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

In the Matter of	)	
	)	
Expanding Flexible Use of the 3.7 to 4.2 GHz Band	)	GN Docket No. 18-122
	)	
Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz	)	GN Docket No. 17-183 (Inquiry Terminated as to 3.7-4.2 GHz)
	)	
Petition for Rulemaking to Amend and Modernize Parts 25 and 101 of the Commission's Rules to Authorize and Facilitate the Deployment of Licensed Point-to-Multipoint Fixed Wireless Broadband Service in the 3.7-4.2 GHz Band	)	RM-11791
	)	
Fixed Wireless Communications Coalition, Inc., Request for Modified Coordination Procedures in Bands Shared Between the Fixed Service and the Fixed Satellite Service	)	RM-11778

JOINT COMMENTS OF INTEL CORPORATION, INTELSAT LICENSE LLC, AND SES AMERICOM, INC.

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October 29, 2018

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JOINT COMMENTS OF INTEL CORPORATION, INTELSAT LICENSE LLC, AND SES AMERICOM, INC.

I. INTRODUCTION AND SUMMARY

The Notice of Proposed Rulemaking ("NPRM") in the above-captioned proceeding lays out a bold vision to close the digital divide and win the race to 5G.[1] To make that vision a reality, the Commission should take steps to facilitate the joint, market-based approach (the "Market-Based Approach") of Intel Corporation ("Intel"), Intelsat License LLC ("Intelsat"), and SES Americom, Inc. ("SES," and collectively, the "Joint Parties") and bring highly valuable mid-band spectrum to market voluntarily, in an efficient and expeditious manner, and with minimal Commission administration, while preserving important incumbent satellite services.

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[1] *See Expanding Flexible Use of the 3.7-4.2 GHz Band*, Order and Notice of Proposed Rulemaking, GN Docket No. 18-122, FCC 18-91, ¶ 2 (rel. July 13, 2018) ("NPRM").

The Market-Based Approach enjoys cross-industry support and is a win-win-win for consumers, terrestrial 5G interests and Fixed-Satellite Service ("FSS") operators. To enable terrestrial services in the 3.7-4.2 GHz band (the "C-Band Downlink") in the fastest, most efficient way possible and maximize consumer benefits, the FCC should adopt the Market-Based Approach without delay.

The Market-Based Approach will advance the United States' efforts in the race to 5G. The Joint Parties agree with the Commission that the Market-Based Approach can "make [C-Band Downlink] spectrum available more quickly than other available mechanisms, such as an FCC auction, and thus could facilitate rapid deployment of next generation wireless broadband networks."[2] Speed to market has enormous value to society. For instance, an economic white paper from The Brattle Group (the "Brattle Paper") estimates that the accelerated pace of the Market-Based Approach will create billions of dollars in total public benefit compared to other alternatives in the NPRM.[3]

Equally important, the Market-Based Approach is the only mechanism that considers the "unique characteristics" of the C-Band Downlink, adequately "account[s] for incumbent operations" and solves the problem that "terrestrial mobile operations could cause harmful interference to the [co-frequency] earth station receivers."[4] Avoiding involuntary disruption of incumbent satellite service is paramount because FSS operators have invested billions of dollars in C-Band infrastructure that has become the backbone of U.S. content distribution and an invaluable failsafe for viewers and listeners due to its unmatched reliability and ubiquity.

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2 *Id.*, ¶ 67.

3 *See* Appendix A, Coleman Bazelon, The Brattle Group, *Maximizing the Value of the C-Band, Comments on the FCC's NPRM to Transition C-Band Spectrum to Terrestrial Uses*, at 31 (Oct. 29, 2018) ("Brattle Paper").

4 NPRM, ¶¶ 10, 50, 52.

The Market-Based Approach provides the optimal way to enable terrestrial mobile operations in the 3.7-4.2 GHz band.[5] It creates market-based incentives for FSS space station incumbents to undertake cooperatively and voluntarily the complicated, arduous, costly process of clearing C-Band Downlink spectrum and facilitating coordinated terrestrial mobile use as rapidly as possible. This ability and incentive to cooperate allows the satellite operators to bring solutions to the problem that they would not do individually, such as, for example, relocating an existing satellite or launching new satellites to densify coverage over the United States. The FSS industry has embraced this idea—Intelsat, SES, Eutelsat, and Telesat, which account for virtually all of the C-Band revenue in the continental United States, already have formed the C-Band Alliance to act as the Transition Facilitator envisioned in the NPRM and facilitate the Market-Based Approach.

The Joint Parties encourage the Commission to provide the C-Band Alliance with as much flexibility as possible to allow market forces to identify and enable the highest and best use of spectrum. The Market-Based Approach will let the market—rather than the government—determine the optimal amount of C-Band Downlink spectrum made available for terrestrial services and ensure operating conditions that permit productive use of that spectrum by new terrestrial providers while protecting incumbent satellite services. Indeed, the Brattle Paper confirms that "the Market-Based Approach has many advantages and solves the problems created by the market and regulatory failures" that none of the alternative government-run frameworks adequately address.[6] The Market-Based Approach will benefit all interested parties and advance the public interest without the risk and delay associated with attempting to impose a

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5 *See, e.g.*, Brattle Paper, at 45.
6 *Id.*, at 29.

sharing framework by regulatory fiat, including the proposal to mandate new fixed operations in the band. A government directive to allow new fixed point-to-multipoint ("P2MP") operations in the C-Band Downlink is the antithesis of a market-based solution and would create a major roadblock to enabling access to the spectrum for mobile operations by making it more difficult for satellite operators to reassign FSS customers to uncleared spectrum.

The Commission should not adopt any proposal that creates unneeded delay or unnecessary regulatory impediments to efficient terrestrial use of this band. The Joint Parties agree that the "United States will not get a second chance to win the global 5G race."[7] The Joint Parties urge the Commission to adopt the Market-Based Approach promptly and provide wireless operators quick access to new mid-band spectrum to accelerate the introduction of terrestrial 5G services, while protecting incumbent satellite operations, benefitting American consumers of both terrestrial mobile and satellite services.

II. THE MARKET-BASED APPROACH WILL ENABLE OPTIMAL USE OF THE MID-BAND SPECTRUM IN THE MOST ECONOMICALLY EFFICIENT MANNER

Only the Market-Based Approach achieves the difficult task of expeditiously reconciling the terrestrial mobile industry's need for more mid-band spectrum for 5G with the need to protect existing and future C-Band satellite operations. It harnesses market incentives to make mid-band spectrum available for terrestrial 5G voluntarily, quickly, and with minimal FCC intervention, and it enjoys cross-industry support.

Intelsat and SES, by far the two largest providers of FSS in the United States, make extensive use of the C-Band Downlink, utilizing the entire 3.7-4.2 GHz band nationwide to provide a thriving communications network. FSS customers and, by extension, U.S. consumers,

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7 *China Holds Narrow Lead in Global Race to 5G, Report Finds*, Press Release, CTIA.org (Apr. 16, 2018) (quoting Meredith Atwell Baker, CTIA President and CEO).

depend on C-Band for its unrivaled availability and reliability. Fueled by decades of private investment and assurances of replacement expectancy, FSS operators have invested heavily in the C-Band Downlink as the means of video and radio programming delivery to more than 100 million American households. Put differently, almost all national video and radio programming travels over C-Band satellites that have full coverage of the continental United States. C-Band FSS also provides numerous other critical services, including emergency alerts and communications offerings vital to government users, public safety and disaster recovery.

Terrestrial 5G proponents maintain that the band is ideal for their service. As the NPRM observes, "[m]id-band spectrum is well-suited for next generation wireless broadband services due to the combination of favorable propagation characteristics (compared to high bands) and the opportunity for additional channel re-use (as compared to low bands)."[8] Moreover, as global terrestrial deployment in portions of the C-Band Downlink accelerates, unlocking the band for mobile use domestically has become critical in the race to 5G.[9]

The "unique characteristics" of the C-Band Downlink call for a unique approach, and the Market-Based Approach answers the call. The Market-Based Approach efficiently overcomes the complexities in the C-Band Downlink by providing FSS operators the necessary incentive to make C-Band Downlink spectrum available for terrestrial 5G by undertaking the extremely complicated and costly task of clearing incumbent operations in a manner that protects those existing users. It enables satellite operators—the entities that face the opportunity cost trade-offs—to make implementation decisions based upon their first-hand knowledge and technical expertise. The Brattle Paper affirms that the C-Band Alliance "would be best placed to know all

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8 NPRM, ¶ 5.

9 *See id.*, ¶ 6.

of the interconnected trade-offs and to find the value maximizing solution to them."[10] Consumers thus will benefit from both the deployment of innovative terrestrial mobile services *and* the continued operation of media and other applications supported by FSS.

With 5G deployment a national priority, speed is paramount. Getting C-Band spectrum to market quickly enhances consumer welfare, serves the larger public interest, and will help the U.S. win the race to 5G. The Joint Parties agree with the Commission that "a significant benefit of a market-based approach may be a more rapid introduction of C-Band spectrum to the market."[11] The Market Based Approach will clearly provide the speediest, most effective way to repurpose C-Band Downlink spectrum for flexible use—within 18-36 months of a final Report and Order.[12] No other proposal could even come close to making C-Band spectrum available for terrestrial 5G use in such a short time frame.

The Brattle Paper confirms that "[a]ny delay in a beneficial transition is costly, both to the parties and to society."[13] Indeed, "[t]he impact of delay can be significant," as "[t]he economic value of spectrum is only a fraction of its total social value."[14] The Brattle Paper estimates that delays inherent in alternative, command-and-control proposals would reduce social value by between 7% and 12% for each year of delay. "Consequently, any of the other proposals, which could easily be expected to add years of delay to the Market-Based Approach, would significantly decrease the value of repurposing any C-Band frequencies."[15]

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[10] Brattle Paper, at 30.
[11] NPRM, ¶ 69.
[12] *See* Brattle Paper, at 31.
[13] *Id.*
[14] *Id.*
[15] *Id.*

Importantly, providing FSS operators with maximum flexibility in secondary market transactions with mobile operators is essential to the approach's success in enabling terrestrial 5G deployment in C-Band spectrum within 36 months of a final Commission order. Limiting Commission oversight will speed 5G deployment in the band by letting the marketplace determine the adjustments deemed necessary by the parties to protect their respective interests. The Commission correctly observes that parties will "negotiate a full range of transition commitments," and "the private agreements between new terrestrial licensees and incumbent users would contain provisions and penalties sufficient to address either party's failure to satisfy their respective contractual obligations in a timely manner."[16]

Furthermore, the Brattle Paper conclusively rebuts concerns in the NPRM that the Market-Based Approach would inefficiently reallocate spectrum,[17] demonstrating that the C-Band Alliance will not have the market power or incentive to limit artificially the spectrum made available for terrestrial 5G. First, given other spectrum available now or in the near term for terrestrial 5G, the potential supply of C-band spectrum does not convey a meaningful amount of market power.[18] Second, the C-Band Alliance would lose money by artificially withholding spectrum from secondary market transactions.[19] Simply put, "[a]s beneficiaries of any transactions that result from a reallocation, the members of the Transition Facilitator will have the incentive to come to agreement on an efficient solution, without the concerns about the holdout problem an unfettered market would create."[20] These clear economic incentives counsel against heavy-handed, *ex ante* Commission restrictions on the Market-Based Approach.

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16 NPRM, ¶¶ 85, 97.
17 *Id.* at. ¶ 81.
18 Brattle Paper, at 40-42.
19 *Id.* at 40.
20 *Id.* at 32.

The formation of the C-Band Alliance represents an important milestone in making the Market-Based Approach a reality. Intelsat, SES, Telesat, and Eutelsat, the four operators that provide virtually all C-Band services to the continental United States, stand ready to facilitate secondary-market transactions through the C-Band Alliance to feed America's 5G spectrum pipeline in the quickest way possible.

III. ALTERNATIVE PROPOSALS ARE LESS EFFICIENT AND CREATE UNNECESSARY RISK TO INCUMBENT SATELLITE SERVICES

By contrast, other proposals would slow and impair deployment of 5G operations in the C-Band Downlink because they involve government mandates and intervention, not market-based solutions. Any forced solution is likely to result in years of regulatory and legal challenges and delay the availability of C-Band spectrum for wireless use.

A. Mandating Fixed P2MP Is Not Market-Based and Would Impair Satellite Operators' Ability to Clear Spectrum

The proposal for the Commission to mandate fixed P2MP co-frequency sharing in the C-Band Downlink that will be retained for satellite services is the antithesis of a market-based solution. The Broadband Access Coalition proposal to have the Commission dictate C-band operations acknowledges that P2MP use produces less benefit than competing terrestrial 5G uses or the satellite operations P2MP would displace. Mandating P2MP co-frequency sharing with FSS operations will "limit[] the flexibility to incorporate other uses of the C-Band" by "lock[ing] in one approach"—fixed wireless—"that would predetermine how the C-Band would be repurposed without considering and reacting to dynamically evolving market information."[21] Moreover, to the extent sufficient demand exists for fixed wireless services, the Market-Based Approach does not block potential buyers from deploying P2MP if that is the highest and best

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21 Brattle Paper, at 45.

use of the C-Band Downlink. The Commission should reject P2MP co-frequency sharing and avoid placing unnecessary, market-distorting constraints on the efficiency of the Market-Based Approach.

Moreover, a command-and-control decision to force P2MP in the C-Band Downlink will impair future 5G use of the band by greatly reducing the flexibility and incentive for FSS operators to clear spectrum. Simply put, the P2MP proposal is incompatible with expanded terrestrial mobile 5G use of the band. The Joint Parties agree with Commissioner O'Rielly that for the Market-Based Approach to best help the U.S. win the race to 5G, "[t]here can be no unnecessary delays or distractions" and that inserting fixed P2MP in the C-Band Downlink presents "serious concerns."[22] The ability of satellite operators to clear spectrum by compressing their operations will be greatly hindered if satellite operators have less spectrum into which to move their customers as the result of P2MP operations near satellite earth stations. It is illogical to incentivize FSS operators to clear spectrum for 5G mobile use while also mandating new P2MP fixed operations that will make that clearing much more difficult, if not impossible.

B. A Government-Run C-Band Auction Would Result in Significant Delay and Could Harm Incumbent Satellite Operations

Government-run auction approaches in this band would be inefficient, fraught with regulatory delay, and misalign market incentives. Both market and regulatory failures make a government-run reallocation of the C-Band Downlink inferior to the Market-Based Approach.

Market failure stems from existing legal rights, which pose obstacles to achieving the highest and best use of the C-Band Downlink. Satellite operators have overlapping rights in the C-Band. While efficient for satellite services, this commonality of rights creates a "significant holdout problem" in any reallocation process because to clear "any portion of the band at any

[22] NPRM, Statement of Commission Michael O'Rielly, at 1-2.

specific location requires the agreement of all relevant rights holders."[23] Holdouts will prevent value-creating trades, which the NPRM acknowledges makes an approach where "FSS licensees act independently unlikely to succeed."[24] The Joint Parties agree with the NPRM that "[a] market-based approach that uses a Transition Facilitator would enable the satellite operators to use private negotiations to obtain participation and agreement from the relevant satellite operators, rather than requiring the Commission to address holdouts using more regulatory mechanisms."[25]

Regulatory failure stems both from the difficulty of predicting the optimum use of the C-Band resource and an informational deficit that the Commission cannot overcome without extensively delaying 5G deployment in the C-Band Downlink. The FCC is unlikely to collect "all of the relevant information about current and potential uses and the relevant alternative means of meeting those uses" in a timely matter that would allow it to make a decision that benefits the public interest.[26] This information includes: (i) identification of earth station locations, responsible parties, technical uses, and economic uses; (ii) identification of satellite capacity and potential investments; and (iii) identification of potential new terrestrial licensees.[27] Gathering this information will take years, during which time it is likely to become outdated. The U.S. cannot afford delay in the race to 5G. And crucially, this information is dynamic and adapts to market forces, making the Commission's challenge of finding an optimal policy solution even more daunting. The Market-Based Approach eliminates this problem, because the C-Band Alliance already has this information or can easily get additional information from its

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23 Brattle Paper, at 13.
24 NPRM, ¶ 70.
25 *Id.*
26 Brattle Paper, at 13.
27 *Id.* at 14-15.

customer relationships. For this reason, the C-Band Alliance is "best placed to evaluate the trade-offs presented."[28]

None of the alternative government-run auction mechanisms mentioned in the NPRM overcome these fundamental flaws, and all will take significantly longer to implement than the Market-Based Approach. Delay compared to the Market-Based Approach will cost Americans an untenable 7% to 12% annually in social welfare.[29] The Market-Based Approach solves the problems of market and regulatory failure and represents the fastest path to bring 5G spectrum to market. Accordingly, the Commission should expeditiously act to authorize the Market-Based Approach.

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[28] *Id.* at 30.

[29] *See id.* at 31.

IV. CONCLUSION

The Market-Based Approach can unleash mid-band spectrum for terrestrial 5G deployment in the quickest, most economically efficient way while also protecting valuable incumbent FSS operations. The Joint Parties urge the Commission to afford FSS operators maximum flexibility and adopt the Market-Based Approach as soon as possible.

Respectfully submitted,

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Appendix A

Maximizing the Value of the C-Band

Comments on the FCC's NPRM to Transition C-Band Spectrum to Terrestrial Uses

PREPARED BY

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October 29, 2018

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This report was commissioned by Intel, Intelsat, and SES. All conclusions, results, views and any errors are the sole responsibility of the authors and do not necessarily represent the opinions or views of Intel, Intelsat, SES, The Brattle Group, Inc. or any particular affected party.

Acknowledgement: We acknowledge the valuable contributions of many individuals to this report and to the underlying analysis, including members of The Brattle Group for peer review.

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Executive Summary

Radio spectrum is a scarce natural resource that can be put to many valuable uses. This proceeding examines the uses of the C-Band satellite downlink allocation and explores possibilities to permit additional terrestrial use in some amount of these frequencies. It is important to recognize that the C-Band is currently used very productively for satellite services that create significant economic and social value. However, carriers have expressed a desire for additional frequencies for their new 5G terrestrial networks. Consequently, policymakers should evaluate trade-offs involved in consolidating and moving C-Band satellite users in order to accommodate new potential terrestrial uses.

To the extent C-Band spectrum could be redeployed to a higher-value use, market and regulatory failures exist. Given the overlapping nature of their legal rights to use radio spectrum, C-Band users are not free to change uses, which prevents potential value-creating transactions. As the analysis here indicates, benefits of reallocation may exceed costs, but that is not a certainty. If the entire band was reallocated, the expected costs would likely significantly exceed $19.7 billion and have to be balanced against revenue estimates of between $96 million and $65 billion. The significant range of potential net benefits highlights the uncertainty about what the transition should be. In fact, these market and regulatory failures prevent the testing of the proposition that benefits may exceed costs. Consequently, alternative mechanisms to facilitate a transition are needed to lead to the efficient amount of spectrum being made available for terrestrial use.

In the proposed Market-Based Approach, the Commission would authorize incumbent FSS operators to voluntarily relinquish the C-Band spectrum they currently use. Satellite operators in the band could choose to make some or all of their spectrum available to terrestrial operators on the secondary market, in exchange for compensation. This proposal would make satellite operators responsible for clearing the portion of the band that would be made available for flexible use, including notifying earth stations of the need to modify their operations and compensating them for any costs associated with that transition.

The Market-Based Approach eliminates problems due to poorly defined legal rights and the public goods issues that arise. Insufficiently defined legal rights limit the ability of markets to form and function properly. Problems of informational inefficiencies, holdout, and delay hinder efficient repurposing from taking place. By creating a Transition Facilitator, with clearly defined limits on providers that are not part of the Transition Facilitator, the overlapping legal rights are brought under common consideration. This significantly limits the ill effects of the overlapping rights. Consequently, the affected parties, with the necessary specific knowledge, are able to work out an optimal solution.

Several alternative proposals to the Market-Based Approach are being considered. All of these alternative proposals for reallocating or repurposing C-Band spectrum are inferior to the Market-Based Approach. They do little or nothing to solve the central impediments to finding an efficient repurposing. None of them provides a mechanism to solicit the information needed about costs

and benefits of the many aspects of transitioning users. They do not solve the holdout problem or resolve the ill-defined legal rights in the band. They would deprive satellite operators of their existing rights and investment-based expectations generated by the current licensing regime and renewal rights. They also require the FCC to bear the burden and costs of implementation. All would take significantly longer to effectively assign or clear spectrum than expected by a Transition Facilitator. And none of these proposals can course correct or adjust in response to market developments.

Although all the proposals aim to increase the beneficial uses of the C-Band, the Market-Based Approach will create the most value in the shortest timeframe, and will preserve incumbent services more efficiently. With societal benefits from repurposed spectrum estimated to be 10 to 20 times the value of spectrum, missed opportunities and delay can have significant costs. By developing the detailed information needed, and adjusting to changing circumstances, the Transition Facilitator will be incentivized to repurpose as much spectrum as possible where doing so increases value, but not to transition too much (or any, if uneconomic). Any benefits created will be as result of their efforts and would not materialize under the other proposals. Their incentives are aligned with the public's in that they do not have any practical incentive to withhold supply. Because the Transition Facilitator will be able to create value much more quickly than any of the alternatives proposed, the private parties they are negotiating with can start their planning processes even quicker. Consequently, the Market-Based Approach should create the greatest amount of benefits to consumers and society.

I. Background

Radio spectrum is a scarce natural resource that can be put to many valuable uses. This proceeding examines the uses of the C-Band satellite downlink allocation and explores possibilities to permit additional terrestrial use in some amount of these frequencies.[1] It is important to recognize that the C-Band is currently used very productively for satellite services that create significant economic and social value. However, carriers have expressed a desire for additional frequencies for their new 5G terrestrial networks. Consequently, policymakers should evaluate trade-offs involved in consolidating and moving C-Band satellite users in order to accommodate new potential terrestrial uses. This begins with understanding current uses of the C-Band and the potential new terrestrial uses.

A. The C-Band – Current Uses and Value Creation

The Lower C-Band is currently used predominantly for Fixed Satellite Service ("FSS") space-to-Earth transmissions in the 3.7 GHz to 4.2 GHz band.[2] In this band, FSS is provided by geostationary satellites, whose distance from the Earth (approximately 36,000 kilometers) means that they appear fixed relative to the Earth.[3] C-Band FSS relies on a network of earth stations, the vast majority of which are receive-only and located at fixed positions, and typically provides communication services, such as video and audio distribution and data broadcasting. The Earth-to-satellite transmissions occur at different frequencies, 5.925 GHz to 6.425 GHz, which are not part of this proceeding.

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1 See Order and Notice of Proposed Rulemaking, *In the Matter of Expanding Flexible Use of the 3.7 to 4.2 GHz Band,* GN Docket No. 18-122, GN Docket No. 17-183, RM-11791, RM-11778, July 13, 2018, accessed October 1, 2018, https://docs.fcc.gov/public/attachments/FCC-18-91A1.pdf ("Order and Notice of Proposed Rulemaking").

2 The band is also used for fixed service point-to-point microwave links, but remaining FS use of the spectrum is "relatively minimal." See Notice of Inquiry, *In the Matter of Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz,* GN Docket 17-183, August 3, 2017, ¶¶ 9-10, accessed September 30, 2018, https://docs.fcc.gov/public/attachments/FCC-17-104A1_Rcd.pdf.

3 Geostationary satellites revolve around the Earth's equator at an altitude of roughly 36,000 kilometers (or 22,000 miles). Their location above the Earth causes them to take 24 hours for a single orbit around the Earth, thus making them appear to be stationary from the ground. See Bruce R. Elbert, *Introduction to Satellite Communication*, Third Edition (Boston: Artech House, 2008): pp. 1-2 and 22, accessed October 25, 2018, http://sedighy.ir/wp-content/uploads/2014/10/ebooksclub.org__Introduction_to_Satellite_Communication__Artech_House_Space_Applications_.pdf; and Larry Thompson and Brian Enga, "Analysis of Satellite-Based Telecommunications and Broadband Services," VantagePoint, November 2013, pp. 1-4.

The C-Band was the first band to be used for commercial FSS, though the Ku-Band and Ka-Band now also are used to provide FSS.[4] The C-Band is primarily used for video distribution in North America. According to Northern Sky Research, video distribution accounted for 70.9% of C-Band demand in North America in 2017.[5] Other key C-Band applications include Contribution & Occasional Use TV ("OUTV") (17.1% of total demand), Telephony & Carrier (5.6% of total demand, and Enterprise Data (2.9% of total demand).[6]

Because the C-Band is at a lower frequency than either the Ku- or Ka-Bands, C-Band communications are less susceptible to atmospheric attenuation (known as "rain fade") than other bands.[7] For instance, PSSI Global Services, LLC ("PSSI"), a television transmission service provider for event broadcasting, stated that it recently converted some of its Ku-Band equipment to C-Band equipment because its customers preferred the reliability of C-Band, particularly in areas subject to frequent rain.[8] Table 1 provides an overview of the C-, Ku-, and Ka-Bands.

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4 Zahid Zaheer, "The Battle for C-Band," *Space News*, March 17, 2015, accessed October 25, 2018, http://spacenews.com/op-ed-the-battle-for-c-band/.

5 Calculation: 70.9% = 256.5 TPE demand for distribution / 361.9 TPE demand for all C-Band services. TPE refers to "transponder equivalent" capacity. See *Ex Parte* Filing of Ericsson, GN Docket No. 17-183, filed March 29, 2018, slide 6, accessed September 21, 2018, https://ecfsapi.fcc.gov/file/10329453530188/Ericsson%20Mid%20Band%20Ex%20Parte%20GN%2017-183%20COMBINED%20TO%20BE%20FILED.pdf (citing Northern Sky Research).

6 C-Band also represents nearly 40% of total FSS demand for Contribution & OUTV and 95% of total FSS demand for Telephony & Carrier. See *id*.

7 Higher frequency satellite beams, such as the Ka- and Ku-Bands, often use more focused beams that cover smaller geographic areas to counteract potential attenuation issues from rain fade. See José Albuquerque, "Satellite Operators Challenge Mobiles' Use of C-Band," *International Telecommunication Union News Magazine*, accessed October 25, 2018, http://www.itu.int/itunews/manager/display.asp?lang=en&year=2007&issue=08&ipage=C-band.

8 *Ex Parte* Filing of PSSI Global Services, LLC et al., GN Docket Nos. 17-183, 18-122, filed June 25, 2018, accessed September 30, 2018, https://ecfsapi.fcc.gov/file/10625001180125/as-filed%20PSSI_ex_parte.pdf.

Table 1: Commercial Fixed Satellite Frequency Bands

Band	Advantages	Disadvantages	Satellite Services
C-Band	Reliable service resistant to "rain fade." Offers a wide beam.	Moderately-sized antennas (typically 4-6 meters in diameter) are needed to accommodate lower power levels.	Video Distribution, video contribution / occasional use, telephony, enterprise data, government / military, commercial mobility
Ku-Band	Allows use of smaller antennas (4 meters in diameter or less) due to higher power.	More susceptible to "rain fade" than C-Band (may be at least partially mitigated with high-power narrow beams and other technologies).	Direct-to-home, enterprise data, commercial mobility (e.g. aeronautical), government / military, video contribution /occasional use, video distribution, telephony
Ka-Band	Allows use of even smaller antennas (less than 1 meter). Increased data throughput.	Severely susceptible to "rain fade" relative to C-Band (may be at least partially mitigated with high-power narrow beams and other technologies).	Broadband access, government/military, commercial mobility, video contribution / occasional use

Sources: "A Practical Introductory Guide on Using Satellite Technology for Communications," Intelsat, p. 6, accessed October 25, 2018, http://www.intelsat.com/wp-content/uploads/2018/04/5941-SatellitePrimer-2017.pdf; Larry Thompson and Brian Enga, "Analysis of Satellite-Based Telecommunications and Broadband Services," VantagePoint, November 2013, p. 8-9, accessed October 25, 2018, https://ecfsapi.fcc.gov/file/7520956711.pdf; "C-Band Spectrum for Satellite Services Drives Industries & Economies in Asia," Intelsat, accessed October 25, 2018, http://www.intelsat.com/wp-content/uploads/2014/10/10-Critical-Facts-about-C-band-for-Satellite-Services-asia-infograhic.jpg; "C-Band Satellite Spectrum Vital to Global Communications," Intelsat, accessed October 25, 2018, http://www.intelsat.com/wp-content/uploads/2014/03/Infographic_C-band.pdf; Jorn Christensen, "ITU Regulations for Ka-Band Satellite Networks," ITU, accessed October 25, 2018, http://www.itu.int/md/dologin_md.asp?id=R12-ITURKA.BAND-C-0001!!MSW-E; "Ka vs. Ku - An Unbiased Review," Skyware Technologies, July 2, 2015, accessed September 21, 2018, http://www.skywaretechnologies.com/news/item/84-ka-vs-ku-an-unbiased-review; Notice of Inquiry, *In the Matter of Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz,* GN Docket 17-183, August 3, 2017, accessed September 30, 2018, https://docs.fcc.gov/public/attachments/FCC-17-104A1_Rcd.pdf; and Global Satellite Capacity Supply and Demand Study, 14th Edition, Northern Skies Research, 2017.

B. 5G, IoT, and Mid-Band Bandwidth Demand

Mobile networks have grown dramatically over the past 15 years, and this growth is projected to continue. According to Ericsson, global monthly mobile data traffic on macro (non-Wi-Fi) wireless networks was 617 petabytes ("PB") per month in 2011. By 2017, this mobile data traffic had increased to almost 14,900 PB per month, representing growth of over 2,300%.[9] Mobile data traffic is projected to grow by more than 600% from 2017 to 2023, reaching 106.5 exabytes ("EB") per month.[10]

Mobile data demand likely will continue to grow as smartphones become ubiquitous and the use of data-intensive applications, like video streaming, increases. Cisco projects five-fold growth of mobile data traffic in the U.S. from 2016 to 2021, reaching 6.1 EB per month by 2021.[11] Cisco also estimates that 81% of mobile data traffic will come from smartphones by 2021 and that the share of mobile traffic dedicated to video will increase from 64% of all traffic in 2016 to 76% in 2021.[12]

Mobile networks constantly evolve to support growing demand for mobile broadband. The current leading mobile network technology, known as the fourth-generation ("4G"), was largely designed to provide "more capacity for faster and better mobile broadband experiences."[13] Whereas a 4G network can support speeds around 300 Mbps, the next generation "5G" wireless networks are expected to reach speeds as high as 20 Gbps downlink and 10 Gbps uplink in ideal conditions.[14] In addition to faster data speeds, a 5G network is envisaged to have six other key

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9 "Ericsson Mobility Visualizer," Ericsson, June 2018, accessed October 25, 2018, https://www.ericsson.com/en/mobility-report/mobility-visualizer.

10 One EB is equal to 1,000 PB. See *id.*

11 "VNI Mobile Forecast Highlights: United States," Cisco, 2016, accessed September 6, 2018, https://www.cisco.com/assets/sol/sp/vni/forecast_highlights_mobile/#~Country. However, this exponential growth is not likely to continue forever. See Richard Womersley, Director Spectrum Consulting, LS Telecom, "When will Exponential Mobile Growth Stop?," October 9, 2017, accessed October 25, 2018, https://www.lstelcom.com/fileadmin/content/marketing/news/2017_LStelcom_Report_WhenWillExponentialMobileGrowthStop.pdf.

12 "VNI Mobile Forecast Highlights: United States," Cisco, 2016, accessed September 6, 2018, https://www.cisco.com/c/dam/assets/sol/sp/vni/forecast_highlights_mobile/index.html#~Country.

13 "The Evolution of Mobile Technologies," Qualcomm PowerPoint presentation, June 2014, slide 6, accessed October 25, 2018, https://www.qualcomm.com/media/documents/files/download-the-evolution-of-mobile-technologies-1g-to-2g-to-3g-to-4g-lte-qualcomm.pdf.

14 "The Evolution of Mobile Technologies," Qualcomm, June 2014, slide 5. User experienced data rates are often not as high as the peak data rate in a given network: for instance, the average user experienced data speed of 4G networks in the U.S. is approximately 10 Mbps. Similarly, the ITU envisions 5G to have peak data rates of 20 Gbps and user experienced rates as high as 100 Mbps. See "State of Mobile Networks: USA (January 2018)," Open Signal, January 2018, accessed October 25, 2018, https://opensignal.com/reports/2018/01/usa/state-of-the-mobile-network; and "IMT Vision –

capabilities, including: (i) ultra-low latency (as low as one millisecond); (ii) increased capacity (as high as 10 Mbps per square meter);[15] and (iii) increased connection density (as high as one million devices per square kilometer).[16]

The evolution of 5G networks is expected to facilitate the deployment of new applications including the Internet of Things ("IoT"). IoT refers to the linking of and communication between physical objects, such as roadways and bridges, using wired and wireless networks.[17] Ericsson estimates that there could be over 30 billion connected devices by 2023, with nearly 20 billion of those IoT devices.[18] IoT is expected to lead to increased demand for wireless network capacity, even though many connections will be relatively low bandwidth.

The exact course and levels of both the consumer-oriented and IoT sources of increased demand that are expected to develop as a result of deploying the 5G platform are uncertain. Although the idea that there will be an IoT is fairly certain at this point, the scope of services and connections that will constitute IoT are still speculative. What exactly will drive any increased consumer demand – augmented and virtual reality are touted as possibilities – is unknown. Just as the increased capacity made available by 3G networks was not fully utilized until smart phones and tablets took off, 5G networks will only truly be a success if new applications that use the greater capacity and lower latency develop. History suggests new applications and services will come to make use of the new networks, but, of course, there will be uncertainty about that until the new demands are realized.

Mobile networks are limited in their ability to add capacity for data traffic. There are three primary options for adding network capacity: 1) increase spectral efficiency, 2) reuse existing spectrum by adding additional cell sites or nodes to the network, or 3) deploy additional spectrum. The evolution of more advanced networks, such as the current 4G and upcoming 5G networks, has increased the efficiency of spectrum, and mobile network operators have deployed additional cell sites as their networks have expanded. Even with these gains in efficiency and infrastructure,

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Framework and Overall Objectives of the Future Development of IMT for 2020 and Beyond," International Telecommunications Union (ITU), September 2015, Figure 3, p. 14, accessed October 25, 2018, https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf.

15 Capacity refers to the bandwidth available rather than the speed of connections. For instance, see Chandan Singh Takuli, "Bandwidth vs Speed," The Cisco Learning Network, October 16, 2015, accessed September 21, 2018, https://learningnetwork.cisco.com/blogs/vip-perspectives/2015/10/16/bandwidth-vs-speed.

16 The other three key capabilities listed by the ITU are: increased spectrum efficiency; increasing mobility; and increased network energy efficiency. See "IMT Vision," ITU, Figure 3, p. 14.

17 Michael Chui, Markus Löffler, and Roger Roberts, "The Internet of Things," McKinsey Quarterly, March 2010, accessed October 25, 2018, http://www.mckinsey.com/industries/high-tech/our-insights/the-internet-of-things.

18 Ericsson Mobility Report, June 2018, accessed October 28, 2018, https://www.ericsson.com/assets/local/mobility-report/documents/2018/ericsson-mobility-report-june-2018.pdf.

however, some amount of additional spectrum is expected to be necessary to meet the increasing demand for mobile broadband, particularly for new 5G networks.

The architecture of a robust 5G network will require spectrum in a variety of different bands. Low-band spectrum below 1 GHz will provide coverage for wide-area and long-range communications; mid-band spectrum between 1 GHz and 6 GHz will support applications that would benefit from a combination of coverage and capacity support; and high-band spectrum above 6 GHz (mostly focused on various millimeter wave bands) will provide capacity for short-range communications that require fast data rates and low latency.[19]

The FCC recently released a 5G spectrum strategy that encompasses low-, mid-, and high-band spectrum, as well as unlicensed spectrum for Wi-Fi, to make additional frequencies available for 5G services.[20] But just how much demand exists for each type of spectrum will only be known with more certainty as operator plans evolve in response to changing consumer demands and technological possibilities. For example, it took longer than expected for the 3G frequencies to be fully utilized.

The licensed low-band frequencies – 600 MHz, 700 MHz and 800 MHz (cellular and SMR) bands – have a total of 204 MHz licensed.[21] There are limited opportunities to reallocate additional frequencies, and none are likely in the near term. Some high-band millimeter wave frequencies are already licensed (including parts of the 28 and 39 GHz bands);[22] one is due to be auctioned later this year (28 GHz); and yet others are in the pipeline (including 700 MHz of the 24 GHz band scheduled for after the 28 GHz auction, 1,000 MHz each of 37 GHz and 47 GHz spectrum along with 1,400 MHz of 39 GHz band spectrum expected in late 2019, and 500 MHz of 42 GHz spectrum expected in 2020 or later).[23]

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[19] Letter to Marlene H. Dortch, FCC, from Reed Hundt, "Use of Spectrum Bands Above 24 GHz for Mobile Radio Services, GN Docket No. 14-177; IB Docket Nos. 15-256, 97-95; WT Docket No. 10-112; RM-11664," July 1, 2016, accessed October 25, 2018, https://ecfsapi.fcc.gov/file/1070164539932/Hundt%20Letter%20on%205G%20(7-1-2016).pdf; and Tom Wheeler, "The Future of Wireless: A Vision for U.S. Leadership in a 5G World," prepared remarks at the National Press Club, Washington, D.C., June 20, 2016, accessed October 25, 2018, http://transition.fcc.gov/Daily_Releases/Daily_Business/2016/db0620/DOC-339920A1.pdf.

[20] FCC, "The FCC's 5G FAST Plan," accessed October 25, 2018, https://docs.fcc.gov/public/attachments/DOC-354326A1.pdf.

[21] This includes 70 MHz each of 600 MHz and 700 MHz, 50 MHz of Cellular, and 14 MHz of Specialized Mobile Radio Service (SMR) spectrum. See Coleman Bazelon and Giulia McHenry, "Mobile Broadband Spectrum: A Vital Resource for the U.S. Economy," May 11, 2015, Table 2, https://ecfsapi.fcc.gov/file/60001117200.pdf ("Coleman Bazelon and Giulia McHenry, "Mobile Broadband Spectrum: A Vital Resource for the U.S. Economy"").

[22] Final Rule, *Use of Spectrum Bands Above 24 GHz for Mobile Radio Services*, GN Docket No. 14-177, FCC, July 20, 2018, accessed October 25, 2018, https://www.gpo.gov/fdsys/pkg/FR-2018-07-20/pdf/2018-14806.pdf.

[23] Robert Kaminski, "Spectrum Auction Tracker," Capital Alpha, October 15, 2018.

The focus of unmet need for 5G is on the mid-band frequencies. Just how much more mid-band spectrum will be needed, however, is uncertain. There is some trade-off between mid-band and millimeter wave frequencies in meeting any 5G generated demands. The scope of this trade-off will be defined by the limits of where millimeter wave spectrum will be deployed, itself still to be determined. For example, Verizon launched its 5G Home service October 1 in four cities utilizing 28 GHz spectrum.[24] What these trials prove and whether they lead to mobile applications remains to be seen. Consequently, demand for mid-band frequencies, and their associated values, will evolve over time in response to changing marketplace conditions.

Not including the 3.7-4.2 GHz band, existing licensed mid-band frequencies for terrestrial mobile include a total of 511.5 MHz, and an additional 70 MHz of licensed CBRS is expected soon.[25] Not all of these frequencies are deployed yet. Nevertheless, these frequencies may be insufficient for meeting future 5G needs for two reasons. First, a significant quantity of these frequencies will continue to be needed to service existing 4G (and legacy 2G and 3G) customers. Second, the need for mid-band spectrum for 5G is likely larger than what can be met by these frequencies, even if they were all available for 5G deployments. In particular, new mid-band spectrum may be deployed in wide channels for 5G and provide capacity gains relative to previous bands that have been deployed in much narrower bands.[26]

Given the apparent demand for additional mid-band frequencies, the C-Band downlink, covering frequencies from 3.7 to 4.2 GHz, is ideal spectrum to meet this need. C-Band spectrum is particularly suitable for 5G because it can provide sufficiently-sized contiguous blocks of spectrum to 5G networks.[27]

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24 Ryan Whitman, "Verizon Will Offer 5G Home Internet Next Month in Select Cities," Extremetech.com, September 12, 2018, accessed October 25, 2018, https://www.extremetech.com/internet/276822-verizon-will-offer-5g-home-internet-next-month-in-select-cities.

25 This 511.5 MHz of existing licensed spectrum consists of 90 MHz of Advanced Wireless Service (AWS)-1, 120 MHz of Personal Communications Service (PCS), 10 MHz of G Block, 10 MHz of H Block, 65 MHz of AWS-3, 40 MHz of AWS-4, 20 MHz of Wireless Communications Service (WCS), and 156.5 MHz of Broadband Radio Service (BRS) & Education Broadband Service (EBS). See Coleman Bazelon and Giulia McHenry, "Mobile Broadband Spectrum: A Vital Resource for the U.S. Economy," Table 2.

26 Peter Rysavy, "Industry Voices—Rysavy: Midband spectrum for 5G is needed now," Fierce Wireless, August 13, 2018, accessed September 21, 2018, https://www.fiercewireless.com/5g/industry-voices-rysavy-mid-band-spectrum-for-5g-needed-now.

27 "5G Spectrum," Huawei Public Policy Position, 2017, accessed September 21, 2018, https://www-file.huawei.com/-/media/CORPORATE/PDF/public-policy/public_policy_position_5g_spectrum.pdf?la=en; and Jon Mundy, "C-Band not mmWave key to 5G rollout", 5G.co.uk, December 7, 2017, accessed September 21, 2018, https://5g.co.uk/news/c-band-key-kickstarting-5g/4244/.

II. Market and Regulatory Failure

From an efficiency standpoint, at any point in time a given band of radio spectrum should be used for satellite services if the value of the spectrum deployed in this use (inclusive of transition costs) is higher than it would be if the spectrum were deployed in some other use, notably terrestrial mobile wireless networks. Similarly, any given band at any specific time should be deployed for terrestrial uses if it creates more value (inclusive of transition costs). In fact, a well working market would provide just this result.

To the extent C-Band spectrum could be redeployed to a higher valued use, market and regulatory failures exists. Given the nature of their legal rights to use radio spectrum, C-Band users are not free to change uses, which prevents potential value-creating transactions. C-Band satellite operators Intelsat, SES, Eutelsat, and Telesat have formed the C-Band Alliance and signaled a willingness to clear spectrum for terrestrial mobile use within 18 to 36 months after the time of the final Commission order to the extent that they are compensated for their costs – including lost opportunity costs – of doing so.[28] If this transaction would create value, then the fact it has not happened already supports the conclusion that markets and regulators have failed to put these frequencies to their highest-valued use. Furthermore, the fact that FSS operators and their customers have non-exclusive rights to operate requires an additional degree of coordination to reallocate spectrum successfully in this band.

This section will show that transitioning some amount of the C-Band downlink from satellite services to terrestrial wireless services could be efficient and could be expected to occur voluntarily in a well-functioning market. First, I will discuss the market and regulatory failures that prevent the resource finding its highest valued use. I will explain the value of C-Band spectrum if used for mobile wireless networks and the costs of moving satellite services out of the C-Band under one extreme scenario. These costs include the value lost from early retirement of satellites, the associated transition costs that facilitate the early retirements, and satellite earth stations currently using the C-Band. This section will conclude by arguing that a value-creating transition of spectrum is likely but indeterminate.

A. The Specific Market and Regulatory Failures Preventing Reallocation of the C-Band

A threshold question is whether C-Band spectrum is being put to its highest and best uses today. Answering this question will provide a foundation for evaluating potential solutions proposed for more efficiently using the C-Band. The answer lies in what is preventing market transactions from

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28 "C-band Joint-Use Proposal Fact Sheet," Intelsat, Intel, SES, accessed October 25, 2018, http://www.intelsat.com/wp-content/uploads/2018/06/C-band-Fact-Sheet-Intelsat-Intel-SES.pdf; and "Intelsat, SES, Eutelsat and Telesat Establish the C-Band Alliance (CBA), a Consortium to Facilitate Clearing of U.S. Mid-band Spectrum for 5G While Protecting U.S. Content Distribution and Data Networks," Intelsat, SES, Eutelsat and Telesat, October 1, 2018, accessed October 1, 2018, http://www.intelsat.com/news/press-release/intelsat-ses-eutelsat-and-telesat-establish-c-band-alliance/.

creating additional value from the C-Band. A well-functioning market will put resources to their highest-valued uses. Consequently, this section identifies the market and regulatory failures that impede the C-Band from being used more efficiently.

The central market failure that prevents C-Band spectrum from being put to higher-valued uses is the nature of the legal rights the users of the band hold. Under current regulatory policies, satellite providers have access to specific orbital slots with rights to transmit across the entire 500 MHz of the C-Band to their customers who receive signals from across the band at a particular geographic location. This is known as "full-band, full-arc" licensing and means that many entities have overlapping (not mutually exclusive) rights to use the band. The satellite transmission rights cover the entire spectrum band across the entire country.

The problem created by these overlapping rights is that to reallocate any portion of the band at any specific location requires the agreement of all relevant rights holders. This creates a significant holdout problem.[29] Agreement among all but one of the satellite rights holders is not sufficient. One recalcitrant rights holder can demand all of the value created from a potential reallocation. But, of course, any of the rights holders could act as the holdout. There is no mechanism to guarantee that all of the rights holders will agree on how to share the gains from a potential trade. Consequently, trades may not take place, even though doing so would create value. Hence, a market failure exists. Together the lack of flexibility and the problem of overlapping rights both explain why efficient repurposing of spectrum use could not occur and represent the central challenges any proposal to facilitate efficient repurposing must overcome.

Of course, the allocation (and reallocation) of the C-Band are not controlled by a market, but are controlled by a regulatory body – the FCC. But a regulatory failure also exists that prevents the FCC from getting to the economically efficient solution. This regulatory failure is based on the complexity of determining which portions of the band to reallocate, if any, to which parties and at which point in time, and in a manner that most cost-effectively keeps the affected incumbent users whole. That is, for a regulator such as the FCC to make a decision that benefits the public interest, it would need to have all of the relevant information about current and potential uses and the relevant alternative means of meeting those uses. But that is too much information for the FCC to develop in a timely manner. The complex information needed to find the efficient solution includes:

- **For Earth Stations.**
    - <u>Identify location and responsible party.</u> The FCC recently opened windows for registering previously unregistered earth stations. On April 19, 2018, the FCC issued a freeze on applications for new receive-only C-Band earth station licenses and registration but opened a 90-day window for existing earth stations to become

29 This holdout problem is one of the economic problems the FCC seeks to solve in finding the correct mechanism for expanding the flexible use of the spectrum. See Order and Notice of Proposed Rulemaking, ¶ 59.

registered or licensed.[30] The FCC later extended the deadline for registration of existing earth stations to October 17, 2018 and then extended again to October 31, 2018.[31] As of October 26, 2018, there were approximately 16,500 earth station using the 3.7-4.2 GHz frequencies in the FCC's International Bureau Filing System ("IBFS").[32]

  - Identify current technical uses. To know how much of a guard band or exclusion zone around an earth station is needed to protect current uses, specific technical parameters are needed. These parameters are also needed to evaluate potential mitigation techniques such as adding filters or creating physical barriers to protect reception. Furthermore, these technical details have an important economic component. For example, two larger but slightly encumbered licenses might be more valuable than two fully cleared channels that are smaller because of a larger guard band.
  - Identify current economic uses. To evaluate the feasibility and cost of relocating the services facilitated by any given earth station, it is necessary to know the commercial services provided, as well as the larger business context in which those services are provided.[33]

- **For Satellites.**
  - Identify available capacity. The optimal solution will depend to some extent on the alternatives available for satellite operators' existing customers. Of course, the availability of alternative capacity itself has an important economic dimension.
  - Identify potential investments. Accommodating clearing of C-Band spectrum might entail additional investments, such as deploying new satellites, relying upon

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30 FCC, Temporary Freeze on Applications for New or Modified Fixed Satellite Service Earth Stations and Fixed Microwave Stations in the 3.7-4.2 GHz Band, 90-Day Window to File Applications for Earth Stations Currently Operating in 3.7-4.2 GHz Band, Freeze and Filing Window in Furtherance of the Commission's Pending Inquiry in GN Docket Nos. 17-183, 18-122, DA 18-398, April 19, 2018, accessed September 21, 2018, https://transition.fcc.gov/Daily_Releases/Daily_Business/2018/db0419/DA-18-398A1.pdf.

31 FCC, International Bureau Announces 90-Day Extension of Filing Window, to October 17, 2018, to File Applications for Earth Stations Currently Operating in 3.7-4.2 GHz Band, Filing Options for Operators with Multiple Earth Station Antennas, GN Docket Nos. 17-183, 18-122, DA 18-639, June 21, 2018, accessed September 21, 2018, https://docs.fcc.gov/public/attachments/DA-18-639A1.pdf; and FCC, International Bureau, International Bureau Announces Two-Week Extension of Filing Window for Earth Stations Currently Operating in 3.7-4.2 GHz Band, GN Docket No. 18-122, October 17, 2018, accessed October 25, 2018, https://docs.fcc.gov/public/attachments/DA-18-1061A1.pdf.

32 Comments of the C-Band Alliance, *In the Matter of Expanding Flexible Use of the 3.7 to 4.2 GHz Band,* GN Docket No. 18-122, GN Docket No. 17-183, RM-11791, RM-11778, October 29, 2018, Section II.B.

33 The FCC is seeking comments on whether to ask earth station operators to provide additional information on the specific uses of the earth stations. This could include the type of content, identity of the content provider, and bandwidth occupied by particular users or content feeds. See Order and Notice of Proposed Rulemaking, ¶ 42.

existing and new fibre, or deploying technical fixes for earth stations such as new equipment, filters, etc.

- **For potential new terrestrial licensees.** The FCC would typically seek inputs from interested parties on use cases and spectrum requirements to assess demand, and on the economic potential value each use might create, as well as the trade-off between more or less spectrum over more or fewer geographies, and any interference concerns with in-band or adjacent incumbents. The timing of the availability of the cleared C-Band frequencies would also impact value creation.[34]
- **The challenge of an optimal solution.** Even if the FCC could gather all of the relevant information in a timely manner, it would still be a daunting task for a regulator to find the optimal policy solution. It would have to optimize across many dimensions. And given the complexity of the optimization, the solution may be sensitive to small changes in inputs or calculations. Consequently, the complex dynamic solution may need to change over time in response to new information and developments, adding to a regulator's challenge.

B. Benefits of Terrestrial Uses

The Notice of Proposed Rulemaking ("NPRM") contemplates proposals that could make some or all of 500 MHz of C-Band downlink spectrum available for mobile wireless.[35] There are currently 715.5 MHz of low- and mid-band spectrum available for mobile wireless in the U.S., with the 70 MHz of licensed CBRS the only near-term additions expected.[36] (It is also anticipated that millimeter wave frequencies will be used in 5G networks, but they have not yet been deployed commercially.) However, the demand for mobile wireless services could soon exceed spectrum supply; in 2015, I estimated that the U.S. would need more than 350 additional MHz of licensed spectrum by 2019.[37] As noted above, the arrival of 5G will likely increase demand for frequencies, including in the mid-band.

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34 The FCC is seeking comments on the economic benefit of such new terrestrial uses, including the benefits of any international harmonization, the benefit to end users in areas that are currently unserved or underserved by broadband providers, and how long such a transition would take. See Order and Notice of Proposed Rulemaking, ¶ 56.

35 Order and Notice of Proposed Rulemaking, ¶ 1. This section addresses the FCC's request for comment on the economic benefits of introducing an allocation for mobile in the C-Band. See Order and Notice of Proposed Rulemaking, ¶ 56.

36 Coleman Bazelon and Giulia McHenry, "Mobile Broadband Spectrum: A Vital Resource for the U.S. Economy"; and Report and Order and Second Further Notice of Proposed Rulemaking, *In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, GN Docket No. 12-354, April 21, 2015, ¶ 4, accessed October 25, 2018, https://docs.fcc.gov/public/attachments/FCC-15-47A1.pdf.

37 The 350 additional megahertz is in reference to a base of 650 megahertz. That is, even with the addition of 140 megahertz of spectrum in the next few years the U.S. will still need over two hundred additional megahertz of spectrum to meet commercial wireless demand. See Coleman Bazelon and Giulia McHenry, "Substantial Licensed Spectrum Deficit (2015-2019): Updating the FCC's Mobile Data

The value of new mid-band frequencies, including the C-Band, is uncertain. There are no domestic market comparable transactions. The impact of the evolving 5G market creates upward pressure on value, but also introduces significant uncertainty. Over the past year and a half there have been seven foreign auctions of C-Band frequencies. The prices in these auctions ranged from less than $0.01/MHz-pop to almost $0.42/MHz-pop. See Table 2. This range of prices in part reflects differences in license term as well as country differences in mobile broadband markets. For example, the Italian auction may overstate the value expected for this band, because the regulator offered just a "few tranches of frequency and no visibility on when further packages might become available," leaving the carriers little option but to pay top dollar for the current offering.[38] These differences among the auction results and complicating country-specific circumstances underscore the uncertainty that surrounds any auction result in particular and the process of determining the value for 5G use in the U.S. in general. With these caveats in mind, I will use this unadjusted range of potential values to illustrate the potential value of C-Band spectrum in the U.S.

Table 2: International 5G Mid-Band Auction Prices

	Date	Country	Band	Allocation (MHz)	Population (mm)	MHz-pops (mm)	Payment ($mm)	Price/MHz-pop ($)
[1]	May-17	Ireland	3.6 GHz	350	4.8	1,677.4	$86.4	$0.051
[2]	Dec-17	Latvia	3.4-3.8 GHz	100	1.9	193.4	$0.6	$0.003
[3]	Apr-18	UK	3.4 GHz	150	66.0	9,906.0	$1,638.8	$0.165
[4]	Jun-18	South Korea	3.5 GHz	280	51.3	14,355.6	$2,740.9	$0.191
[5]	Jul-18	Spain	3.6-3.8 GHz	200	46.7	9,331.9	$511.3	$0.055
[6]	Oct-18	Finland	3.4-3.8 GHz	390	5.5	2,150.1	$89.5	$0.042
[7]	Oct-18	Italy	3.6-3.8 GHz	200	60.5	12,096.8	$5,015.8	$0.415

Sources and Notes:

Monthly average exchange rates from FRED Economic Data, Federal Reserve Bank of St. Louis, accessed October 28, 2018, https://fred.stlouisfed.org/categories/95.

[1]: Commission for Communications Regulation, "Results of the 3.6 GHz Band Spectrum Award," Information Notice, May 22, 2017, Annex 1, accessed October 7, 2018, https://www.comreg.ie/media/dlm_uploads/2017/05/ComReg-1738.pdf; and Central Statistics Office, "Population and Migration Estimates, April 2017," September 28, 2017, accessed October 7, 2018, https://www.cso.ie/en/releasesandpublications/er/pme/populationandmigrationestimatesapril2017/.

Demand Projections," June 23, 2015, accessed October 25, 2018 http://www.brattle.com/system/news/pdfs/000/000/891/original/Substantial_Licensed_Spectrum_Deficit_%282015-2019%29_-_Updating_the_FCC's_Mobile_Data_Demand_Projections.pdf?1435613076.

38 Alex Webb, "Italy's $7 Billion Cash Grab Sends the Wrong Signal," Bloomberg.com, October 2, 2018, accessed October 25, 2018 https://www.bloomberg.com/opinion/articles/2018-10-02/italy-s-7-billion-cash-grab-sends-the-wrong-signal; and Manuel R. Marti, "Italy's 5G bidding war pushes auction prices up to 6.5 billion Euros," Policy Tracker, October 3, 2018, accessed October 25, 2018 https://www.policytracker.com/blog/italys-5g-auction-is-over-but-will-the-e6-5bn-spectrum-investment-ever-pay-off/.

[2]: "LMT secures 5G-compatible spectrum," TeleGeography, December 11, 2017, accessed October 7, 2018, https://www.telegeography.com/products/commsupdate/articles/2017/12/11/lmt-secures-5g-compatible-spectrum/ ; and Central Statistical Bureau of Latvia, "In 2017, usually resident population of Latvia declined by 15.7 thousand," Press Release, May 28, 2018, accessed October 7, 2018, https://www.csb.gov.lv/en/statistics/statistics-by-theme/population/number-and-change/search-in-theme/2402-number-population-latvia-2017.

[3]: Ofcom, "Award of 2.3 and 3.4 GHz spectrum bands- Publication under regulation 111 of the Wireless Telegraphy (Licence Award) Regulations 2018 of results of auction," April 13, 2018, accessed October 7, 2018, https://www.ofcom.org.uk/__data/assets/pdf_file/0018/112932/Regulation-111-Final-outcome-of-award.pdf; and Office for National Statistics, "United Kingdom population mid-year estimate," June 28, 2018, accessed October 7, 2018, https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/timeseries/ukpop/pop.

[4]: "MSIT announces results of 5G spectrum auction," TeleGeography, June 19, 2018, accessed October 7, 2018, https://www.telegeography.com/products/commsupdate/articles/2018/06/19/msit-announces-results-of-5g-spectrum-auction/; and Statistics Korea, "Complete Enumeration Results of the 2016 Population and Housing Census," August 31, 2017, accessed October 7, 2018, http://kostat.go.kr/portal/eng/pressReleases/8/7/index.board?bmode=download&bSeq=&aSeq=363132&ord=1.

[5]: "Spanish 5G auction generates EUR437.6m; Vodafone tops bidding," TeleGeography, July 26, 2018, accessed October 7, 2018, https://www.telegeography.com/products/commsupdate/articles/2018/07/26/spanish-5g-auction-generates-eur437-6m-vodafone-tops-bidding/; and Instituto Nacional de Estadistica, 2018, accessed October 7, 2018, http://www.ine.es/en/welcome.shtml.

[6]: Finnish Communications Regulatory Authority, "Auctioning of the 3410–3800 MHz band," October 1, 2018, accessed October 7, 2018, https://www.viestintavirasto.fi/en/spectrum/radiospectrumuse/spectrumauction.html; and Statistics Finland, "Population: Population structure 31 December," April 4, 2018, accessed October 7, 2018, https://www.stat.fi/tup/suoluk/suoluk_vaesto_en.html.

[7]: Iain Morris, "Italy's $7.6B 5G Bonanza Puts Telcos on the Rack," Light Reading, October 3, 2018, accessed October 25, 2018, https://www.lightreading.com/mobile/spectrum/italys-$76b-5g-bonanza-puts-telcos-on-the-rack/d/d-id/746528; and Istituto Nazionale di Statistica, "National Demographic Balance," Press Release, June 13, 2018, accessed October 25, 2018, https://www.istat.it/en/archivio/217005.

Of course, in addition to uncertainty about value, it is also uncertain how much C-Band spectrum will be made available for new terrestrial use. The economically efficient amount to repurpose is unknown. Given the regulatory failures discussed above, a new process is needed to discover just how many and which frequencies should be repurposed. Without intending to suggest any specific amount of spectrum will be made available for terrestrial use, I show illustrative values of spectrum within the value ranges discussed above for 100 MHz, 300 MHz, and 500 MHz. See Table 3. The

value of cleared spectrum covers a broad range, from $96 million for 100 MHz at the low end of the valuation range to nearly $65 billion for 500 MHz at the high end of the valuation range.

Table 3: Value of C-Band Spectrum Repurposed for Mobile Wireless in the U.S.

		Price: $0.003/MHz-pop			Price: $0.415/MHz-pop		
[1]	Additional Spectrum (MHz)	100	300	500	100	300	500
[2]	Base Population for C-Band Valuation (mm)	312	312	312	312	312	312
[3]	Total MHz-pops (mm)	31,247	93,741	156,236	31,247	93,741	156,236
[4]	Value of C-Band Spectrum ($ mm)	$96	$287	$478	$12,956	$38,869	$64,781

Sources and Notes:

For spectrum prices, see Table 2.

[1]: Additional spectrum to be made available through reallocation of the C-Band for terrestrial mobile use.

[2]: Total U.S. population based on the 2010 census.

[3]: [1] x [2].

[4]: Price per MHz-pop x [3].

These valuations are fairly generic and based on freeing up significant spectrum (100 MHz or more) over large geographic areas (nationally or near nationally). They are expectations of likely value, but as with all future spectrum valuations include a significant amount of uncertainty. Here, in particular, the nascent nature of 5G introduces additional uncertainty, and the potential mid-band alternatives (discussed more fully in Section II.B) add to that uncertainty. In fact, this added uncertainty about future values only serves to underscore the importance of a process for repurposing C-Band spectrum that is flexible and responsive to marketplace conditions. Nevertheless, as long as the minimum criteria of 100 MHz and near national geographic availability are met, these valuations should hold up on a proportionate basis. That is, even if spectrum beyond the first 100 MHz cover less than national footprints, the valuations outlined here should still be reasonable when applied to the portions of the C-Band made available.

C. Costs of Reallocating Current C-Band Users

The Commission states that it intends to keep the incumbent users whole.[39] Consequently, the costs of reallocating current C-Band users are those incurred by lost C-Band assets and transition costs related to moving services to alternative frequencies or platforms.[40] Although we know that several satellite providers have said an initial swath of 200 MHz could be available in as little as 18 to 36 months from the time of the final Commission order (assuming their transition costs could

39 See Order and Notice of Proposed Rulemaking, Section IV.B.1.

40 This section addresses the FCC's request for comments on the cost of transitioning spectrum to a new allocation for mobile, the "current and future economic value of FSS in the [C-]band," and how much it would cost to transition current uses of the band to alternatives. See Order and Notice of Proposed Rulemaking, ¶¶ 56-57.

be covered),[41] it is uncertain what the timeline for a large transition should be. The optimal path would balance the speed of receiving the benefits against the costs of making the spectrum available on any given schedule. As discussed below, any process that causes C-Band users to transition too quickly will add significant additional costs.

The economic value of lost satellite assets can be thought of as "transition costs" because they reflect capital costs that must be written off as a result of the spectrum clearing. These costs are equal to the lost economic profits from using these assets. The relevant profits from satellite companies using the spectrum include the profits to satellite service providers who lease capacity on satellite transponders.

1. Value of Prematurely Decommissioned C-Band Satellites

First, I estimate the cost of in-orbit equipment that would be prematurely abandoned if its use was discontinued as a result of repurposing the entire C-Band by calculating the lost profits to satellite providers from leasing C-Band transponder capacity. Initially, as an upper bound, I estimate the impact of all C-Band satellite services in the U.S. being relocated by January 1, 2021 and estimate the lost profits related to these services as of January 1, 2019.

To start I identify the number of C-Band transponders currently deployed on satellites with coverage of the U.S. The FCC maintains a listing of all satellite space stations that are approved to access the U.S. market. Currently 84 satellites with C-Band transponders are approved by the FCC to communicate with U.S. earth stations.[42] Of these 84 approved satellites only 72 of the satellites are currently active with coverage of North America, with several operating from inclined orbits.[43] Of the 72 approved satellites currently covering North America, roughly 90% are operated by one of four companies: Eutelsat, Intelsat, SES, or Telesat.[44] Table 4 provides a breakdown of the FCC's current approvals of satellites with C-Band transponders. I focus my analysis on the 64 satellites operated by one of these four companies.

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41 "C-Band Alliance Proposal Fact Sheet: October 22 Update," C-Band Alliance, October 22, 2018, accessed October 25, 2018, https://c-bandalliance.com/wp-content/uploads/2018/10/20181022-200-MHz-FactSheet-Clean-and-Final.pdf.

42 There are more than 84 FCC approvals for satellites with C-Band transponders. Some of these approvals, however, are for a single satellite listed under two different names, such as Galaxy 23 and Intelsat Americas 13, leaving 84 distinct satellites for analysis. See Table 4; and "EchoStar 9 (Telstar 13, Intelsat Americas 13, Galaxy 23)," Gunter's Space Page, accessed October 25, 2018, https://space.skyrocket.de/doc_sdat/echostar-9.htm.

43 For instance, Intelsat 904 has FCC approval but operates beams covering only Europe, Africa, and Asia. See Intelsat, "Intelsat 904 at 45° E," accessed October 27, 2018, available at http://www.intelsat.com/fleetmaps/?s=IS-904. SES' AMC-2 has FCC approval but operates in the inclined orbit covering North America. See SES Government Solutions, "Inclined Capacity," accessed October 25, 2018, available at https://ses-gs.com/solutions/fixed-sat-solutions/uav/inclined-capacity/.

44 Calculation: 89% = 64 satellites with FCC approval in analysis / 72 active satellites covering North America with FCC approval. See Table 4.

Table 4: Approved C-Band Satellites with North American Coverage

Satellite Operator	Satellites of Four Major Operators in Analysis	FCC Approvals: Active Satellites Covering North America	FCC Approvals: Total	Proportion of FCC Approvals for Active North America Satellites
[1]	[2]	[3]	[4]	[5]
Eutelsat	5	5	5	7%
Intelsat	33	33	45	46%
SES	21	21	21	29%
Telesat	5	5	5	7%
Other	0	8	8	11%
Total	64	72	84	100%

Sources and Notes:

The FCC space station approvals list includes satellites that currently operate in inclined orbit and those that are co-located or operate in multiple frequency bands for multiple operators.

"Find Your Satellite", Eutelsat, accessed October 11, 2018, https://www.eutelsat.com/en/satellites/find-your-satellite.html; Intelsat S.A., Form 20-F for the Fiscal Year Ended December 31, 2017, p. 30, accessed September 24, 2018, http://www.sec.gov/Archives/edgar/data/1525773/000119312516495452/d26989d20f.htm; and "Intelsat Satellite Fleet," Intelsat S.A., accessed October 11, 2018, http://www.intelsat.com/global-network/satellites/fleet/; "Our Coverage: Satellites," SES, September 2018, accessed October 11, 2018, https://www.ses.com/our-coverage/satellites; Telesat Holdings Inc., Form 20-F For the Fiscal Year Ended December 31, 2017, pp. 41, accessed October 11, 2018, https://www.sec.gov/Archives/edgar/data/1465191/000161577418001535/s108785_20f.htm; "Our Fleet," Telesat, accessed October 11, 2018, https://www.telesat.com/our-fleet#fleet; and "Approved Space Station List," accessed October 25, 2018, available at https://www.fcc.gov/approved-space-station-list.

[2]: Total number of FCC approvals of active satellites serving North America for the four operators in analysis in [1].

[3]: Total number of FCC approvals of active satellites with coverage of North America for the satellite operator in [1].

[4]: Total number of FCC approvals for the satellite operator in [1].

[5]: Percent of total active North American satellites in [3].

The lost profits to satellite providers from the repurposing of C-Band downlink spectrum will be equal to the net present value of the profits of C-Band transponders over the remaining service life of the satellite.[45] I reviewed company websites and other online resources to identify: (1) the

[45] A satellite's service life is its estimated operational life based on fuel levels and power considerations. In contrast, a satellite's design life is its estimated operational life under normal operating conditions. See

number of 36 MHz-equivalent C-Band transponders located on each of these 64 satellites; and (2) the remaining service life of each of these 64 satellites. Intelsat reports that the annual average global price of a 36 MHz C-Band transponder will be $1.2 million by 2022.[46] I discount this annual revenue stream over the remaining life of the satellite to estimate the net present value of lost profits. The following table lists all 64 satellites included in the analysis and their estimated lost profits. Total lost profits from C-Band transponders are estimated to be $7.29 billion.[47]

Intelsat S.A. 20-F form for the year ended December 31, 2017, p. 31, accessed September 11, 2018, http://phx.corporate-ir.net/External.File?item=UGFyZW50SUQ9NDA0NTc2fENoaWxkSUQ9LTF8VHlwZT0z&t=1&cb=636610592570432516 ("Intelsat S.A. 20-F for the year ended December 31, 2017").

46 In its annual report Intelsat references a Euroconsult projection as the source of this figure. See Intelsat S.A. 20-F form for the year ended December 31, 2017, p. 49. This projected price translates into a monthly $/MHz price of roughly $2,750. Calculation: $2,755 / MHz / month = $1.19 million / 36 MHz /12 months.

47 Table 4 shows that there are 8 active North America satellites with FCC approval that are not included in my analysis. Of the 64 satellites included in my analysis, I calculate that the average asset write-off cost per satellite is $114 million – reflecting an average remaining service life of 4 years and an average of 33 C-Band transponders per satellite. Using this average asset write-off cost I calculate that the omitted asset write-off cost of the satellites excluded from my analysis would not exceed $912 million. Calculation: $912 million = 8 satellites x $114 million asset write-off cost.

Table 5: C-Band Satellites with Coverage of North America for Intelsat, SES, Telesat, and Eutelsat

Operator	Satellite	36 MHz Equivalent C-Band Transponders	Launch Date	Service Life (Years)	Years Remaining (as of 2021)	Asset Write-Off Costs, $ millions (as of 2019)
[1]	[2]	[3]	[4]	[5]	[6]	[7]
	Total Costs					**$ 7,289**
Eutelsat	Eutelsat 113 West A	36	May-06	17	2	$ 71
Eutelsat	Eutelsat 115 West B	12	Mar-15	15	9	$ 83
Eutelsat	Eutelsat 117 West A	24	Mar-13	15	7	$ 139
Eutelsat	Eutelsat 172B	14	Jun-17	15	11	$ 111
Eutelsat	Eutelsat 174A	18	Dec-05	16	1	$ 19
Intelsat	Galaxy 3C	24	Jun-02	21	2	$ 48
Intelsat	Galaxy 12	24	Apr-03	15	0	$ -
Intelsat	Galaxy 13 / Horizons 1	24	Oct-03	19	2	$ 48
Intelsat	Galaxy 14	24	Aug-05	16	0	$ -
Intelsat	Galaxy 15	24	Oct-05	16	1	$ 25
Intelsat	Galaxy 16	24	Jun-06	18	3	$ 69
Intelsat	Galaxy 17	24	May-07	17	3	$ 69
Intelsat	Galaxy 18	24	May-08	18	5	$ 106
Intelsat	Galaxy 19	24	Sep-08	18	6	$ 123
Intelsat	Galaxy 23	24	Aug-03	20	2	$ 48
Intelsat	Galaxy 25	24	May-97	22	0	$ -
Intelsat	Galaxy 28	24	Jun-05	17	2	$ 48
Intelsat	Horizons-3e	86	Sep-18	15	13	$ 755
Intelsat	Intelsat 1R	36	Nov-00	15	0	$ -
Intelsat	Intelsat 5	24	Aug-97	23	0	$ -
Intelsat	Intelsat 10-02	45	Jun-04	17	0	$ -
Intelsat	Intelsat 11	25	Oct-07	15	2	$ 50
Intelsat	Intelsat 14	48	Nov-09	18	7	$ 278
Intelsat	Intelsat 18	40	Oct-11	17	8	$ 255
Intelsat	Intelsat 19	24	Jun-12	16	7	$ 139
Intelsat	Intelsat 21	24	Aug-12	18	10	$ 179
Intelsat	Intelsat 23	46	Oct-12	18	10	$ 343
Intelsat	Intelsat 25	38	Jul-08	16	3	$ 109
Intelsat	Intelsat 29e	24	Jan-16	15	10	$ 179
Intelsat	Intelsat 30	8	Oct-14	15	9	$ 54
Intelsat	Intelsat 31	8	Jun-16	15	11	$ 61
Intelsat	Intelsat 34	24	Aug-15	16	11	$ 190

Intelsat	Intelsat 35e	121	Jul-17	15	12	$	1,013
Intelsat	Intelsat 37e	90	Sep-17	15	12	$	754
Intelsat	Intelsat 901	72	Jun-01	17	0	$	-
Intelsat	Intelsat 903	76	Mar-02	15	0	$	-
Intelsat	Intelsat 905	76	Jun-02	18	0	$	-
Intelsat	Intelsat 907	76	Feb-03	18	0	$	-
SES	AMC-1	24	Sep-96	15	0	$	-
SES	AMC-2	24	Jan-97	15	0	$	-
SES	AMC-3	24	Sep-97	15	0	$	-
SES	AMC-4	24	Nov-99	18	0	$	-
SES	AMC-6	24	Oct-00	15	0	$	-
SES	AMC-7	24	Sep-00	18	0	$	-
SES	AMC-8 / Aurora III	7	Dec-00	17	0	$	-
SES	AMC-10	24	Feb-04	15	0	$	-
SES	AMC-11	24	May-04	15	0	$	-
SES	AMC-18	24	Dec-06	15	1	$	25
SES	SES-1	24	Apr-10	15	4	$	88
SES	SES-2	24	Sep-11	15	6	$	123
SES	SES-3	24	Jul-11	15	6	$	123
SES	SES-4	52	Feb-12	15	6	$	267
SES	SES-6	43	Jun-13	15	7	$	249
SES	SES-11	24	Oct-17	15	12	$	201
SES	SES-14	28	Jan-18	15	12	$	234
SES	NSS-5	38	Sep-97	15	0	$	-
SES	NSS-7	50	Apr-02	15	0	$	-
SES	NSS-9	44	Feb-09	15	3	$	126
SES	NSS-10	49	Feb-05	15	0	$	-
Telesat	Telstar 18 / APSTAR-5	18	Jun-04	15	0	$	-
Telesat	Telstar 18 Vantage	24	Sep-18	15	13	$	211
Telesat	Anik F1R	24	Sep-05	17	2	$	48
Telesat	Anik F2	24	Jul-04	23	6	$	123
Telesat	Anik F3	24	Apr-07	19	5	$	106

Sources and Notes:

All discounting occurs as of January 1. Assumed cost of capital values are: Eutelsat: 8.0%; Intelsat: 8.0%; SES: 8.0%; and Telesat: 8.0%. Years remaining rounded to the closest year.

[1] - [5]: "Find Your Satellite", Eutelsat, accessed October 11, 2018, https://www.eutelsat.com/en/satellites/find-your-satellite.html;Intelsat S.A., Form 20-F for the Fiscal Year Ended December 31, 2017, p. 30, accessed September 24, 2018, http://www.sec.gov/Archives/edgar/data/1525773/000119312516495452/d26989d20f.htm; "Intelsat Satellite Fleet," Intelsat S.A., accessed October 1, 2018, http://www.intelsat.com/global-network/satellites/fleet/;"Our Coverage: Satellites," SES, September 2018, accessed October 11, 2018, https://www.ses.com/our-coverage/satellites; Telesat Holdings Inc., Form 20-F For the Fiscal Year Ended December 31, 2017, p. 41, accessed October 25, 2018, https://www.sec.gov/Archives/edgar/data/1465191/000161577418001535/s108785_20f.htm; "Our Fleet," Telesat, accessed September 24, 2018, https://www.telesat.com/our-fleet#fleet; and "Approved Space Station List,"

FCC, accessed October 11, 2018, https://www.fcc.gov/approved-space-station-list.

[5]: Assumed a service life of 15 years if no information on service life is provided.

[6]: Years remaining from launch date to end of service life rounded to nearest integer.

[7]: Net present value of C-Band transponders, shown in [3], as of 2019 with an assumed satellite relocation date in 2021. Annual transponder value in future years is discounted using providers' cost of capital.

This estimate likely overestimates the total lost profits from C-Band transponders for three primary reasons. First, I estimate the profits a C-Band transponder using a cited revenue figure and do not incorporate any incremental costs of operating a C-Band transponder that would be saved if the service was discontinued. Satellite providers must control and operate each of their satellites and manage the satellite's communication services throughout its orbital life.[48] The incorporation of any of these costs would be subtracted from revenues and reduce the estimated benefits. Second, although I am assuming 100% fill rates on these satellites, satellite providers frequently have transponder fill rates of around 70-80%.[49] Finally, I am valuing the capacity at retail rates, not allowing for volume or other discounts. The one potentially offsetting impact that could lead to higher revenues (and profits) would be if the reduction in C-Band transponder capacity lead to increases in the cost of other transponder pricing. Such an impact would be mitigated by the long-term nature of many transponder sales as well as the presumption that incumbent users are kept whole. On balance, in my judgment the estimate of $7.29 billion in lost profits is still likely an underestimate.

2. Transition Costs

As noted, it is unlikely that the entire 500 MHz of the C-Band will be transitioned, and certainly not immediately. But whatever amount is transitioned, additional transition costs beyond the lost economic value of the transponder capacity are likely to be incurred. These are difficult to estimate as they will depend on the specifics of many individual optimal transition scenarios. An optimal transition will seek to maximize value, which will include minimizing these transition costs. Nevertheless, some amount of transition costs are likely to be incurred.

One such cost is the added costs to satellite providers to launch new equipment to accommodate transitioned customers. If less than the entire C-Band is transitioned, the transponders that use the remaining C-Band frequencies will be more intensively used. But to accommodate the added usage on the remaining frequencies, additional investments by satellite carriers will be needed. Such added capacity could cost $150 million or more per satellite launched.

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48 Intelsat S.A. 20-F form for the year ended December 31, 2017, p. 32.

49 See, *e.g.*, Intelsat S.A. 20-F form for the year ended December 31, 2017, p. 31; and Eutelsat Communications, 2016-2017 Reference Document, p. 8, accessed September 11, 2018, https://www.eutelsat.com/files/contributed/investors/pdf/Eutelsat_Communications_Reference_Document_2016-17.pdf.

Depending on the amount of spectrum cleared, completely new content distribution methods may need to be procured – the costs of which could be extremely high. For example, building redundant fibre to more than 16,500 thousand existing earth stations would cause transition costs to soar.[50] Such buildout might never occur to large portions of the country, especially rural areas, and could exacerbate the digital divide that U.S. policy seeks to mitigate.[51]

Other costs could include mitigation costs incurred by earth stations. Such costs could include adding new equipment such as filters designed to exclude signals from terrestrial users that would be introduced into the repurposed portion of the band. Similarly, whether preventing interference on the same band (used for mobile in some geographies and satellite reception in others) or adjacent bands, physical barriers around earth stations may be needed. These earth station mitigation costs are particularly important in the more realistic scenarios where less than the entire band is repurposed.

Beyond the costs of physically accommodating the transition, contractual costs may be relevant. Customers may have penalty provisions if the service they contracted for is not provided. Consequently, any transition that caused these provisions to come into force, such as a mandated non-voluntary transition, would incur significant additional costs. Even if these provisions are not triggered, there could be costs of moving customers beyond the economic profits and physical transition costs noted above.

These additional transition costs cannot be estimated without knowing more about the nature of the specific transition. Consequently, I do not endeavor to estimate them. But they are likely to be significant and, depending on the scenario, could easily be of the same or greater order of magnitude as the economic value of the retired satellite assets.

3. Value of Prematurely Decommissioned Satellite Earth Stations

Next, I estimate the cost of prematurely decommissioned satellite earth stations by calculating the added costs of reallocation to users of current downlink earth stations. The FCC requires that C-Band transmitting earth stations obtain authorization prior to transmitting.[52] Operators of receive-only earth stations may register their antennas in the FCC's database and have been encouraged to do so by recent FCC actions, but are not required to do so.[53]

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50 See *supra,* at footnote 32.

51 Federal Communications Commission, "Bridging The Digital Divide For All Americans," 2018, accessed October 25, 2018 https://www.fcc.gov/about-fcc/fcc-initiatives/bridging-digital-divide-all-americans.

52 See 47 CFR §25.115, accessed October 25, 2018, https://www.gpo.gov/fdsys/pkg/CFR-2010-title47-vol2/pdf/CFR-2010-title47-vol2-sec25-115.pdf. All earth station authorizations are published on the FCC's website: "Earth Station Licensing & Sample Form 312 Applications," Federal Communications Commission, accessed October 25, 2018, https://www.fcc.gov/earth-station-licensing-sample-form-312-applications.

53 Graham A. Jones, David H. Layer, Thomas G. Oskenkowsky, *National Association of Broadcasters Engineering* Handbook, (Taylor & Francis, 2013), p. 1695, accessed October 25, 2018,

As of October 26, 2018, there were approximately 16,500 earth stations using the 3.7-4.2 GHz frequencies in the FCC's IBFS.[54] The total number of unregistered receive-only C-Band terminals is unknown. However, because the FCC has initiated a process for previously unregistered C-Band earth stations to become registered, I assume that any remaining unregistered receive-only earth stations will not be protected by the FCC or receive any compensation from repurposing C-Band spectrum.[55] For the extreme scenario that clears the entire C-Band, I estimate the cost of the premature decommissioning of all C-Band earth stations by calculating their replacement costs, *i.e.*, the cost of replacing all of the C-Band earth station equipment.[56] I obtain all earth station cost estimates from Satcom Resources, one of the leading global suppliers of satellite communication equipment.[57] I estimate the cost as Satcom Resources' highest-reported C-Band earth station cost.[58] In total, I calculate that the value of these prematurely abandoned earth stations is roughly $12.4 billion.[59]

4. Total Economic Value of Lost C-Band Assets

The lost satellite assets are conservatively estimated to have a present value of about $7.3 billion, with additional transition costs potentially doubling that number. The estimated lost economic value of all C-Band earth station assets is as much as $12.4 billion. Taken together, the direct economic loss in the extreme case of the entire C-Band being repurposed is therefore at least $19.7 billion, but likely much higher. Of course, it is unlikely that the entire C-Band would be repurposed so it is unlikely that all of the value of these assets would be lost. Nevertheless, this provides an upper bound on the costs of making C-Band frequencies available for alternative uses.

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https://books.google.com/books?id=K9N1TVhf82YC&pg=PA1695&lpg=PA1695&dq=antenna+vs+earth+station+fcc&source=bl&ots=RswceGe-tz&sig=54J5YCpOoXfCbICwxL4Kft_3EoI&hl=en&sa=X&ved=0ahUKEwj_jKzB7ZvNAhVGeSYKHa6ICJcQ6AEISjAG#v=onepage&q=antenna%20vs%20earth%20station%20fcc&f=false.

54 See *supra,* at footnote 32.

55 See *supra*, at footnotes 30-31. This is consistent with the FCC's proposal to define incumbent earth stations as those that were operational as of April 19, 2018, are licensed or registered (or had a pending application) as of October 17, 2018 (a date that has now been extended to October 31, 2018), and have certified the accuracy of their information on file with the FCC. See Order and Notice of Proposed Rulemaking, ¶ 27.

56 This methodology will overestimate the cost of the premature decommissioning of the C-Band earth stations. In reality, the majority of these earth stations have already been deployed for a number of years and have depreciated in value. By using the replacement cost I assume that no depreciation has occurred.

57 "About Us," Satcom Resources, accessed October 25, 2018, https://www.satcomresources.com/about-us.

58 Satcom Resources does not report prices for its high-end earth stations on its website but I was told in a telephone call with the company that high-end C-Band earth stations range in price from $30,000 to $750,000. See, *e.g.*, "General Dynamics Satcom Technologies 2244 2.4 M High Wind Antenna," Satcom Resources, accessed October 25, 2018, http://www.satcomresources.com/catalogsearch/result/?q=SATCOM-Technologies-2244-2-4M-High-Wind-Antenna.

59 Calculation: $12.375 billion = 16,500 x $750,000.

The lost satellite and earth station asset values as well as the additional potential transition costs noted above are particularly salient given the complicated, dynamic process of transitioning C-Band frequencies to terrestrial mobile uses. As noted, the problem of determining which frequencies to transition, when and where is very complicated. Furthermore, the efficient solution will evolve as uncertainty about the 5G market is resolved. These transition costs are a key component to finding the efficient solution.

D. Potential Net Benefits

As the analysis in the previous sections indicate, benefits of reallocation may exceed costs, but that is not a certainty. If the entire band was reallocated, the expected costs would likely significantly exceed $19.7 billion and have to be balanced against revenue estimates of between $96 million to $65 billion. The significant range of benefits highlights the uncertainty about what the transition should be. Clearing the entire band may not be feasible or even the optimal reallocation. As noted, the benefits are basically proportional to the amount of spectrum cleared. But the costs of making the spectrum available are not. In fact, costs to clear spectrum should increase with the amount of spectrum cleared. That means that it may be the case that benefits do not exceed costs if a full 500 MHz are cleared, but benefits would exceed costs at some smaller amount of spectrum cleared. Of course, the exact optimal amount to transition is a complex dynamic optimization that cannot happen under current band rules and would be extremely difficult for the FCC to calculate and mandate. In fact, these market and regulatory failures prevent the testing of the proposition, illustrated in this section, that benefits may exceed costs. Consequently, alternative mechanisms to facilitate a transition are needed that will lead to the efficient amount of spectrum to be made available for terrestrial use.

III. The Market-Based Approach

A. Overview of Proposal

In the proposed Market-Based Approach, the Commission would authorize incumbent FSS operators to voluntarily relinquish the C-Band spectrum they currently use. Satellite operators in the band could choose to make some or all of their spectrum available to terrestrial operators on the secondary market, in exchange for compensation. This proposal would make satellite operators responsible for clearing the portion of the band that would be made available for flexible use, including notifying earth stations of the need to modify their operations and compensating them for any costs associated with that transition.

The incumbent FSS operators would coordinate through a Transition Facilitator.[60] The Transition Facilitator would include most or all of the C-Band satellite operators with service to the

60 Order and Notice of Proposed Rulemaking, ¶¶ 70, 73.

Continental United States ("CONUS").[61] The Transition Facilitator would help mitigate holdout problems and allow operators to coordinate negotiations and clearing and repacking the band. The Transition Facilitator would act as an efficiency-enhancing mechanism that would enable the satellite operators to use private negotiations to obtain participation and agreement from any relevant satellite operators. Working with their customers, the members of the Transition Facilitator would determine the efficient solution for transitioning spectrum from satellite downlink use to terrestrial wireless uses, including the timing and scope of the repurposing and the mitigation techniques to be employed to protect FSS users.

B. Correction of Market and Regulatory Failures

The Market-Based Approach eliminates problems due to poorly defined legal rights and the public goods issues that arise.[62] As described above, insufficiently defined legal rights limit the ability of markets to form and function properly. By creating a Transition Facilitator, with clearly defined limits on providers that are not part of the Transition Facilitator, the overlapping legal rights are brought under common consideration. This significantly limits the ill effects of the overlapping rights.[63] Consequently, the affected parties, with the necessary specific knowledge, are able to work out an optimal solution.

The great benefit of using a market to allocate scarce resources is that uses of resources are coordinated through a decentralized process where market participants share private information. Prices, which reflect the value of resources, signal the opportunity cost (their value in alternative

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61 Order and Notice of Proposed Rulemaking, ¶¶ 74-75. On October 1, 2018, Intelsat, SES, Eutelsat, and Telesat established the C-Band Alliance ("CBA"), a consortium meant to act as the Transition Facilitator and coordinate among the four largest operators of C-Band satellites in the U.S. See "Intelsat, SES, Eutelsat and Telesat Establish the C-Band Alliance (CBA), a Consortium to Facilitate Clearing of U.S. Mid-band Spectrum for 5G While Protecting U.S. Content Distribution and Data Networks," Intelsat, SES, Eutelsat and Telesat, October 1, 2018, accessed October 1, 2018, http://www.intelsat.com/news/press-release/intelsat-ses-eutelsat-and-telesat-establish-c-band-alliance/.

62 This section addresses the FCC's request for comments on the merits of cooperation among FSS providers compared to more formal mechanisms in light of the economic problems the FCC seeks to solve. The first of these is the holdout problem, which arises because FSS licensees have non-exclusive rights to the entire frequency band, which creates the incentive for providers to overstate the value of their spectrum access and reduce the amount of spectrum repurposed. The converse problem is that reducing the amount of spectrum available for FSS may result in higher prices for these services, which could create the incentive to increase the amount of spectrum repurposed. See Order and Notice of Proposed Rulemaking, ¶¶ 59, 62.

63 The ill-defined legal rights frustrate market transactions across firm boundaries. By bringing satellite operators under a Transition Facilitator, the boundaries of the firms are in essence altered by making transactions within the Transition Facilitator internal and not market-based. This is related to Ronald Coase's observation that firm boundaries are set to optimize transaction costs by internalizing to a firm contracting that would be inefficient to execute across firm boundaries through a market. See Ronald H. Coase, "The Nature of the Firm," *Economica*, 4(16): 386-405, November 1937.

uses) of using a resource. Through the process of maximizing profits, firms create the most value from the set of resources with the least opportunity cost. The overlapping and non-exclusive legal rights in the C-Band prevent a market from using price signals to transmit information to find the efficient solution. Consequently, the information about the value and opportunity cost of resources must be developed and coordinated through a different, non-price mechanism.

One approach is through a regulatory process. Here the regulator needs to learn all of the relevant information and decide on an outcome. Doing so not only requires all of the information about the value of the uses of the C-Band satellite-based services, but also the costs of the next best alternatives to current uses. These alternatives include both providing services over alternative networks (whether other satellite networks or fibre optic networks) as well as the options (and costs) of mitigation techniques that allow continued C-Band operations in an environment with terrestrial uses. But the regulator's problem is even more complicated because in evaluating alternative feasible reallocations, the FCC would have to choose which of the alternatives is best. Doing so requires also developing information on all of the value creating activities facilitated by various reallocations of portions of the C-Band to terrestrial uses. Informationally, the FCC would be taking on a daunting task to lay the groundwork to make a decision about what spectrum should be reallocated, to whom, when, under what conditions and costs, and any requirements imposed on existing users.

In contrast to a regulatory process, a consortium of satellite operators acting through a Transition Facilitator would much more easily and likely be able to come to the optimal value-creating solution. The Market-Based Approach has many advantages and solves the problems created by the market and regulatory failures outlined above. In doing so, it approaches the efficient solution that an unfettered market would achieve, absent market failures.[64] Indeed, it already appears to have overcome some of the market failures through formation of the C-Band Alliance.

<u>Informational efficiencies.</u> Much of the relevant information is already known to the satellite operators – they know their own operations. Furthermore, they are best placed to garner the remaining information needed. They know who the users – their customers – are and already have commercial relationships with them. The final information needed – demand for the C-Band frequencies – can be generated from potential users. But those potential users of C-Band spectrum are unlikely to fully reveal their private knowledge to regulators. Rather, they would have an incentive to exaggerate the value of the spectrum in terrestrial mobile uses so as to have as much as possible made available to them. They are more likely to reveal their private knowledge over the course of negotiations with the Transition Facilitator, especially when they would be making payments.[65]

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64 This addresses the FCC's request for comments about whether a market-based approach and the use of Transition Facilitator would arrive at an efficient outcome. See Order and Notice of Proposed Rulemaking, ¶ 71.

65 Revealing such information in private negotiations is what markets, such as the secondary market for spectrum, are all about. A fairly robust secondary market for spectrum licenses exists, suggesting

With this knowledge, the Transition Facilitator is also best placed to evaluate the trade-offs presented between different potential amounts of spectrum to repurpose. Issues such as whether to move a particular earth station or leave it and mitigate any impact from terrestrial operations are fundamentally questions of costs and benefits. But these questions can be very complicated and multidimensional. For example, if a given swath of clear spectrum is more valuable if the clearing is nationwide, then in addition to local trade-offs, the cost-benefit calculus must take into account the impact of each decision on national value creation. More broadly, a Transition Facilitator would be best placed to know all of the interconnected trade-offs and to find the value maximizing solution to them.

Both the specific amounts of spectrum to transition and the timing of the transition create added dimensions of complications to finding the efficient solution. For example, it may be the case that block sizes are not the same across the nation. It may allow much more spectrum to be repurposed if exclusion zones are created around limited geographic areas for certain frequencies. This may be necessary to accommodate a potential holdout or unusually high cost user to relocate. Similarly, the sequencing and timing of repurposing portions of the C-Band add significant complexity to the task of finding the efficient solution.

But the informational advantage of a Transition Facilitator is even greater in the context of a dynamically changing marketplace. As noted above, there is still significant uncertainty to resolve about the exact path of the 5G market and the specific role of mid-band frequencies in that market evolution. Whether uncertainties around 5G are resolved more or less favorably will affect the value of spectrum generally, mid-band spectrum in particular and the C-Band specifically. Only a Transition Facilitator made up of market participants can adjust and react to these changing developments and correct course over time.

<u>Holdout problem.</u> The proposal for a Transition Facilitator solves the holdout problem. As an initial matter, the four primary operators that represent about 90% of the installed capacity have already agreed to join in a consortium that would be a likely candidate for the Transition Facilitator.[66] Other satellite operators will be faced with the choice of joining the Transition Facilitator or not.[67] If they join, they will be entering a commercial venture with rules and expectations aimed at finding a value-creating reallocation of C-Band spectrum. Although there is no guarantee that all Transition Facilitator members will agree on the details of spectrum repurposing, they will have every incentive to do so. Moreover, once the Transition Facilitator

potential purchasers of C-Band frequencies are already adept at facilitating such value creating trades. For discussion of robustness and economic importance of secondary markets see, *e.g.*, John W. Mayo and Scott Wallsten, "Secondary Markets: The Quiet Economic Value Creator," Georgetown University Economic Policy Vignette, December, 2011.

66 On October 1, 2018, Intelsat, SES, Eutelsat, and Telesat announced that they would be forming the C-Band Alliance, which would act as the Transition Facilitator. See *supra*, at footnote 61 and Table 4.

67 This addresses the FCC's request for comment on what the Transition Facilitator will do if not all eligible satellite operators elect to participate. See Order and Notice of Proposed Rulemaking, ¶ 75.

reaches a commercial agreement to repurpose spectrum, the Commission could mandate that all C-Band satellite operators would lose primary protection in those frequencies, thus eliminating any residual hold-out problem.

Delay. Any delay in a beneficial transition is costly, both to the parties and to society.[68] Spectrum is not a storable asset so any potential gains delayed are lost forever. The Market-Based Approach will clearly facilitate the speediest transition, with an estimated transition time of 18-36 months from the time of a final Commission order, and identify new users likely even sooner, allowing them to start the initial planning of their deployments, saving even more time.[69] The impact of delay can be significant. The specific magnitude of delay depends on a number of assumptions about which discount rate to use and the path of cash flows.[70] Under reasonable assumptions, I find that one year of delay would reduce value by between 7% and 11%.[71] The economic value of spectrum is only a fraction of its total social value.[72] For example, every $1 billion in delay costs would create total social costs of $10 billion to $20 billion. Consequently, any of the other proposals, which could easily be expected to add years of delay relative to the Market-Based Approach, would significantly decrease the value of repurposing any C-Band frequencies.

Considering all of the benefits of the Market-Based Approach, this proposal would be expected to get to the efficient solution as quickly as possible. The Transition Facilitator will have the information and incentives to find the value-maximizing solution. The Transition Facilitator will be composed of firms with the most specific knowledge needed and be best placed to garner the additional information required. As beneficiaries of any transactions that result from a reallocation, the members of the Transition Facilitator will have the incentive to come to agreement on an efficient solution, without the concerns about the holdout problem an unfettered

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68 This addresses the FCC's question as to how the Market-Based Approach would ensure a timely transition process. See Order and Notice of Proposed Rulemaking, ¶ 97.

69 *Ex Parte* Letter of Intel, Intelsat, and SES, GN Docket No. 17-183, WTB Docket No. 18-122, filed August 20, 2018, p. 1, accessed October 25, 2018, https://ecfsapi.fcc.gov/file/1042067576471/as-filed%204-20-18%20ex%20parte%20notice.pdf.

70 For an investment such as deploying wireless spectrum in a network, cash flows are initially negative and then turn positive. Delay can be modeled as pushing out all cash flows by a fixed time period, such as one year. What matters for measuring the impact of delay is how long it takes for the net present value of the cash flows to return to $0. This is because after this point the cash flows will always be expected to be positive and, by assumption, steady. Consequently, I can estimate the impact of delay by only specifying the discount rate, the year in which the net present value of cash flows return to $0, and an assumption that after they return to zero they are steady. (It would be easy to incorporate a constant growth rate, but I forgo that for simplicity of exposition.)

71 This range is based on discount rates of 8% to 12% and the present value of cash flows turning positive in years 3 to 5.

72 Economists have estimated that the social value of spectrum is between 10 and 20 times its economic value. The ratio of 10-to-1 is calculated using a conservative discount rate of 10% while the ratio of 20-to-1 is calculated using a discount rate of 5%. See Coleman Bazelon and Giulia McHenry, "Mobile Broadband Spectrum: A Vital Resource for the U.S. Economy," pp. 15-17.

market would create. And the Transition Facilitator, engaged in an ongoing dynamic process, is also best placed to incorporate new information and course correct as needed.

IV. The Alternative Proposals

A. Administrative FCC Reallocation

1. Overview

One option, not actually proposed in the NPRM, would be for the FCC to undertake a traditional spectrum reallocation. Specifically, through the rule making process, the FCC would collect information about the current uses of the C-Band, alternatives to those uses, and potential benefits of the spectrum in new uses. This process, if it led to any reallocation at all, would result in cleared frequencies that would be expected to have competing applications, leading to an auction process. While the FCC does not propose this traditional reallocation approach, it is instructive to consider how it would work and its deficiencies, as it does not solve the holdout problem and other challenges effectively met by the Market-Based Approach. Ultimately, it would require the FCC to make many top-down, difficult, and controversial determinations which are also likely to lead to inefficient results and long delays. As will be seen below, the other approaches proposed in the NPRM to varying degrees suffer from the same fundamental deficiencies.

2. Deficiencies

The potential advantage of this approach would be an auction of the reclaimed frequencies with the associated revenue for the government. The disadvantages are numerous. The informational challenges the FCC would face noted above could easily lead to no action on their part, forgoing any benefits of reallocating any of the C-Band frequencies. In addition, this would likely be a very lengthy process as the lack of incentives for FSS incumbents to cooperate would lead to costly delays and larger information gaps. CTIA has noted that past spectrum reallocations have taken from 6 to 18 years, with an average of 13 years to reallocate spectrum.[73] Given that earlier reallocations were likely the easiest to accomplish, this historical analysis may understate the time it would take the FCC to reallocate C-Band spectrum administratively. Clearly with an annual cost of delay of 7% to 11%, an administrative reallocation could easily increase the transition time over the Market-Based Approach by a decade and would destroy most of the value that could be created by a timelier reallocation.

Another serious problem with an administrative reallocation is that the inherent uncertainty could lead to overly cautious policy choices. If the FCC does not know exactly how much spectrum can be reallocated, it will presumably err on the side of protecting incumbent uses and likely lose out on potential value-creating reallocations. There is precedent for this. When WCS, which is

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73 Thomas K. Sawanobori and Robert Roche, “From Proposal to Deployment: The History of Spectrum Allocation Timelines,” CTIA, p. 2, accessed September 30, 2018, https://api.ctia.org/docs/default-source/default-document-library/072015-spectrum-timelines-white-paper.pdf.

adjacent to the satellite radio SDARS band, was first allocated, its service rules made the band unusable for high-powered mobile terrestrial operations. This was in large part because at the time the SDARS service was not operational so it was not known what would be required of WCS to coexist with SDARS. It took more than 15 years to revise the service rules so that WCS could be deployed for mobile broadband and coexist with SDARS.[74]

B. The Overlay Auction Proposal

1. Overview

This option envisions holding a competitive auction for one or more overlay licenses.[75] Overlay licenses have previously been used by the Commission to transition spectrum from site based licenses to geographic-area based licenses,[76] and would allow each overlay licensee to operate in an entire geographic area, while protecting incumbents from interference.[77] The overlay licensee would be allowed to negotiate band allocation directly with the FSS operator. In addition, the amount of spectrum allocated to overlay licensees would be limited in each market and would provide them with the flexible use rights for the spectrum given up by incumbents. One of the overlay auction's key premises is that FSS operators could bid only as individual entities to ensure that the bidding process remains competitive and to encourage participation of other potential bidders.

2. Deficiencies

While the overlay auction proposal could potentially lead to development of new spectrum-clearing strategies, it still leaves many legal and implementation questions unanswered and will almost certainly fail to clear contiguous spectrum as quickly and efficiently as the Market-Based

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74 WCS spectrum was originally auctioned in 1997, and the FCC adopted rules to allow the use of WCS spectrum while also protecting the SDARS operations in 2012. See FCC, "Wireless Communications Service (WCS)," March 8, 2017, accessed October 27, 2018, https://www.fcc.gov/wireless/bureau-divisions/broadband-division/wireless-communications-service-wcs.

75 Order and Notice of Proposed Rulemaking, ¶¶ 99-100.

76 See, *e.g.*, Order and Notice of Proposed Rulemaking, footnote 144, citing Amendment of Part 90 of the Commission's Rules to Provide for the Use of the 220-222 MHz Band by the Private Land Mobile Radio Service, Third Report and Order and Fifth Notice of Proposed Rulemaking, 12 FCC Rcd 10943 (1997); Revision of Part 22 and Part 90 of the Commission's Rules to Facilitate Future Development of Paging Systems, Second Report and Order and Further Notice of Proposed Rulemaking, 12 FCC Rcd 2732 (1997); Amendment of Part 90 of the Commission's Rules to Facilitate Future Development of SMR Systems in the 800 MHz Frequency Band, First Report and Order; Eighth Report and Order; Second Further Notice of Proposed Rulemaking, 11 FCC Rcd 1463, 1474 (1995).

77 See, *e.g.*, Order and Notice of Proposed Rulemaking, footnote 144, citing Amendment of Parts 1 and 22 of the Commission's Rules with regard to the Cellular Service, including Changes in Licensing of Unserved Areas, Notice of Proposed Rulemaking and Order, 27 FCC Rcd 1745, 1757 (2012).

Approach.[78] The proposed mechanism fails to address the underlying market and regulatory failures and does not resolve the crucial problems stemming from ill-defined legal rights. Since both FSS operators and earth station owners all have full band access, significant and costly coordination between them and the potential overlay licensee is required *ex-ante*. Hence, the incentives to play spoiler by being a holdout are not at all diminished in this scenario. Simply selling overlay rights does not solve these key problems related to ill-defined legal rights. As a part of the spectrum-clearing process, an overlay license would create an entity that could benefit from developing and optimizing all of the information needed to facilitate a reallocation of C-Band spectrum. But since, by design, the licensee will not include multiple satellite operators, if any, it will start with much less relevant information than the Transition Facilitator of the Market-Based Approach. Not having commercial relationships with most, if any, of the earth stations will make it more difficult to develop information from this key stakeholder group. In addition, because earth station operators would enjoy protection from future uses of the band,[79] an overlay licensee would have to engage in complex negotiations with both FSS operators and many earth stations to clear each license for terrestrial use. It is unclear if all of these negotiations would be fruitful, thus increasing the likelihood of suboptimal amount of spectrum being cleared.

Ultimately, the overlay license would not contain sufficient rights to effectively facilitate repurposing of the C-Band and, consequently, would not be very valuable. Given the difficulty of achieving a value creating deal with all of the participants and the continuing incentive for the participants to extract any value created, as well as the potential for significant delay, it is unlikely that any potential bidder for an overlay license would find the license very valuable and, therefore, it is unlikely such an auction would raise any more than a nominal amount, undercutting its one potential advantage.

C. The Incentive Auction Proposal

1. Overview

This option contemplates a variation of the incentive auction mechanism[80] similar to the Broadcast Incentive Auction.[81] In this sequential auction scenario, the incumbent operators would first bid on the price they would be willing to accept in exchange for surrendering a certain amount of spectrum. In order for the market for spectrum to clear, a second auction would then take place where potential licensees would bid what they would be willing to pay for the spectrum made available in the first auction. Although not well specified, the proposal envisions some variation of

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78 This section addresses several of the FCC's request for comments regarding an overlay auction mechanism. See Order and Notice of Proposed Rulemaking, ¶ 99.

79 Order and Notice of Proposed Rulemaking, ¶ 28.

80 Order and Notice of Proposed Rulemaking, ¶¶ 103-105.

81 FCC, "Broadcast Incentive Auction and Post-Auction Transition," May 9, 2017, accessed October 25, 2018, https://www.fcc.gov/about-fcc/fcc-initiatives/incentive-auctions.

this process to incentivize competition by FSS and earth station operators to give up spectrum in exchange for revenue sharing from an auction of new licenses for that spectrum.[82]

2. Deficiencies

The incentive auction proposal and its variations suffer from several significant flaws and are far inferior to the Market-Based Approach.[83] Similar to the overlay auction proposal discussed above, the incentive auction does not solve the fundamental market failures stemming from ill-defined legal rights and related commons issues. Any variation of the incentive auction would still necessitate substantial *ex-ante* coordination between satellite operators, earth station owners, and potential licensees since all incumbents have rights to full band access. Because of this, the holdout incentives would persist.

Moreover, the incentive auction proposal would exacerbate market failure problems by introducing additional ambiguity about spectrum rights being procured in the second auction. It is unclear if potential licensees would be bidding for FSS transmission rights, terrestrial receive rights, or a combination of the two. This would further diminish efficiency of the incentive auction approach and increase its transaction costs. While this alternative appears to share many common elements with the Broadcast Incentive Auction, one key difference between the two makes the incentive auction approach highly inadequate for C-Band reallocation. The Broadcast Incentive Auction worked because of competition to provide supply of spectrum created by the existence of multiple broadcasters in most geographic areas and a mandatory repacking requirement for the remaining TV broadcasters. However, in this case four FSS satellite operators represent almost all of the market. Nor is there the equivalent of mandatory repacking. Mandatory repacking of operators with rights to use the full band and full arc would in effect require at least the threat of a traditional forced reallocation and would likely lead to contention and delay. Put simply, the holdout problem is not solved.

A two-sided auction approach would not be quick. The Broadcast Incentive Auction will end up taking almost a decade.[84] And in that auction what was being bought in the procurement side of the auction was very straightforward. Here, defining what is procured (as explained more in the capacity auction discussion below) will be time consuming. Consequently, when compared to the Market-Based Approach, this path will significantly delay spectrum being repurposed for mobile terrestrial uses.

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82 Order and Notice of Proposed Rulemaking, ¶ 103.

83 This section addresses the FCC's request for comments regarding an incentive auction mechanism. See Order and Notice of Proposed Rulemaking, ¶ 105.

84 Congress began exploring the possibility of a broadcast incentive auction in 2011, and the transition period is expected to end in mid-2020. See "Using Spectrum to Advance Public Safety, Promote Broadband, Create Jobs, and Reduce the Deficit," Congressional Subcommittee on Communication and Technology Hearing, April 12, 2011, accessed October 2, 2018, https://www.gpo.gov/fdsys/pkg/CHRG-112hhrg67523/html/CHRG-112hhrg67523.htm; and FCC, "Transition Schedule," May 8, 2017, accessed October 2, 2018, https://www.fcc.gov/about-fcc/fcc-initiatives/incentive-auctions/transition-schedule.

Finally, other proposed mechanisms to efficiently allocate public goods, such as one developed by Hal Varian,[85] would fail to resolve the ill-defined legal rights present here. In such proposals, bidders can subsidize other bidders, somewhat internalizing the public good problem. Nevertheless, holdout incentives would persist and dominate any voluntary subsidization of spectrum by auction participants. In addition, it is unlikely that Varian's proposed mechanism if applied here would lead to the most efficient outcome. His models assume that all participants have perfect information (*i.e.*, "each agent knows the preferences and wealth of the other agent").[86] However, that is far from the case here and, in effect, assumes away many of the market and regulatory failures. Even if the holdout risk was not an issue, and some variation of this mechanism was feasible to implement, the presence of uncertainty and dynamically changing market conditions would likely still prevent an efficient amount of spectrum from being cleared.[87]

D. The Capacity Auction Proposal

1. Overview

The third alternative option seeks to compensate incumbents for giving up C-Band spectrum via a reverse auction for satellite transponder capacity, and allows the Commission to reallocate all cleared C-Band spectrum to flexible use.[88] This reverse auction approach assumes that incumbents' bidding to clear transponder capacity would help enable alternative use of cleared spectrum associated with specific transponders. Under this option, any FCC licensee with available transponder capacity could be a bidder in a reverse auction, and FSS operators in the C-Band or Ku-Band could offer capacity created by introducing new satellites and/or by clearing their existing capacity.

2. Deficiencies

Similar to other proposed alternatives, the capacity auction proposal is plagued by the same market failures stemming from ill-defined legal rights and public good issues. For example, because satellite operators all have rights to use the full band and full arc, the coordination requirements of freeing up the same frequencies (in the same geographic areas) still exist. Furthermore, the lack of mandatory repacking requirement means the holdout problem still exists.

Another flaw of this proposal lies in its underlying assumption that satellite transponder capacity is a homogenous good that can be easily standardized and substituted across different transponders,

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85 Order and Notice of Proposed Rulemaking, ¶ 62; and Hal Varian, "Sequential contributions to public goods," *Journal of Public Economics*, 53(2): pp. 165-186, February 1994.

86 Hal Varian, "Sequential contributions to public goods," p. 183.

87 For example, an introduction of uncertainty in only one simple example with two agents leads to an increase in free riding incentives and reduced contributions to public goods in Varian's mechanism.

88 Order and Notice of Proposed Rulemaking, ¶¶ 106-108.

uses, and bands.[89] However, that is not the case. Not only are transponder signals different even within the same band,[90] but also transponder capacity in C-Band is not equivalent to that in Ku-Band. For example, the C-Band's resistance to atmospheric attenuation is one of its most attractive features. Because measures to mitigate signal fade used in other bands are inconsistent with the requirements of nationwide content delivery, what defines equivalent service becomes a vexing problem.[91] In addition, if transponder capacity to be offered was contingent on introduction of new satellites, the time required to clear the required C-Band spectrum could be significantly increased – particularly given that capacity offerors could be contemplating different timelines for the introduction of new satellites. Earth station users could also be expected to be more distrustful of this process. In the Market-Based Approach, many earth station users likely will continue to be customers of the existing satellite operators and could be expected to be treated accordingly. As stated above, the existing satellite operators would have superior information about their customers and their situations and often the earth station and satellite operators have long term contractual rights and obligations to each other. If the capacity auction were perceived to disrupt these relationships, it would likely be strenuously opposed by the satellite operators and many earth station users.

E. THE T-MOBILE PROPOSAL

1. Overview

The T-Mobile phased auction proposal blends elements of both an incentive auction and the Market-Based Approach.[92] It envisions a combination of forward and reverse auction components involving participation of both a consortium of satellite operators and potential wireless bidders. In the first phase, the Commission would determine the initial price per area with a simultaneous

89 This addresses the FCC's request for comments on whether other bands (the FCC specifically addresses the Ku-Band) can be used as a replacement for C-Band. See Order and Notice of Proposed Rulemaking, ¶ 107.

90 For example, Intelsat 31 and 35e satellites both operate in C-Band and cover similar areas of the U.S., but 35e uses circular polarization while 31 uses linear polarization. The two satellites also have different EIRP and G/T specifications in the C-Band. See Intelsat 31 Fact Sheet, accessed October 25, 2018, http://www.intelsat.com/wp-content/uploads/2016/05/5533-IS-31-1.pdf; and Intelsat 35e Fact Sheet, accessed October 25, 2018, http://www.intelsat.com/wp-content/uploads/2017/06/Intelsat-35e-fact-sheet.pdf

91 For instance, PSSI, a television transmission service provider for event broadcasting, stated that it recently converted some of its Ku-Band equipment to C-Band equipment because its customers preferred the reliability of C-Band, particularly in areas subject to frequent rain. See *supra*, at footnote 8.

92 Order and Notice of Proposed Rulemaking, ¶¶ 112-115; and *Ex Parte* Filing of T-Mobile, Letter from Steve B. Sharkey, Vice President, Government Affairs Technology and Engineering Policy, to Marlene H. Dortch, Secretary, FCC, GN Docket No. 17-183, GN Docket No. 18-122, filed June 15, 2018, p. 4, accessed October 25, 2018, https://ecfsapi.fcc.gov/file/106150005816668/T-Mobile%203.7-4.2%20GHz%20Ex%20Parte%2006152018.pdf.

or near simultaneous auction. In the second phase, spectrum would be sold in areas where satellite operators are willing to clear all 500 MHz for flexible terrestrial wireless use. Then the Commission would repeat the forward and reverse auction process until the amount of spectrum the Commission had found to be appropriate is cleared.

2. Deficiencies

As with the other proposals, the T-Mobile proposal also fails to solve the fundamental market and regulatory failures stemming from ill-defined legal rights and significant informational complexity.[93]

Delay from this proposal would be significant. The proposal lacks incentives for FSS operators to clear all 500 MHz *ex-ante*, so the process would likely spiral into a multi-stage sequential auction. Because that sequential auction would be a lengthy and costly process, the resulting delay in desired C-Band frequencies being cleared would make the process highly inefficient. That is, direct negotiations by the interested parties would likely find an efficient solution much quicker than the back and forth of a multistage auction process.

This proposal also requires the Commission to act as a middleman between the two sides of the market, an approach that produces no apparent net advantages. The Commission is not in a better position to develop and evaluate the information needed to find the efficient solution to repurposing C-Band frequencies. Relying on government rather than on market forces to make many contentious decisions in the process[94] would further reduce the efficiency of the process, leading to costly delays relative to the Market-Based Approach.

F. The BAC Proposal

1. Overview

The Broadband Access Coalition ("BAC") proposal seeks to facilitate deployment of point-to-multipoint service in parts of the C-Band while opening other parts of the band for mobile.[95] The BAC proposes that the Commission provide mobile access for 5G in the 3.7-3.8 GHz band in dense urban areas and for point-to-multipoint service in the remainder of the band (3.8-4.2 GHz) and outside of urban areas in the 3.7-3.8 GHz portion of the band.[96] The proposal envisions

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93 This section addresses the FCC's request for comments on whether T-Mobile's proposal would solve the economic problems the FCC seeks to solve with its choice of mechanism. See Order and Notice of Proposed Rulemaking, ¶ 113.

94 Order and Notice of Proposed Rulemaking, ¶ 114.

95 Order and Notice of Proposed Rulemaking, ¶116; and *Ex Parte* Filing of Broadband Access Coalition and Google LLC, GN Docket No. 17-183, filed March 29, 2018, slide 3, accessed October 11, 2018, https://ecfsapi.fcc.gov/file/10329174176162/Notice%20of%20Ex%20Parte%20Meetings%20-%20Broadband%20Access%20Coalition%20and%20Google%20LLC.pdf.

96 See *id.,* slide 3.

coordinating with FSS operators to avoid interference. According to the BAC, this proposal complements the Market-Based Approach and would provide a means of "closing the digital divide" and providing broadband access to rural communities.[97]

2. Deficiencies

This proposal does not address the market failures discussed and is not a complement to the Market-Based Approach. It fails in at least two dimensions. Its first failing is that it presupposes the answer as to what the most efficient use of the C-Band would be. By asking the FCC to choose what alternative to satellite uses are allowed, this proposal blocks other potentially efficient uses. The central question should not be *can* fixed wireless uses coexist with satellite in some portions of the band, but *should* they? That question is not answered by whether or not this proposal is feasible, but by considering all potential alternative uses in all areas. If in a marketplace test the uses envisioned in the BAC proposal were found to create the most value, then those uses of the C-Band frequencies would be chosen by the Transition Facilitator under the Market-Based Approach. Furthermore, the Market-Based Approach allows for a mix of solutions, if optimal, such as the possibility of some fixed wireless operations in rural areas with higher-valued mobile operations in more densely populated areas. Mandating that the only alternative allowed in certain areas is fixed wireless takes away the choice of having the C-Band put to more efficient uses.

Beyond its initial inflexibility, the BAC proposal also creates a longer-term detriment to efficient spectrum use. Should the number of incumbent fixed wireless users increase significantly, any future improvements in how efficiently C-Band spectrum is used will become much more challenging. If this proposal is implemented, satellite operators will lose the ability to use the C-Band more intensively. This will negatively impact the ability to repurpose spectrum to support 5G in the future and diminish the C-Band's ability to meet future demand for satellite services if it is not cleared.

G. Summary

All of these alternative proposals for reallocating or repurposing C-Band spectrum are inferior to the Market-Based Approach. They do little or nothing to solve the central impediments to finding an efficient repurposing. None of them provides a mechanism to solicit the information needed about costs and benefits of the many aspects of transitioning users. They do not solve the holdout problem or resolve the ill-defined legal rights in the band. They would deprive satellite operators of their existing rights and investment-based expectations generated by the current licensing regime and renewal rights. They also require the FCC to bear the burden and costs of implementation. All would take significantly longer to effectively assign or clear spectrum than expected by a Transition Facilitator. And none of these proposals can course correct or adjust in response to market developments.

[97] See *id.,* slide 4.

V. Potential Concerns

Various commenters in the record to date have raised concerns with the Market-Based Approach. In this section I directly address and evaluate these concerns. As elaborated in the sections below, legitimate concerns are raised, but none of them shifts the balance of considerations against the Market-Based Approach.

A. The Transition Facilitator Market Power

One concern raised is that the Transition Facilitator could exercise market power.[98] The basic concern is that by withholding the supply of C-Band spectrum, the Transition Facilitator could increase the price received for the spectrum that is reallocated. This is the classic concern about a monopoly withholding supply. Although on the margin this incentive exists for the Transition Facilitator (as for all sellers of any good), the magnitude of this incentive is likely to be quite small and unlikely to have any meaningful effect on the actions of the Transition Facilitator.

As an initial matter, it will not be clear to observers if spectrum is artificially withheld. There are many reasons that less than 500 MHz nationwide could be the efficient solution. These include costs above benefits, including as discussed above that value may be maximized when the last, most expensive incumbent uses are not cleared. There is also an issue of timing – it may become less expensive, and therefore more efficient, to clear additional frequencies in a predetermined sequence over some period of time. For example, some satellite operations may be able to be moved immediately, but others will require significant transition costs and some amount of time to implement. Consequently, initial tranches of spectrum may be cleared within the relatively short time frame noted, but additional tranches may take longer to make available and may only be economical to repurpose once 5G spectrum values are firm.

The threshold question in evaluating market power is the definition of the relevant market. If the relevant market here was C-Band spectrum and the Transition Facilitator was the only supplier, then it would indeed have significant market power for this market and concerns about anticompetitive behavior would be justified. But the relevant market here is not C-Band spectrum, but rather licensed spectrum that has some substitutability for C-Band spectrum. Consequently, the market may be as wide as all licensed spectrum usable for 5G services, and probably contains all existing licensed spectrum, but at a minimum would include all licensed mid-band spectrum.

For any of the relevant market definitions (all spectrum, low- and mid-band spectrum, or just mid-band spectrum) the potential supply of C-Band spectrum is simply not significant enough to create a meaningful amount of market power. As noted, there are 715.5 MHz of currently licensed low- and mid-band spectrum.[99] There are also about 200 MHz of mid-band spectrum and over 5 GHz of high-band spectrum in the pipeline of potential reallocations in coming years (see Table 6). Even restricting the analysis to low- and mid-band frequencies, there is an expected base of

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98 Order and Notice of Proposed Rulemaking, ¶ 83.

99 See *supra*, at footnotes 21 and 25.

approximately 900 MHz that the C-Band would add to. As discussed above, other bands such as other mid-band and millimeter wave frequencies may impact the demand for (and price of) C-Band spectrum. Consequently, the analysis presented here is conservative.

Table 6: Spectrum Pipeline

Band [1]	Frequencies [2]	Quantity [3]	Auction Date [4]
Mid-Band Spectrum			
3.5 GHz CBRS	3550 - 3700 MHz	Max 70 MHz licensed	Est. 2020
2.5 GHz EBS	2496 - 2690 MHz	18-114 MHz	Est. 2020 - Beyond
3.5 GHz	3450 - 3550 MHz	100 MHz	Est. 2021 - 2022
NOAA Meteorological Spectrum	1675 - 1680 MHz	5 MHz	Beyond 2020
Sub-total Mid-Band Spectrum		193-289 MHz	
High-Band Spectrum			
28 GHz Band	27.5 - 28.35 GHz	850 MHz	November 2018
24 GHz Band	24.25 - 24.45 GHz 24.75 - 25.25 GHz	700 MHz	Est. Late 1Q 2019/2Q 2019
37 GHz Band	37.6 - 38.6 GHz	1,000 MHz	Est. Late 2019
39 GHz Band	38.6 - 40.0 GHz	1,400 MHz	Est. Late 2019
47 GHz Band	47.2 - 48.2 GHz	1,000 MHz	Est. Late 2019
42 GHz Band	42.0- 42.5 GHz	500 MHz	Est. 2020 - Beyond
Sub-total High-Band Spectrum		5,450 MHz	

Sources: Robert Kaminski, "Spectrum Auction Tracker," Capital Alpha, October 15, 2018; Report and Order, In the Matter of Policies Regarding Mobile Spectrum Holdings and Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, WT Docket No. 12-269 and Docket No. 12-268, FCC, June 2, 2014, ¶¶ 122-125, https://apps.fcc.gov/edocs_public/attachmatch/FCC-14-63A1_Rcd.pdf.

To illustrate the potential size of the incentive to anticompetitively withhold spectrum, consider the case where the Transition Facilitator would optimally reallocate 300 MHz of spectrum, but is considering reallocating only 200 MHz to artificially increase the price. The impact on price can be calculated by applying an elasticity of price of spectrum to the percentage change in quantity. Assuming a price elasticity of -1,[100] a 33% increase in quantity[101] implies a 33% decrease in price of C-Band spectrum. Alternatively, a 22% increase in quantity[102] implies a 22% decrease in price. In this example withholding 100 MHz of spectrum would represent a price that is 11 percentage

100 In prior work I have used an elasticity of demand for spectrum of -1.2, but use -1 here as elasticity should tend to -1 over time. See Coleman Bazelon, "Analysis of an Accelerated Digital Television Transition," May 31, 2015, p. 7.

101 Calculation: 33% = 300 MHz / 900 MHz.

102 Calculation: 22% = 200 MHz / 900 MHz.

points higher than if the spectrum was not withheld. Although this suggests that 200 MHz sold would garner more money per MHz, it would lead to an overall total loss in revenues.[103] Given that the Transition Facilitator will only be selling a fraction of the available spectrum, the elasticity would have to be much closer to zero before withholding would be a profitable strategy. Reasonable changes in the quantity potentially withheld or what constitutes the relevant market will not change the conclusion that a Transition Facilitator artificially withholding supply would lose money. Other potential negatives to delaying repurposing would be the induced substitution toward other frequencies if the price of C-Band were artificially high. Consequently, although a reasonable concern, in practice this is unlikely to have a negative impact on any reallocation proposed by a Transition Facilitator.

B. The Consortium Reaping Uneconomic Profits

The Market-Based Approach aligns the Transition Facilitator's incentives with the public interest. It does this by allowing the Transition Facilitator to keep a portion of any net benefits created by a reallocation. As noted above in Section II, evidence of a market failure is provided by the potentially positive expected net benefits from a reallocation of C-Band spectrum. If there are net benefits that create a surplus, they will be divided amongst the participants in the reallocation process. There are concerns that these potential benefits may be significant and that the Transition Facilitator will keep most of them, creating a so-called windfall for the Transition Facilitator.[104]

As an initial matter, if the alternative proposals take several more years to clear spectrum for public auction than the Market-Based Approach, then any such auction proceeds must be discounted against the larger public interest benefits from expeditiously and more efficiently clearing spectrum for terrestrial mobile use. It is well understood that the most significant benefits from reallocating spectrum and putting it to higher-valued use accrue to consumers. As noted, prior work suggests that consumer benefits are 10 to 20 times the economic value of spectrum.[105] Therefore, benefits to society would likely dwarf any appropriated discounted forgone auction revenues. Furthermore, the increased economic activity also has positive impacts on federal government finances. Consequently, it would be inaccurate to argue that absent a direct financial contribution to the Treasury the government does not benefit from a C-Band spectrum reallocation.

Second, the size of any benefits to the Transition Facilitator are unknown. The inherent uncertainty and evolving market dynamics mean that any excess revenue generated is uncertain, subject to change, and carries significant risks for the Transition Facilitator. Given the delays and

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[103] With an elasticity of -1, revenue would be neutral if the entire quantity of good was sold at once. In this case, for revenue to increase, the elasticity would have to be more inelastic than -1 (-1 < elasticity < 0) *and* all spectrum would have to be included in what is sold.

[104] For instance, see Chris Forrester, "Satellite's multi-billion dollar windfall," IBC, October 10, 2018, accessed October 24, 2018, https://www.ibc.org/delivery/satellites-multi-billion-dollar-windfall/3374.article.

[105] See *supra*, at footnote 72.

other inefficiencies that are likely to occur absent cooperation among satellite operators via the Transition Facilitator, any potential net benefits (and thus any potential social benefits) for alternatives to the Market-Based Approach would likely be much smaller.

Moreover, any net benefits to the Transition Facilitator would be generated by its efforts and risk-taking. Internal knowledge needs to be marshalled and significant external knowledge from both satellite customers and potential users of repurposed spectrum must be developed. With the costly knowledge, significant effort will be expended finding the efficient solution. This will require much back and forth between all stakeholders as creative ideas are explored and various trade-offs are evaluated. For the reasons discussed above, the Market-Based Approach will generate more benefits than any of the other proposals. In short, any net benefits generated by the efforts of the Transition Facilitator will be earned.

How the potential net benefits would be distributed is also uncertain. The benefits are created through the cooperation of the relevant stakeholders, including the satellite operators and their earth station customers and the terrestrial wireless network operators who will purchase the reallocated spectrum. Although the primary level of negotiations will be between the satellite operators and the new users of the repurposed spectrum, the satellite operators' earth station customers will be at least as well off, too. As customers of the satellite operators, the earth stations will receive the equipment or compensation needed to be kept whole. There is no doubt they will be made no worse off, but may be better off if their revised services or equipment represents an improvement over current services. The shares of net benefits that go to each group will be the outcome of private bargaining between the participants. There is nothing in theory or practice to suggest that the Transition Facilitator is in a position to reap all of the gains.

Bargaining theory suggests that gains are divided in proportion to the bargaining power of the negotiating participants. Bargaining power, in turn, is related to the credibility of the threat to walk away from the bargain. This in turn is related to the relative gains of each party compared to no bargain. In this case, no bargain results in a continuation of the status quo. To the extent that the satellite operators, and their customers, are content with the status quo, they have a credible threat to walk away. The credibility of wireless network operators' threat to walk away is related to how great their need for the spectrum is and their alternative opportunities for meeting that need. It is difficult to forecast these factors with precision, but even if wireless operators' benefit from the spectrum is significant, that does not mean they will not share in some of the net benefits created. Consequently, the net benefits created by a C-Band reallocation can be expected to be shared by all of the participants whose cooperation facilitates the reallocation.

C. The Transition Facilitator Making Regulatory Decisions

The Transition Facilitator will make many specific decisions about the uses of the C-Band that traditionally have been made by the FCC. For example, the size of guard band needed between satellite and mobile terrestrial uses will be determined by the Transition Facilitator in consultation with relevant stakeholders. Implicit in its determination of the efficient solution will be revisions

to licensee rights, including levels of interference. There is potential concern that the Transition Facilitator will be making decisions traditionally left to the regulator – the FCC.

Under the Market-Based Approach, the FCC will retain the ability to review the C-Band and its uses. It will simply be deferring initially to a more informed private entity, the Transition Facilitator. The Transition Facilitator will face strong marketplace incentives and set technical and licensing parameters so as to maximize the value of the cleared spectrum to the ultimate terrestrial mobile license holders. In the absence of any perceived market failure it is reasonable to defer to market forces. The FCC's service flexibility and technology neutrality polices are based on this rationale. Also, the FCC regularly uses private entities as spectrum coordinators.[106] Furthermore, in the SDARS/WCS proceeding, the relevant private parties negotiated an efficient solution, which the FCC adopted.[107] By deferring to the Transition Facilitator to develop the efficient solution to repurposing C-Band frequencies, the FCC is allowing the entity with the best specific knowledge find the right changes to the band. And by allowing the Transition Facilitator to make these decisions with the FCC's ability to review, the FCC is supporting a far quicker process than a traditional FCC reallocation or any other of the alternative proposals discussed in the NPRM.

D. Rural Issues

Serving rural customers often has unique challenges. They tend to be more expensive to serve and, as a result, tend to have fewer choices in service offerings. Any repurposing of C-Band spectrum should be cognizant of this reality. The Market-Based Approach will best meet rural needs.

The central feature of rural markets that is relevant here is the lack of choice of alternative broadband providers. This influences considerations about the C-Band in two ways. First, without robust fibre optic infrastructure, rural areas are more dependent on satellite-provided services than are urban areas. This suggests that the value of satellite services in rural areas may be higher, especially on the margin. Second, again because of the lack of infrastructure, the demand for additional broadband services is high. One potentially economical way to meet this demand is through terrestrial fixed wireless services, suggesting the increased value of repurposed C-Band spectrum that can be used to meet this need.

Fortunately, the incentives created under the Market-Based Approach align with the interests of serving rural communities. The efficient solution to balancing the demands of continued satellite service and repurposed terrestrial service are exactly the considerations the Transition Facilitator

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106 See, *e.g.*, "Public Safety Frequency Coordinators," FCC, March 15, 2018, accessed October 24, 2018, https://www.fcc.gov/general/public-safety-frequency-coordinators.

107 Order on Reconsideration, *In the Matter of Amendment of Part 27 of the Commission's Rules to Govern the Operation of Wireless Communications Services in the 2.3 GHz Band and Establishment of Rules and Policies for the Digital Audio Radio Satellite Service in the 2310-2360 MHz Frequency Band,* WT Docket No. 07-293, IB Docket No. 95-91, October 17, 2012, accessed October 25, 2018, https://docs.fcc.gov/public/attachments/FCC-12-130A1.pdf.

will make in finding the efficient solution. Although the majority of value from repurposed spectrum will come from mobile terrestrial operations, the needs for fixed wireless will also be in the mix. But unlike the BAC proposal that locks in fixed wireless and limits the flexibility to incorporate other uses of the C-Band, the Market-Based Approach maximizes options. By considering all the ways C-Band spectrum can serve rural customers – satellite broadband, fixed wireless, and mobile – the Transition Facilitator will not lock in one approach that would predetermine how the C-Band would be repurposed without considering and reacting to dynamically evolving market information.

VI. Conclusion: The Market-Based Approach Maximizes Benefits-to-Costs

The FCC requested cost-benefit analyses ("CBAs") of the various proposals.[108] Proposals at this level of policy direction do not lend themselves to formal CBA. This is because the proposals are not for specific repurposing of spectrum, but rather for an approach to repurposing spectrum. Formal CBA would be better suited to evaluating alternative specific proposals involving details about frequencies, geographies, and timing.

Nevertheless, the principles behind a CBA can be applied to evaluating the proposals for repurposing some or all of the C-Band frequencies. In essence, the categories of benefits and costs of each proposal can be identified and potentially evaluated, at least in a relative sense. In doing so, it is important to keep in mind the high-level policy objectives. These include maximizing the value created from the C-Band spectrum resource (deploying it as efficiently as possible) as well as making sure those gains are shared by society.[109]

Although all the proposals aim to increase the beneficial uses of the C-Band, the Market-Based Approach will create the most value. By developing the detailed information needed, and adjusting to changing circumstances, the Transition Facilitator will be incentivized to repurpose as much spectrum as possible where doing so increases value, but not to transition too much (or any, if uneconomic). As discussed above, the Transition Facilitator will also be able to create value much more quickly than any of the alternatives proposed and the private parties they are negotiating with can start their planning processes even quicker. Consequently, the Market-Based Approach should create the greatest amount of benefits to consumers and society.

The one potential benefit that the auction-based proposals have that is absent from the Market-Based Approach is that an auction may raise revenue for the Treasury. As noted above, it is unlikely that such revenues will be significant, and any revenues above costs earned by the Transition Facilitator will be earned from the extensive knowledge development efforts and risk-taking inherent in repurposing C-Band spectrum. Furthermore, the public will benefit far more from the new services enabled by repurposing C-Band spectrum than from any pecuniary benefit

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108 Order and Notice of Proposed Rulemaking, ¶ 54.

109 Order and Notice of Proposed Rulemaking, ¶¶ 1-2.

to the Treasury. Any public revenues would come at the cost of significant, harmful delay and a likely less than optimal repurposing of the C-Band.

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