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Washington, D.C. 20554

In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	Docket No. 12-268

COMMENTS OF GOOGLE INC. AND MICROSOFT CORPORATION

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I. INTRODUCTION AND SUMMARY.

The Commission's Notice of Public Rulemaking ("NPRM") finds that "usage of our wireless networks is skyrocketing, dramatically increasing demands on both licensed and unlicensed spectrum," and that "[m]eeting this challenge is essential to continuing U.S. leadership in technological innovation, growing our economy, and maintaining our global competitiveness."[1] Google and Microsoft agree. Our companies offer technologies that span the entire wireless economy—including mobile phones, tablets, mobile operating systems, cloud-based services, machine-to-machine services, maps, and gaming. These businesses depend on access to robust licensed services as well as access to robust unlicensed spectrum resources. One without the other simply will not allow U.S. businesses to meet accelerating consumer demand for wireless products and services.

Google and Microsoft therefore commend the Commission for recognizing the need for a balanced spectrum policy, and especially for the NPRM's commitment to designating substantial new sub-1-GHz unlicensed frequencies for broadband services and protecting access to the TV white spaces in the post-auction broadcast band. These comments describe how the FCC can achieve these goals.

Section II demonstrates that the Commission's commitment to expanding unlicensed spectrum designations is critical to U.S. economic growth and innovation. Section III explains

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[1] *Expanding the Economic and Innovation Opportunities of Spectrum through Incentive Auctions,* Notice of Proposed Rulemaking, 27 FCC Rcd. 12357, ¶ 1 (2012) ("*NPRM*"). Similarly, the National Broadband Plan states that "[i]n order to meet growing demand for wireless broadband services, and to ensure that America keeps pace with the global wireless revolution, 500 megahertz should be made newly available for mobile, fixed and unlicensed broadband use over the next 10 years . . . Ultimately, the cost of not securing enough spectrum may be higher prices, poorer service, lost productivity, loss of competitive advantage and untapped innovation." FCC, *Connecting America: The National Broadband Plan,* at § 5.8 (2010) ("*Connecting America*").

that the FCC can both free additional unlicensed spectrum and ensure adequate federal revenues for public safety needs and broadcaster relocation. Section IV outlines how the Commission can succeed in supporting unlicensed wireless innovation and investment by creating a band plan with new unlicensed designations that are large enough to support investment. Section V explains how the FCC can repack remaining broadcast licensees while protecting access to white space spectrum by consumers using unlicensed wireless devices. Section VI proposes how the Commission should advance its core policy of promoting intense and efficient use of 600 MHz spectral resources through rules related to wireless microphones.

II. FREEING ADDITIONAL UNLICENSED SPECTRUM IN THE 600 MHZ BAND IS CRITICAL TO U.S. ECONOMIC GROWTH, INNOVATION, AND THE EXPANSION OF BROADBAND AVAILABILITY.

Commission action to both create new unlicensed wireless designations in the 600 MHz band and protect remaining white spaces in the broadcast band will promote economic growth, support innovation, and expand access to broadband. Additional unlicensed spectrum resources assuredly will produce these public interest benefits because: (1) the unlicensed wireless sector is huge and growing rapidly, (2) unlicensed wireless technologies already contribute many billions of dollars annually to the U.S. economy, (3) access to unlicensed spectrum allows licensed wireless and wireline broadband providers to increase the reach of their networks and improve network management, and (4) innovators and investors need substantial new sub-1-GHz unlicensed spectrum resources to address skyrocketing consumer demand, support the expansion of cellular offload, and network the millions of devices that will compose the coming Internet of Things.

A. The Unlicensed Wireless Sector is Huge and Growing Rapidly.

The Commission should be proud of the exceptional engine for economic growth and innovation it enabled through its unlicensed spectrum designations. In 1985, the FCC broke ground by enabling widespread communications uses in unlicensed spectrum.[2] Since that time the FCC has supported wireless technologies by designating additional licensed and unlicensed frequency bands as spectrum became available. For decades, this balanced approach has ensured consumers, innovators, and investors access to higher-barrier-to-entry licensed spectrum, as well as to low-barrier-to-entry unlicensed spectrum, each of which plays an important role in the overall wireless ecosystem. This strategy has led to an explosion of consumer unlicensed device adoption and the deployment of an important and growing set of unlicensed applications that are contributing billions to the national economy, as described below.[3]

The Commission's commitment to providing unlicensed spectrum resources allowed innovators to invest in research and development that produced thousands of new unlicensed

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[2] *See generally Authorization of Spread Spectrum & Other Wideband Emissions Not Presently Provided for in the FCC Rules & Regulations*, First Report and Order, 101 FCC 2d 419 (1985) (*"ISM Band Order"*) (authorizing the use of spread spectrum technology to enable communications uses in so-called "junk band" spectrum previously used only for non-communications industrial uses).

[3] The expansion of unlicensed spectrum has meant that unlicensed devices are freed from the requirement to make high-cost investment in licensing, *see* Kenneth R. Carter, Ahmed Lahjouji, & Neal McNeil, FCC, *Unlicensed and Unshackled: A Joint OSP-OET White Paper on Unlicensed Devices and Their Regulatory Issues*, OSP Working Paper Series, at 5 (May 2003) ("OSP Paper"), and that innovators can therefore develop "low-power consumer devices such as cordless phones, where the cost of coordination and licensing would probably far exceed the cost of the equipment." Jon M. Peha, Carnegie Mellon University, Carnegie Institute of Technology Department of Engineering and Public Policy, Paper 5, *Sharing Spectrum through Spectrum Policy Reform and Cognitive Radio*, at 6 (Jan. 2008).

technologies each year, leading to rapid consumer adoption.[4] Wi-Fi enabled devices are the best-known class of such technologies. In 2005, "tens of millions" of Wi-Fi devices were sold globally.[5] By 2011, the market had increased dramatically, with 800 to 900 million devices sold globally and with at least 150 million of those sales occurring in the United States.[6] Wi-Fi device sales figures have seen double-digit growth in recent years, with growth in 2011 estimated to be between 25 and 30 percent.[7] The sale of Wi-Fi routers alone "has sustained a compound average growth rate over 30 percent for almost a decade."[8]

This boom in sales of Wi-Fi enabled devices has been accompanied by a boom in Wi-Fi traffic. Wi-Fi today accounts for an estimated 80 percent of all traffic from smartphones and

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4 Because unlicensed devices are "free from the burden of normal delays associated with the licensing process," and the use of the unlicensed spectrum itself is free, manufacturers can design equipment to "fill a unique need [that can] be introduced into the marketplace rather quickly." And they have done so, creating devices ranging from remote control toys to wireless routers to networked home thermostats. OSP Paper; *see also* Richard Thanki, *The Economic Value Generated By Current And Future Allocations Of Unlicensed Spectrum*, Final Report at 36 (Sept. 2009) ("Thanki 2009") (citing Greg Raleigh as noting that "[i]n the cellular market things take longer: you've got the service providers who pay for the spectrum, the spectrum is licensed so in order to operate a piece of hardware you have to have a license from the carrier, and the carriers work with very large equipment providers who develop equipment over a longer period of time than the short cycles we have in Wi-Fi.").

5 Mark Cooper, *Efficiency Gains and Consumer Benefits of Unlicensed Access to the Public Airwaves* at 7 (Jan. 2012) ("Cooper") (citing *Case History: A Brief History of Wi-Fi,* ECONOMIST, June 12, 2004).

6 *Id.* at 7-8 (citing Nick Flaherty, *Consumer WiFi Drives Global Growth*, THE EMBEDDED BLOG, May 26, 2010, http://embeddedblog.blogspot.com/2010/05/consumer-wifi-drives-global-growth.html).

7 Comments of Edgar Figueroa, CEO, Wi-Fi Alliance, at Center for Internet and Society at Stanford Law School, "The Power and Potential of the Unlicensed Economy" (July 11, 2012), *available at* http://stanfordvideo.stanford.edu/stream/saapanel.html ("Stanford Unlicensed Economy Conference").

8 Cooper at 10.

tablets,[9] and Cisco's Virtual Networking Index found that traffic from devices connecting to the network via Wi-Fi represented 37 percent of *all* IP traffic in the United States in 2011.[10] That number is expected to rise to 45 percent by 2016.[11] In comparison, traffic from devices relying solely on wired connections to the network will drop from 62 percent in 2011 to 45 percent by 2016.[12]

Wi-Fi devices are not the only unlicensed devices experiencing meteoric sales.[13] For example, in 2011, American consumers and businesses purchased an estimated three-quarters of a billion to a billion RFID devices.[14] Moreover, Bluetooth and ZigBee, as recognized by the President's Council of Advisors on Science and Technology ("PCAST"), also "offer an overwhelming array of new services."[15] Bluetooth is increasingly a standard feature in new automobiles, facilitating hands-free operation of music players, smartphones, and other

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9 *Id.* at 13.

10 Cisco Virtual Networking Index 2011-2016, Forecast Highlights Tool, United States – Network Connections, *available at* http://www.cisco.com/web/solutions/sp/vni/vni_forecast_highlights/index.html#~Country ("CVNI Forecast"). In comparison, mobile data traffic was 2 percent of all IP traffic in 2011. *Id.*

11 *Id.*

12 *Id.*

13 *See* Cooper at 9 & n.35.

14 *See RFID Market Reaches $7.67 Billion in 2012 – Up 17% from 2011*, IDTECHEX, July 18, 2012, http://www.idtechex.com/research/articles/rfid-market-reaches-7-67-billion-in-2012-up-17-from-2011-00004585.asp (noting that 2.93 billion RFID tags were sold globally in 2011); Thanki 2009 at 35 (estimating that U.S. unlicensed sales account for up to 25 percent of the global market); *RFID Forecasts, Players and Opportunities 2011-2021*, Summary, IDTECHEX (2011), http://www.idtechex.com/research/reports/rfid_forecasts_players_and_opportunities_2011_2021_000250.asp (showing figures estimating that the North American share of RFID sales will amount to nearly 35 percent of global sales by 2016).

15 Executive Office of the President, President's Council of Advisors on Science and Technology, *Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth*, Report to the President, at 40 (July 2012) ("*PCAST Spectrum Report*").

devices.[16] ZigBee powers technologies that benefit from ad-hoc and mesh networking solutions, such as home automation.[17] Almost one billion Bluetooth chipsets were sold in 2008,[18] with sales increasing 23 percent between 2009 and 2010.[19] Total Bluetooth sales will reach 2.4 billion by 2014, according to a recent estimate.[20] Similarly, ZigBee devices are experiencing rapid growth, from about 15 million in 2008[21] to an estimated 350 million by 2016.[22] Combining the growth in Wi-Fi, Bluetooth, RFID, ZigBee, and unlicensed devices based on other protocols, a recent study found that consumers are fueling an astonishing demand for unlicensed devices, which are experiencing a "compound annual growth rate approaching 50 percent."[23]

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16 James Hamel, *Which 2010 Cars Have Bluetooth Capability*, YAHOO! VOICES, Dec. 4, 2009, http://voices.yahoo.com/which-2010-cars-bluetooth-capability-5016758.html ("Bluetooth is becoming a more and more common feature on new cars").

17 *See* ZigBee Home Automation Overview, http://www.zigbee.org/Standards/ZigBeeHomeAutomation/Overview.aspx (describing the ZigBee Alliance's Home Automation standard).

18 Thanki 2009 at 18.

19 In-Stat/MDR, Summary, *Bluetooth 2011: Rapid Growth for Established Interface*, RESEARCH AND MARKETS, Aug. 2011, http://www.researchandmarkets.com/research/11da13/bluetooth_2011_ra.

20 Thanki 2009 at 18.

21 *Id.*

22 *Bluetooth and ZigBee on Collision Course in the Connected Home and Wireless Sensors*, ABI RESEARCH, July 12, 2012, http://www.abiresearch.com/press/bluetooth-and-zigbee-on-collision-course-in-the-co.

23 Cooper at 7; Thanki 2009 at 19 ("[S]hipments of devices using only licensed spectrum, including phones and 3G and 4G dongles, televisions and radios, will remain stable, perhaps even decline [while] shipments of hybrid devices, including Wi-Fi and Bluetooth enabled mobile phones, 3G and 4G enabled laptops, Wi-Fi enabled televisions and set-top boxes, and cars possessing Bluetooth will likely double….The sales of devices using only unlicensed spectrum are likely to soar, led by Wi-Fi and Bluetooth enabled consumer electronics and laptops, 802.15.4 devices in the consumer, commercial and industrial sectors, and RFID devices.").

B. The Unlicensed Wireless Sector Contributes Billions to the National Economy.

Because of the enormous number of unlicensed devices described above, the growth of consumer demand seen each year, and the efficiency gains produced by these technologies, the unlicensed wireless sector has contributed substantially to the U.S. economy in an era where growth in other sectors has been limited. Recent studies calculate the annual contribution of the unlicensed wireless sector to be between $50 and $100 billion per year.[24]

These estimates include economic contributions created by unlicensed wireless technologies and services that enable applications such as:

- Internet access in homes;
- Internet access in retail establishments;
- Machine-to-machine connectivity;
- Hospital and healthcare connectivity;
- Cellular offload;
- Rural connectivity through WISPs; and
- Smart-grid connectivity.

In addition, recent investments by cable companies such as Cablevision, Comcast, and Time Warner Cable have added another dimension to the economic contribution made by unlicensed technologies—Wi-Fi metropolitan networks ("metronets"). These cable investments, and the growing trend of augmenting and improving wireline networks with metronets more generally, represent an enormous new contribution to the national economy powered by unlicensed technologies that are not yet reflected in economists' estimates.

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[24] *See* Cooper at 21-24 & Ex. IV-2. Other studies have estimated the global economic impact from connected devices (the majority of which will use unlicensed spectrum) will reach $4.5 trillion by 2020. *See generally* GSMA, *The Connected Life: A USD 4.5 Trillion Global Impact in 2020* (Feb. 2012), *available at* http://connectedlife.gsma.com/wp-content/uploads/2012/02/Global_Impact_2012.pdf.

1. Internet access in homes.

Strategy Analytics estimates that 61 percent of U.S. households depend on unlicensed technologies for home networking.[25] The best-known use of unlicensed technologies by home users is wireless access to a wired-broadband connection. Economist Richard Thanki estimates this extension of fixed broadband networks by use of unlicensed spectrum generates $15.5 billion of consumer surplus in the United States every year.[26] Indeed, he estimates that between 4 and 9 million additional households in the United States subscribe to fixed broadband *because of* the availability of Wi-Fi;[27] he also estimates that without Wi-Fi, between 10 and 23 million fixed broadband connections would be disconnected in North America.[28]

American households' dependence on unlicensed technologies, and the value of this unlicensed technology application to the economy, is likely to grow substantially in the near future. Whole-home distribution of online video will contribute greatly to this growth. By 2016, two-thirds of all mobile broadband traffic is expected to consist of online video.[29] Video and gaming, more than other wireless applications, rely heavily on unlicensed spectrum because 3G

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[25] Press Release, *Strategy Analytics: A Quarter of Households Worldwide Now Have Wireless Home Networks*, BUSINESSWIRE, Apr. 4, 2012, http://www.businesswire.com/news/home/20120404006331/en/Strategy-Analytics-Quarter-Households-Worldwide-Wireless-Home.

[26] Richard Thanki, *The Economic Significance of Licence-Exempt Spectrum to the Future of the Internet*, at 35 (June 2012) ("Thanki 2012"). Unlicensed advocates in Europe have estimated that "the value created by dedicating high quality spectrum to unlicensed would be over $110 billion per year." Those advocates are calling for dedicating 50 MHz of spectrum to unlicensed use. Cooper at 30-31.

[27] Thanki 2009 at 27.

[28] Thanki 2012 at 36.

[29] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2011–2016, Executive Summary, http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html.

and 4G networks are simply not capable of handling the amount of bandwidth consumers of online video and gaming demand.[30] Even if carrier networks had or could increase capacity to accommodate that demand, access would be very expensive for consumers. As online video and gaming applications become an ever-greater percentage of wireless content, consumers will need additional unlicensed spectrum to ensure access to the applications they demand, when and where they demand them.

2. Internet access in retail establishments.

Wi-Fi hotspots provided by retailers and other commercial establishments are becoming an ever-more important part of the unlicensed ecosystem as well. Although Wi-Fi has long been available at universities, government buildings, and libraries, more and more commercial establishments are realizing the value of providing broadband connectivity via hotspots for customers. In addition to access points administered by individual retailers, many other Wi-Fi hotspots are provided by nationwide wireless carriers—as of 2011, for instance, AT&T stated that it alone operated 29,000 hotspots in the United States[31] and a study by HSBC found that the four nationwide wireless carriers in the U.S. operate four hotspots for every cell site.[32]

A recent paper estimated that this commercial hotspot connectivity creates $10 billion of value per year,[33] and that this value will grow as more and more restaurants, malls, hotels, and convention centers make Wi-Fi available throughout their properties. Many businesses view Wi-Fi as critical for driving in-store consumers to mobile commerce and marketing applications

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30 *Cf.* Comments of Vijay Nagarajan, Broadcom, at Stanford Unlicensed Economy Conference (noting that even current-generation Wi-Fi networks will be unable to accommodate the growing demand for online video).

31 Cooper at 11 (citing AT&T).

32 *Id.*

33 *Id.* at 19.

"due to its pervasive presence in consumer smartphones and the lack of adequate 3G/4G cellular data network coverage within many brick-and-mortar facilities."[34] For example, the hospitality industry has begun to realize that hotel and convention guests not only want but also expect wireless access everywhere—and by ensuring that access is available, they strengthen their bottom line.[35]

3. Machine-to-machine connectivity and the Internet of Things.

Machine-to-machine ("M2M") communications permit a huge variety of automated data exchange, including connections needed for supply chain management, asset tracking, access control, and smart grid implementation—and rely almost exclusively on unlicensed spectrum.[36]

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[34] Andrew Vonnagy, "A Look Ahead to Possible Wi-Fi Industry Trends in 2011," Revolution Wi-Fi, Dec. 21, 2010, http://revolutionwifi.blogspot.com/2010/12/look-ahead-to-possible-wi-fi-industry.html.

[35] *See* Justin Herrman, *Don't Underestimate the Power of Public WiFi Networks*, FORBES.COM, Dec. 3, 2012, http://www.forbes.com/sites/ciocentral/2012/12/03/dont-underestimate-the-power-of-public-wifi-networks/.

[36] *See* Yochai Benkler, *Open Wireless vs. Licensed Spectrum: Evidence from Market Adoption*, at 11-12 (Nov. 2011) (working draft); Thanki 2012 at 59-60 ("The overwhelming majority of connections to the internet by things will use licence-exempt spectrum"). While licensed wireless connectivity will likely play an important role in the IOT as well, the lower costs offered by unlicensed connectivity will be far better suited to most M2M systems. *See* Benkler at 12. When relying on unlicensed technologies, manufacturers or operators of the networked devices that compose the IOT can focus investment on device design, manufacture, component acquisition, and certification rather than on fees paid to CMRS carriers. Critically, because there is no need to acquire or lease unlicensed spectrum access, the barriers to entry are lower, devices can be simpler and more interoperable, and companies can avoid the higher barriers to entry associated with establishing business arrangements and acquiring carrier-specific devices or components—resulting in the cheaper and simpler environment needed for companies to network of hundreds of millions of previously isolated devices. *See* John M. Chapin & William H. Lehr, *SCADA for the Rest of Us: Unlicensed Bands Supporting Long-Range Communications*, TPRC 2010, at 7 ("[W]e have identified a communications requirement for [Supervisory Control and Data Acquisition (SCADA) for the rest of us]. The requirement is chosen to require the least amount of communications resources, such that the largest possible group of applications is served, under the condition that those applications are not well supported today…We think it is plausible that there are a

Unlicensed spectrum is perfectly suited to this so-called Internet of Things ("IOT") because for these machines to be networked cost-efficiently and effectively, designers require access to low-cost spectrum, low-cost components, and standardization.

M2M applications spur economic growth in a variety of ways, such as by increasing efficiency, automating previously manual functions, and eliminating waste.[37] For instance, use of RFID tags in the retail sector can permit companies to track components and raw materials into the factory, and finished products out of the factory into warehouses and retail stores, allowing them to manage their stock, track consumer preferences, and reduce personnel costs.[38] Thanki estimates that inventory management via RFID tags in the retail clothing sector alone could generate $2 to $8 billion per year in economic value in the United States between 2009 and 2025.[39]

4. Hospital and healthcare connectivity.

Unlicensed wireless networks in hospitals and other healthcare facilities also generate enormous value for the U.S. economy. Hospitals have deployed unlicensed wireless technologies both for intra-campus communications as well as for "in-hospital medical grade,

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large number of systems and activities where the benefit of automation per endpoint is significantly less than the communications cost currently charged by mobile service providers to small-volume users, and that the sum of available benefits over all those systems and activities is significant.").

[37] *See* Michael Vizard, *GE Values "Internet of Things" in the Trillions*, ITBUSINESSEDGE, Nov. 30, 2012, http://www.itbusinessedge.com/blogs/it-unmasked/ge-values-internet-of-things-in-the-trillions.html ("[W]hat GE refers to as the "Industrial Internet" could spur annual productivity gains of 1 to 1.5 percentage points in the U.S. alone… GE estimates that a truly Industrial Internet would also eliminate $150 billion in waste across major industries, while a one percent increase in productivity would generate savings of $30 billion in aviation, $66 billion in power generation and $63 billion in health care over 15 years.").

[38] Thanki 2009 at 32.

[39] *Id.* at 34.

mission-critical wireless networks."[40] Eighty percent of the healthcare wireless market, in fact, is served by unlicensed technologies.[41] Those technologies include campus-wide Wi-Fi as well as RFID, Bluetooth, and ZigBee trackers used to access and update patient records, order tests and prescriptions, and monitor patient conditions.[42]

As of 2009, economist Richard Thanki estimated that wireless local area networks in U.S. hospitals generated as much as $16 billion of value per year.[43] That value will grow. Unlicensed technologies are particularly well-suited for the large number of healthcare applications, including many patient monitoring services, that depend on connectivity in healthcare facilities, homes, and offices, but not while in transit between these locations.[44] In addition, unlicensed wireless technologies operating at lower power are less likely to cause interference with critical medical equipment.[45] Additional unlicensed spectrum at lower frequencies can also enable hospitals to provide campus-wide coverage with fewer antennas, lowering costs and improving service.

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40 Benkler at 10 (emphasis omitted).

41 *Id.* (citing Kalorama Information, *Wireless Technologies in Healthcare*, Sept. 2011).

42 *See id.* at 11; Thanki 2009 at 28.

43 Thanki 2009 at 31.

44 *See* Benkler at 18.

45 *Cf.* Erik J van Lieshout, et al., *Interference By New-Generation Mobile Phones On Critical Care Medical Equipment*, 11 CRITICAL CARE R98 (2007), *available at* http://ccforum.com/content/pdf/cc6115.pdf.

5. Cellular offload.

Unlicensed technologies also contribute to economic growth by serving as an increasingly common part of network management by licensed wireless broadband providers. Access to unlicensed spectrum allows these carriers to offload traffic from congested networks,[46] thereby "lower[ing] their own costs and expand[ing] their service offerings,"[47] while reducing the amount of physical infrastructure needed to support growing mobile broadband demand.[48]

Individual cellular providers are working hard to keep up with the huge quantity of traffic that mobile Internet access generates. To do so, each carrier must make massive investments in its infrastructure. These network operators frequently find it efficient to offload traffic to bands reserved for unlicensed use in combination with a strategy of acquiring new spectrum rights, building additional towers, and otherwise investing to increase the capacity of their systems.[49] Use of the unlicensed capabilities of consumers' devices to deliver data also allows carriers to take advantage of one of the great strengths of unlicensed systems—commercial establishments, networks such as cable operators, and the combined millions of individual consumers can install far more access points than can any individual wireless carrier, even a large carrier with

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[46] Cooper at 5 ("Faced with a flood of traffic, the operators of networks based on exclusive licenses found it cost-effective to offload huge volumes of traffic onto the unlicensed spectrum.").

[47] *Id.* at 41.

[48] Thanki 2012 at 8-9.

[49] *See* Savio Dimatteo, Pan Hui, Bo Han, & Victor O.K. Li, *Cellular Traffic Offloading Through WiFi Networks*, at 10 (Oct. 2011), *available at* http://www.deutsche-telekom-laboratories.de/~panhui/publications/mass11offload.pdf ("[W]e present an architecture for the integration of WiFi networks and mobile-to-mobile Pocket Switched Networks (PSN) with cellular networks to provide a low-cost solution to handle the exponential growth of mobile data traffic. Using real mobility traces from the city of San Francisco, we have shown that only few hundreds of WiFi APs deployed in an area of 313.83km^2 can offload half of the mobile data from the 3G network in our scenario settings for both download and upload cases.").

enormous resources. If consumers use these unlicensed networks when they are available in conjunction with a carrier's licensed network, the coverage and quality experienced by that consumer improves without the need for additional investment by the carrier.

While carriers continue to make huge investments in their networks, and to make use of microcells and picocells, they are unlikely to replicate the coverage and quality of the nation's huge number of unlicensed access points. Doing so would be uneconomic given the costs associated with securing building access, power, and backhaul for each of the millions of access points in homes, commercial locations, hotels, offices, and now cable metronets. Moreover, the addition of that large a number of new cell sites is likely not possible in "urban areas where the vast majority of end-users reside."[50] Furthermore, each different CMRS carrier would have to repeat this Herculean labor for its own customers, meaning that the cost to the economy of building individual overlapping private microcell/picocell networks of the quality and pervasiveness of today's unlicensed network would be quadrupled, even counting only the four national wireless carriers.

It is therefore not surprising that unlicensed offload is so popular. Today over one-third of the Internet-bound mobile data traffic carried by the CMRS carriers is offloaded to unlicensed bands. That percentage is expected to rise over the next decade.[51] According to ComScore, by mid-2011, 37 percent of smartphone traffic was offloaded by cellular carriers to Wi-Fi

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[50] Cooper at 22.

[51] *See* Cisco Virtual Networking Index, VNI Mobile Forecast Highlights, 2011-2016, *available at* http://www.cisco.com/web/solutions/sp/vni/vni_mobile_forecast_highlights/index.html; Janko Roettgers, *Wi-Fi to Overtake Wired Network Traffic by 2015*, GIGAOM, June 1, 2011, http://gigaom.com/2011/06/01/cisco-wifi-vni-report/ (citing Cisco Virtual Networking Index Global IP Traffic Forecast 2011-2015); Cooper at 12; *see also id.* at 5 ("Faced with a flood of traffic, the operators of networks based on exclusive licenses found it cost-effective to offload huge volumes of traffic onto the unlicensed spectrum.").

networks.[52] Devicescape, a Wi-Fi offload company, reports that carriers in the U.S. market can offload as much as 50 percent of cellular traffic to Wi-Fi, a number that far surpassed its initial estimates.[53] And a recent study estimates that Wi-Fi offload has saved licensed wireless carriers as much as $26 billion per year in infrastructure costs already[54] and the worldwide cost savings to mobile operators has been estimated to reach $250 billion in the next four years.[55] Wi-Fi traffic already exceeds mobile network traffic by smartphone users in many places[56] and in North America, the absence of Wi-Fi for mobile network offloading would result in an increase of between $4 and $8 billion worth of new base stations alone to accommodate the traffic currently handled by Wi-Fi networks.[57]

In the absence of adequate unlicensed spectrum, operators would almost certainly have to raise prices to pay for the necessary infrastructure costs. This would also reduce the value of the network to consumers compared with today's hybrid licensed/unlicensed system (because, as

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52 Press Release, ComScore, Smartphones and Tablets Drive Nearly 7 Percent of Total U.S. Digital Traffic (Oct. 10, 2011), http://www.comscore.com/Insights/Press_Releases/2011/10/Smartphones_and_Tablets_Drive_Nearly_7_Percent_of_Total_U.S._Digital_Traffic; Cooper at 12.

53 Remarks of Dave Fraser, CEO, Devicescape, at Stanford Unlicensed Economy Conference.

54 Cooper at 22.

55 Thanki 2012 at 9.

56 Informa Telecoms & Media, *White Paper: Understanding Today's Smartphone User: Demystifying Data Usage Trends on Cellular & Wi-Fi Networks* at 3 (Feb. 2012), *available at* http://www.informatandm.com/wp-content/uploads/2012/02/Mobidia_final.pdf; Thanki 2012 at 36-37.

57 Thanki 2012 at 38-39; *see also* Cooper at 17-18. These conclusions are supported by data indicating that cell-site construction has slowed beyond what would be expected. ("[T]he deployment of cell sites slowed dramatically in late 2008. In the ten quarters between December 2008 and June 2011, the industry added 15,000 cell sites. In the ten quarters before December 2008, the industry added 64,000 cell sites—over four times as many. The drop-off in the addition of cell sites coincided with the offloading of traffic onto the unlicensed use spectrum.").

described above, it would be uneconomic or impossible to build a replacement network with the quality and coverage of today's unlicensed network) and hamper innovation (because the absence of unlicensed spectrum would raise barriers to entry).[58] Carriers are increasingly expanding their offload capabilities and investing in the unlicensed ecosystem,[59] showing that they recognize the value of a balanced spectrum policy that makes room for both licensed and unlicensed uses.

6. Rural last-mile connectivity through WISPs.

Unlicensed technologies also contribute to the national economy by permitting last-mile broadband expansion to areas that are un- or underserved by traditional ISPs. This broadband expansion is critical for job creation and economic growth and "can provide significant benefits to the next generation of American entrepreneurs and small businesses—the engines of job creation and economic growth for the country."[60] Areas where high-speed broadband is unavailable "will find it more difficult to attract investment and IT-intensive jobs, particularly because they face growing national and international competition."[61] Broadband and broadband-enabled technologies allow businesses to "increase efficiency, improve market access, reduce costs and increase the speed of both transactions and interactions."[62]

Wireless Internet Service Providers ("WISPs") use unlicensed technologies to provide service to rural areas where other broadband providers cannot economically build out wired

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58 Thanki 2012 at 40.

59 *See, e.g.*, Tammy Parker, *AT&T: Wi-Fi Will Be in All of our Small Cell Deployments*, FIERCEBROADBANDWIRELESS, Jan. 9, 2013, http://www.fiercebroadbandwireless.com/story/att-wi-fi-will-be-all-our-small-cell-deployments/2013-01-09.

60 *Connecting America* at § 13.1.

61 *Id.* § 13.4.

62 *Id.* § 13.1.

systems.[63] Many ISPs cannot justify the expense required to build out to rural and low-population areas.[64] Wireline build-out costs to the last mile—including deployment of customer premises equipment—can cost $100,000 per mile of cable laid.[65] While these costs may be reasonable in high-population areas where one mile of cable or a single cell site can serve many thousands of customers, they are often uneconomic in rural areas where one mile of cable may serve only a few hundred customers.

WISPs, however, can provide cost-effective wireless broadband service in rural and low-population areas because they avoid the high cost of building out wireline facilities. Up to the last mile, their costs are largely the same as any other traditional provider, but by using unlicensed spectrum, they are able to avoid the high per-customer cost of laying last-mile cable or licensing spectrum for last-mile wireless broadband in rural and low-population areas.

Additional unlicensed spectrum, particularly in the TV band, with its superior propagation characteristics for wide-range, non-line of sight operations, will facilitate further broadband expansion by WISPs into areas least likely to be served by traditional ISPs. Lower frequency spectrum will allow deployment of fewer antennas operating at lower power levels.[66]

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63 *See* Eric Butterman, *Want Wireless Broadband Today? Try a WISP*, PCMAG.COM, Feb. 6, 2009, http://www.pcmag.com/article2/0,2817,2340369,00.asp (quoting a WISP spokesman who noted that "[p]hone companies said they'd never bring DSL connections to his community" and who, in response, was able to bring up to 10 mbps service to his town).

64 *Connecting America* at § 6.8 ("Although pushing fiber deeper into broadband networks considerably improves the performance and reliability of those networks, deploying a mile of fiber can easily cost more than $100,000"); *see also* Thanki 2012 at 29.

65 *Connecting America* § 6.8.

66 *See* Thanki 2012 at 45 (noting that TV band spectrum can be used to "spread coverage over an entire area, such as a large farm or village centre, using only a single access point"); Sascha D. Meinrath & Michael Calabrese, *"White Space Devices" & The Myths of Harmful Interference*, 11 N.Y.U. J. LEGIS. & PUB. 495, 501 (2008).

Lower deployment and operating costs will permit faster deployment and keep consumer costs down, both critical to realizing the full economic potential of broadband expansion.

7. Smart grid connectivity.

The use of unlicensed technologies for smart grid connectivity also illustrates the value of unlicensed spectrum to the national economy. The availability of even a small slice of sub-1-GHz unlicensed spectrum in the United States—through the limited and problematic 900 MHz band—has permitted innovation and expansion of smart grid technologies that are unmatched in Europe and in other countries. Smart grid applications permit utility meters to communicate on a short- and long-range basis to meter readers, substations, and central stations, providing information about utility usage and permitting utility providers to increase efficiency, reliability, economics, and sustainability of services. In the United States, most smart grid applications operate over the unlicensed 900 MHz band, while in Europe, the unavailability of sub-1-GHz spectrum has forced many countries to find alternatives, such as connectivity through power line carriers. Richard Thanki notes that the unavailability of sub-1-GHz spectrum for smart grid operations "severely hinders the next steps in the development of the smart grid" in Europe.[67] He estimates that delays in implementation caused by lack of full deployment could result in up to $240 billion in costs for Europe.[68]

In contrast, smart grid technologies in the U.S. have taken off. Advanced meters are being deployed in the U.S. at almost three times the rate in Europe.[69] Yochai Benkler notes that speedy deployment is largely the result of investment and innovation by "communications

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[67] Thanki 2012 at 71.

[68] *Id.* at 72.

[69] *See PCAST Spectrum Report* at 40 (citing Benkler).

players who specialized in smart grids and could develop solutions without asking permission … [t]his is exactly the power of open innovation over open wireless bands."[70] And the economic benefits that accrue from smart grid deployment are very real; access to real-time usage information, for instance, can lead to usage reductions of up to 20 percent. Adding additional unlicensed spectrum not only would speed deployment of smart grids nationwide, permitting cost savings and recovery by consumers, utilities, and government, but would also make possible a set of other longer-range, outdoor unlicensed wireless applications like smart metering that are not possible today because of the constraints of currently available spectrum resources.

8. Cable metronets.

The emergence of wireless cable metronets adds a new and potentially enormous additional contribution by unlicensed technologies to the national economy. Several cable companies have invested in networks that provide subscribers with access to nomadic and mobile networks so that customers have broadband access not only inside the home, but also outside the home and while traveling.[71] These metronets are based exclusively on unlicensed spectrum bands.[72]

For instance, Cablevision has invested heavily to create a cohesive, organized deployment of city-wide Wi-Fi in New York. It has deployed tens of thousands of unlicensed access points not only in retail and commercial establishments but also in convention centers,

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[70] Benkler at 10.

[71] Comments of Robert Cerbone, Vice President, Wireless Products, Time Warner Cable, at Stanford Unlicensed Economy Conference.

[72] *Id.*

along the streets, and in areas where the public gathers outdoors,[73] with an app that allows subscribers to find a Cablevision hotspot while away from home.[74] Comcast has made its XFINITY Wi-Fi service available to its subscribers for free throughout the Philadelphia area[75] and in its California footprint.[76] Bright House Networks customers have access to free Wi-Fi throughout Florida,[77] while Cox has made free Wi-Fi available in Connecticut and Northern Virginia.[78] Time Warner similarly has invested in a large unlicensed network in Los Angeles, offering its customers Internet access in tens of thousands of retail establishments, businesses, and in outdoor public areas.[79]

Furthermore, cable operators are working together to provide reciprocal access for each other's subscribers. Time Warner Cable, Comcast, Cox, Cablevision, and Bright House Networks have announced a platform called CableWiFi, which permits subscribers of any of the five companies to connect to the other providers' Wi-Fi networks in the New York City area,

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73 David Pogue, *Free Wi-Fi for Cablevision Subscribers? Yep.*, N.Y. TIMES, May 1, 2009, http://pogue.blogs.nytimes.com/2009/05/01/free-wi-fi-for-cablevision-subscribers-yep/.

74 Jon Fingas, *Cablevision launches iOS app to track down Optimum WiFi hotspots, keep you off the 3G sauce*, ENGADGET, June 27, 2012, http://www.engadget.com/2012/06/27/cablevision-launches-ios-app-to-track-down-optimum-wifi-hotspots/.

75 Chloe Albanesius, *Comcast Launches Xfinity Wi-Fi Hot Spots in Philadelphia, N.J.*, PCMAG.COM, Oct. 11, 2010, http://www.pcmag.com/article2/0,2817,2370607,00.asp.

76 Angela Moscaritolo, *Comcast Rolls Out Free Wi-Fi in California for Xfinity Customers*, PCMAG.COM, Sept. 27, 2012, http://www.pcmag.com/article2/0,2817,2410276,00.asp.

77 Press Release, Bright House Networks Customers Can Now Stay Connected on the Go with Bright House Networks WiFi, Jan. 12, 2012, http://brighthouse.com/central-florida/about/9939.htm.

78 Cox WiFi, http://ww2.cox.com/aboutus/connecticut/our-story/our-services/wifi-hotspot-map.cox?campcode=ln_wifi_find_011313.

79 TWC WiFi, http://www.twcwifi.com/support, *Time Warner Cable Rolls Out Wi-Fi Service in Los Angeles*, LA TIMES, Sept. 9, 2011, http://latimesblogs.latimes.com/entertainmentnewsbuzz/2011/09/time-warner-cable-rolls-out-wi-fi-service-in-los-angeles.html.

Los Angeles, Tampa, Orlando, and Philadelphia, just as though they were connecting in their home market.[80] In all, the five providers expect to provide access to 50,000 hotspots nationwide.[81]

Cable metronets are just beginning to emerge, and have therefore not been part of any prior economic analysis. Thus the economic values estimated by Richard Thanki, Mark Cooper, and others that are discussed above do not account for this additional contribution to the national economy. Therefore, the overall contribution of unlicensed to the economy is likely much, much higher than the figures cited in these comments.

C. New Spectrum Designations Are Needed To Support and Expand the Economic Growth, Job Creation, and Innovation Created by Unlicensed Wireless Technologies.

To maintain the exceptional growth and economic contribution of the unlicensed wireless sector, the FCC must designate diverse frequencies for use by unlicensed technologies. Additional frequencies are necessary to support new innovations that are not possible with existing unlicensed designations and to improve and enrich existing applications that are limited by today's unlicensed spectrum bands. Studies predict that traffic on unlicensed networks will grow rapidly in the near future[82]—as noted above, Wi-Fi traffic already accounts for more than

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80 Comments of Robert Cerbone, Vice President, Wireless Products, Time Warner Cable, at Stanford Unlicensed Economy Conference; Chenda Ngak, *Time Warner, Comcast, Cablevision to offer free Wi-Fi hotspots*, CBSNEWS.COM, May 22, 2012, http://www.cbsnews.com/8301-501465_162-57439268-501465/time-warner-comcast-cablevision-to-offer-free-wi-fi-hotspots/.

81 Daniel Cooper, *CableWiFi ties up 50,000 WiFi hotspots for cable subscribers to share*, ENGADGET, May 21, 2012, http://www.engadget.com/2012/05/21/50000-cablewifi-hotspots/.

82 CVNI Forecast. *See also* Cooper at 28, 35; *see, e.g.*, Mass Consultants Limited, *Estimating the Utilisation of Key Licence-Exempt Spectrum Bands*, Final Report, Issue 3, at 2, 27 & 80 (Apr. 2009), *available at* http://stakeholders.ofcom.org.uk/binaries/research/technology-

one-third of all IP traffic in the United States and for 80 percent of IP traffic from mobile devices. To keep pace with consumer demand, innovators and investors will need both additional licensed spectrum resources and additional higher-frequency, middle-frequency, and lower-frequency unlicensed spectrum resources.

Google and Microsoft are therefore pleased that the FCC is pursuing new spectrum auctions, and, in addition, new unlicensed designations in the 600 MHz, 3.5 GHz,[83] and 5 GHz,[84] bands. The Commission should rapidly make available new resources in each of these frequency ranges to address growing consumer demand for different types of wireless devices and applications, with different ranges and capabilities.

The FCC has already recognized the inherent benefits of providing unlicensed access in the 600 MHz band in its television white spaces proceeding.[85] The Commission recognized the value of sub-1-GHz spectrum for wide-area wireless broadband access, such as that provided by WISPs, noting that "transmissions in the TV band are subject to less propagation attenuation than transmissions in the spectrum where existing broadband unlicensed operations are

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research/wfiutilisation.pdf ("MCL Utilization Report"); *cf. supra* Part II.A (noting the explosive growth in unlicensed device sales).

83 *See Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550- 3650 MHz Band*, Notice of Proposed Rulemaking and Order, GN Docket No. 12-354 (rel. Dec. 12, 2012).

84 Middle Class Tax Relief and Job Creation Act, Pub. L. 112-96, 126 Stat. 156, § 6406 ("Spectrum Act").

85 *See generally Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, Notice of Inquiry, 17 FCC Rcd. 25632 (2002); *Unlicensed Operation in the TV Broadcast Bands, Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, Notice of Proposed Rulemaking, 19 FCC Rcd. 10018 (2004) ("*White Spaces NPRM*"); *Unlicensed Operation in the TV Broadcast Bands, Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, First Report and Order and Further Notice of Proposed Rulemaking, 21 FCC Rcd. 12266 (2006) ("*White Spaces First Report & Order*").

permitted," and that "allowing unlicensed operation in the TV bands could benefit wireless internet service providers (WISPs) by improving the service range of their existing operations, thereby allowing WISPs to reach new customers."[86] The Commission also noted that permitting unlicensed use of sub-1-GHz spectrum is likely to facilitate innovation by device manufacturers, and that "[g]iven the favorable propagation characteristics of the TV spectrum, these new devices could provide more effective service at greater ranges than other unlicensed devices that operate at higher frequency bands."[87] The Commission rightly expected this innovation to "have significant benefits for economic development and for consumers and businesses by providing additional competition in the broadband market."[88]

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86 *White Spaces NPRM* ¶ 1.

87 *Id.* ¶ 7

88 *Id.*; *see also White Spaces First Report & Order* ¶ 1 ("Because transmissions in the TV band are subject to less propagation attenuation than transmissions in other bands where lower power operations are permitted (such as unlicensed operations in the 2.4 GHz band), operations in the TV bands can benefit a wide range of service providers and consumers by improving the service range of wireless operations, thereby allowing operators to reach new customers."); *id. at* ¶ 13 ("Because of the favorable propagation characteristics of the TV spectrum, these new devices could provide more effective service at greater ranges than unlicensed devices that operate at higher frequency bands. These new devices and services could also have significant benefits for economic development and for consumers and businesses by providing additional competition in the broadband market."); *Unlicensed Operation in the TV Broadcast Bands, Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band,* Second Report and Order and Memorandum Opinion and Order, 23 FCC Rcd. 16807 (2008) ¶ 32 (*"White Spaces Second Report & Order"*) ("this decision will provide significant benefits for the public by enabling the development and operation of a wide range of new unlicensed wireless communications devices and systems in spectrum where signals are less subject to propagation losses than they are in the bands currently available for such devices. The propagation characteristics of these bands will allow the development of devices that can provide service at greater ranges than existing unlicensed devices. Proponents of broadband devices and services in particular indicate that there is need for new broadband devices that will take advantage of the more desirable propagation characteristics of the TV bands. As indicated above, we believe that the propagation advantages of this spectrum will make it possible for WISPs and others to improve or extend their reach to customers in rural and other less densely populated area.

Unlicensed access in the 600 MHz spectrum band therefore offers a substantial improvement for consumers and businesses that need longer-range communications and whole-home or whole-office coverage. This will also enable new and better unlicensed wireless applications, which could include:

- Broadband deployment in rural and other underserved areas where fiber deployment is too expensive;
- More efficient smart grid networking;[89]
- Healthcare applications available throughout a hospital from fewer access points;
- "Smart city" municipal applications such as lighting control, parking services, security cameras, and resources monitoring;
- Inventory management throughout factories or warehouses;
- Mobile payments systems across wide areas;[90]
- Fleet management in short and wide-range applications;[91] and
- Access/security, including smart card and biometric products, in areas where wired access is not possible.[92]

Furthermore, having access to high, middle, and low-frequency unlicensed bands will provide innovators far greater flexibility in designing equipment to enable a wide range of use cases. This will give engineers access to less expensive components that operate at a lower power on lower frequencies, where line-of-sight operations are not possible and where interference must be avoided, and at higher power in higher-frequency bands, permitting focused

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We also anticipate that these new devices will have economic benefits for consumers and businesses by facilitating the development of additional competition in the broadband market.").

89 *See* Benkler at 8-10.

90 *Cf. id.* at 12-13.

91 *See id.* at 14 ("The most likely important potential application of a dedicated open wireless band in the TV bands would be to permit innovation and experimentation with wider coverage that could begin to offer alternatives to licensed-spectrum approaches even in very wide area applications that have low tolerance for latency: like fleet management.").

92 *Id.* at 12.

point-to-point communications. Finally, unlicensed devices operating in the broadcast bands require less power for a given range and throughput, which increases battery life and reduces operating costs.

In addition to the innovation potential of the 600 MHz band, additional unlicensed designations at lower-frequency bands can provide a much-needed alternative to higher-frequency bands currently used intensively by unlicensed technologies. The 2.4 GHz band, while critical to the success of Wi-Fi and other unlicensed technologies, is increasingly congested, particularly in major cities and population centers[93]—the very areas where it will be most expensive to build further licensed network capacity. For example, a study commissioned by Ofcom in 2009 found that Wi-Fi suffered from congestion problems in the most populated parts of London, noting that at least some believed that increasing use of streaming video would eventually "cause the downfall of WiFi."[94]

In addition to congestion caused by too many people trying to access the same Wi-Fi channels at the same time, the study found that the increased numbers of other, non-Wi-Fi devices using the 2.4 GHz band also caused degradation in Wi-Fi quality.[95] Where there are more people, there will be more baby monitors, security cameras, and microwave ovens, and many other types of devices that increase congestion. In the near future, if not already in some locations, it is likely that the 2.4 GHz band will not be able to support growing consumer demand, notwithstanding Wi-Fi's efficiency and advances in technology, unless innovators can pair this band with new spectrum resources—just as licensed wireless carriers have explained

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93 Cooper at 22 (Expansion of mobile networks in the absence of wireless offloading is likely not possible in "urban areas where the vast majority of end-users reside.").

94 MCL Utilization Report at 27.

95 *Id.* at 2, 27.

that existing licensed bands may become unable to support growing licensed operations, despite their substantial investments and technological improvements.

Furthermore, while the 5 GHz band is an important part of the unlicensed ecosystem, it has serious regulatory, interference, and physical limitations.[96] First, the physical characteristics of the high-frequency 5 GHz band make it unsuitable for many unlicensed applications, such as those that require transmission over a wider range and through obstructions. Lower-frequency spectrum is ideal for two-way communications over a wider area, where non-line-of-sight operation is important, and to serve entire offices or homes.[97] Anyone who has attempted to cover more than a small area with a 5 GHz Wi-Fi router understands the limitations of these frequencies. Some will argue that consumers and businesses can mitigate the limitations presented by the physical characteristics of the 5 GHz band by buying more access points to serve their home or business. But this adds significant cost and complexity for consumers and businesses. A single unlicensed device operating at 600 MHz will have far greater range, operate effectively even through walls and in other difficult environments, and will therefore allow more cost-effective networking.[98]

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[96] *See, e.g.*, 47 C.F.R. § 15.407(a)(1), (e) & (h) (prescribing highly restrictive technical limitations on operations in 5 GHz); FCC Office of Engineering and Technology Laboratory Division, Interim Plans to Approve UNII Devices Operating in the 5470 - 5725 MHz Band with Radar Detection and DFS Capabilities, KDB # 443999 (Oct. 14, 2010) ("notching out" 5 GHz channels that overlap with spectrum used by weather radar systems).

[97] Lehr at 15.

[98] *See id.* at 15-16 (describing a study by Wanichkorn and Sirbu that found a 2.6 GHz system would require twice as many cell sites as one operating at 700 MHz). In the context of M2M communications like smart grid technologies, discussed above, the "important potential application of a dedicated open wireless band in the TV bands would be to permit innovation and experimentation with wider coverage that could begin to offer alternatives to licensed-spectrum applications even in very wide area applications that have low tolerance for latency." Benkler at 14.

Second, the FCC has mandated a series of highly restrictive technical limitations on 5 GHz operations. In particular, the FCC requires unlicensed National Information Infrastructure ("U-NII") devices that operate in portions of the 5 GHz band to use low transmit power—including a 50 mW limit in 100 MHz of spectrum,[99] restrict operations to indoor use,[100] detect and avoid radar systems,[101] and/or "notch out" any channels that overlap with 50 MHz of spectrum used by weather radar systems.[102] Such limitations make all but the U-NII 3/U-NII Upper band (5.725-5.825 GHz) unsuitable for many consumer and business needs, such as cable metronets and other wireless networks that provide outdoor coverage, and wireless access points with coverage throughout the home.

Third, even for the U-NII 3 band, operations in the overlapping ISM band at 5.8 GHz pose interference risks that limit the utility of this band since U-NII 3 devices must operate in an increasingly crowded portion of the 5.8 GHz ISM band alongside video monitors, perimeter and motion sensors, cordless phones, microwave ovens, and other non-broadband uses.

Finally, while Google and Microsoft support the Commission's announcement that it will begin a proceeding to consider designating the 5.35-5.47 and 5.825-5.9 GHz bands for unlicensed uses,[103] access to this additional 5 GHz spectrum will be of limited benefit for many wireless broadband applications if the Commission's rules include operating restrictions similar

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99 47 C.F.R. § 15.407(a)(1).

100 47 C.F.R. §15.407(e).

101 47 C.F.R. § 15.407(h).

102 *See* FCC Office of Engineering and Technology Laboratory Division, Interim Plans to Approve UNII Devices Operating in the 5470 - 5725 MHz Band with Radar Detection and DFS Capabilities, KDB # 443999 (Oct. 14, 2010).

103 *See* News Release, FCC Chairman Julius Genachowski Announces Major Effort To Increase Wi-Fi Speeds And Alleviate Wi-Fi Congestion At Airports, Convention Centers, And In Homes With Multiple Devices And Users (Jan. 9, 2013).

to those in the existing U-NII 1, 2, or 2 Extended rules. In sum, while 5 GHz must be a part of the plan to address the unlicensed spectrum crunch, it is not a silver bullet.

Despite the clear benefits to consumers and innovation of substantial low-frequency unlicensed spectrum, the only sub-1-GHz spectrum available for unlicensed technologies today is the small 26 MHz slice of spectrum in the 900 MHz band and the TV white spaces, which have been hampered by persistent regulatory uncertainty. Furthermore, the FCC's proposed TV channel repack following an incentive auction may substantially reduce white spaces that are available for unlicensed use. Without additional dedicated unlicensed spectrum in the 600 MHz band, innovators and investors will not have adequate spectrum resources and the economic growth and innovation described above will suffer. It is therefore critical that the FCC take the opportunity presented in this proceeding and designate additional spectrum for unlicensed use.

III. FREEING A BALANCE OF LICENSED AND UNLICENSED SPECTRUM IN THE 600 MHZ BAND WILL ENSURE ADEQUATE FEDERAL REVENUES FOR PUBLIC SAFETY NEEDS AND BROADCASTER RELOCATION.

The preeminent economic goal of the incentive auction proceeding should be to provide innovators and investors with the licensed and unlicensed spectrum resources they need to create economic growth for the country.[104] As described above, designating spectrum for unlicensed use from reclaimed spectrum in the 600 MHz band will generate enormous economic value for the national economy. The public benefit from this economic growth will dwarf the direct revenues the Commission could ever hope to generate through an auction.

[104] *See NPRM* ¶ 26 ("Congress passed the Spectrum Act in early 2012 [and] authorized the Commission to conduct incentive auctions to help meet the increasing demand for spectrum to provide highly valued wireless broadband services…"); *see* Spectrum Act §§ 6402 (codified at 47 U.S.C. § 309(j)(8)(G)(i)), 6403(c)(1).

The FCC also must ensure that the auction produces enough revenue to cover financial requirements needed for public safety and relocation, as required by the statute.[105] Furthermore, Members of Congress have stated that they expect that the auction will produce additional revenues that can be used to address the country's financial crisis. Designating spectrum resources for unlicensed technologies within the framework of the Spectrum Act is fully consistent with both goals because unlicensed spectrum designation will not reduce, and may increase, the value of the spectrum that is auctioned, and therefore will not reduce the revenues directly recovered through the auction.

This is the case for several reasons. First, according to a recent paper by Jeremy Bulow, Jonathan Levin, and Paul Milgrom, assuming the demand for licensed spectrum is relatively inelastic, "leaving some spectrum unlicensed reduces the supply of licensed spectrum,"[106] and this reduction in supply will raise the per unit price of the licensed spectrum.[107] The result is that the auctioned spectrum generates more revenue per unit than it otherwise would have, compensating for the reduction in the amount of spectrum auctioned.

Second, even if demand for spectrum is elastic, Bulow, Levin, and Milgrom have shown that the overall revenue in spectrum auctions tends to reflect the aggregate budgets of the winning bidders rather than the price per MHz-pop.[108] They demonstrate that those entities that

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[105] *See* Spectrum Act at § 6402; *see also NPRM* ¶ 26 ("[Congress] directed that certain proceeds from the incentive auction be deposited in the Public Safety Trust Fund to fund a national first responder network, state and local public safety grants, public safety research, and national debt reduction.").

[106] Paul Milgrom, Jonathan Levin, and Assaf Eilat, *The Case for Unlicensed Spectrum*, 2-3, 23 (Oct. 2011) ("Milgrom, et al.").

[107] *See* Cooper at 46 & n.150 (citing Milgrom, et al.).

[108] Jeremy Bulow, Jonathan Levin, and Paul Milgrom, *Winning Play in Spectrum Auctions*, at 2, 7-12 (2009), *available at* http://www.stanford.edu/~jdlevin/Papers/AWS.pdf ("If a bidder

intend to bid on the available spectrum will have determined how much they will spend, and they are likely to spend that entire amount regardless of the total amount of spectrum they obtain, provided they obtain the minimum amount of spectrum they need. Thus, a reduction in spectrum available for auction due to the designation of a reasonable amount of spectrum for unlicensed technologies is not likely to result in significant reductions in overall revenue generated.[109]

Third, designating spectrum for unlicensed use will raise the inherent value of licensed spectrum by "encourag[ing] the development of complementary, demand-enhancing services that raise the economic value of the licensed spectrum networks."[110] In other words, the availability of unlicensed spectrum increases the value consumers receive from licensed mobile broadband networks because licensed and unlicensed networks together provide consumers with far greater coverage and quality than licensed networks alone offer. This makes licensed spectrum more valuable to wireless carriers because it means that consumers see more value for what they pay for licensed wireless broadband services, which is reflected in even higher consumer demand for those services. And this increase in the value of licensed wireless networks accrues to the benefit of wireless carriers at far lower cost than if they were forced to try to replicate the benefits of the nation's unlicensed access points on their own by vastly increasing the number of microcells, femtocells, and backhaul using licensed spectrum in each of their networks, as

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faces a binding budget constraint and has broad interests, then as prices increase from round to round, its total exposure will eventually level off at an amount approximating its budget. If all bidders were to fall in this category, then the total exposure of all bidders in the auction would rise to the level of the aggregate bidder budgets and level off, forecasting the final auction prices."); Milgrom, et al. at 23; *see also* Cooper at 46 & n.150 (citing Milgrom et al).

[109] Milgrom, et al. at 23; *see also* Cooper at 46 & n.150.

[110] Milgrom, et al. at 3; *see also id.* at 23, Cooper at 46.

discussed above. The result: a stronger unlicensed ecosystem leads to higher auction bids for licensed spectrum, and more auction revenue.[111]

IV. THE POST-AUCTION 600 MHZ BAND SHOULD ENSURE AN OPTIMAL MIX OF LICENSED AND UNLICENSED SPECTRUM.

In order to support and expand the economic growth and innovation described above, the NPRM wisely proposes to design the 600 MHz band plan to make "a substantial amount of spectrum available for unlicensed uses, including a significant portion that would be available on a uniform nationwide basis for the first time."[112] The Commission can best achieve this goal by:

1. Adopting a simple and proven frequency division duplex ("FDD") band plan for licensed broadband services with technically reasonable duplex gap/guard band designations;

2. Enabling unlicensed broadband operations in the duplex gap/guard band spectrum; and

3. Permitting unlicensed use in the 600 MHz band in areas where auction winners have not yet begun providing service.

Taking these steps will ensure that the public receives the full benefits of both licensed and unlicensed spectrum access for new broadband services in the 600 MHz band.

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[111] Milgrom, et al. at 23. The authors note that additional unlicensed spectrum can reduce revenue for licensed service providers by creating competition. The result in that scenario, however, is still positive, as consumers benefit from increased competition. *Id.* at 23 n.58. *See also* Lehr at 6 & n.12 ("[W]ireless technologies can support increased reliance on edge-based infrastructure which can both substitute for *and* complement investments in the core of the network." "[C]ustomers may shift functionality from network services to applications run on end-user controlled boxe[s]…[T]he increased functionality will also drive increased demand for core services.").

[112] *NPRM* ¶ 9.

A. The FCC Should Adopt a Proven FDD Band Plan Design With a Technically Reasonable Duplex Gap.

The NPRM seeks comment on several band plan options for 600 MHz operations, including a preferred "modular" band plan that creates a nationwide downlink band while varying the amount of uplink spectrum.[113] As the Commission explains, this proposal "strive[s] to maximize the amount of spectrum we can repurpose for both licensed and unlicensed wireless broadband services."[114]

Although the FCC should explore generally how to maximize unlicensed spectrum resources, its particular aim should be to produce the maximum amount of *usable* unlicensed spectrum, taking technical and economic factors into consideration. With this as the goal, and so as to produce an unlicensed spectrum designation that will create the greatest possible economic growth and innovation, the FCC should ensure that the designation: (1) contains sufficient spectrum available on a nationwide basis to support unlicensed deployments, and (2) occupies an interference environment that allows a high-quality consumer experience with equipment that is affordable. An unlicensed designation that has these characteristics will support significant investment by chipmakers, manufacturers, and service providers.

The Commission can create an unlicensed designation with these attributes by implementing a traditional FDD band plan, such as the band plan depicted in Figure 12 in the NPRM,[115] and enabling unlicensed operations in the duplex gap, the guard band separating TV operations from the LTE downlink, and TV white spaces. An FCC band plan that allows unlicensed devices access to a duplex gap that is large enough to support robust unlicensed

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[113] *See id.* ¶ 124.

[114] *Id.* ¶ 125.

[115] *Id.* ¶ 178.

operations will more effectively support innovation and investment than would the "modular" band plan for the following reasons.

First, such a duplex gap, along with other unlicensed designations in the guard band separating TV operations from the LTE downlink and the remaining TV white spaces, will result in a 600 MHz band with substantial enough usable unlicensed spectrum resources to support investment. This will produce a healthy unlicensed ecosystem under 1 GHz.

Second, some amount of contiguous spectrum in the duplex gap will give developers the flexibility to harness more bandwidth from aggregated carrier channels, enabling greater data throughput and a wider range of potential applications, and to account for the interference environment.

Third, a band plan that enables unlicensed operations in the duplex gap is the best way to meet the FCC's goal of making as much unlicensed spectrum as possible available on a "nationwide basis."[116] This is the case because unlicensed spectrum in the duplex gap will be available even in cities where there are few white spaces. Sufficient unlicensed spectrum in all markets will provide developers with the certainty they need to create innovative unlicensed applications and services. Without adequate unlicensed spectrum in every market, application, device, and service providers may not invest in developing new products.

For these reasons, an unlicensed designation in a duplex gap that produces substantial spectrum resources would deliver greater benefits to consumers, and support greater levels of innovation and investment, than would the unlicensed designations in the "modular" band plan. As discussed above, spectrum in the duplex gap would be used in connection with spectrum in a guard band separating TV operations from the LTE downlink, as well as spectrum

[116] *Id.* ¶ 9.

available because of the continued availability of the smaller 6 MHz white spaces among remaining television channels. It is the collective availability of each these complementary resources that will provide a strong foundation for continued healthy growth in unlicensed operations.

B. Establishing a Significant Duplex Gap and Meaningful Guard Bands Supplemented with "Remainder Spectrum" Is Technically Reasonable.

The NPRM notes that "the Spectrum Act constrains the FCC to guard bands 'no larger than is technically reasonable to prevent harmful interference between licensed services outside the guard bands,' and requires a forward auction in which 'the Commission assigns licenses for the use of the spectrum that the Commission reallocates.' Under these provisions, [the FCC] must license the spectrum [the FCC] recover[s] through the broadcast television spectrum reorganization, with the exception of guard bands."[117] This statutory authority permits the FCC to establish a duplex gap/guard band plan with a sizeable gap to reduce interference between LTE downlink and uplink bands, and 6 MHz guard bands supplemented by any so-called "remainder spectrum," to reduce interference between LTE operations and high-power broadcast operations.

The NPRM notes that the Commission seeks to "minimize interference between dissimilar adjacent operations."[118] In addition, the Commission has raised concerns that "[m]inimizing the duplex gap size … could have a negative impact on mobile performance."[119] Finally, the NPRM recognizes that wireless broadband services adjacent to television services may not operate at "the same level of performance as spectrum blocks adjacent only to other

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[117] *Id.* ¶ 234.

[118] *Id.* ¶ 152.

[119] *Id.* ¶ 178 & n.262.

spectrum blocks used for wireless broadband service."[120] Thus, it is "technically reasonable" for the Commission to designate substantial frequency ranges that will reduce negative impacts on mobile performance, allow neighboring services to function, and ensure substitutability among spectrum blocks.

1. The Spectrum Act's "technically reasonable" standard gives the Commission broad discretion to determine the appropriate amount of spectrum to address potential interference concerns.

The NPRM asks how to interpret Congress's mandate that guard bands be "no larger than is technically reasonable to prevent harmful interference between licensed services outside the guard bands."[121] The plain meaning of "technically reasonable" and judicial precedent combine to establish that Congress granted the Commission wide discretion in determining the size of any frequency range set aside for interference prevention.

"Reasonable" is an adjective meaning "in accord with reason."[122] "Reason" means "a statement offered in explanation or justification," or "a rational ground or motive."[123] A guard band that is "no larger than is technically reasonable to prevent harmful interference" therefore means a frequency block of any size that the FCC, on the record before it, rationally finds appropriate to prevent harmful interference.

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[120] *Id.* ¶ 152.

[121] *Id.* ¶ 234. *See also id.* ¶¶ 156, 158.

[122] Reasonable, MERRIAM-WEBSTER.COM (2013), http://www.merriam-webster.com/dictionary/reasonable.

[123] Reason, MERRIAM-WEBSTER.COM (2013), http://www.merriam-webster.com/dictionary/reason.

"Reasonable" does not mean necessary. "Necessary" means "of an inevitable nature," "logically unavoidable," "that cannot be denied without contradiction," "compulsory," "absolutely needed," or "required."[124] If Congress had intended to limit the Commission to setting guard bands that were as small as possible without creating harmful interference, it would have required the FCC to set guard bands that were no larger than technically *necessary* to prevent harmful interference. That it did not use that language (or any words to similar effect) is evidence that Congress intended to give the Commission the discretion to use its expert technical judgment to set appropriate guard band sizes.

Courts have recognized that the term "reasonable" gives an agency wide discretion to act. Especially when an issue is "fairly technical" and involves "policy judgments that lie at the core of the regulatory mission," judicial review of agency action is "highly deferential."[125] Put more simply, the D.C. Circuit has found that in administrative law, "reasonable" means "not arbitrary and capricious."[126] Therefore, the Commission may adopt a duplex gap/guard band plan that it can rationally explain is reasonable to prevent harmful interference.

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[124] Necessary, MERRIAM-WEBSTER.COM (2013), http://www.merriam-webster.com/dictionary/necessary.

[125] *See N. States Power Co. (Minnesota) v. FERC*, 30 F.3d 177, 180 (D.C. Cir. 1994).

[126] *See DIRECTV, Inc. v. FCC*, 110 F.3d 816, 829 (D.C. Cir. 1997). For instance, in the environmental context, where agencies are required to consider "all reasonable alternatives" with regard to environmental impact, courts have found that "reasonable alternatives" are those "that are technically and economically practical or feasible *and* meet the purpose and need of the proposed action." *See Theodore Roosevelt Conversation P'ship v. Salazar*, 661 F.3d 66, 72 (D.C. Cir. 2011) (internal citations and quotation marks omitted) (emphasis added) ("*Salazar*"); *see also Barnes v. Babbitt*, 329 F. Supp. 2d 1141, 1159 (D. Ariz. 2004) ("Reasonable alternatives are those that are feasible, consistent with the reasonable objections of the action, and sufficient to permit a reasoned choice.").

2. A band plan with a duplex gap large enough to be usable for robust unlicensed operations is a technically reasonable approach to avoiding harmful interference.

Consistent with the discretion granted by the Spectrum Act, the Commission seeks comment on both the "necessary size of the duplex gap" for the 600 MHz band plan, as well as the "appropriate" size of that gap.[127] The NPRM notes that the LTE frequency band allocation with the smallest duplex gap in absolute terms is LTE Band 8. This band provides for separation of only 10 MHz.[128] As the Commission recognizes, however, this small duplex gap results in degraded receiver sensitivity due to harmful interference.[129] Specifically, receivers in LTE Band 8 require signals to be 3 dB stronger than signals in LTE bands with superior interference environments in order to compensate for this interference and achieve similar performance.[130] In contrast, the FCC recognizes that the 3GPP bands with "duplex gaps of at least 28 megahertz and at least 1.4 times the pass band size"[131] reduce harmful interference resulting from degraded receiver sensitivity much more effectively than do smaller duplex gaps.

This actual experience is the appropriate starting point for determining a reasonable size for the 600 MHz band duplex gap. A band plan with a duplex gap of 28 MHz is technically reasonable.

First, as the FCC's calculations demonstrate, duplex gap design necessarily involves a tradeoff between, on the one hand, the performance (more specifically the abruptness in the filter transition from the "pass band" to the "stop band"), size, and cost of filters and, on the other

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[127] *NPRM* ¶ 167.

[128] *See NPRM* ¶ 178 & n.262.

[129] *See id.*

[130] *See id.*

[131] *Id.*

hand, the reduction in the power of the desired signal caused by filters.[132] Dr. David Borth, in his attached declaration, explains that a smaller duplex gap would require the use of filters that could either substantially reduce the power of the desired signal, and therefore lead to inferior receiver performance, or the use of large, and/or expensive filters that may increase cost to even attempt to address the degraded interference environment.[133] A larger duplex gap, conversely, allows the use of filters that reduce desired signal levels less and support better performance, without driving up the cost of devices. Filter considerations are especially important for end user devices, where the cost and size of duplex filter design is felt most acutely.[134] Furthermore, Dr. Borth shows that because the LTE network architecture intensively reuses spectrum, any performance loss caused by a smaller duplex gap would be felt throughout the network, potentially significantly reducing system capacity.[135]

Dr. Borth also explains that the Commission's duplex gap should account for interference caused by intermodulation created by LTE transmissions.[136] Because this intermodulation interference would fall in a receiver's desired frequency band, no amount of filtering could prevent the undesired signals from reaching the receiver.[137] This intermodulation issue alone would justify a gap that—at an absolute minimum—exceeds the pass band size.[138]

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[132] Borth Declaration ¶¶ 6-8.

[133] *Id.* ¶ 8.

[134] *Id.* ¶ 10.

[135] *Id.* ¶ 12.

[136] *Id.* ¶ 14.

[137] *Id.*

[138] *Id.* ¶ 15.

Finally, Dr. Borth shows that other factors such as "allowances for temperature and manufacturing variation in components" also can "affect the appropriate duplex gap" determination.[139] Indeed, temperature shifts and manufacturing shifts would require additional duplex gaps on the order of .12 percent—or an additional .72 MHz—for the duplexer, over and above what would otherwise be required.[140] While this is not a large increase in reasonable duplex gap size, it is nonetheless important to recognize.

3. A meaningful guard band between LTE downlink and digital television is a technically reasonable approach to avoiding harmful interference.

The Commission also seeks comment on its proposal to implement a 6 MHz guard band between wireless broadband operations in the 600 MHz band and digital television services.[141] As the Commission has recognized, guard band spectrum will play a critical role in avoiding harmful interference to cellular networks and digital television receivers by minimizing the effects of undesired out-of-band emissions ("OOBE") or receiver overload from adjacent services.[142] Given the significant chance of harmful interference to broadband and broadcast licensees, the Commission should implement a conservative guard band that is larger than 6 MHz. Furthermore, a larger guard band between cellular downlink and DTV will be necessary for the Commission to implement a band plan with "spectrum blocks that are as similar and technically interchangeable as possible."[143]

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[139] *See NPRM* ¶ 167; Borth Declaration ¶ 16.

[140] Borth Declaration ¶ 16.

[141] *NPRM* ¶ 158.

[142] *See id.* ¶ 156.

[143] *See id.* ¶ 152.

As a threshold matter, the Commission should account for worst-case interference scenarios when determining the appropriate guard band size. This is so for two reasons. First, the Commission will not have any indication of actual television assignments and power levels until after the conclusion of the auction and repack. Second, there is a dearth of published information about interference susceptibility for DTV systems into LTE systems and for LTE systems into DTV systems.[144] The lack of such references hampers prediction of probable interference levels and, consequently, appropriate minimum guard band width determinations.[145]

In the absence of comprehensive studies on the subject, the Commission should take heed of the experiences elsewhere where DTV transmitters and modern cellular systems co-exist, which underscore the need to implement conservative guard bands. For example, in Europe, CEPT (the European Conference of Postal and Telecommunications Administrators) examined co-existence of DVB-T digital television systems with IMT/UMTS cellular systems.[146] One of the conclusions reached by CEPT was that, even with an 8 MHz guard band between these two systems, there was a 14 percent capacity loss in the cellular system due to interference from a digital television transmitter.[147]

Similarly, in the Asia Pacific region, the Asia Pacific Telecommunity ("APT") evaluated the required minimum guard band size between a DVB-T transmitter and LTE device transmissions under multiple interference scenarios using deterministic, probabilistic, and

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[144] Borth Declaration ¶ 17.

[145] *Id.* ¶ 18.

[146] CEPT Report 23, *Technical Options for the Use of a Harmonised Sub-Band in the Band 470 - 862 MHz for Fixed/Mobile Application (including Uplinks)*, at 7 (Dec. 21, 2007), *available at* http://www.erodocdb.dk/docs/doc98/official/pdf/CEPTRep023.pdf.

[147] *Id.*

empirical studies.[148] The APT report concluded that, for an LTE device transmission bandwidth of 10 MHz, a 9 MHz guard band was the smallest separation distance required to minimize interference between LTE operations and the DTV receiver.[149]

Furthermore, in the U.S., LTE operations in the lower 700 MHz band and DTV operations on television channel 51 similarly counsel for the adoption of conservative separation distances to address DTV/LTE co-existence issues.[150] One of the most significant concerns in that proceeding relates to reverse intermodulation interference to an LTE device transmitter caused by the presence of a strong DTV signal.[151] The record demonstrates that even with a guard band separation of 6 or 12 MHz between the DTV transmitter frequency and the LTE device frequency *and* an LTE duplex gap separation of 24 MHz, significant LTE device receiver sensitivity degradation can occur over many square miles near the DTV transmitter.[152]

Finally, the Commission notes in the NPRM that it has found a 6 MHz separation distance to be sufficient to avoid harmful DTV-to-DTV interference in the 600 MHz band, and that no separation distance is required for low power personal/portable white space devices operating at 40 mW.[153] However, as Dr. Borth explains in his attached declaration, a study conducted at the University of Kansas and submitted in the white spaces proceeding strongly

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148 APT Report, Implementation Issues Associated With Use Of The Band 698-806 MHz By Mobile Services," No. APT/AWG/REP-24 (Sept. 2011), *available at* http://www.apt.int/sites/default/files/Upload-files/AWG/APT-AWG-REP-24_APT_Report_698-806_Band_Implementation_UHF.pdf.

149 *Id*. at 12.

150 *See generally* Promoting Interoperability in the 700 MHz Commercial Spectrum, WT Docket No. 12-69.

151 Borth Declaration ¶ 19.

152 *Id.*

153 *NPRM* ¶ 156 & n.239.

suggests that 6 MHz would *not* be sufficient separation between DTV and cellular base stations, which are capable of operating at much greater power than either portable or fixed white spaces devices.[154]

4. Designating remaindered spectrum for unlicensed use is a technically reasonable approach to avoiding harmful interference.

Google and Microsoft agree with the FCC that, as the NPRM correctly explains, adding remainder spectrum to the guard bands will "further mitigate any potential interference concerns" in the 600 MHz band.[155] As described above, even a 6 MHz guard band will result in an unacceptable level of interference risk for both broadcast and LTE operations. Using remainder spectrum to augment the guard band would be technically reasonable because the increased separation will reduce the likelihood of harmful interference, improving customer experience and reducing costs for carriers. Alternatively, using remainder spectrum to increase the size of the duplex gap would also be technically reasonable because a larger gap will contribute to reducing interference between the uplink and downlink bands (unless the FCC establishes a maximum duplex gap size and is able to achieve that ideal without remainder

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[154] Borth Declaration ¶¶ 20-26 *See Quantifying the Impact of Unlicensed Devices on Digital TV Receivers*, The University of Kansas, Technical Report ITTC-FY2007- 44910-01 (Jan. 31, 2007), *available at* http://www.newamerica.net/files/NAF%20Spectrum%20Technical%20Report%20_FINALSUBMITTED_0.pdf. The KU Study examined measurements of several DTV receivers to characterize their adjacent and subsequent adjacent channel interference potential. Specifically, the authors used a 6 MHz OFDM signal as an interfering signal to a DTV receiver that received a -68 dBm DTV signal, which they considered to be a weak signal for a consumer grade receiver. The authors intended the OFDM signal to be representative of modern Wi-Fi or WiMAX systems. Accordingly, the results of this study are useful in this proceeding, as LTE signals can similarly employ OFDM modulation over a comparable bandwidth. Borth Declaration ¶ 22.

[155] *NPRM* ¶ 156.

spectrum). This will enable licensees to provide service more cheaply and efficiently, increasing demand for this spectrum at auction.

In contrast, using remainder spectrum for a new licensed service, with base stations and user equipment operating at substantially higher powers than allowed under unlicensed rules, would eliminate these additional interference mitigation benefits and could itself be a new source of interference. The increased risk of interference to core 600 MHz band services likewise would be reflected in the prices paid for these licensees at auction—in other words, smaller separations will result in less valuable spectrum blocks in the auction and depress auction revenue.

Additionally, auctioning remainder spectrum is incompatible with the proposed 5 MHz "building block" model for the forward auction, which will promote the greatest amount of flexibility and efficiency for new licensed services.[156] This is because any remainder spectrum necessarily will be too small to license on a 5 MHz block basis.[157] Soliciting separate bids for the remaining small spectrum slivers in the simultaneous forward and reverse auction will introduce needless complexity to the auction process, particularly if the Commission auction design contemplates bids for interchangeable licensed spectrum pairs rather than specific frequency bands.[158]

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[156] *Id.* ¶ 128.

[157] *See id.* ¶ 175 (designating remainder spectrum for unlicensed use will "maximize the number of valuable blocks for licensing").

[158] *See id.* ¶¶ 173-74.

C. The FCC Should Permit Unlicensed Operations in the 600 MHz Band in Areas Where Auction Winners Have Not Yet Begun Providing Service.

The NPRM further seeks comment on appropriate build-out and performance rules for licensees in the 600 MHz band.[159] Consistent with the Commission's goal of "promot[ing] the efficient use of spectrum in order to meet the current and future needs of the American public,"[160] the 600 MHz band rules should enable unlicensed spectrum operations in areas where a licensee has yet to deploy its network or has ceased operations.

In the White Spaces Order, the Commission allowed unlicensed white space devices to operate throughout what will become the 600 MHz band after the incentive auction. All white space devices are controlled by one of the databases approved by the Commission. Specifically, unlicensed devices must communicate with a database to determine the frequencies they may use in their geographic location.[161] These databases are constantly updated, and if a particular frequency band is designated as off limits to unlicensed devices, devices must then vacate those frequencies.

While the Commission designed these rules to protect broadcast operations, they also give the FCC the opportunity to allow unlicensed devices to access frequencies within the 600 MHz band that are unused by wireless broadband providers. In order to promote robust and efficient use of the 600 MHz band, the Commission should therefore harness the white spaces databases to include frequencies where 600 MHz licensees have not yet begun operations, and permit unlicensed operations in the appropriate locations. As soon as a licensee notifies the

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159 *See id.* ¶¶ 394-413.

160 *Id.* ¶ 23.

161 *See generally* 47 C.F.R. Part 15 Subpart H.

Commission that it is ready to begin operations, the rules should require database providers to update their database to prohibit unlicensed operations in the relevant frequencies.

Importantly, because white space devices must check with a database to determine channel availability at least once a day, a 600 MHz spectrum license area can be quickly cleared of unlicensed operations, and made available for the licensed use, once a licensee has determined it is ready to deploy service in a particular service area.[162] Thus, the Commission can ensure that the public benefits from access to extraordinarily valuable spectrum in the 600 MHz band from the outset with no burden on licensees. In fact, carriers themselves may be among the users to take advantage of unlicensed operations prior to build-out. As noted above, carriers already significantly supplement their licensed networks using unlicensed spectrum. Enabling unlicensed operations would permit carriers to get a head start on offering wireless services to subscribers as they determine how best to build out their licensed networks.

The Commission also should enable continued access to 600 MHz band spectrum on an unlicensed basis if a licensee fails to meet its build-out requirement during the time period set by the 600 MHz band rules, as well as in cases where the Commission has determined that the licensee has "permanently discontinued" operations.[163] Although Part 27 of the Commission's rules includes a relicensing process that presumably could be applied to 600 MHz band licenses,[164] this process takes time, during which otherwise usable spectrum would lie fallow. Unlicensed access in areas where the licensee has stopped providing service—or never provided it in the first place—may be especially critical as these areas are more likely to be underserved.

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[162] *See* 47 C.F.R. § 15.711(b)(3)(iii).

[163] *See NPRM* ¶¶ 405, 413 (seeking comment on a "user it or share it" approach following the build-out term).

[164] *See* 47 C.F.R. § 27.14(g)(2).

Granting unlicensed access to 600 MHz band spectrum, again via the white spaces databases, until licensees are ready and able to provide service would help ensure that the public realizes the full potential of this spectrum for innovative broadband services. As described above, once a licensee is ready to begin providing service, it would notify the database administrator and, within a short period of time, any unlicensed users would vacate those frequencies.

V. THE INCENTIVE AUCTION RULES SHOULD ENSURE THE CONTINUED VIABILITY OF WHITE SPACES OPERATIONS IN THE TELEVISION BROADCAST BANDS.

As the NPRM observes, the U.S. "leads the world in wireless infrastructure and innovation" in several key areas, including being the "first country to enable unlicensed use of white space spectrum in the television bands."[165] It is critical that the Commission's incentive auction rules ensure the continued viability of the white spaces in the remaining television broadcast bands during and after the incentive auction process.

A. The Commission's Decision to Open Up Unused Television Spectrum for Unlicensed Wireless Broadband Will Bring Enormous Benefits.

As the Commission has recognized, white spaces networks will provide substantial benefits to American consumers. Among other things, access to the white spaces will result in more pervasive and powerful broadband connections with "extended range, fewer dead spots, and improved individual speeds" and reduced congestion on existing networks.[166] Indeed, the many white spaces pilot programs already underway confirm that unlicensed access to this beachfront spectrum will enable developers to create many innovative applications.

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[165] *NPRM* ¶ 1.

[166] *Unlicensed Operation of the TV Broadcast Bands*, Second Memorandum Opinion and Order, 25 FCC Rcd. 18661, 18662 (2010) ("*White Spaces Second M&O*").

The "opportunistic" spectrum use enabled by the FCC's white spaces rules also creates a framework for more efficient spectrum use in other frequency bands.[167] For example, according to the President's Council of Advisors on Science and Technology, "the extension of today's emerging White Spaces based wireless systems into the broader and more complex dynamic shared spectral domains offers immediate and compelling uses" to meet increasing spectrum demand.[168]

The Commission already has devoted substantial resources to white spaces deployment, including conducting multiple workshops on database performance and administration,[169] testing and approving database administrators for commercial use,[170] and certifying white spaces equipment for marketing and use.[171] In parallel, industry has made substantial investments in reliance on the FCC's approval of TV Band White Space devices, and is continuing to develop innovative white spaces solutions. Indeed, the IEEE has already finalized one standard for white spaces operation (IEEE 802.22) and is nearing completion of another (IEEE 802.11af).[172] IEEE standardization brings many important benefits for emerging technologies, including

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167 *Id.*

168 *PCAST Spectrum Report* at 132.

169 *See generally* FCC Office of Engineering and Technology, White Space Database Administration, http://www.fcc.gov/encyclopedia/white-space-database-administration.

170 *See* Public Notice, Office of Engineering and Technology Announces the Approval of Telcordia Technologies, Inc.'s TV Bands Database System for Operation, ET Docket No. 04-186 (rel. Mar. 26, 2012) ("Spectrum Bridge PN"); Public Notice, Office of Engineering and Technology Announces the Approval of Spectrum Bridge, Inc.'s TV Bands Database System for Operation, ET Docket No. 04-186 (rel. Dec. 22, 2011) ("Telcordia PN").

171 *See* Spectrum Bridge PN; Telcordia PN.

172 *See* IEEE 802.22 Working Group on Wireless Regional Area Networks, http://www.ieee802.org/22/; Official IEEE 802.11 Working Group Project Timelines, http://grouper.ieee.org/groups/802/11/Reports/802.11_Timelines.htm#tgaf.

interoperability for equipment, economies of scale that result in reduced product costs, and best practices to facilitate rapid development and deployment.

The FCC finalized the rules for white spaces devices less than a year ago, in April 2012, and authorized nationwide use of devices just late last year.[173] It approved the first database providers, which are required under the rules for any white spaces device to operate, in December 2011 and March 2012.[174] This all means that, as a practical matter, users could not take advantage of TV Band White Space technology nationwide until very recently. That white spaces devices are becoming available at the same time that the FCC authorized their nationwide use should not be a surprise. Indeed, this timeline confirms that the technology will bring great value to consumers if given adequate spectrum and regulatory certainty.

B. The Commission's Repacking Methodology Should Specifically Account for Unlicensed White Space Use as an Input.

The NPRM seeks comment on "how to best preserve and improve the use of the unused spectrum in the broadcast television bands for unlicensed operations."[175] One of the most important tools the Commission will have to achieve this goal is the repacking methodology used to assign television stations in the remaining TV broadcast spectrum.[176] As the NPRM explains, repacking television stations is "analogous to the process of packing boxes into a trunk when

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[173] *See generally Unlicensed Operation in the Television Broadcast Bands*, Third Memorandum Opinion and Order, 27 FCC Rcd. 3692 (2012) ("*Third White Spaces Report & Order*"). In December 2012, the FCC authorized nationwide use of the wireless microphone registration system. This authorization allows database administrators to collect a key input for availability calculations. Before the authorization was issued, nationwide use of the databases was not practicable. Public Notice, Office of Engineering and Technology and Wireless Telecommunications Bureau Announce Nationwide Launch of Unlicensed Wireless Microphone Registration System, ET Docket No. 04-186 (rel. Dec. 6, 2012).

[174] *See* Spectrum Bridge PN; Telcordia PN.

[175] *NPRM* ¶ 227.

[176] *See id.* ¶¶ 43-50.

these boxes have different sizes and values."[177] In determining how best to pack the trunk, the Commission's methodology should specifically take into account the value of unlicensed white space use and adopt criteria that will ensure maximum utility of the remaining white spaces.

The NPRM recognizes that "white space spectrum … will continue to exist after the repacking of the broadcast services."[178] This is true for two reasons. First, in many markets, there will be several vacant television channels even after spectrum is deployed for the new 600 MHz band. Second, "the Commission's Part 73 rules restrict digital television stations from being placed on co- and adjacent channels, but do not restrict the placement of stations if they are separated by 6 megahertz or greater of spectrum."[179]

The FCC's repacking methodology should not be designed merely to yield the minimum number of white spaces that persist for these reasons, however. Instead, the methodology should assign value to the preservation of white spaces for their own sake as well, because of the substantial benefits to consumers, innovation, and economic growth described above and relied on by the Commission in adopting the recent white spaces orders.[180]

Furthermore, white spaces will facilitate the incentive auction process. As the Commission has explained, the repacking procedure must be both efficient and fast.[181] Accommodating additional white spaces serves each of these goals by removing the need to design and implement a complicated repacking methodology that forces large numbers of

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[177] *Id.* ¶ 43.

[178] *Id.* ¶ 126 n.198.

[179] *See id.* ¶ 156 n.239 (citing 47 C.F.R. § 73.623 (c)(2)).

[180] *See Third White Spaces Report & Order*; *White Spaces Second M&O*; *White Spaces Second Report & Order*; *White Spaces First Report & Order*. TV white spaces, moreover, are not subject to the Spectrum Act's "technically reasonable" provision.

[181] *See NPRM* ¶ 45.

broadcasters to engage in costly and disruptive relocations with the aim of obtaining the absolute minimum number of vacant channels at the end of the process. Indeed, attempting to achieve the theoretically tightest repacking would be ill-advised—and perhaps entirely futile—given the multiple reverse auction bid options available to broadcasters who wish to participate (*e.g.* license termination bid, UHF to VHF bid, channel sharing bid) and the fact that the reverse and forward auctions must occur at the same time.[182]

Additionally, as the Commission contemplates channel assignments in the remaining TV band spectrum, it should be mindful that not all white spaces are created equal. For example, personal/portable white space devices can access vacant television channels that are adjacent to broadcast stations operating above 512 MHz, but first adjacent white spaces located below 512 MHz cannot be used by any white space device.[183] Similarly, if there are three white space channels in a row, the Commission's rules enable use of higher power fixed/access devices.[184] Thus, in less populated areas with substantial vacant television spectrum, groupings of three or more white space channels are substantially more useful than groupings of two channels. The Commission should maximize the value of the remaining TV band spectrum by taking these considerations into account as it repacks the band by explicitly building these facts into the repacking methodology.

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[182] *See* Spectrum Act § 6403(a)(2).

[183] *See* 47 C.F.R. §§ 15.703(i); 15.712(a)(2).

[184] *See* 47 C.F.R. § 15.712(a)(2) (excluding fixed white space operations for both co-channel and first adjacent channel stations).

VI. THE FCC SHOULD ADOPT WIRELESS MICROPHONES RULES THAT PROMOTE THE EFFICIENT AND INTENSIVE USE OF THE 600 MHZ BAND.

A. The Commission Should Allow Unlicensed Devices to Operate in the Two Channels Currently Reserved for Wireless Microphones.

Under the Commission's existing rules, white space devices must avoid the first vacant channels immediately above and below Channel 37 in order to accommodate legacy wireless microphone systems.[185] As a result, 12 MHz of extremely valuable spectrum often are left bereft of broadband services that tens of millions of consumers could use. The result is a huge loss of utility—and is flatly inconsistent with the Commission's goal in this proceeding of "preserv[ing] and improv[ing] the use of unused spectrum in the broadcast television bands for unlicensed operations."[186]

Google and Microsoft therefore urge the Commission to make the two channels currently designated for wireless microphone use available for white space devices, as proposed in the NPRM.[187] Unlicensed devices and wireless microphones can share the two channels currently reserved for exclusive wireless microphone use if the FCC designates both channels for wireless microphone use as well as unlicensed use, rather than eliminating the current designation completely. This approach will ensure that Part 74 wireless microphone users will always have two channels where they can be assured of primary rights through a white spaces database, and both non-Part-74 wireless microphone users and users of white spaces devices will have access

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[185] *See* 47 C.F.R. §15.707(a).

[186] *NPRM* ¶ 227. The Commission has concluded that legacy wireless microphone systems are a "very inefficient use of valuable spectrum." Public Notice, The Wireless Telecommunications Bureau and the Office of Engineering and Technology Seek to Update and Refresh Record in the Wireless Microphones Proceeding, WT Docket Nos. 08-166, 08-167, ET Docket No. 10-24, 27 FCC Rcd. 12067 (rel. Oct. 5, 2012) ("Wireless Mic PN").

[187] *NPRM* ¶ 9.

to these channels on an unlicensed basis. This will properly balance the goal of ensuring wireless microphone users have a migration path after the incentive auction and the goal of substantially improving spectral efficiency and intensity of use.

If the Commission adopts this approach, wireless microphone users will retain many frequency options after the incentive auction. Microphone users will have access to (1) the two channels currently designated for their exclusive use (as described above); (2) other white spaces in the broadcast band; (3) other frequency bands including Part 90 frequencies, the 900 MHz band, the 2.4 GHz band; and, as discussed below, (4) co-channel operation with television channels.

B. UHF Band Wireless Microphones Should Be Eligible to Operate Co-Channel with Remaining Broadcasters Because This Would Promote Efficient Spectrum Use Without Undermining Incumbent Operations.

Finally, the Commission seeks comment on whether it should enable wireless microphones to operate on a co-channel basis with television stations under certain circumstances.[188] As the Commission notes, doing so could "enable intensive use by wireless microphones of the broadcast television spectrum that is not available for white space devices."[189] Developments in the white spaces proceeding confirmed that co-channel operation of wireless microphones is commonplace. The Commission's rules should legitimize this longstanding practice, which will promote efficient spectrum use without harming incumbent broadcasters.

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[188] *Id.* ¶ 225.

[189] *Id.*

The NPRM seeks comment on appropriate operating parameters under which co-channel operations could be permitted.[190] The best way to determine these parameters is to invite wireless microphone users to submit information about their current co-channel uses without fear of an enforcement action.

Co-channel operations are occurring, and are widespread. This point was amply illustrated during the field tests performed by the Office of Engineering and Technology in the white spaces proceeding. On two separate occasions, in midtown Manhattan and at FedEx Field in Landover, MD, wireless microphone operators transmitted on the same channels as occupied television stations while in the presence of FCC engineers.[191] In fact, one of the channels used by wireless microphones at FedEx Field was the very channel used to carry the high definition broadcast of the football game taking place that day.[192]

In addition, the wireless microphone industry has recently told the Office of Engineering and Technology that wireless microphones which operate on VHF television channels are not typically available.[193] This fact further underscores that co-channel operation takes place routinely. For example, in New York City's theatre district, two UHF channels in addition to the two channels currently reserved for wireless microphones are available, which translates to

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[190] *Id.*

[191] Letter from Edmond Thomas, Senior Technology Policy Advisor, White Spaces Coalition, to Marlene H. Dortch, Secretary, FCC, ET Docket No. 04-186 (filed Aug. 19, 2008).

[192] *Id.* at 2.

[193] *See* Public Notice, Office of Engineering & Technology & Wireless Telecommunications Bureau Announce Nationwide Launch of Unlicensed Wireless Microphone Registration System, ET Docket No. 04-186 (rel. Dec. 6, 2012) ("It is our understanding at this time, through feedback from the wireless microphone industry, that as a practical matter there is very little professional quality equipment available in the VHF spectrum (Channels 2-13). Accordingly, we will not require that applicants use available VHF channels before requesting registration because such use is not generally 'practicable' at this time.").

24 to 32 available wireless microphone frequencies, assuming that legacy systems maximize the use of each TV channel. But given that users claim that even a single theatre operating on Broadway uses up to 40 frequencies during a performance,[194] and that a musical may use many more, literally thousands of co-channel operations occur every day.

The Commission should call for data about these operations and, given the lack of interference issues, legitimize the vast majority of them. Doing so will enable *de facto* channel reservations for Part 15 microphones without harming innovative broadband services, as white space devices will not operate on these channels.

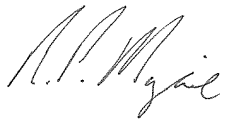
VII. CONCLUSION.

Google and Microsoft applaud the Commission for its efforts to make additional spectrum resources available through the world's first incentive auction. In designing rules in this proceeding, the FCC should support economic growth and technological innovation by continuing the Commission's long-term strategy of providing American consumers and businesses with both licensed and unlicensed spectrum. More specifically, the Commission should: (1) create a band plan with unlicensed designations that are large enough to support investment; (2) preserve white spaces in the remaining television broadcast bands; and (3) promote efficient use of the UHF spectrum by establishing new rules for wireless microphone operations. By taking these actions, the Commission can deliver the most value to American

[194] Ex Parte Comments of the Broadway League, ET Docket No. 04-186, at 3 (filed Jun. 10, 2008).

consumers, produce enormous auction revenues, and provide innovators with a band that supports the next generation of wireless technologies.

Respectfully submitted,



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January 25, 2013

APPENDIX:
DECLARATION OF DAVID BORTH

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

In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	Docket No. 12-268

DECLARATION OF DAVID BORTH

1. My name is David Borth. I am a professor in the Department of Electrical and Computer Engineering at the University of Illinois-Chicago and a member of the National Academy of Engineering. I teach graduate communications theory courses, supervise Ph.D. students, and conduct research in the area of wireless communications. From 1980-2010 I worked for Motorola, Inc. in a number of positions: Corporate Vice President, Chief Technology Officer, and Director of Advanced Technology and Research and Emerging Business Office, Enterprise Mobility Solutions (2005-10); Corporate Vice President and Director, Wireless Access Research, Motorola Labs (2001-5); Vice President and Director, Communications Systems and Technologies Labs, Motorola Labs (1998-2001); Vice President and Director, Corporate Communications Systems Labs, Corporate R&D (1996-8); Manager, Communications Systems Research Lab, Corporate R&D (1990-6); and Technical Staff Member, Systems Research Lab (1980-90). I currently serve on the U.S. Department of Commerce Spectrum Management Advisory Committee, and I have served on the FCC's Technical Advisory Committee from 2005-6. I hold 113 patents worldwide, and received a B.S, M.S., and Ph.D in Electrical Engineering at the University of Illinois at Urbana-Champaign.

2. I have worked extensively on matters regarding wireless technologies, interference, network design, and spectrum management in general, and on matters regarding LTE, WiMAX, unlicensed standards such as Wi-Fi and Bluetooth, and the television white spaces in specific.

3. I have reviewed the FCC's Notice of Proposed Rulemaking ("NPRM") in this proceeding. This declaration contains my analysis of certain technical matters related to the Commission's consideration of certain questions contained in that NPRM.

GUARD BAND/DUPLEX GAP DESIGN

4. For a traditional FDD band plan, such as the band plan depicted in Figure 12 in the NPRM, a duplex gap of greater than 20 MHz is technically reasonable to prevent harmful interference between licensed services.

5. The NPRM notes that the LTE frequency band allocation with the smallest duplex gap in absolute terms is LTE Band 8. This band provides for separation of only 10 MHz, and results in degraded reference sensitivity of 3 dB; specifically, 3 dB worse than the LTE bands with the best reference sensitivities. In contrast, the NPRM observes that the "3GPP bands with the best reference sensitivities have duplex gaps of at least 28 megahertz and at least 1.4 times the pass band size." NPRM ¶ 178 n. 262. These statements alone support the implementation of a duplex gap larger than 20 MHz as a technically reasonable measure to avoid harmful interference.

6. Duplex gap design necessarily involves a tradeoff between, on the one hand, the abruptness in the duplex filter transition from the pass band to the stop band where transmitters do not operate and, on the other hand, insertion loss in the pass band.

7. Insertion loss of the duplex filter contributes directly to the noise figure (*i.e.* the degradation of the signal to noise ratio) and, therefore, the ultimate sensitivity and performance of the receiver.

8. A smaller duplex gap would require the use of filters that could either substantially reduce the power of the desired signal (and therefore lead to inferior receiver performance), or the use of large and/or expensive filters that may increase cost to attempt to address the degraded interference environment.

9. For a given pass band, if the transition to the stop band is reduced, the insertion loss in the pass band will correspondingly increase. In contrast, a larger duplex gap increases the transition region of the stop band and lowers insertion loss.

10. Filter considerations are especially important for end user devices, where duplex filter design must emphasize size and cost of a filter along with filter performance.

11. Importantly, the duplexer, which separates transmit and receive spectrum, appears in a device's architecture after the antenna and before the receiver amplifier. Accordingly, insertion loss in the pass band that is created as a result of a smaller duplex gap cannot be remedied by other components in the device.

12. Because the LTE network architecture intensively reuses spectrum, any performance loss caused by a smaller duplex gap would be felt throughout the network, potentially significantly reducing system capacity.

13. Each of the above factors affects the appropriate size of the duplex gap, and should be examined by the Commission when determining duplex gap size.

14. The Commission's duplex gap should also account for spurious radiofrequency issues caused by third order ($2f_1$ +/- f_2 or $2f_2$+/- f_1) intermodulation created by LTE transmissions entering the LTE receiver pass band. These intermodulation concerns are due to imperfections (specifically, nonlinearities) in transmitter amplifiers and/or receivers. Because intermodulation frequencies would fall in the receiver pass band, no amount of filtering could filter out these spurious/undesired signals.

15. Third order intermodulation issues can occur either at a base station or on an LTE device. At the base station, however, the presence of additional RF signals further complicates the intermodulation issue. The intermodulation issue alone would justify a gap that—at an absolute minimum—exceeds the pass band size, and taken with the other duplex gap considerations underscores the need for a reasonable duplex gap with characteristics similar to existing LTE bands with the best reference sensitivities.

16. Allowances for temperature and manufacturing variation in components can also affect the appropriate duplex gap determination. Indeed, typical temperature shifts are on the order of 200 ppm (or 0.02%) and manufacturing shifts are on the order of 500-1000 ppm (or 0.05-0.1%). Taken at their maximums, these considerations alone would require additional duplex gaps on the order of .12%—or an additional .72 MHz—for the duplexer, over and above what would otherwise be required.

GUARD BAND BETWEEN 600 MHZ DOWNLINK AND TELEVISION

17. There is limited information available about interference susceptibility for DTV systems into LTE systems and for LTE systems into DTV systems.

18. The lack of such references hampers prediction of probable interference levels and, consequently, appropriate minimum guard band width determinations. Furthermore, to address the resulting uncertainty, the Commission should take particular care to ensure that enough spectrum is allocated to be confident of avoiding harmful interference.

19. I have reviewed filings in WT Docket No. 12-69, *Promoting Interoperability in the 700 MHz Commercial Spectrum*. One of the most significant concerns in that proceeding relates to reverse intermodulation interference to an LTE device transmitter caused by the presence of a strong DTV signal. In particular, the record demonstrates that even with a guard band separation of 6 or 12 MHz between the DTV transmitter frequency and the LTE device frequency *and* an LTE duplex gap separation of 24 MHz, significant LTE device receiver sensitivity degradation can occur over many square miles near the DTV transmitter.

20. I have also reviewed the University of Kansas TV Band Interference Study submitted by the New America Foundation in ET Docket No. 04-186, *Unlicensed Operation in the Television Broadcast Bands* (the "KU Study").

21. In the KU Study, measurements were made of several DTV receivers to characterize the adjacent and subsequent adjacent channel interference potential.

22. Specifically, the authors of the KU Study used a 6 MHz OFDM signal as an interfering signal to a DTV receiver that received a -68 dBm DTV signal, which they considered to be a weak signal for a consumer grade receiver. The authors intended the OFDM signal to be representative of modern Wi-Fi or WiMAX systems. Accordingly,

the results of this study are useful in this proceeding, as LTE signals can similarly employ OFDM modulation over a comparable bandwidth.

23. The KU Study found that, for a -68 dBm DTV signal level at the receiver, a -34 dBm OFDM signal in either of the adjacent 6 MHz channels or a -23 dBm signal level in any channel more than one TV channel away would cause a degraded DTV picture.

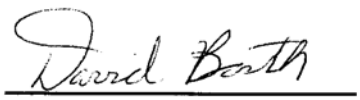
24. Thus, assuming a 600 MHz LTE base station with a transmit power of one kilowatt, for the DTV receivers examined in the KU Study, the LTE transmitter could cause observable interference to the DTV receiver at distances less than approximately 2,000 feet away from the DTV receiver (*i.e.* a free space path loss of less than 83 dB) even with a frequency separation of more than 6 MHz.

25. Because LTE base site transmitters operate in fixed locations, the interference into the DTV receiver might always be present.

26. The data provided by the KU Study therefore strongly suggest that there are real-world scenarios in which a guard band of greater than 6 MHz will be required to avoid harmful interference.

I, David Borth, declare under penalty of perjury that the foregoing declaration is true and correct.

Executed on January 25, 2013



David Borth