tr>
<tr>
<td>slot time</td>
<td>13us</td>
</tr>
<tr>
<td>SIFS</td>
<td>32us</td>
</tr>
<tr>
<td>BSM CW\text{\textsubscript{min}}</td>
<td>3</td>
</tr>
<tr>
<td>AIFSN</td>
<td>2</td>
</tr>
<tr>
<td>transmit power</td>
<td>10mW</td>
</tr>
<tr>
<td>BSM transmission duration</td>
<td>448us</td>
</tr>
<tr>
<td>antenna type</td>
<td>isotropic</td>
</tr>
</tbody>
</table>

We compare our simulation radio model to lab-measured data described in Section 7.2.2.2 to ensure that the simulation depicts radio interactions appropriately. As seen in the graph below, the simulator produces more conservative results than the better-performing Wi-Fi and DSRC products. DSRC is measured to be more resilient to adjacent-channel interference than depicted in the simulation, and therefore we overestimate the impact of Wi-Fi in our simulation, as we also do with respect to Wi-Fi activity factors.
7.2.2.3. Vehicular Traffic Model (Bologna, Italy)

A large-scale, empirical vehicular traffic data set is incorporated in the simulation to examine radio interactions in a field environment. We use a dataset describing traffic involving more than 22,000 vehicles during rush hour in the Italian city of Bologna.\textsuperscript{27} This traffic data study was funded by the European Commission for the purpose of evaluating large-scale traffic management solutions via vehicular communications. This data is a primary input to SUMO and VEINS in the simulation, which in combination with the

mobility and radio models, enables a real-world perspective on V2V performance in actual driving scenarios. The Bologna roadway and traffic data overlay are depicted below.

Figure 7 - Bologna Ringway Map
We report results for five different intersection locations in Bologna, examining a 400 meter radius around each location center. Wi-Fi APs are located in the centroid of each of these locations in accordance with the parameters described above. The intersections of interest have varying vehicular density, as described in Table 3 below, which provides an insightful range of field performance indicators.
### Table 3 - Intersections Observed in Simulation and Vehicular Density

<table>
<thead>
<tr>
<th>Location Number</th>
<th>Vehicular Density (OBU count)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>96</td>
</tr>
<tr>
<td>2</td>
<td>176</td>
</tr>
<tr>
<td>3</td>
<td>245</td>
</tr>
<tr>
<td>4</td>
<td>288</td>
</tr>
<tr>
<td>5</td>
<td>580</td>
</tr>
</tbody>
</table>

#### 7.3. Key Performance Indicators

We describe in this section the performance metrics related to the DSRC safety alert feature, namely critical BSM media access delay, packet transmission, reception and error rate with respect to critical BSMs. We first mathematically formulate the definition of a risky condition between two OBUs, based on which the definition of critical BSM is given. DSRC BSMs are intended to prevent these scenarios from developing into a vehicular collision by decoding critical BSMs in a timely manner. In our simulation we find that critical BSMs are a fraction of total BSMs (consistent with our assertion in Section 6.2.1 that the vast majority of DSRC transmissions have no safety function), but substantial enough in number to validate our conclusions. A successful safety alert through a critical BSM to a particular OBU relies on the success of each of the following events: The transmit OBU must receive access to the channel from EDCA contention within a particular 100ms time interval; the transmitted critical BSM must trigger the reception at the destination OBU, and the BSM must be successfully decoded.
A risky condition between a pair of OBUs is described by their position and velocity. We define the risky condition by considering the current relative Euclidean distance and velocity between a pair of OBUs, the human response time, and the minimum safety distance between vehicles on a road, which we set at two seconds and four meters, respectively. The risky condition definition implemented in our simulation is shown below:

\[
\begin{align*}
\sqrt{\|P_1 - P_2\|^2 - \left(\frac{(P_1 - P_2) \cdot (v_1 - v_2)}{\|v_1 - v_2\|}\right)^2} & \leq D_0 \\
\min\{d(0), d(t_0)\} & \leq D_0
\end{align*}
\]

Where \(t_0\) is the driver react and respond time, and \(D_0\) is the minimum safety distance.

Put simply, a risky condition is when the predicted future paths for any two vehicles come within a minimum safe distance at any time in the projected time window. The projected time window is based on NHTSA stated unalerted driver react and respond times, averaged for a braking versus steering crash avoidance decision.\(^{28}\)

A critical BSM is a BSM sent between a pair of OBUs during the time interval in which the criteria for a risky condition are met.

DSRC architects typically define PER as the key performance metric. PER on received packets reflects the reliability of successful data reception in the considered network. However, a BSM reception failure does not yield a failed driver warning leading to a possible vehicular collision if a receiver (vehicle) is not in a critical condition with the transmit OBU (vehicle). Therefore, PER alone does not reflect the reliability of DSRC from

a safety performance perspective. Due to the broadcast nature of DSRC, two cars positioned at far enough distance may scarcely hear each other; PER can be high in this scenario, but there is no risk of vehicular collision. In fact, we observe in our simulation (detailed in the following section) that even in the absence of Wi-Fi, the DSRC average PER can be significant in dense vehicular traffic scenarios. However, our goal is to perform a risk-informed interference analysis and therefore we look deeper than DSRC average PER.

7.3.1. Safety Alert Failure Rate

SAFR more appropriately captures the efficacy of the DSRC system during critical operational environments where there may be some impact to driver safety. SAFR is derived from three sub-metrics.

First, we need to evaluate whether a critical BSM will be sent in time when two OBUs fall into risky condition. An EDCA channel access contention failure may cause a critical BSM not to be transmitted at all. For example, noise or non-DSRC interference above the DSRC energy detection threshold will freeze the CCA process of an OBU. We have the following definition of probability of this failure to transmit event. The critical BSM packet transmission rate (PTR) is the probability that a critical BSM is transmitted within 100ms upon the detection of a risky condition.

A successful transmission does not guarantee a reception will be triggered at its intended receiver. Noise and interference could overwhelm the transmitted BSM at the receivers. The small contention window of DSRC, hidden node and collision may cause a critical BSM not to be synchronized to some receivers at all. For example, an OBU will not be able to detect the preamble of a critical BSM if a previous BSM (e.g. from an adjacent vehicle) has not finished receiving yet. We next define packet reception rate of critical BSM. The critical BSM packet reception rate (PRR) is the conditional probability that a
critical BSM is received conditioned on its transmission. PRR will be 0 if a critical BSM is not transmitted at all.

Lastly, we define the decoding error rate for a critical BSM in reception, which is given below. The critical BSM packet error rate (PER) is the conditional probability that a receiver failed to decode a critical BSM conditioned on its transmission and its attempted reception.

Based on the definitions of PTR, PRR, and PER, we characterize the DSRC SAFR, which is the joint probability that a critical BSM fails to be transmitted, received or decoded. DSRC fails a safety alert at probability defined by:

\[ \text{SAFR} = 1 - \text{PTR} \times \text{PRR} \times (1 - \text{PER}) \]

We present simulation results based on these three parameters.

7.3.2. Media Access Delay

While SAFR is our primary novel figure of merit, we also measure the DSRC media access delay for every critical BSM as the time from when this BSM enters EDCA queue to the time it is ready to be transmitted on the radio medium. In our simulation, we record the DSRC media access delay as the maximum observed media access delay for each duration, region and Wi-Fi channel utilization. This value is related to PTR defined above. The primary reason for tracking this value is as a gauge of how often, if at all, an OBU is close to failing to transmit within a critical 100ms interval due to delay accessing the channel. This serves as a check on our conclusions.
7.4. RESULTS

We report results for the five representative intersection locations noted in Section 7.2.2.3, across the performance indicators outlined in Section 7.3.

We did not find any BSMs which failed to transmit in any scenarios, therefore we have PTR = 1 across the entire simulation.

The critical BSM PRR is measured in the following way. We schedule a repetitive timer inside the mobility instance of each OBU. Every 100ms, the OBU scans its relative position and velocity with all the rest OBUs in the DSRC analysis area. If an OBU detects a risky condition, it will record this into our simulator output statistics. This statistic is collected independent of the radio simulation. Since the DSRC BSM update interval is also 100ms, for each risky condition detected by each car, there should be a corresponding critical BSM being received by a certain OBU. The sum of the risky condition detected will be the number of critical BSMs that are supposed to be received. We record statistics on the number of critical BSM being actually received at each OBU. We then divide by the number of the critical risky conditions detected resulting in the PRR, which is plotted in the figure below. We find that critical BSM PRR is independent of Wi-Fi channel utilization. BSM PRR does vary across our scenarios, and a relationship with vehicular density is apparent.
We then find the average critical BSM PER as the mean BSM PER for all received critical BSM, which is shown in the figure below. Critical BSM PER is negligible and independent of Wi-Fi channel utilization.
The primary metric we derive for the risk informed interference analysis we call the Safety Alert Failure Rate, or SAFR. Given the critical BSM PTR, PRR and PER collected above, we plot the DSRC SAFR which reflects the observed Wi-Fi impact on DSRC safety alert efficacy, under various Wi-Fi channel utilizations.
Overall, the existence of Wi-Fi on an adjacent channel, at any channel utilization rate, does not increase SAFR. It can be seen in Figure 11 that the traffic density has a more direct impact than Wi-Fi interference on SAFR; this is evident from SAFR values remaining constant across Wi-Fi utilization levels, but varying as a function of vehicular density across observed intersections. In fact, in most scenarios the safety alert failure rate is higher than the 10 percent to 20 percent thresholds specified by DSRC architects as acceptable PER, though this outcome is entirely independent of Wi-Fi. This suggests instability in DSRC performance in real-world traffic environments.
We can infer why Wi-Fi does not impact DSRC SAFR. The Wi-Fi in-band transmit power is 20 dB higher than the transmit power of the DSRC OBUs. However, the Wi-Fi adjacent channel signal power, the power seen by the DSRC systems, is 20 dB or more lower than the in-band Wi-Fi power due to the Wi-Fi spectral mask. The net result is that the Wi-Fi traffic appears very similar to high density DSRC traffic with respect to the system noise floor. In addition, in critical PER scenarios, vehicles at risk of collision are near one another, with OBUs enjoying high signal-to-noise ratios.

![Figure 12 - Average BSM MAC Delay Across Observed Intersections](image)

The media access delay is collected as the maximum media access delay for all transmitted BSMs, which is plotted below. The primary reason for collecting MAC delay in the simulation was to clarify the source of any observed PTR. However, we observed the existence of Wi-Fi on the adjacent channel does not add significant media access
delay for DSRC transmitters. This is also reinforced by the 100% PTR shown above. Furthermore, it can be seen that the maximum observed media access delay is well below the threshold (100ms) at which it may impact DSRC PTR.

7.5. SIMULATION CONCLUSIONS

In this section we have detailed a simulation of Wi-Fi / DSRC adjacent-channel spectrum sharing using real-world traffic scenarios and a realistic RF channel model to determine the potential impact to the safety efficacy of DSRC. This detailed, data-intensive simulation is unique in the literature, both for the specific 5.9 GHz scenario of interest, and as a model for spectrum sharing analysis more generally. To conduct risk-informed analysis, we define and measure a key safety performance indicator - safety alert failure rate, or SAFR - which defines DSRC safety system failure in scenarios of probable vehicular collision. This metric should properly be of primary interest to policymakers seeking to enable sharing in 5.9 GHz, as it captures safety relevant DSRC system performance. Our simulation results show no negative impact from adjacent-channel Wi-Fi on the safety performance of the DSRC system. Therefore, our results suggest that spectrum sharing between Wi-Fi and DSRC in 5.9 GHz will not impact DSRC safety efficacy.

8. C-V2X ROBUSTNESS

CableLabs has conducted extensive analysis of Wi-Fi / ITS adjacent-channel coexistence, with a particular focus on DSRC ITS technology due to the availability of products for testing. C-V2X ITS technology is more recent in its development; however, its architects have made technical information available that enables an assessment of its performance. We review that relevant information in this section as pertains to its robustness to adjacent-channel Wi-Fi operations, as proposed in the 2019 NPRM.
8.1. 5GAA Test Results

5GAA, the industry consortium that includes technology manufacturers and automotive OEMs supporting the development of C-V2X, has conducted comparative testing that characterizes its performance relative to DSRC.\textsuperscript{29} This testing reveals that C-V2X employs superior signal processing and congestion control that makes it more resilient to OOBE, as seen in the table below.

Table 36: Range Comparison between DSRC and C-V2X for an 11 dBm Transmit Power (at SV for MV approaching)

<table>
<thead>
<tr>
<th>Test Procedure</th>
<th>Range in (m) at 90% reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DSRC</td>
</tr>
<tr>
<td>Line-of-Sight (LOS) Range</td>
<td>925</td>
</tr>
<tr>
<td>Non-Line-of Sight (NLOS) Blocker (5GAA)</td>
<td>425</td>
</tr>
<tr>
<td>Non-Line-of-Sight (NLOS) Intersection</td>
<td>90/400</td>
</tr>
<tr>
<td>Co-existence with Wi-Fi 80 MHz Bandwidth in UNII-3</td>
<td>550</td>
</tr>
<tr>
<td>Co-existing of V2X with Adjacent DSRC Carrier</td>
<td>100/325</td>
</tr>
</tbody>
</table>

\* First drop below 90% PRR

\** C-V2X range >1350m since we reached the end of the track

Table 4 – 5GAA Comparison of DSRC and C-V2X Performance

5GAA testing results show that C-V2X requires approximately 11 dB less signal-to-noise-ratio (SNR) to maintain PER below 10\%, as shown in Table 5 below, which consolidates results from 5GAA testing.

\textsuperscript{29} 5GAA, “V2X Functional and Performance Test Report; Test Procedures and Results”, 5GAA P-190033, April 11, 2019.
### 8.2. 3GPP STUDIES

In addition to the 5GAA testing demonstrating C-V2X robustness, CableLabs reviewed two 3GPP studies. The first study TR 36.785 was developed during the creation of the PC5 sidelink C-V2X 5.9 GHz standard, while the second report was developed during the study phase for evolving C-V2X to include support for 5G NR.

In the first study, 3GPP performed a coexistence study examining the adjacent-channel coexistence between DSRC and C-V2X. 3GPP found that DSRC will not cause harmful interference to C-V2X, and vice versa, as shown in the below extract of the relevant 3GPP technical report.\(^{30}\)

![Figure 13 – 3GPP DSRC / C-V2X Coexistence Conclusion](image)

\(^{30}\) 3GPP TR 36.785 V14.0.0 (2016-10), section 5.6, page 36.
In the second study, 3GPP found that NR V2X can coexist with LTE V2X or DSRC in ITS spectrum, as shown in the below extract of the relevant 3GPP technical report.31

1. For coexistence in ITS spectrum of n47(Case1, Case2, Case3 and Case4), following observations are made:
   - Based on the simulation results, NR V2X can coexist with LTE V2X or DSRC in ITS spectrum of n47.

Figure 14 - 3GPP DSRC / NR V2X / LTE V2X Coexistence Conclusion

This result is particularly important because it speaks to the system performance (for DSRC, NR V2X and LTE V2X) in the presence of adjacent channel signal leakage, concluding that adjacent-channel ITS operations will not negatively impact system performance.

8.3. EXTRAPOLATION TO CABLELABS RESULTS

We can extrapolate the work of 5GAA and 3GPP to determine relevant implications.

In particular, since CableLabs found no plausible real-world interference risk to DSRC from adjacent-channel Wi-Fi, we anticipate that C-V2X will remain even more robust to OOBE from adjacent-channel Wi-Fi, given that 5GAA's study demonstrates increased resiliency of C-V2X.

In addition, 3GPP’s studies suggest that Wi-Fi will not interfere with C-V2X operations given that it concluded successful coexistence with adjacent-channel DSRC signals that

31 3GPP TR 38.886 v0.6.0 (2020-04), section 5.4, page 42
are likely to be higher than Wi-Fi signal strength seen at C-V2X receivers due to transmit power, bandwidth, and geographic proximity.

5GAA’s testing and 3GPP’s simulations therefore strengthen CableLabs’ conclusion that Wi-Fi will not cause harmful interference to ITS.

9. OVERALL CONCLUSIONS AND RECOMMENDATION

This technical report has examined the potential for harmful interference to ITS from adjacent-channel Wi-Fi operations, in order to inform FCC action to expand Wi-Fi access into the 5.9 GHz band. Such an expansion would benefit Wi-Fi and broadband performance by providing additional capacity and access to wider channels. CableLabs has determined through lab measurement, risk-informed interference analysis, and city-scale simulation that Wi-Fi poses no risk of harmful interference to ITS. We therefore recommend that the FCC proceed with its proposal to expand Wi-Fi access into the 5.9 GHz band.
EXHIBIT B
The Economics of Unlicensed and Dedicated Use Spectrum in the 5.9 GHz Band

5.9 GHz NPRM REPLY COMMENTS

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NCTA
The Internet and Television Association

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April 27, 2020
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I. Introduction

Twenty years ago, in October 1999, the FCC allocated 75 megahertz of spectrum in the 5.9 GHz band (5.850-5.925 GHz) to Intelligent Transportation Systems (ITS) uses, specifically, to Dedicated Short Range Communications (DSRC) technology. The goal was to push forward the use of car-to-car communication and other safety-related transportation technologies. After two decades and an expansion of potential ITS technology options to include Cellular Vehicle-To Everything (C-V2X), DSRC has not been widely deployed. In December 2019, the FCC released an NPRM that proposed to open 45 megahertz (5.850-5.895 GHz) of the 5.9 GHz band for unlicensed use. The FCC has further proposed to allow ITS services to retain co-primary allocation in the upper 30 megahertz band segment (5.895-5.925 GHz) of the 5.9 GHz band, allocating 20 megahertz to C-V2X technology and inquiring whether the remaining 10 megahertz should be used for DSRC, C-V2X, or for some other purpose.

Commenters supporting the NPRM have argued that the 30 megahertz of spectrum is sufficient to deliver transportation safety-of-life services through non-line-of-sight communications, that Out-Of-Band-Emissions (OOBE) will not cause harmful interference to those services, and that exclusive spectrum in the 5.9 GHz band is not needed for uses beyond the safety-of-life services. Additionally, they argue that this band has been underutilized and that the band can be more effectively utilized by sharing with unlicensed devices. Commenters opposing the reallocation have argued that the benefits of using this spectrum for ITS safety outweigh benefits from unlicensed use, that 30 megahertz of spectrum is not sufficient for ITS safety and efficiency services, and most such services cannot be offered over other spectrum.

On balance, we find that the comments filed support the sharing proposed by the NPRM. In considering a final order, the FCC should weigh the benefits and costs of sharing against the status

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4 “5.9 GHz NPRM 2019,” ¶ 11-12.
quo. There is no evidence provided on the record that any unique safety-of-life benefits of DSRC or C-V2X could not be maintained on 30 megahertz of spectrum or that any of the other benefits these services might offer are uniquely tied to the 5.9 GHz band (or even specifically to DSRC or C-V2X technology). Thus, the costs of adopting the Commission’s proposal identified on the record are primarily the transition costs associated with refocusing DSRC and C-V2X technologies to accommodate the new band configuration. Comments provided to the FCC put these costs at well under $1 billion. When weighed against the benefits of 45 megahertz of additional unlicensed spectrum that would enable another 80 MHz channel and the first 160 MHz channel within the existing Wi-Fi ecosystem suitable for widespread use it is clear that benefits would be expected to far outweigh costs.
II. Adverse Economic Impact Arguments by ITS Stakeholders Are Unsupported

Several commenters in the docket make assertions about the potential costs of this NPRM, including how the benefits of various ITS technologies would be lost without the full 75 megahertz of spectrum, the financial loss due to research and deployment based on the current band-plan, and transition costs. Representative commenters who filed such information are the US Department of Transportation (DoT), Panasonic, the US Technical Advisory Group to the ISO/TC 204 Intelligent Transport Systems Administrator (US TAG), Alliance for Automotive Innovation (AAI), DSRC Auto Safety Coalition (DSRC Coalition), American Automobile Association (AAA), Securing America’s Future Energy (SAFE), and the Motor and Equipment Manufacturer’s Association (MEMA).5

These commenters’ arguments that are relevant for any economic analysis of the proposed NPRM fall into four categories. Here we summarize their main points. We note, however, that with safety-of-life benefits preserved even with the reduced dedicated ITS allocation, and the non-safety-of-life benefits unlikely to be lost to society as a result of other spectrum bands available for their use, the only costs that should be weighed against the benefits of this proposal are the transition costs.

- First, commenters argue that the entire 75 MHz of the ITS allocation is needed on a dedicated basis to realize the safety-of-life benefits. The commenters do not however, identify which safety-of-life benefits would be lost or which benefits require the 5.9 GHz band as opposed to another band or a non-ITS technology.

- Second, a number of commenters argue that costs exceed benefits. Although none of the commenters provides a complete accounting of costs or benefits, several put information in the record suggesting the potential benefits of ITS technologies are as high as $940 billion. Commenters argue that loss of dedicated access to the entire 75 megahertz of ITS spectrum will prevent ubiquitous adoption of ITS technologies and prevent future innovations in the band. These costs are grossly overstated.

- Third, commenters argue that reconfiguring the band will result in a loss of $2.7 billion in research and development (R&D) and investments. This cost is a mix of sunk and ongoing R&D investment and arguing that this is a cost of the reallocation is wrong.

- Fourth, it is argued that the reconfiguration of the band assuming 10 megahertz is dedicated to DSRC and 20 megahertz to C-V2X will cause an incremental $645 million in transition costs. This cost is overstated but in any case is dwarfed by the anticipated benefits of designating 45 megahertz of the band for unlicensed use.

In this section, we will address each of these arguments. Following that, we will briefly discuss the expected benefits of reallocating the band. In the final section, we conclude that the evidence in the record strongly suggests that the benefits of the proposed reallocation would exceed the costs.

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6 “Panasonic Comments on the 5.9 GHz NPRM,” p. 6; “US TAG Comments on the 5.9 GHz NPRM,” pp. 4-5; “DSRC Coalition Comments on the 5.9 GHz NPRM,” p. 4; “MEMA Comments on the 5.9 GHz NPRM,” p. 3.
A. ITS Technologies Do Not Need the Entire 75 Megahertz to Realize Anticipated Benefits

ITS stakeholders assert that the entire 75 megahertz is needed to reap the benefits of ITS technologies. When comparing the relative benefits and costs of a proposed policy, it is important to compare the status quo or “baseline” to the world in which a change is made. Here, the baseline is leaving all 75 MHz for ITS services and the alternative is to reallocate 45 megahertz for unlicensed use and leave 30 megahertz dedicated to ITS-related uses. Consequently, what is relevant is not the total benefits created by ITS, but the incremental benefits that would be lost if only 30 megahertz of the 5.9 GHz band is dedicated to ITS instead of the entire 75 megahertz. In assessing the incremental loss from shifting 45 megahertz to unlicensed uses, it is important to distinguish between the safety-of-life benefits, which can all be provided in the 30 megahertz, and the other non-safety-of-life technologies. The record supports the fact that 30 megahertz is sufficient to provide all safety-of-life benefits from deploying ITS. The non-safety-of-life technologies, even if no longer provided on those 45 megahertz of spectrum, will not be lost to society because they can be offered over other spectrum bands or through alternative technologies.

We note that of the seven 10 megahertz-wide channels available under today’s DSRC band plan, only two, Channel 172 and 184, were designated for “safety of life and property applications.” Four of the remaining five channels were designated as service channels “to support related vehicle-to-everything (V2X) applications. The last channel, 178, was designated as a control

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7 “DoT Comments on the 5.9 GHz NPRM,” Supplementary Technical Comments, p. 2; “DSRC Coalition Comments on the 5.9 GHz NPRM,” p. 5; “Alliance for Automotive Innovation Comments on the 5.9 GHz NPRM,” p. 5; “Panasonic Comments on the 5.9 GHz NPRM,” p. 8; “US TAG Comments on the 5.9 GHz NPRM,” p. 5; “MEMA Comments on the 5.9 GHz NPRM,” p. 4; “SAFE Comments on the 5.9 GHz NPRM,” p. 6.


channel.” Some stakeholders nonetheless argue that the entire 75 megahertz is needed for safety-of-life technologies. They argue that other technologies such as radar, cameras, and sensors, although important in advanced driver assistance settings, are not as effective “where the vehicles involved do not have a direct line-of-sight relationship with each other.” However, based on the record, the primary safety-of-life function DSRC or C-V2X offer is to deliver Basic Safety Messages (BSM) for crash-avoidance, particularly in non-line-of-sight situations. In fact, it is only these limited non-line-of-sight safety features that require dedicated ITS spectrum and could not be provided by other means – all other functionality can be provided without the dedicated spectrum. 30 megahertz is sufficient to provide this core safety functionality.

As Commissioner O’Rielly stated in 2016, there are three main considerations when characterizing safety-of-life and non-safety-of-life functions that need dedicated spectrum. First, the feature should not be available or expected to be produced by the market in the near future. Second, it should not be a function that the stakeholders can monetize with any improvement of safety benefits. Third, it should not be a function that could distract the driver and undermine safety. Some examples listed in his discussion are mapping and navigation, traffic updates, entertainment, parking spot location and the like. All such non-safety use cases envisioned for additional 5.9 GHz spectrum can be provided using other spectrum or other technologies. Much of the information

11 “DoT Comments on the 5.9 GHz NPRM,” p. 16; See also, “DSRC Coalition Comments on the 5.9 GHz NPRM,” p. 3.
provided in the record does not distinguish between safety-of-life and other benefits from proposed ITS applications. For example, MEMA does not distinguish between the core safety-of-life type applications that could require DSRC or C-V2X and other applications, such as inclement weather warnings, construction zone, and roadwork warnings, that can be provided using other technology, such as GPS or other licensed spectrum.16

Certain commenters argue that dedicated spectrum is needed for functionalities such as video surveillance, mapping and navigation, traffic updates, parking and entertainment.17 Nevertheless, the record supports the idea that the non-safety-of-life benefits can be provided through other technologies such as GPS, radar and LIDAR. For example, even today’s real-time maps, navigation, traffic updates, and congestion re-routing can be provided through GPS integrated in cars or through mobile phones using licensed spectrum. For autonomous vehicles, LIDAR provides a 360-degree view of a car’s surroundings “helping them to drive themselves safely.”18

In addition, commenters such as Panasonic and AAI argue, “all 75 MHz available in the 5.9 GHz band” is needed “to support the United States’ connected and automated driving future.”19 To argue that automated vehicles (AV) and the associated benefits will not be realized save for the dedicated 75 megahertz of spectrum is unsupported by the evidence provided. For example, Honda states that the current “state of the art Automated Driving Systems (ADS) rely primarily on perception based sensing systems (e.g. Camera, RADAR, LIDAR) to navigate the driving environment safely and avoid crashes.”20 Some industry observers believe that the AV technology will be deployed on a hybrid system that will encompass some DSRC, some C-V2X on dedicated spectrum, some CV2X on LTE, and radar, laser and LIDAR deployed on other licensed frequencies.21 There is also ongoing

16 “MEMA Comments on the 5.9 GHz NPRM,” p. 6.
17 For example, see, “Alliance for Automotive Innovation Comments on the 5.9 GHz NPRM.”
19 “Alliance for Automotive Innovation Comments on the 5.9 GHz NPRM,” p. 17.
research on AVs that may not need any dedicated V2X spectrum.\textsuperscript{22} To say that only 5.9 GHz ITS can be used in autonomous vehicles, as the commenters do, is not to say we will not have autonomous vehicles without the entire 75 megahertz of ITS spectrum in the 5.9 GHz band, as the commenters seems to assert. Therefore, the only costs that should be considered here should be costs involved in moving the non-safety deployments to other bands. Given that these deployments have yet to be made, such ‘transition’ costs should be minimal, as discussed below.

B. Costs of Not Dedicated 75 Megahertz to ITS Are Overstated

As described above, when quantifying the cost of not preserving all 75 megahertz of spectrum for ITS services, stakeholders conflate the possible benefits of ITS that can still be realized in 30 megahertz of spectrum with the incremental benefits of an additional 45 MHz of dedicated ITS spectrum. Consequently, the cost estimates, which primarily come from DoT, are wrong. Below we explain three reasons why the cost figures cited by commenters to justify their opposition to the NPRM lead to grossly overestimating the cost of reallocating 45 megahertz for unlicensed use and keeping 30 MHz dedicated to ITS. First, commenters assume that the cost of the reallocation is the loss of all safety and non-safety services and related investments—for example, they argue incorrectly that if 75 megahertz was dedicated to ITS, all crashes and congestion would be prevented. Second, commenters argue that without the entire 75 megahertz dedicated to ITS, future innovation would suffer significant harm, which is unsupported by recent technology developments, as we discuss later.\textsuperscript{23} And third, even the costs that most commenters rely on for their arguments come from a 2014 NHTSA study that grossly overestimated costs.

First, commenters have used DoT data on crashes to imply that unless the full 75 megahertz is dedicated to DSRC, none of these crashes can be prevented, or congestion alleviated, and hence the cost of reallocation is the entire loss arising out of crashes and traffic congestion. Their arguments are wrong for multiple reasons: namely, they are wrong that the proposal to reserve 30 megahertz for safety-of-life uses would diminish automotive safety, and their cost figures assume that DSRC or C-V2X would avoid \textit{all} crashes and congestion.


\textsuperscript{23} “Alliance for Automotive Innovation Comments on the 5.9 GHz NPRM,” p. 17; See also “Panasonic Comments on the 5.9 GHz NPRM,” p. 13-15.
As discussed in sub-section II A, the core safety-of-life benefits provided by ITS technologies can still be provided in 30 megahertz of spectrum. Consequently, any portion of the purported benefits associated with safety-of-life improvements will not be lost with the reduced dedicated ITS allocation. Therefore, the opportunity cost, in terms of safety-of-life, of reallocating the 45 megahertz to unlicensed use is near zero, implying that there will be no incremental loss of life or property due to this reallocation. Hence, the FCC does not need to account for any Value of Statistical Life calculations as asked by commenters such as AAI and Panasonic.

Commenters ignore that reality, however, and recite large statistics like the number of automotive accidents and the costs associated with crashes. At the beginning of its analysis, for example, DoT notes that, based on 2018 data, “over 6 million U.S. police-reported vehicle crashes resulted in 36,560 lives lost, as well as 1,893,704 crashes that led to more than 2.7 million injuries and 4,807,058 crashes resulting in property damage” and “resulted in annual economic harm of approximately $300 billion in direct costs and over $800 billion when accounting for the loss of life, injuries, and other quality-of-life factors” and over $166 billion annually for costs related to traffic congestion. It also notes that the accidents in the trucking industry leads to a loss of $19 billion in goods and services and about 5,000 deaths annually, and the cost of delay and fuel costs due to congestion, adds another $23 billion to the cost.

Commenters like Panasonic, the DSRC Coalition, USTAG and MEMA, amongst others, have quoted an earlier version of these numbers to argue that the cost of not dedicating all 75 megahertz of spectrum to ITS is $940 billion at the very least. However, both the previous version of these numbers and the new version suffer from the same core conceptual failing just discussed.

Commentators state that the FCC has failed to account for $9 billion per year of life saving costs. This is based on two DoT studies, a 2013 study that assumes $9.1 million as the value of a statistical life and the V2V NPRM that estimates that V2V technology could save up to 1,321 lives annually. See, “Panasonic Comments on the 5.9 GHz NPRM,” pp. 10-12, FN 35, 36. See also, “Alliance for Automotive Innovation Comments on the 5.9 GHz NPRM,” pp. 2-3.

Moreover, we note that these commenters’ framing is misleading, as it implies that 100 percent of crashes and congestion will be avoided if all 75 megahertz is dedicated to ITS. In fact, even the DoT does not attribute to V2X a 100 percent reduction, only “a significant role in reducing” such instances. By failing to account for any uncertainties in the deployment of ITS technologies, these commenters wrongly suggest that all or a significant portion of these costs would be saved if all 75 megahertz was dedicated to V2X technology, and that allowing reallocation of a portion of the band will eliminate the safety benefits.

These commenters are thus wrong both in incorrectly asserting that the safety-of-life benefits of DSRC or C-V2X cannot be realized in 30 megahertz, and in overstating the magnitude of those safety-of-life benefits even in the current 75-megahertz allocation.

Second, to the extent that commenters provide other examples in the filings of potential future non-safety benefits that DSRC or C-V2X might offer, they fail to demonstrate that these non-safety benefits cannot be provided through other technologies or using other spectrum. Commenters such as Panasonic, DSRC Coalition, and MEMA argue that in the future, non-safety-of-life technologies and innovation will be harmed unless the entire 75 megahertz is dedicated to ITS technologies. However, none of these comments provides any concrete evidence of such harm, making it impossible to evaluate any trade-off between costs and benefits.

On the issue of future innovation, some commenters also argue that unless the 75 megahertz is dedicated specifically to DSRC technology, the progress of automated vehicle technology will be harmed. Comments by DoT, AAI and others on the detrimental impact of future automated vehicles ignore the facts that (1) connected vehicle technology may not be necessary at all for the development of automated vehicles, given that AVs today focus entirely on vehicle-resident sensing technologies like radar, LIDAR, and cameras; and (2) in a large number of instances, C-V2X may be superior to the DSRC technology and allocating 20 megahertz to C-V2X may enhance future innovation.

On a related note, C-V2X has had no spectrum dedicated to its deployment as of today, but innovation in the technology and its potential use in automated vehicles continues at

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29 “DoT Comments on the 5.9 GHz NPRM,” Supplementary Technical Comments, p. 8.
30 “Panasonic Comments on the 5.9 GHz NPRM,” p. 13-14. See also, “MEMA Comments on the 5.9 GHz NPRM,” p. 6; “DSRC Coalition Comments on the 5.9 GHz NPRM”, p. 9.
a fast pace. Therefore, to argue that autonomous vehicle innovation would stall without 75 megahertz of dedicated ITS spectrum is not supported by the technology development path.

Third, even putting those threshold conceptual problems aside, commenters opposing the Commission’s proposal cite inaccurate and unreliable figures. The Commission cannot credit these gross overestimates for any purposes.

The purported benefits of ITS are noted in a 2014 NHTSA document referred to by DoT. That NHTSA study measured the safety benefits of mandating DSRC in the 5.9 GHz band, as a vehicle-to-vehicle (V2V) communication standard for all light vehicles. DoT notes that “just four V2X collision-avoidance applications reduce the taxpayer burden by $109-$319 billion and results in over 7,000 lives saved, 1.8 Million injuries avoided and a reduction in damages of 4.7 Million vehicles and other property” and a savings of $721 billion (in 2014 dollars) based on “the total crash population that could be resolved by V2V applications.”

These estimates are overstated, as explained in Bazelon & Figurelli (2016). The cost estimates, or alternatively, the loss in benefits if all 75 megahertz are not dedicated to ITS services, are overstated primarily because, as we argue above, all of the benefits could be provided within the 30 megahertz of spectrum that still will be dedicated to these uses. However, putting these issues aside, the estimates are also overstated due to the choice of the wrong baseline of crash reduction that would be expected absent ITS deployments. The baseline in the NHTSA study is 2010-2011, i.e. it takes as given the number of crashes in 2010-2011 and projects this forward, without accounting for safety improvements that would be expected to occur as a result of non-DSRC based technologies.

For instance, the fatality and injury rates between 1992 and 2010 declined by 30.3 and 40.2 percent respectively, which shows that even without DSRC, fatalities and injuries would be expected to decline. Due to this incorrect baseline assumption, the NHTSA grossly overstates, by over 225%,
the expected number of fatalities that would be eliminated from adopting DSRC technology using the full 75 megahertz of spectrum.36

In its current filing, although the DoT acknowledges that there has been a 3.4 percent reduction in fatalities from crashes in the first half of 2019, and that the NHTSA data shows that since the fourth quarter of 2017 there have been seven consecutive year-to-year quarterly declines in fatalities, the DoT makes no attempt to adjust the 2014 NHTSA estimates.37 Hence the Bazelon & Figurelli 2016 analysis, including the criticism of the choice of an incorrect baseline and why these numbers represent gross overestimates of the cost, still stands.

Based on the discussion above, the costs of not dedicating all 75 megahertz to ITS services are grossly over-estimated. The gross cost is over-estimated because of the incorrect assumption that both safety-of-life and non-safety benefits can only accrue if all 75 megahertz are dedicated to ITS. Furthermore, the estimates provided by ITS stakeholders are far too high, given that they are based on the wrong baseline and do not account for offsetting benefits that may accrue from using C-V2X versus DSRC.

C. Research and Investment Costs Are Miscalculated

In estimating the financial cost of the change in the band plan, DoT states that there are significant R&D and investments in DSRC technology and that the change in the band-plan will adversely affect “over $2.7 billion in advanced research and deployment investments across the Nation.”38 There are several reasons why this number is a gross overestimate.

The $2.7 billion R&D investment costs noted by DoT are likely overstated due to three reasons. First, to the extent research and development costs are sunk, they should not be included as costs of the transition proposed by the NPRM. This is because those costs already have been spent and cannot be recouped regardless of whether or not the NPRM’s proposed transition takes place. Second, only those R&D costs that are directly related to reallocating 45 megahertz to unlicensed spectrum should be counted. Third, the benefit of that research may still available, with the caveat that some refocus may be needed. Fourth, such costs of refocusing the research are properly accounted for as transition costs, as discussed below in sub-section D, and are very small when compared to the anticipated benefits of designating 45 megahertz of the band for Wi-Fi.

36 “Bazelon and Figurelli,” p. 17.
38 “DoT Comments on the 5.9 GHz NPRM,” Supplementary Technical Comments, p. 36.
First, the most significant components of this cost, $1.24 billion, are government grants and investment for the DSRC technology and $840 million in research and testing investment by DoT.\textsuperscript{39} These past investments are sunk and should not be taken into account when comparing the costs and benefits of the reallocation.\textsuperscript{40} Therefore, none of this investment should be counted within a cost of reallocation.

Second, the overstatement is also caused by counting investments and R&D that are not directly related to the reallocation of 45 megahertz of spectrum to unlicensed use. When discussing financial costs, most commenters focus on the costs that would potentially arise if C-V2X technology were allowed to deploy in the 20 megahertz of spectrum and DSRC is deployed only in 10 megahertz of spectrum.\textsuperscript{41} That is, even the transition costs reported are mostly focused on \textit{adding} C-V2X, not on transitioning out of the 45 MHz proposed for sharing with unlicensed users.

Third, while it may be the case that going forward the research dollars in DSRC technologies will decline as DoT argues, there will likely be a corresponding increase in R&D and investment in the C-V2X technology that may more than offset these R&D and investment costs. The same argument can be made for investment by academia. Additionally, some of this investment is forward-looking, such as the $23 million that the DoT spends in “Cooperative Automated Driving” research. Such research would possibly still be used for the same purpose going forward, maybe for a different technology such as C-V2X, and is therefore not a net cost.

Fourth, the estimated $2.7 billion in lost investment also includes $645 million in transition costs. It is incorrect to include it within the research as investment cost, as it is a one-time transition cost of the proposed rebanding. This should not be conflated with the other annual level R&D grants and investment. However, this cost is an overestimate as well, as we discuss in detail in the next section.

D. Transition Costs Are Overestimated

The only relevant costs when measuring the tradeoff between benefits and costs of the NPRM’s proposed sharing of ITS spectrum are the costs of transitioning the ITS applications from a dedicated 75 megahertz to a dedicated 30 megahertz. These costs, which ITS advocates

\textsuperscript{39} “DoT Comments on the 5.9 GHz NPRM,” Supplementary Technical Comments, p. 36 and Table 3.


\textsuperscript{41} The comments also fail to call out the tradeoffs between DSRC and C-V2X technologies. and do not address how introducing a second ITS safety technology could impact the estimates of benefits. For example, DSRC safety efficacy is based on near ubiquitous adoption and a competing technology may alter the path of that adoption.
overestimate, are nonetheless far lower than the expected benefits from the NPRM’s proposal, discussed in Section III.

In 2019, the DoT presented an estimate of the costs associated with the band plan change of around $500 million, which they updated to $645 million in their 2020 filing.\textsuperscript{42} The $645 million cost estimate from 2020 can be divided between $408.9 million as replacement cost for 57 existing operational sites and another $236.7 million for 66 planned, under construction and under testing sites.\textsuperscript{43}

There are three major reasons why the costs are insufficiently supported and likely overestimated.

- First, we do not know where the DoT obtained its count of pilot deployment sites. There are no references provided. DoT’s own data on its website, as of January 2020, shows that there are 57 operational sites (projects) and 40 planned sites for a total of 97 sites.\textsuperscript{44} The DoT filing however states that there are 66 planned sites.\textsuperscript{45} Even within the 57 operational sites, there are at least 4, which are either test-beds or pilot projects.\textsuperscript{46} It is therefore unclear exactly how many sites would need to be transitioned under the NPRM reallocation plan.

- Second, although the DoT analysis gives different replacement costs for different sized sites – for example, whether they are urban or rural – it does not account for different costs at sites that are at different stages of planning, construction and testing.

- Third, even the information on different sized sites is insufficient since DoT does not provide information on the breakdown of its sites by size, by rural or urban, at what phase of planning it is at, or any description of what these sites do.

The filing then multiplies the number of sites by average cost numbers to arrive at the headline cost estimates of $645 million. This calculation is sensitive to both the distribution of types of sites and cost estimates for the different types of sites. For the 57 operational sites, the filing uses $7.2 million as the cost of an average site.\textsuperscript{47} If, however, the distribution of sites is skewed this will

\textsuperscript{42} “DoT Comments on the 5.9 GHz NPRM,” at “Critical Discussion Items,” p. 17 at Appendix D for the 2019 estimate; See also p. 37-39 of “Supplementary Technical Comments,” for the 2020 estimate.

\textsuperscript{43} “DoT Comments on the 5.9 GHz NPRM,” p. 37-39 and Table 4 of “Supplementary Technical Comments.”


\textsuperscript{45} “DoT Comments on the 5.9 GHz NPRM,” p. 37-39 and Table 4 of “Supplementary Technical Comments.”

\textsuperscript{46} “Operational Connected Vehicle Deployment in the U.S.”.

\textsuperscript{47} This appears to be a straight average, not weighted by the number of different types of sites. “DoT Comments on the 5.9 GHz NPRM,” p. 38 of “Supplementary Technical Comments.”
provide an inaccurate estimate of total costs. Rather, the DoT should have multiplied the site-type costs by the number of sites of each type.

A similar concern may lead to an even further overestimation of the replacement or upgrading costs for the 66 planned DSRC sites. As noted earlier, the DoT filing does not distinguish between the replacement costs of planned, under-construction, or testing sites. The DoT uses an approximation to address this issue for the 66 non-operational sites. They multiply the 66 sites with fifty percent of the average cost of operational sites (i.e. 50 percent of $7.2 million). Aside from the arbitrary assumption of 50% discounting, this strategy could work as an approximation only if each type of site is roughly similar in number. However, if a majority of the sites, say, are in the planning phase rather than the construction/testing phase, this average approach will overestimate the costs, assuming the replacement cost of sites that are in the planning phase will be significantly lower than those already under construction or in testing.
III. Benefits

As noted in the previous section, the only social costs from the proposed sharing of 45 megahertz of ITS spectrum are the transition costs and, by DoT’s own estimates, those are well under $1 billion. Consequently, as long as the benefits of an additional 45 megahertz of unlicensed spectrum in the 5.9 GHz band are in excess of at most $1 billion, then benefits would exceed costs. The benefits from this reallocation of spectrum are driven by the larger channels in the existing Wi-Fi ecosystem that will be enabled by adding 45 megahertz of unlicensed spectrum to the top of an existing Wi-Fi spectrum band. We do not provide a concrete estimate of those benefits, but do provide analysis that suggests they will easily be valued in the many billions of dollars, well in excess of the costs of the transition.\(^\text{48}\)

The use of mobile data has exploded in the last few years. Cisco estimates that global mobile data traffic will increase 7-fold between 2017 and 2022.\(^\text{49}\) By 2022, 59 percent of traffic from smartphones, 72 percent of traffic from tablets and 71 percent of all 5G mobile traffic will be offloaded to Wi-Fi.\(^\text{50}\) Globally internet traffic is forecasted to grow more than 3-fold between 2017 and 2022, with fixed wired broadband accounting for 29 percent of the traffic in 2022.\(^\text{51}\) By 2022, Wi-Fi traffic from both mobile and Wi-Fi-only devices will account for more than half of total IP traffic, an increase of 43 percent from 2017.\(^\text{52}\) An update of the report predicts that by 2023, mobile broadband speeds will triple and fixed broadband speeds will double compared to 2018.\(^\text{53}\) With this increasing demand for Wi-Fi the probability of congestion increases, and with that a potential degradation in quality of service. In previous years, Wi-Fi channel size generally has been able to

\(^{48}\) There are several studies that attempt to value unlicensed spectrum. Although in most cases, they do not address incremental value, these studies do support the belief that the value of unlicensed spectrum would be measured in the billions of dollars. For example, see Raul Katz, “Assessing the Economic Value of Unlicensed Use in the 5.9 GHz and 6 GHz Bands,” April 2020, http://wififorward.org/wp-content/uploads/2020/04/5.9-6.0-FINAL-for-distribution.pdf.


\(^{50}\) “Cisco VNI 2017-2022,” Figure 16, p. 17.

\(^{51}\) “Cisco VNI 2017-2022,” Figure 20, p. 20. From roughly 120 exabytes per month in 2017, IP traffic is forecasted to grow to roughly 400 exabytes per month, a roughly 3-fold increase.

\(^{52}\) “Cisco VNI 2017-2022,” Figure 20, p. 20.

keep up with wired speeds and was not a bottleneck to delivering broadband over the last few feet. This may no longer be the case without additional spectrum that enables more, larger channels that support greater throughput. The 5.9 GHz band, with its unique ability to enable one additional 80 MHz channel and one 160 MHz bandwidth channel using the 45 megahertz of 5.9 GHz spectrum proposed in the NPRM combined with the adjacent Wi-Fi band, would help Wi-Fi keep up with wired capabilities.54 Last, the increased availability of unlicensed spectrum could further increase innovation in Wi-Fi-enabled products and their positive social benefits.55

A. Incremental Value of Larger Channels

Wi-Fi is an integral part of the broadband ecosystem, with more than half of mobile phone and much of home broadband data delivered the last few feet over the unlicensed wireless technology. In fact, it is difficult to imagine the current success of broadband without Wi-Fi technology. Throughout this development, the speed and capacity of Wi-Fi networks has kept pace with the broadband networks they were connected to. Key to this coevolution has been both increasing channel size of Wi-Fi networks and new Wi-Fi allocations to support the larger channel sizes.56 For this success story to continue as the speed and capacity of wired broadband connections continue to grow, steps need to be taken to assure that Wi-Fi can continue to play the same complementary role. The key policy challenge is to enable larger Wi-Fi channels that will allow consumers to benefit from the new, larger wired broadband connections.

Without additional, wider Wi-Fi channels consumers will not reap the potential benefits of greater wired broadband enabled by new cable platforms such as DOCSIS 3.0 and 3.1.57 Currently the 2.4 GHz and 5 GHz Bands are used for Wi-Fi. In the 2.4 GHz Band there is a total of approximately 80 megahertz allotted to Wi-Fi, with 11 overlapping channels of 20 megahertz spaced 5 megahertz apart from each other.58 These channels are significantly limited.59 In the 5 GHz band, there is a


55 In their paper on the 5.9 GHz Band, Bazelon and Figurelli (2016) touched on some factors when valuing additional unlicensed spectrum, such as the additional spectrum increasing the value of existing uses and creating the potential for new uses; whether the available unlicensed spectrum is congested or not.

56 “5.9 GHz NPRM,” p. 6.


theoretical total of 580 megahertz allotted to Wi-Fi, with devices allowed in 500 megahertz that comprise 25 non-overlapping 20 megahertz channels. Currently, channel bonding can allow 40 MHz and 80 MHz channels, although the bonded 80 MHz channels have not been widely used and a large portion of the band has FCC rules that require dynamic frequency selection (DFS) and sharing with government radar systems, which the FCC has found to reduce its usefulness.

To allow for greater throughput, Wi-Fi 5 and Wi-Fi 6 standards added support for 80-MHz and 160-MHz channels. However, in practice, these cannot be widely used in the current environment due to interference from devices on overlapping channels. The next generation of Wi-Fi, Wi-Fi 6, can be deployed using the wider 160 MHz channels, and can accommodate greater throughput, “multi-gigabit low latency connections,” a higher number of users, and other advanced features. Wi-Fi 6 is expected to enable new applications including machine analytics, remote maintenance, or virtual employee training, and deliver much anticipated augmented reality and virtual reality (AR/VR) use cases for consumer, enterprise, and industrial environments.


The additional 45 megahertz of 5.9 GHz spectrum is valuable because it can be combined with the adjacent U-NII-3 band (5.725-5.850 GHz) and would “enable the next generation of Wi-Fi services (i.e., Wi-Fi 6) to use the full 160 MHz-wide channels that it is designed for, without any additional interference-mitigation requirements.” The larger bandwidth and increased speeds would provide the platform for developing new applications, leading to significant benefits. We do not provide a value of these new applications, but even if they only provided modest value to users, they cumulatively would provide billions of dollars of value. Just to illustrate, if the applications enabled by the larger bandwidths being available sooner created $20 per person in value beyond their costs to 50 million wireless users, the total value would be $1 billion, more than enough to exceed the costs of the proposed reallocation. As discussed above, the 5.9 GHz band is uniquely positioned to fulfill the need quickly.

B. Proximity to Existing Wi-Fi Spectrum

As discussed above, historically, Wi-Fi standards have used the 2.4 GHz ISM band and the 5 GHz band for Wi-Fi services. Most devices on the market today already contain 5 GHz radios, and the latest Wi-Fi standards, IEEE 802.11ac and 802.11ax, are designed to work only in the 5 GHz band. Additionally, the 45 megahertz that the NPRM proposes to shift to unlicensed uses is located in the lower portion of the 5.9 GHz band, which is adjacent to the 5.8 GHz, or the U-NII 3 band, which is the upper range of the 5 GHz that is currently being used for Wi-Fi. Because the new proposed unlicensed spectrum in the 5.9 GHz band has very similar physical properties to existing U-NII-3 spectrum, the 45 megahertz can be used almost as soon as the reallocation is complete, with software and firmware upgrades, and many users will not incur any additional cost for replacing devices or components. The location adjacent to U-NII-3 spectrum also offers an

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67 “Channel Planning Best Practices for Better Wi-Fi.”

important opportunity to fully utilize the latest Wi-Fi standard, and utilize 80 or 160 MHz channels that can accommodate speeds of over 1 Gigabit per second.\textsuperscript{69}

\textsuperscript{69} “Joint Comments of Broadcom, Inc. and Facebook, Inc.,” p. 2.
IV. Conclusion: Evidence in the Record Shows Benefits Exceed Costs

We find that the comments filed support the reallocation proposed by the NPRM. Based on the evidence submitted in the record, the Commission should find that the benefits of its proposal outweigh the costs. Since the safety-of-life benefits can be provided in the remaining dedicated 30 megahertz of ITS spectrum, there are no safety-of-life costs from this proposed reallocation. The non-safety-of-life uses proposed for the ITS band do not require dedicated ITS frequencies and can be provided on other existing frequencies, meaning they will not be lost as a result of the proposed reallocation and therefore are not a cost of the reallocation. The costs of the proposed band-split would be limited to any transition costs associated with reconfiguring existing DSRC deployments to accommodate the new band configuration. As noted in the previous sections, the costs are likely well under the $645 million claimed. Consequently, as long as the benefits of an additional 45 MHz of unlicensed spectrum in the 5.9 GHz band are in excess of these costs, the Commission could confidently adopt its proposal. Given that the 45 MHz of additional unlicensed spectrum would enable another 80 MHz channel and the first 160 MHz channel provided within the existing Wi-Fi ecosystem it is clear that benefits would be expected to far outweigh the minimal transition costs of the FCC’s proposal.