A NPSTC Public Safety Communications Report

The National Public Safety Telecommunications Council is a federation of organizations whose mission is to improve public safety communications and interoperability through collaborative leadership.

T-Band Report

March 15, 2013

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191 Southpark Lane, #205 · Littleton, CO 80120 · Phone 866-807-4755 · Fax 303-649-1844 · Website www.NPSTC.org

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Executive Summary

On February 22, 2012, the President signed Public Law 112-96 which requires the Federal Communications Commission (FCC) to begin auctioning the public safety T-Band spectrum by February 2021 and clear all public safety operations from the band within 2 years of auction close, (i.e., by early 2023). This spectrum is used in 11 metropolitan areas to support critical public safety communications and provide regional interoperability among first responders. These areas are Boston, Chicago, Dallas, Houston, Los Angeles, Miami, New York, Philadelphia, Pittsburgh, San Francisco, and Washington, D.C.

While the law provides that auction revenues can be used toward the cost of relocating public safety operations out of the band, the law is silent on identifying a new spectrum home. The law is also silent on the status of thousands of industrial/business users who also utilize this spectrum and whose frequencies are intermingled with public safety frequencies. In response to the law, the FCC placed a freeze on new and expanded T-Band operations for all licensees, including both public safety and industrial/business entities.

The National Public Safety Telecommunications Council (NPSTC) responded by establishing a T-Band Working Group chartered to study the issue, assess and document the impact of the legislation and the FCC freeze on public safety, evaluate the viability and cost of potential relocation options, and provide its findings to the NPSTC Governing Board. Approximately 60 members of the public safety community and related industry representatives volunteered to serve on the Working Group. This report addresses NPSTC's analysis and findings.

Key Conclusions

Given the lack of alternative spectrum, cost of relocation, major disruption to vital public safety services, and likelihood that the spectrum auction would not even cover relocation costs, NPSTC believes implementing the T-Band legislation is not feasible, provides no public interest benefit, and the matter should be re-visited by Congress.

1. ***SPECTRUM*** *- Analysis of public safety spectrum bands shows that at least 5 of the 11 metro areas do not have sufficient spectrum in any band to relocate their existing T-Band operations. These areas are the Boston, Chicago, Los Angeles, New York, and Philadelphia metros. The adequacy of relocation spectrum in three additional areas, San Francisco, Washington, D.C., and Pittsburgh is marginal. It is not yet viable to rely on the planned Nationwide Public Safety Broadband Network (NPSBN) as a likely option to support mission critical voice operations that would be displaced from the T-Band.*
2. ***COST*** *- The cost to move public safety operations in the 11 metro areas to new frequencies is estimated to be in excess of $5.9 billion, much greater than the likely auction revenue. If TV and industrial/business were also required to move, that would require additional relocation funding, resulting in the net auction revenue being an even greater negative value.*
3. ***PUBLIC GAIN*** *– It appears the intent of the law may be to gain additional broadband spectrum for public use. Extensive TV broadcast operations throughout the country and industrial/business systems in 11 metro markets will remain on T-Band channels even if public safety systems are relocated out of the band. These circumstances are unlikely to produce the auction revenue needed for public safety relocation or result in additional broadband spectrum for public use.*

1. Introduction

1.1 T Band History

The T-Band (470-512 MHz) is a key spectrum resource allocated for land mobile communications operations in 11 top urban areas of the United States. These 11 urban areas, as listed in Section 90.303 are Boston, Chicago, Dallas/Ft. Worth, Washington, D.C. (including parts of Virginia and Maryland), Houston, Los Angeles, Miami, New York City/Northeast New Jersey, Philadelphia, Pittsburgh, and San Francisco/Oakland. This spectrum, which comprises television channels 14-20 throughout most of the country, was allocated on a shared basis for land mobile operations by the FCC in 1971 under Docket No. 18261.

Originally, the FCC planned to make some T-Band spectrum available in Detroit and Cleveland as well, so those additional two markets are also listed in the FCC rules. However, the United States was never able to reach agreement with Canada for T-Band operation in the Detroit and Cleveland border area.[1] Therefore T-Band land mobile operation is only in the 11 market areas listed above. The premise behind the allocation of this spectrum was that these 11metropolitan areas had the greatest challenge in locating needed land mobile spectrum for public safety first responder operations, as well as industrial/business applications. The T-Band provided a significant supplement of channels to support public safety operations in these critical areas. The T-Band is still being used to support and upgrade public safety systems and those investments will be lost if the T-Band is reallocated.

In general, FCC rules allow base stations to be located within 50 miles of a set of reference coordinates listed for each of the 11 metro areas. Mobiles and portables are allowed to operate within a 30-mile radius around the base stations. This allowed public safety operations within 80 miles of these metro areas. It should be noted, however, that operation on some of the T-Band channels in certain metro areas is more restrictive to protect specific co-channel or adjacent channel TV stations. Some operations have also been authorized over the years, via FCC waiver, to allow for operations beyond the 50-mile radius.

Not all the spectrum in 470-512 MHz (TV channels 14-20) is authorized in each of the 11 markets. Each market has the use of only certain TV channels from within the T-Band and the specific channels and amount of spectrum vary by market, as shown in the Table 1. This table reflects channels originally allocated in 1971 plus additional channels that have been added since that time in the Los Angeles and New York areas. Column 3 in Table 1 denotes the nominal amount of total spectrum allocated from the T-Band to public safety and industrial/business land mobile radio services. Note that because this is television spectrum is being shared by land mobile operations, there are situations in some markets where the total amount of nominal spectrum is not actually

[1] The lack of a border agreement allowing use of the T-Band in Detroit and Cleveland did not eliminate the need for additional spectrum. Accordingly, the FCC subsequently made spectrum available for Detroit and Cleveland on some channels in the 421-430 MHz band.

available. This situation occurs so that interference to/from a particular television station can be avoided. It may also result in making a portion of the normal 50-mile radius within which land mobile T-Band base stations could normally be located unavailable. For example, the 50-mile circle may be reduced in the direction of a conflicting TV station.

Table 1.1: **Amount of T-Band Spectrum by Market**

Metro Area	TV Channels Designated for Land Mobile Use	Nominal Amount of Spectrum in MHz (includes both Public Safety and Industrial/Business)	% of Active Land Mobile Channels Licensed to Public Safety. [% Varies Across TV Channels]
Boston	14, 16	12	64%, 87%
Chicago	14, 15	12	40%, 56%
Dallas	16	6	20%
Houston	17	6	3%
Los Angeles	14,15,16,20	24	93%, 100%, 100%, 83%
Miami	14	6	17%
New York	14,15,16	18	69%, 70%, 100%
Philadelphia	19,20	12	82%, 78%
Pittsburgh	14,18	12	41%, 100%
San Francisco	16,17	12	37%, 35%
Washington, DC	17,18	12	28%, 21%

The breakout of T-Band spectrum used by public safety vs. industrial/business licensees varies by market and by TV channel in that market. Originally, when the T-Band allocation was made in 1971, the FCC rules designated a defined portion of the spectrum on each TV channel for public safety and the remaining portion of the channel for industrial/business type operations. Subsequently, the FCC modified the rules such that the categorization of the spectrum between public safety and industrial/business is defined on a land mobile channel-by-channel basis. Under that approach, channels on which the first licensee is public safety are considered to be categorized as public safety channels, whereas channels on which the first licensee is industrial/business are considered to be industrial/business channels.

Over the years, this has resulted in changes to the portion of the T-Band spectrum that is “public safety spectrum.” The portion of the T-Band spectrum used by public safety, i.e., that subject to Section 6103 of Public Law 112-96 as addressed in the following section of this report, is not contiguous and varies by market and by TV channel in each market. The NPSTC T-Band Working Group analyzed this situation. Column 4 in Table 1 provides the range of percentages of active T-Band land mobile channels that are licensed under the public safety services in each region. For example, on TV channel 14 in Boston, 64 percent of the active land mobile channels are public safety and on TV channel 16 in Boston, 87 percent of the active land mobile channels are public safety

While complex, this reality is important to understand because Section 6103 of the legislation refers to reallocating the T-Band spectrum currently used by public safety eligibles. It does not require reallocation and auction of the entire T-Band spectrum in each of the 11 markets. Also as noted in Section 5 of this report, broadcast service operations throughout the U.S. also exist on the T-Band spectrum. There are exceptions in certain areas and on some channels where they are used for land mobile T-Band sharing.

1.2 Provisions of Public Law 112-96

On February 22, 2012, legislation was enacted to reallocate spectrum in the "D Block" within the 700 MHz band to public safety for broadband operation. This legislation, originally known as HR 3630 while it was being developed, became Public Law 112-96 upon enactment. In addition to addressing spectrum at 700 MHz and providing funding and a governance structure for a new public safety broadband network, Public Law 112-96 also included Section 6103 addressing the public safety T-Band spectrum which reads as follows:

> **SEC. 6103. 470–512 MHZ PUBLIC SAFETY SPECTRUM**
>
> *(a) IN GENERAL.—Not later than 9 years after the date of enactment of this title, the Commission shall—*
> *(1) reallocate the spectrum in the 470–512 MHz band (referred to in this section as the "T-Band spectrum") currently used by public safety eligibles as identified in section 90.303 of title 47, Code of Federal Regulations; and*
>
> *(2) begin a system of competitive bidding under section 309(j) of the Communications Act of 1934 (47 U.S.C. 309(j)) to grant new initial licenses for the use of the spectrum described in paragraph (1).*
>
>> *(b) AUCTION PROCEEDS.—Proceeds (including deposits and upfront payments from successful bidders) from the competitive bidding system described in subsection (a)(2) shall be available to the Assistant Secretary to make grants in such sums as necessary to cover relocation costs for the relocation of public safety entities from the T-Band spectrum.*
>
> *(c) RELOCATION.—Relocation shall be completed not later than 2 years after the date on which the system of competitive bidding described in subsection (a)(2) is completed.*

Accordingly, public safety is now faced with the requirement to vacate the T-Band spectrum by 2023, unless the law is subsequently modified. To some, that timeline may seem far away. However, to public safety agencies that have planned and deployed extensive T-Band communications systems, this timeline is relatively near term. Major public safety systems normally require 3 to 5 years to develop and fully test, even after sufficient spectrum and adequate funding are made certain and in place. Furthermore, a number of today's public safety T-Band networks support regional interoperability and the necessary planning required among multiple jurisdictions to yield that benefit can also contribute to the timeline.

For comparison, the timeline to relocate public safety systems within the 800 MHz band, known as "800 MHz rebanding," was originally estimated to take 3 years after provisions for funding and the spectrum relocation home had been decided. However, 800 MHz rebanding is has been in progress now for 7 years and the relocations are still not complete. T-Band licensees face additional timeline challenges since decisions still need to be made on alternative spectrum, specific provisions to ensure sufficient funding for relocations and a process to obtain the necessary funding. Furthermore, if T-Band agencies are relocated to a completely different frequency band, the moves will be more challenging and complex than those in 800 MHz rebanding, where systems stayed in the same overall spectrum band.

The legislation did not identify the spectrum to which current T-Band licensees would move. While the legislation provides that proceeds from auction of the T-Band spectrum can be used to relocate public safety systems, it did not address any relocation cost estimates or whether expected auction proceeds would be sufficient to cover those costs. Note that Section 4 of this report addresses the estimated cost of relocation and Section 5 addresses potential auction revenues.

The legislation made no mention of industrial/business licensees that also could be impacted by an auction of the T-Band spectrum. The primary focus of this report is public safety. However, NPSTC is mindful that neighboring industrial/business licensees also in the band could be impacted. Therefore, NPSTC has been coordinating with associations such as the Land Mobile Communications Council (LMCC) and the Enterprise Wireless Alliance (EWA), as well as a representative for the Personal Communications Industry Association (PCIA).

1.3 FCC Freeze

In April 2012, the FCC imposed a freeze on new T-Band licenses or modifications to existing licenses that would expand their spectrum or geographic footprint.[2] The freeze impacts both public safety and industrial/business users. In imposing the freeze, the FCC indicated applicants may request a waiver but that applicants should carefully review the criteria to submit such waiver requests. To date the FCC has both granted and denied various requests for waivers of the freeze. While the FCC does have jurisdiction to waive or modify the T-Band freeze it has imposed, it cannot "waive" the specific legislative provisions that require reallocation and auction of the T-Band spectrum.

1.4 FCC Public Notice Seeking Comments

[2] WIRELESS TELECOMMUNICATIONS BUREAU AND PUBLIC SAFETY AND HOMELAND SECURITY BUREAU SUSPEND THE ACCEPTANCE AND PROCESSING OF CERTAIN PART 22 AND 90 APPLICATIONS FOR 470-512 MHz (T-BAND) SPECTRUM, Public Notice DA 12-643, released April 26, 2012.

On February 11, 2013, the FCC issued a Public Notice (PN) seeking comment on a number of issues related to the T-Band public safety spectrum auction and relocation mandated in the legislation.[3] The FCC raises a number of questions revolving around characterization of current T-Band operations, availability of alternative spectrum, and estimate relocation costs. Given the legislation discussed in Section 1.2 of this NPSTC Report, the FCC has no option but to address these issues unless and until the legislation is rescinded or modified.

Many of the issues raised by FCC have been addressed by the NPSTC T-Band Working Group. Accordingly, NPSTC believes the information in this report will help provide insight on those issues raised in the FCC Public Notice and the significant impact public safety faces as a result of the legislation.

1.5 NPSTC Approach

Together, the provisions of the legislation and the FCC freeze on new or expanded T-Band licensing unfortunately have placed public safety users of the T-Band in limbo. There is uncertainty in the market on whether the legislation can be changed and, if not, what replacement spectrum is available, what process/timing will be implemented to obtain funding for relocations, and whether that funding will be sufficient to cover legitimate costs.

This NPSTC report clarifies the spectrum and funding challenges public safety faces as a result of the legislation. NPSTC provides this information to assist public safety agencies and organizations as they advance this issue and to seek resolution to the specific needs of the first responder community. This report is divided into five sections which represent different components of the issue. Section 2 characterizes T-Band Usage, Section 3 addresses at a high level the potential availability of alternative spectrum, Section 4 provides an estimate of relocation costs, and Section 5 examines whether T-Band auction revenue is likely to be sufficient to cover estimated relocation cost.

It is beyond the scope of NPSTC's work, however, to develop frequency plans or detailed cost estimates for relocation of specific T-Band agency systems. The availability of any specific frequency is always location dependent and a number of the affected systems are complex with multiple sites, multiple licensees in the area, a mix of conventional and trunking operations, and the need to account for interoperability across neighboring jurisdictions in a region. An analysis of the cost to move any specific system to an alternative spectrum would require significant work to first identify the actual availability of alternative spectrum and to then redesign the system in that spectrum to meet the public safety licensee's operational and interoperability requirements. Furthermore, any such planning for one licensee must not be done in a vacuum, since all adjoining agencies using T-Band spectrum may be impacted by the movement of any one agency. Unless the

[3] Wireless Telecommunications Bureau and Public Safety and Homeland Security Bureau Seek Comment on Options for 47-512 MHz (T-Band) Spectrum, PS Docket No. 13-42, February 11, 2013.

provisions of Section 6103 of the law are rescinded, all T-Band public safety licensees would face the need to relocate to other spectrum. Therefore, planning for such relocation would be a massive undertaking.

2. T-Band Usage and Impact

2.1 Overview Descriptions

Public safety agencies make heavy use of the T-Band spectrum. The spectrum was originally allocated in 1971 because existing spectrum bands in the major urban areas were unable to support needed expansion of public safety systems where demand for public safety services was the greatest. Since that time, local jurisdictions in the 11 major metro markets where the spectrum is allocated have increasingly built out radio and data systems to support their growing mission critical communications requirements. In many cases, these T-Band networks are shared to provide regional interoperability among multiple jurisdictions and first responders. Examples of such regional interoperability include the Boston Area Police Emergency Radio Network (BAPERN), the Los Angeles Regional Interoperable Radios System (LA-RICS), and the Interagency Communications Interoperability System (ICIS).

Public safety communications requirements are not static. Those needs grow and as a result, pent-up demand can exist even considering periodic spectrum allocations and deployment of improved technology that provides greater spectrum efficiency, especially in highly dense areas such as the T-Band cities.

While the T-Band has a common attribute of being critical to public safety, the deployment and operational procedures may vary across the 11 metro areas. Accordingly, specific plans to implement relocation of the systems to alternative spectrum need to consider those differences and ensure operational capabilities are maintained.

2.2 Summary of FCC License Statistics

Members of the NPSTC Working Group gathered and analyzed information on T-Band usage by region. This data mining initiative gathered information regarding the number of frequencies, RF sites, repeaters, and mobiles/portables based on publicly available licensing database records originally sourced from the FCC's Universal Licensing System (ULS).

The ULS license information is built up over time. Use of this information is not as simple as simply copying the records. Additional work is required to "scrub" the data to eliminate what is essentially duplicate information. Given the high level of usage of the T-Band spectrum and the fact that many agencies hold multiple licenses, the volume of data is significant. Members of the Working Group who engaged in the analysis have familiarity with licensing data and removed duplicate information to the best of their abilities.

The following table summarizes the information gleaned from the data mining initiative:

Table 2.1: Summary of Public Safety T-Band Environment by Region

Region	Licensees	Channels Licensed	RF Sites	Repeaters	Mobiles/ Portables
Boston	209	596	636	1,081	30,439
Chicago	114	279	212	477	23,965
Dallas	19	55	51	95	3,392
Houston	6	7	8	8	277
Los Angeles	50	546	474	7,814	41,701
Miami	15	43	28	70	2,067
New York	222	1054	751	3,348	94,831
Philadelphia	150	790	467	2,893	61,734
Pittsburgh	30	107	88	369	9,598
San Francisco	54	216	234	694	16,990
Washington, DC	22	129	87	465	10,103
Totals	925	3,822	3,036	17,314	295,097

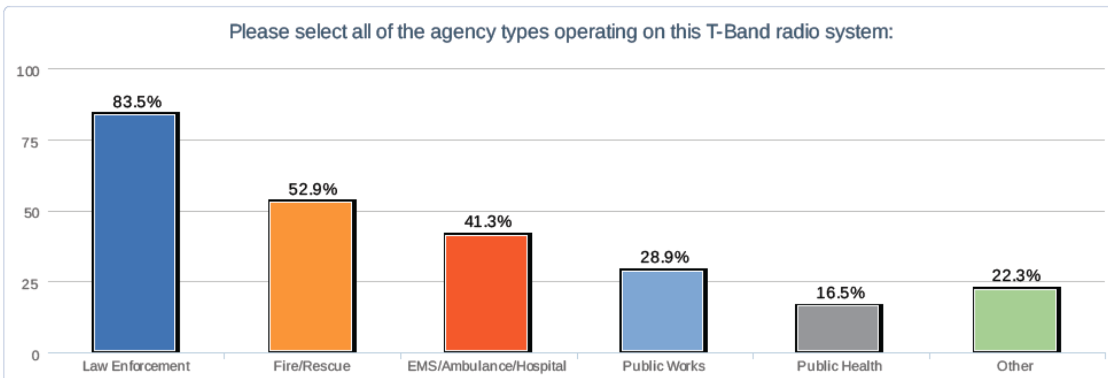
The data listed reflects combined information for conventional and trunked T-Band licenses in each region. The "channels licensed" can include frequency re-use within the region. These channels licensed represent frequency pairs and exclude "mobile only" frequencies for unit-to-unit direct communications.

The analysis reveals that the T-Band environment varies across the 11 regions. Boston, Chicago, Los Angeles, New York, and Philadelphia have the heaviest usage. Usage in Pittsburgh, San Francisco and Washington, D.C. is moderate and in Dallas, Houston, and Miami usage is less. This result is also partially reflective of the disparity in T-Band spectrum available across the 11 markets as addressed previously in this report.

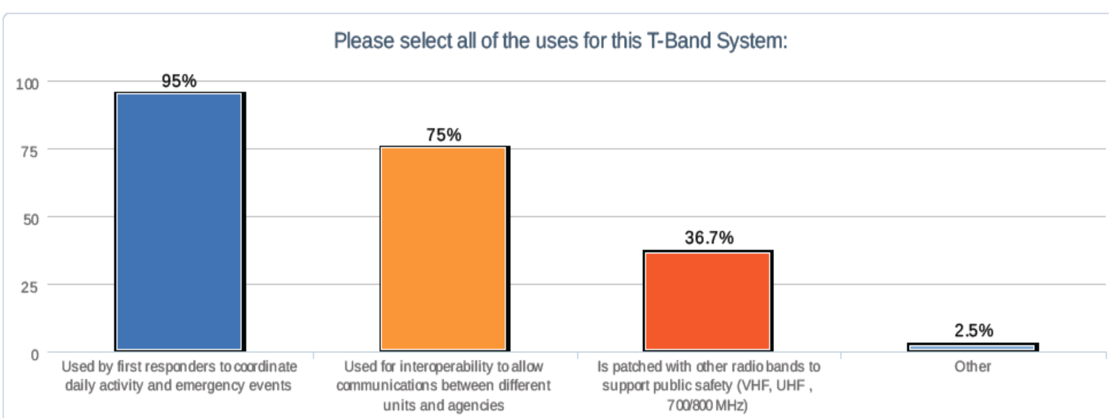
2.3 NPSTC Questionnaire Process and Results

The Working Group decided to develop a web-based questionnaire to which T-Band licensees could respond. The purpose of the questionnaire was to collect information that would add to the understanding of the T-Band environment and usage. Working with T-Band licensees, consultants, and members of industry on the Working Group, NPSTC developed the questionnaire and posted it on the NPSTC web site in August 2012. The availability of the questionnaire, which remained open until early October 2012, was publicized through relevant trade publications and public safety association conferences.

The following charts highlight key results of responses to the questionnaire. NPSTC cautions that these results reflect only the information gathered through the responses received. As with any questionnaire, only a portion of the licensees affected by the provisions of the legislation responded.



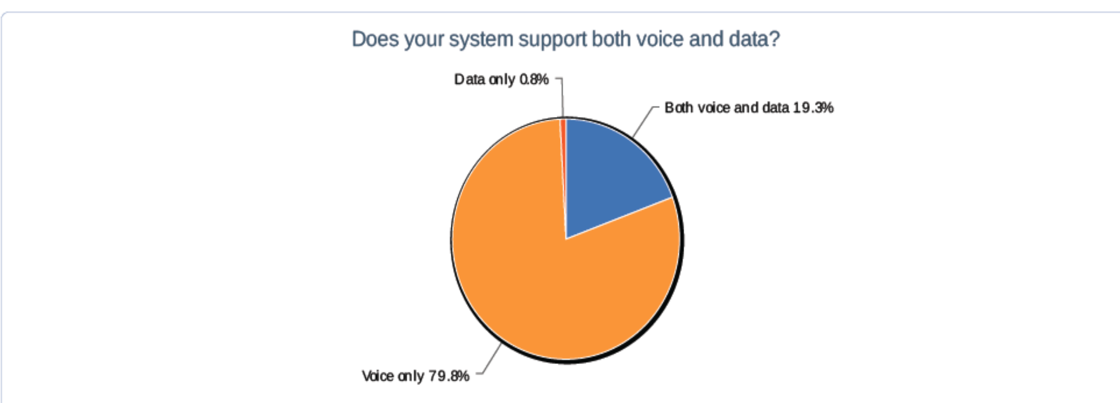
As can be seen in the bar graph above, the T-Band spectrum supports the full range of public safety entities, including law enforcement, the fire service, and the emergency medical services. In addition, there are other state and local government entities critical to the public's well-being that are also served by T-Band systems deployed primarily for public safety operations. Because FCC rules on eligibility vary across different bands, one issue that will be faced is whether all current users of the T-Band spectrum will be allowable users in some potential alternative bands. For example, the eligibility in the 700 MHz band is generally more restrictive than in the T-Band.



The bar graph above shows that T-Band systems are used almost as much for interoperability as for daily activities and emergency events. Further, as indicated in the pie chart below, T-Band systems are not necessarily stand-alone. One-third of the agencies responding indicated they also use spectrum in the adjacent UHF (450-470 MHz) band. A number of current public safety mobile and portable units in operation today incorporate the capability to operate across both the 450-470 MHz UHF band and the 470-512 MHz T-Band. This means that in order to maintain interoperability following a relocation, agencies will need to identify interoperable spectrum assets that extend beyond those used solely in the T-Band. Alternatively, agencies may need multi-band radios that operate on both UHF and the selected relocation spectrum.

The questionnaire also asked about the type of traffic carried on the respondents' current T-Band system,(i.e., whether it is voice, data, or both). The following pie chart shows that the predominant usage is for voice with only one-fifth of the systems providing both voice and data. Less than one percent of the systems are operated for data alone. Therefore, any plan to relocate T-Band systems to 700 MHz broadband would mean that provisions for broadband Long Term Evolution (LTE) mission critical voice must be standardized, tested, and be built out to provide equivalent coverage and reliability to that of today's T-Band systems. As addressed in Sections 3 and 4 of this report, there is significant risk in relying on the Nationwide Public Safety Broadband Network (NPSBN) as there is no solution on the horizon that would enable public safety entities to comply with the current law and retain mission critical public safety grade voice communications.

NPSTC asked about the mode being used in today's T-Band systems, (i.e., whether they are conventional or trunked). The following questionnaire results show these systems are overwhelmingly conventional with about one-fifth including both trunked and conventional modes of operation. It is important to note that current FCC rules require trunked operation for systems with five or more channels in the potential relocation bands of 700 MHz or 800 MHz. The basis of the rule is that trunking is generally regarded as more spectrally efficient than conventional. Those rules are not applicable to the T-Band spectrum, so they would represent a new requirement for T-Band licensees moving to those bands.



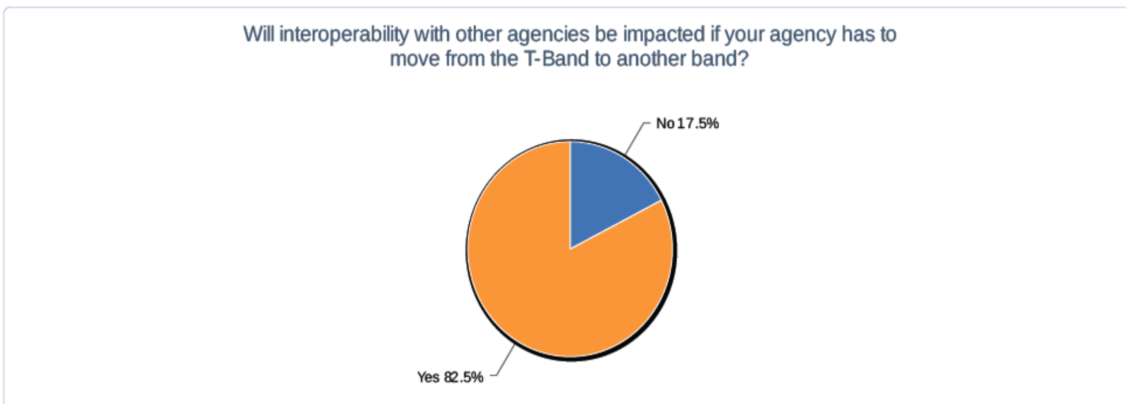
8. Does your system support both voice and data?

Value	Count	Percent %
Both voice and data	23	19.3%
Voice only	95	79.8%
Data only	1	0.8%

Statistics	
Total Responses	119
Skipped	37

There are many differences when comparing trunking and conventional operations. The degree of positive or negative impact can vary with system design, governance, and a given agency's operational structure and procedures. Moving from conventional to a properly designed trunked system could have a positive impact on the relocation spectrum capacity needed and allow each user agency the option to access more channels overall. Those benefits would entail higher incremental relocation costs, but could allow those costs to be shared across multiple agencies that today each have their own system. While not studied extensively for this report, some public safety agencies cite operational differences between trunked and conventional systems. For example, they noted that while trunked operations have benefits for wide-area operations, conventional systems can be better matched to specialized uses such as fire-ground communications.

The T-Band spectrum is a significant resource to support mission critical voice interoperability in the top markets. In the questionnaire, NPSTC asked about the impact to interoperability if the responding agency has to move from the T-Band. As shown below, over 80 percent advised interoperability would be impacted.



In addition to the impact of the legislation, NPSTC included a question to assess the impact of the FCC freeze on new or expanded T-Band licenses. Approximately 40 percent of the agencies responding said they are being impacted by the freeze. [

17. The FCC has frozen certain types of license changes in the T-Band. This will prevent adding sites, channels, and enhancing coverage. Did you have plans to modify your T-Band system to meet operational needs?

Value	Count	Percent %
Yes, we were planning to make system changes that are now prohibited under the freeze	63	40.9%
Yes, we were planning to make system changes that are still allowed under the freeze	13	8.4%
No, our system, as currently licensed, will meet our needs through the year 2023	67	43.5%
Other	11	7.1%

Statistics	
Total Responses	154

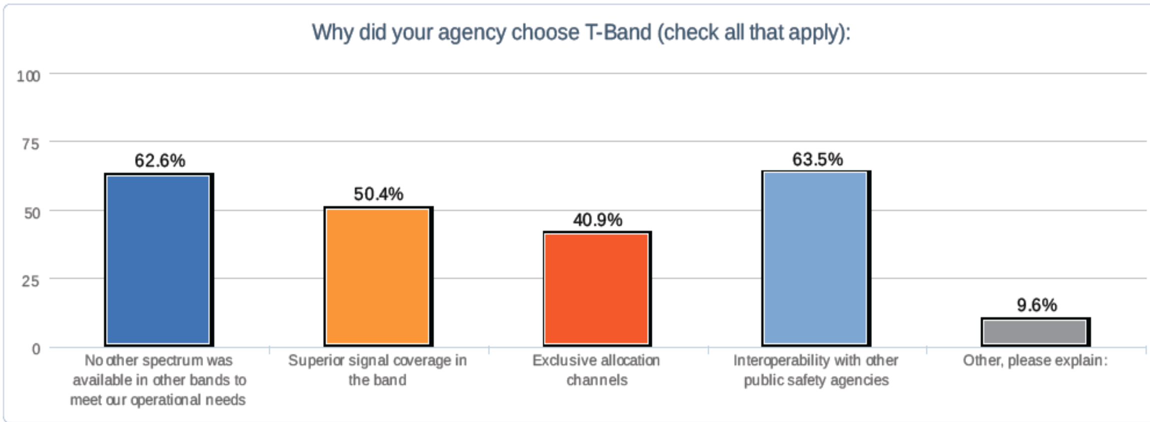
NPSTC requested information from public safety respondents on their ability to move off the T-Band as Congress has directed. The results show that over half of the agencies responding have no spectrum in their area, with an additional 16 percent having spectrum but no funding. At the time the questionnaire was completed approximately 30 percent of the respondents had not studied the problem. Given the multi-year timeline to plan and deploy a new public safety-grade system, it is clear there is much work to do in a relatively short period of time to comply with the Congressional direction. Lack of a clear and viable path in the immediate future places public safety at risk. As the T-Band systems age and the licensees' needs increase or change, the lack of a path will further exacerbate the risks.

18. Can your agency move off of the T-Band to another band? (do you have a solution available to you?)

Value	Count	Percent %
No. There is no spectrum available in our area to support our operations	62	53%
Yes. We have other spectrum we can move to; but have no funding	19	16.2%
Yes. We have other spectrum we can move to; and we have our own funding	1	0.9%
Unknown. We have not studied how we could comply with the Act.	35	29.9%

Statistics	
Total Responses	117
Skipped	39

Finally, NPSTC asked agencies why they selected the T-Band spectrum. The response as summarized in the following chart indicated a lack of other spectrum, superior coverage ability of the T-Band spectrum, access to protected use (exclusivity), and interoperability with other agencies were all found to be significant factors in the spectrum selection. As agencies search for alternatives to the T-Band (as required under the current legislation), these factors will continue to be critical.



19. Why did your agency choose T-Band (check all that apply):

Value	Count	Percent %
No other spectrum was available in other bands to meet our operational needs	72	62.6%
Superior signal coverage in the band	58	50.4%
Exclusive allocation channels	47	40.9%
Interoperability with other public safety agencies	73	63.5%
Other, please explain:	11	9.6%

Statistics	
Total Responses	115
Skipped	41

In summary, these results provide some additional insight into the complexity of the situation created by the legislative direction regarding the future of public safety use in the T-Band.

3. Evaluation of Potential Spectrum Alternatives

3.1 Overview of Spectrum Evaluation

NPSTC started an evaluation of potential spectrum alternatives to support public safety T-Band systems that are displaced by the law. This evaluation began with a focus on the current public safety bands, including the VHF, UHF, 700 MHz narrowband, 800 MHz, and the 700 MHz public safety broadband spectrum. Each of these bands has unique attributes, including some technical and regulatory issues. The following section addresses the environment and analysis in each frequency band.

3.2 The VHF Band (150-174 MHz)

While the VHF band is normally described as 150-174 MHz, local and state public safety agencies only have access to 3.6 MHz of spectrum out of the 24 MHz of total spectrum in this band. Over 12 MHz of the band is used by federal agencies. The remainder is used for maritime, aeronautical, industrial/land transportation/business, and other uses. The VHF spectrum is organized with channel centers normally located every 7.5 kHz with a channel bandwidth of 12.5 kHz. This results in overlap between adjacent channels. Geographic spacing is used on a frequency coordinated basis to help compensate for that adjacent channel spectrum overlap. Such spacing means that all channels would not normally be assignable in the same location. Equipment in this band had traditionally supported 25 kHz channels on centers spaced every 15 kHz, but narrowbanding requirements effective January 1, 2013, require an equivalent efficiency of at least one voice path per 12.5 kHz (unless the FCC granted an agency a waiver and extension of that date). As of January 1, 2013, most operations in the VHF band will be at 12.5 kHz efficiency and operate with a 12.5 kHz channel width. Mixed bandwidths are no longer prevalent but are still possible as the FCC has provided a limited number of waivers of the January 1, 2013, narrowband deadline.[4]

The VHF band is unique among the land mobile bands available to public safety in that there is no standardized pairing of base and mobile frequencies in the band. This is a historical artifact of the original organization of the band. That said, because of heavy existing usage, reorganizing the band to support standardized channel pairing would be a challenging, lengthy, and potentially costly process even though it would be beneficial and a laudable goal if it could be accomplished. Given the non-standard pairing, it is not unusual in the VHF band for one licensee to operate a base transmitter on the exact same frequency as another licensee's base receiver. Compared to other bands, including the T-Band in which standardized base/mobile pairing exists, the VHF environment creates a greater risk of interference and a more challenging environment in which to coordinate frequencies among multiple users over a given area.

The VHF band is heavily used, especially in populated markets including the 11 T-Band regions where demand for spectrum is the greatest. With 3.6 MHz of spectrum and channel centers spaced every 7.5 kHz, there are only about 480 channels in the band. Under FCC rules, these channels are mostly shared on a frequency coordinated basis. Theoretically, given the lack of exclusivity for any given licensee, public safety coordinators can continue to pack more and more systems on these channels. As a practical matter, however, doing so can increase interference among other users on the same or adjacent channels. Therefore, where possible, public safety frequency coordinators strive to ensure some geographic spacing between a newly proposed operation and existing operations on the same channel or the next adjacent channels. Accordingly, not all of the 480 channels in the band can be licensed in the same area without creating some interference. The Association of Public Safety Communications Official-International (APCO), which functions as one of the frequency advisory committees, provided the following summary of VHF licensing statistics by T-Band region:

[4] Also, the rules provide for equivalent efficiency on both voice and data. For example, a data system that meets a minimum equivalent efficiency of 4.8 kilobits per second on a 6.25 kHz channel, 9.6 kilobits per second on a 12.5 kHz channel or 19.2 kilobits per second on a 25 kHz channel would meet the narrowband requirement in the rules.

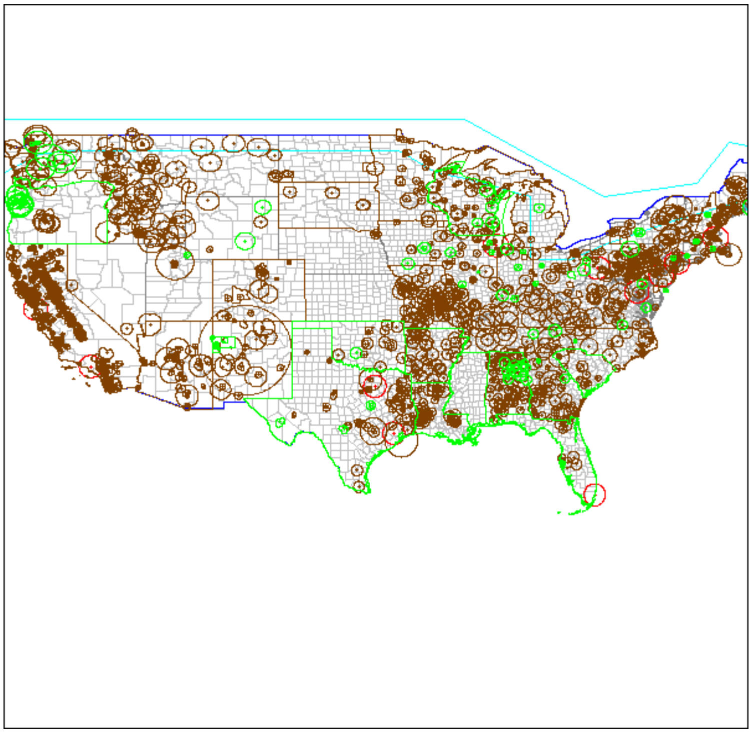
Table 3.1: VHF Licensing by T-Band Region

T-Band Market	VHF: Total PS Channels Licensed 50 mile Radius	VHF: Total PS Licenses 50mi Radius
Boston, MA	783	2612
Chicago, IL	698	4262
Dallas/Fort Worth, TX	594	2206
Houston, TX	588	2141
Los Angeles, CA	639	2176
Miami, FL	515	833
New York/N.E. NJ	799	4687
Philadelphia, PA	745	3889
Pittsburgh, PA	736	3804
San Francisco/Oakland, CA	615	2019
Washington, DC/MD/VA	669	1659

These statistics show that within the 50-mile radius that defines the scope of allowable T-Band base station locations, frequencies are already being re-used. This data also indicates that there are multiple licensees sharing a frequency. For example, the APCO data shows that in the New York area, 799 VHF channels are licensed. These numbers document the frequency reuse in this region, given there are a maximum of 480 public safety channels in the band and not all those channels would be available simultaneously in the New York area without interference. In addition, the data shows 4,687 licenses within the 50-mile radius of New York, which indicates multiple licensees are already licensed and sharing those channels.

Public Safety Coordination Associates (PSCA), International Municipal Signal Association (IMSA's) and the Forestry Conservation Communications Association (FCCA's) frequency coordination arm for public safety land mobile radio services, also conducted some analysis of the VHF public safety spectrum for NPSTC. This analysis used a commercially available computer program to examine each public safety VHF channel on a nationwide basis and rank those channels from "best" to "worst" with respect to adding more systems. The following map depicts licensed operations on the "best" VHF channel from this analysis. The red circles show the 11 T-Band areas and the brown and green figures depict existing licensed facilities on that channel. This "best available" channel, in the VHF band is already being used in 10 of the 11 T-Band urban areas. The Miami market is the only exception. However, even in that area, there are some statewide systems licensed with operations overlapping Miami, which can limit channel availability in that area.

Figure 1: "Best Available" Channel Map



This is an extremely challenging and crowded spectrum environment in which to try to accommodate the additional 1,054 channels for public safety use that would be displaced from T-Band. In summary, relying on the VHF band public safety spectrum to accommodate displaced T-Band systems is an untenable solution.

3.3 UHF Band (450-470 MHz)

Public safety is allocated only 3.7 MHz of spectrum out of 20 MHz that exists in the 450-470 MHz UHF band. Since the UHF spectrum is paired, the number of channels will equal one half the 3.7 MHz (1.85 MHz) divided by the channel width (12.5 kHz), yielding 148 channel pairs.[5] In the UHF band, the FCC rules also provide for an additional channel pair interleaved in-between these main channels. Under the rules, those additional 147 interleaved channels have a maximum channel bandwidth of 6.25 kHz.[6] Similar to the situation at VHF, mixed channel bandwidths exist in the UHF band.

APCO International provided NPSTC with some license statistics by T-Band region for the UHF band using the same process as they did for the VHF band. However, in the UHF band the APCO numbers reflect channel pairs, not unpaired channels as in the VHF statistics.

[5] As of January 1, 2013, FCC rules require licenses in the VHF and UHF band to operate with an efficiency of one voice path per 12.5 kHz of bandwidth or equivalent. The FCC has granted some waivers of the rule on a licensee-by-licensee basis to continue operating at an efficiency of one voice path per 25 kHz or equivalent. As of February 12, 2013, the FCC had granted only 28 such waivers to public safety and industrial/business licensees combined. Therefore, NPSTC bases it analysis of the UHF band on 12.5 kHz channel pairs.

[6] While the FCC VHF/UHF narrowbanding rules do not require public safety users to implement a 6.25 kHz efficiency, these additional 147 interleaved channels at UHF are limited in channel bandwidth to 6.25 kHz.

Table 3.2: UHF Channel Pairs In Use in Metro Areas

T-Band Market	UHF: Total PS Channel Pairs Licensed 50mi Radius	UHF: 12.5 kHz PS Channel Pairs Licensed within 50 mile radius	UHF: 6.25 kHz PS Channels Pairs Licensed within 50 mile radius	UHF: Total PS Licenses within 50 mile radius
Boston, MA	760	719	41	1148
Chicago, IL	741	691	50	924
Dallas/Fort Worth, TX	572	435	137	495
Houston, TX	536	475	61	448
Los Angeles, CA	843	722	121	897
Miami, FL	617	598	19	566
New York/N.E. NJ	770	722	48	2007
Philadelphia, PA	649	530	119	1488
Pittsburgh, PA	645	531	114	1531
San Francisco/Oakland, CA	774	712	62	842
Washington, DC/MD/VA	666	416	250	733

These statistics document that the UHF band is also heavily used in most of the T-Band markets. Depending on the market, the 148 channel pairs for 12.5 kHz operation are re-used between 3.2 times (Houston) to a maximum of 4.9 times (Los Angeles) within the 50-mile radius around each market center. The number of licenses issued in each market also indicates that public safety UHF channels are already being shared across more than one licensee in all T-Band markets except Houston. The number of T-Band channel operations would need to be re-accommodated and, added on top of the current UHF licensees, makes this potential solution also untenable. There is some unused capacity on the UHF channels limited to 6.25 kHz, as the statistics show public safety users exhibit a much greater demand for 12.5 kHz channels in the UHF band.

3.4 800 MHz Band

From a public safety perspective, the 800 MHz band is divided into sections. One section is known as the National Public Safety Planning Advisory Committee (NPSPAC) channels, so named because the National Public Safety Planning Advisory Committee defined the approach the FCC used in administering these channels when they were first allocated to public safety in 1984 under FCC docket number 84-1233. These channels were originally located at 821-824/866-869 MHz but are being transitioned to 806-809/851-854 MHz. The second section is known as the "interleaved channels" located at 809-815/854-860 MHz. There is also a section of “expansion band” channels located at 815-816/860-861 MHz and a section of “guardband channels” at 816-817/861-862 MHz.[7] This configuration in the 800 MHz band results from rebanding decisions.

800 MHz Band NPSPAC Channels:

The NPSPAC channels are supported by 3+3 MHz of spectrum in the 800 MHz band. There are 225 channel pairs in the band used for public safety operations and licensed on a site-by-site basis, plus five channel pairs reserved for use by all licensees specifically for interoperability and mutual aid. The band plan was designed to accommodate “modified” 25 kHz equipment on the 225 channels operating under tighter bandwidth/mask restrictions than normal because channel centers are spaced every 12.5 kHz. Geographic spacing is used in assigning adjacent channels to help compensate for the overlapping bandwidth channels. Regional plans for the NPSPAC channels are based on this approach. Over time, some users, but not all, have voluntarily transitioned to 12.5 kHz channel width equipment, which minimizes any adjacent channel overlap. Distinct from the 225 channels, the five designated NPSPAC interoperability channels are spaced at 25 kHz intervals.

Originally, the NPSPAC channels were located at 821-824/866-869 MHz. However, because of interference issues to high-site public safety systems from low-site commercial Enhanced Special Mobile Radio (ESMR) operations in other parts of the 800 MHz band, as well as an interest by ESMR licensees in holding contiguous spectrum, the FCC, public safety, and industry agreed on a plan for “rebanding” the 800 MHz spectrum. This plan maintained the same amount of spectrum but relocated various blocks of channels to separate public safety from ESMR operations. Under the plan, the cost of relocating public safety systems is borne by the predominant ESMR licensee, (i.e., Nextel, subsequently acquired by Sprint). The plan relocates the NPSPAC channels from 821-824/866-869 MHz to 806-809/851-854 MHz, and as discussed below, the rebanding process is still ongoing.

The NPSPAC channels may only be licensed based on the requirements of the associated regional plan. Within the U.S. and its territories there are 55 regions. The concept of allotting channels under a master plan developed by each region was designed to help maximize the available use of the channels by knowing up front the approximate number of channels each jurisdiction in the region needed. Adjustments must be made to the plan from time to time to accommodate additional requirements, and even with regional planning, the requirements outstrip the resources available.

The process of relocating public safety communication systems to alternative spectrum, even in the same band, has taken more than double the time originally envisioned when the FCC rebanding decision was adopted. The completion of 800 MHz rebanding, or lack thereof, is defined on a by region-by-region basis. Details on the status of rebanding can be found in periodic update reports

[7] The guardband channels are designed to separate high site public safety and industrial/business operations in the band from low site enhanced specialized mobile radio (ESMR) operations. Licensees locating in the guardband channels are subject to interference from adjacent ESMR operations starting at 817/862 MHz.

by the Transition Administrator, which the FCC designated to have oversight on the 800 MHz rebanding process.[8]

Whether operating on the original NPSPAC frequencies at 821-824/866-869 MHz or the revised NPSPAC frequencies at 806-809/851-854 MHz, these channels are heavily used. NPSTC analyzed the NPSPAC channel licensing across the 11 urban areas. For the analysis the Working Group examined licensing records for the 225 NPSPAC channels within a 70-mile radius of the T-Band market center coordinates. While T-Band operation is only allowed within a 50-mile radius, channel exclusion analysis must look further out. The analysis must consider both licensed facilities within the 50-mile radius and licensed facilities further out that would prevent assignment of the channel within the 50-mile radius to protect against co-channel interference. For purposes of the high-level NPSTC analysis regarding the NPSPAC channels, a 70-mile radius was chosen.

Given that public safety licensees operating on the NPSPAC channels are still in transition from 821-824/866-869 MHz to 806-809/851-854 MHz, licenses on both band segments were examined. If neither the original NPSPAC channel within the 821-824/866-869 MHz nor its counterpart channel in the new 806-809/851-854 MHz band segment shows a site-based licensed station within 70 miles of the metro center, the channel was counted as potentially available for T-Band relocation. Also, channels in the new NPSPAC spectrum at 806-809/851-854 MHz on which only site-based Sprint/Nextel channels are shown as a licensee are counted as vacant and reported separately in the table. These channels are also viewed to be potentially available following completion of the rebanding transition, since Sprint must vacate any channel it is using in the new NPSPAC band segment.

However, until 800 MHz band reconfiguration is complete in a given market, any frequency shown as "available" or licensed only to "Sprint Nextel" could in fact be active rendering it unavailable. The following table shows the results of that analysis. Cities denoted with an asterisk have not yet completed rebanding. Cities without the asterisk appear to be ones in which 800 MHz rebanding is complete or close to completion.

NPSTC believes this approach provides the best approximation of potential NPSPAC channel availability once the 800 MHz rebanding is concluded. Channel availability for any given system would need to be determined by more specific analysis incorporating actual technical parameters and specific site locations relevant to a channel at the time licensing was actually being pursued.

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[8] For example, see Transition Administrator Report, submitted to FCC January 2, 2013 in Docket No. WT 02-55. The Report shows the status as the 3rd quarter, 2012.

Table 3.4: 800 MHz NPSPAC Channel Availability

T-Band Market	Number of 800 MHz NPSPAC Channels (out of 225) Not Site Licensed within 70-mile radius of market	Number of 800 MHz channels in the new NPSPAC band licensed only to site-based Sprint/Nextel within 70-mile radius of market
Boston	31	33
Chicago**	8	4
Dallas	69	0
Houston	1	0
Los Angeles**	15	TBD, given special 800 MHz rebanding circumstances in this area
Miami**	29	0
New York	20	0
Philadelphia**	5	0
Pittsburgh**	9	3
San Francisco**	34	8
Washington, DC**	18	7
**** = 800 MHz Band Rebanding Incomplete**		

As shown in the summary table, some 800 MHz NPSPAC channels appear to be potentially available, but far fewer than are needed for T-Band relocation in most of the top markets. Also, it is possible that some of the channels that appear to be "potentially available" actually cannot be used because of various interference mechanisms. For example, in Los Angeles and San Francisco, the 70-mile radius over which we examined the channels may not have captured all operations within interference range, given the prevalence of high mountaintop sites in those areas. Further analysis would need to be done on a finer detailed basis to determine if these relatively few "potentially available" channels would actually be available.

<u>800 MHz Band Interleaved Channels</u>

In addition to the 230 NPSPAC channels, public safety has 70 channels in the "interleaved" portion of the 800 MHz band between 809-815/854-860 MHz. This spectrum is noted as the "interleaved" portion of the 800 MHz band because when the FCC rules were defined this block of spectrum included channels for public safety, industrial/business, and SMR operations all interleaved with one another.

The NPSTC Working Group used publicly available licensing information and a commercially available computer program to map out the licensed operations on the public safety interleaved channels. Including all of the maps generated for all public safety interleaved channels in all 11markets in this report would be overwhelming. A summary of the results is provided and the following sample maps can be used to depict the approach used to do the analysis of channel availability.

Each map includes a 50-mile radius circle depicted in red. That is the area within which T-Band base stations may be located under the current rules.[9] The green contours on the map show the service area (coverage contour) of a licensed station on the 800 MHz channel being analyzed. The blue contours depict adjacent channel licensed systems. Viewing the map with coverage contours of existing stations provides an indication of whether the channel is already in use and would block deployment of any relocated T-Band stations.[10]

The following sample map depicts current licensing on one public safety 800

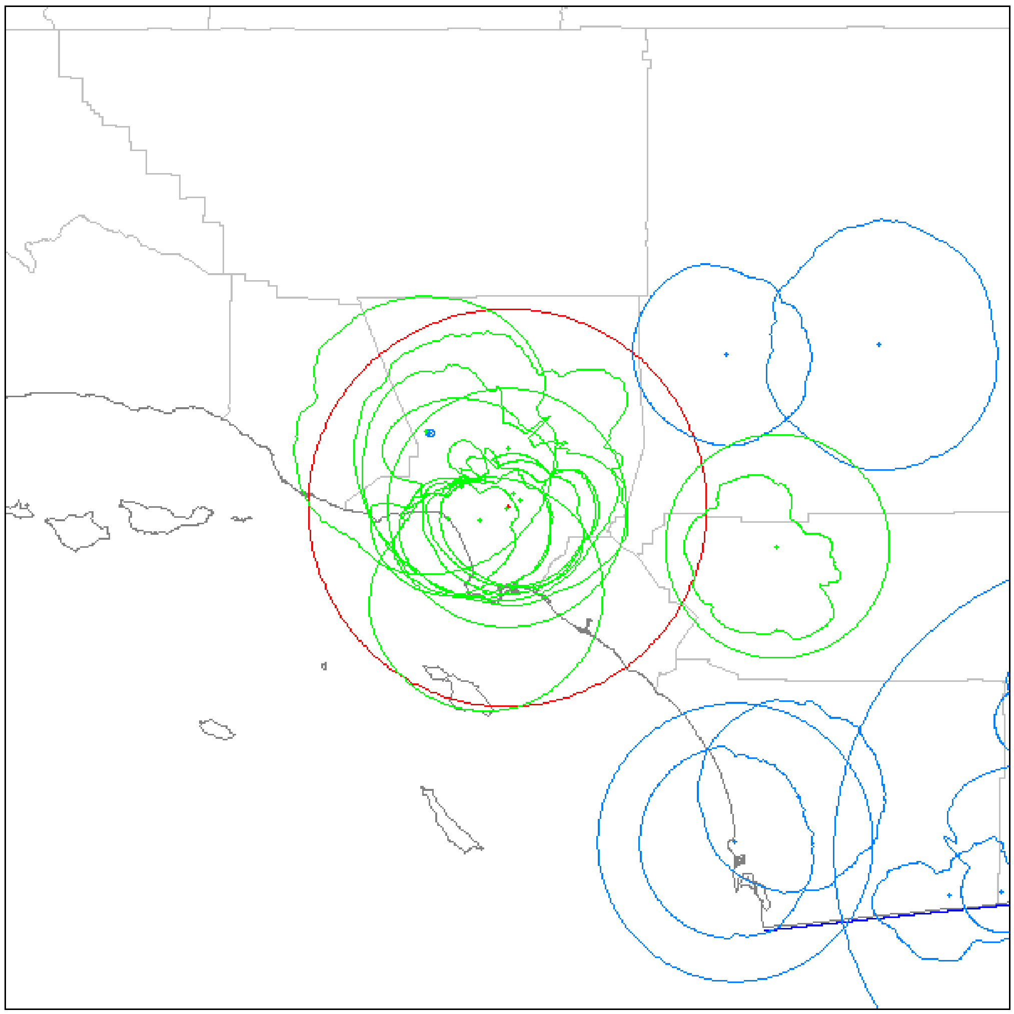

Figure 1: Los Angeles 856.2375 MHz

[9] Over the years, FCC has granted a few case-by-case waivers to locate base stations beyond the standard 50 mile radius.

[10] Actually, it is the interference contour that is used to define channel availability. A station's interference contour extends beyond its coverage contour. To minimize the risk of interference, a proposed station's coverage contour cannot overlap an incumbent station's interference contour and vice-versa.

MHz band interleaved channel. As seen from the map, this channel is already occupied and unavailable to accommodate a system potentially relocated from the T-Band.

In contrast, the following map from Pittsburgh indicates it might be possible to add additional sites in the lower portion of the 50-mile circle, if there were demand for a site in that area. Additional analysis would need to be made to confirm if there are any reasons the spectrum appears not to be in use in that area.

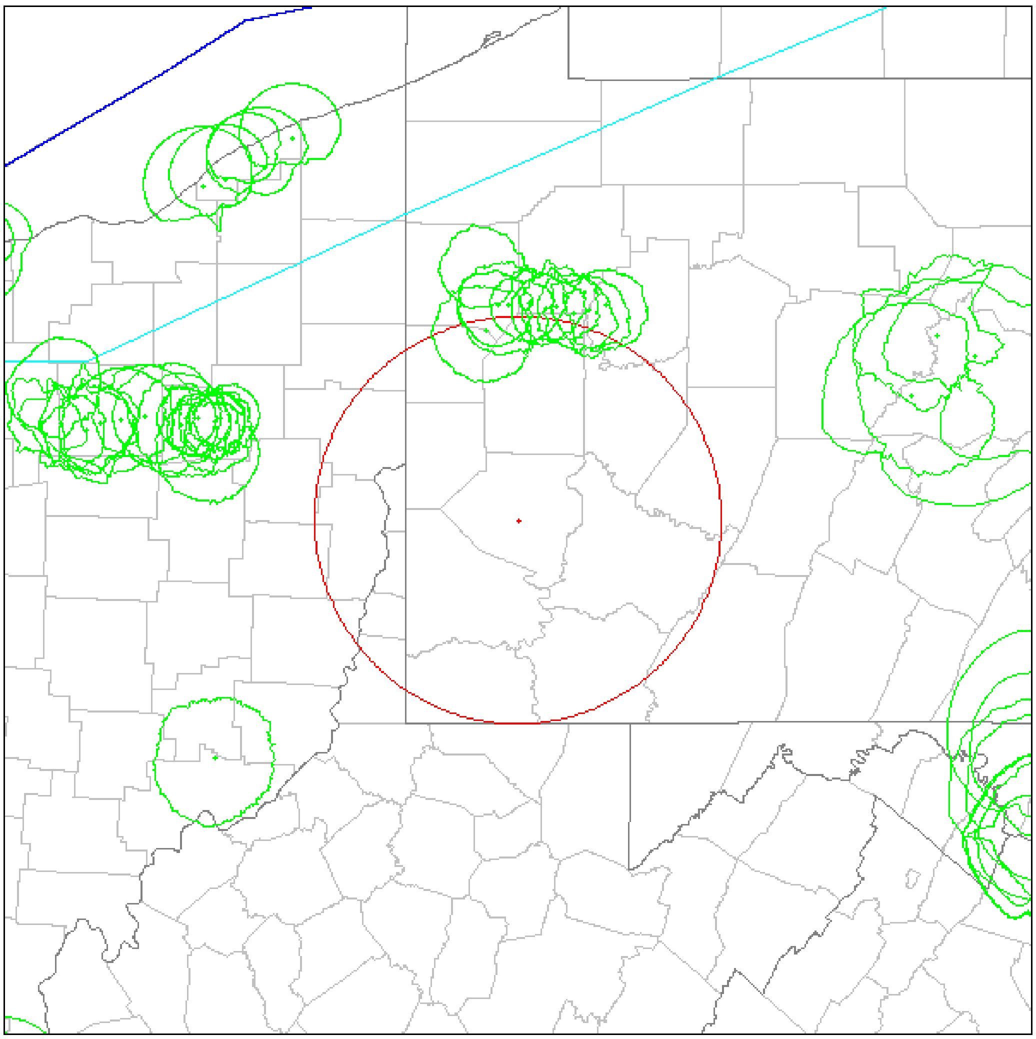

Figure 2: Pittsburgh 854.9875 MHz

These types of maps were generated as described above for each of the 70 channels allotted to public safety across the 11 T-Band markets.[11] These maps were then manually reviewed to

[11] Actually, given the ongoing status of 800 MHz rebanding, analysis for the 70 public safety interleaved channels required generation and review of maps for 82 channels in each market. Of the 70 interleaved channels originally allocated for public safety, 58 are common to "before 800 MHz rebanding" and "after 800 MHz rebanding" scenarios. To round out the 70 channels, there are 12 interleaved channels previously used for public safety that will transition to SMR use and a replacement set of 12 SMR interleaved channels that will become public safety channels. All 82 channels were reviewed

determine if a channel is “open” or “partially open.” Channels fitting neither description are considered “closed” for purposes of re-accommodating T-Band users.

The following approach was used in the manual review of the maps. If no licensees were found within the 50-mile radius circle, the channel was counted as “open.” A partially open channel would be one that has an existing licensee located such that another system could potentially be licensed in select portions of the area defined by the 50 mile radius circle. 800 MHz co-channel systems are normally spaced at 70 miles, except when systems are “short-spaced” at closer distances based on more detailed engineering analysis. Short-spaced systems are generally placed no closer than approximately 50 miles from a co-channel neighbor. Accordingly, in reviewing the channel maps the presence of a licensed 800 MHz system in or near the center of the 50 mile radius circle would mean that the channel is already taken and most likely to be unavailable for T-Band relocation. Those channels were counted as “closed.” Similarly, if there are two or more existing 800 MHz systems licensed on opposite sides near the outer edges of the 50 mile radius circle, it is also unlikely that another system could use the channel elsewhere within the 50 mile radius of the market under study. Those situations were also counted as the channel being “closed.”

Review of the maps for all 70 channels across all eleven T-Band areas shows vacant channels in the 800 MHz interleaved spectrum are relatively few and far between. Table 3.5 summarizes the findings on the number of interleaved channels out of the 70 allotted to public safety that are open or partially open. It is possible that some of the open or partially open channels shown are still in the midst of the transition of being converted as part of the 800 MHz rebanding, (i.e., the channel has been cleared of its former operation but is not yet supporting the new operation).

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and judgment was used on which block of 12 were applicable to public safety at this point, based on the status of rebanding. The numbers in Table 3.5 are relative to a total number of 70 channels.

Table 3.5: Analysis of the Public Safety 800 MHz Interleaved Channels

T-Band Market	800 MHz Interleaved Channels Open	800 MHz Interleaved Channels Partially Open	T-Band Channels Licensed in Market that Need to Be Re-accommodated
Boston	0	0	596
Chicago	0	1	279
Dallas	3	5	55
Houston	3	0	7
Los Angeles	0	0	546
Miami	1	1	43
New York	1	0	1054
Philadelphia	1	7	790
Pittsburgh	3	5	107
San Francisco	3	2	216
Washington, DC	1	2	129

As part of the FCC's rebanding of the NPSPAC band, Sprint/Nextel was required to relinquish all spectrum it holds below the guardband, i.e., below 817/862 MHz. That part of the spectrum is already used extensively by both public safety and industrial/business licensees. However, to the extent that a relinquished channel is not encumbered by another non-Sprint/Nextel licensee, public safety will have access to the released spectrum in the interleaved band (809-815/854-860 MHz) and the expansion band (815-816/860-861 MHz). The amount of released spectrum varies by region and the incumbent license issue is more acute in the urban areas. Also, new licensees would be constrained to fit within the footprint of the Sprint/Nextel operation that moved off the vacated channel. It is expected that many existing public safety 800 MHz operators will license and include these vacated channels in their communications systems. Public safety has first right to any of these vacated channels for 3 years. Otherwise the vacated channels will be available to industrial/business licensees well before any T-Band transition. The vacated channels are made available on a region-by-region basis. To date, the demand has generally exhausted the supply of channels when they are made available.

Positive FCC action on the Enterprise Wireless Alliance (EWA) Petition for Rulemaking to add interstitial channels into the interleaved spectrum at 800 MHz could create some additional channels for public safety and industrial/business use.[12] Deployment of new interstitial channels would need to be geographically spaced a sufficient distance from the existing adjacent channel deployments to avoid interference, except in cases where systems on the existing interleaved channels are already voluntarily operating with 12.5 kHz channels. Under existing FCC rules, licensees on current 800 MHz band interleaved channels are allowed to operate at 25 kHz efficiency and bandwidth. The resulting channel availability in the core T-Band areas could be further improved as public safety licensees on the existing 800 MHz interleaved channels voluntarily migrate to Project 25 (P25) operations with 12.5 kHz channels. Doing so reduces any geographic spacing that otherwise would be required between 25 kHz wide operations on current interleaved channels and the new interstitial 12.5 kHz channels EWA has proposed. The EWA petition is a positive step and should be pursued even though it would not solve the spectrum shortfall in all areas.

3.5 700 MHz Narrowband Spectrum

Public safety is allocated 6+6 MHz of 700 MHz narrowband spectrum located at 769-775/799-805 MHz. The FCC rules defined a building block channel plan in which the underlying structure consists of 960 building blocks, each 6.25 kHz wide. These 6.25 kHz building blocks can be aggregated to accommodate 12.5 kHz and 25 kHz channel widths. Most operations in this spectrum today use 12.5 kHz channels and the P25 standard. Based on that channel width, there are 480 channel pairs in the band. A portion of those are beginning to use the P25 Phase 2 trunking standard which operates at a 6.25 kHz equivalent efficiency by placing two traffic slots within the 12.5 kHz channel. Under current FCC rules at the time this report was drafted, 700 MHz narrowband licensees are required to transition to an efficiency of 6.25 kHz per voice channel or equivalent starting by December 31, 2016. There have been requests from some public safety entities to delay that date and FCC has indicated it expects to address the issue in the near term.

The 700 MHz narrowband spectrum is divided into four types of channels. These include General Use channels, designated state channels, interoperability channels, and a portion of the band currently held as reserve channels. The 700MHz General Use channel pairs are subject to regional planning and are licensed on a site-basis. That is, FCC licensing records depict specific frequencies at specific sites. In contrast, 700 MHz narrowband designated state channels are licensed as "wide area" channels which may be used over the states' entire jurisdiction. Information on specific sites and frequencies at each site is not included in the FCC license database. Accordingly, minimal analysis that can be done regarding licensing and use of the designated state channels without additional knowledge of deployment beyond that which appears in the FCC licensing records. Current FCC rules provide that state channels not built out to certain levels of use by certain

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[12] Petition for Rulemaking filed by the Enterprise Wireless Alliance (EWA) on April 29, 2009. The FCC issued Public Notice DA 09-2183 on October 8, 2009 assigning rulemaking number RM-11572 and requesting comments on the Petition.

deadlines be added to the General Use channel pool and then would be subject to regional planning. Specifically, by June 13, 2014, a state must be providing or prepared to provide substantial service to one-third of the state's population or territory. Similarly, by June 13, 2019, a state must be providing or prepared to provide substantial service to two-thirds of the state's population or territory. State channels not used in a system meeting these benchmarks would be added to the General Use channel pool and be subject to regional planning. There are also reserve channels not made available. One jurisdiction recently petitioned the FCC to release those reserve channels so they may be used as part of a re-accommodation of T-Band operations.[13] The following chart depicts the breakout of these categories, the amount of spectrum and number of channels in each category:

Table 3.6: Categorization of 700 MHz Narrowband Channels

700 MHz Channels	Channel Pairs				
	Total (MHz)	**If 6.25 kHz or equiv CHs**	**If 12.5 kHz CHs**	**If 25 kHz CHs**	**Notes**
General Use	7.70	616	308	154	Digital Primary, Subscribers Analog Secondary
State	2.40	192	96	48	Digital Primary, Subscribers Analog Secondary
Interoperability	0.80	0	32	0	P25 FDMA Primary, Subscribers Analog Secondary
Reserve	0.80	64	32	0	Digital Primary, Subscribers Analog Secondary [Note: only 24 - 12.5 kHz channels remain. The other 8 have already been dedicated]
Low Power	0.30	24	12	6	No Base, Subscribers Analog or Digital Primary
Total	**12.00**				

[13] Public Notice: Public Safety and Homeland Security Bureau Seeks Comment on Request for Waiver by Los Angeles Regional Interoperable Communications System Joint Powers Authority to Apply for 700 MHz "Narrowband Reserve Channels", DA 13-39, RM-11433, released January 11, 2013.

700 MHz General Use Channels

The Working Group examined the relevant 700 MHz narrowband regional plans applicable to the areas in which a T-Band system would need to be relocated under the legislation. In the 700 MHz regional plans, a computer program known as CAPRAD (Computer Assisted Pre-Coordination and Resource Database System) was used to allot channels primarily on a county by county basis nationwide. NPSTC's analysis compared the channels allotted in the regional plan in a given county to those actually licensed in the same county. Whether or not channels allotted but not licensed are actually available can also depend on whether those channels are licensed in another county in the area where T-Band operations would need to be relocated. Therefore, information on licensing of allotted channels in a nearby county was also captured. While the CAPRAD program shows channel allotments in terms of 25 kHz channels for a number of regions, NPSTC converted those to 12.5 kHz allotments given the predominant operations in the band are at 12.5 kHz channel widths. In other words, an allotment on 40 25 kHz channels in CAPRAD would be shown as 80 12.5 kHz channels in the following table. In a few regions CAPRAD showed a mix of 25 and 12.5 kHz allotments for a county.

Also, note that the aggregate number of frequencies allotted across multiple counties in region could be more than the 308 General Use channels (at 12.5 kHz) shown in Table 3.6 above as a result of frequency re-use in the 700 MHz region.

Table 3.7: Breakout of the Public Safety Narrowband Spectrum by Channel Categories

T-Band Market	700 MHz General Use Channel Pairs Allotted in Plan to Counties within 50 Mile Radius (Based on 12.5 kHz CH Pairs)	700 MHz General Use Channel Pairs Allotted in Plan to Counties within 50-Mile Radius but Not Yet Licensed (based on 12.5 kHz CH Pairs)	T-Band Channel Pairs Licensed in Market that Need to Be Re-accommodated
Boston	164	164	596
Chicago	183	153	279
Dallas	92	44	55
Houston	201	90	7
Los Angeles	342	203	546
Miami	136	93	43
New York	368	261	1054
Philadelphia	575	473	790
Pittsburgh	140	140	107
San Francisco	346	216	216
Washington, DC	220	147	129

As shown in the Table 3.7, there are some 700 MHz narrowband General Use channels allotted and not yet licensed., While these channels may serve as a home for relocated T-Band systems, it should be noted that some of these channels could be designated to accommodate planned expansions of the existing 700 MHz systems - and are therefore not a resource for T-Band relocation planning.

Furthermore, as noted above, 700 MHz general use channels were purposely pre-allotted by county and the resultant plan was submitted to the FCC for each 700 MHz region. T-Band spectrum was not allocated in this manner. Each region's T-Band spectrum was available for each licensee in every county covered by the 50-mile radius. Table 3.7 adds up all the 700 MHz channel pairs pre-allotted for each county covered by the 50-mile radius and compares 700 MHz General Use channels allotted but not yet licensed to the T-Band channel requirement. This provides some general information about the potential channel availability in the 700 MHz General Use spectrum. However, until coverage analysis for each existing T-Band system is completed, it will not be known how many existing T-Band licensees will require channel resources from more than one 700 MHz county allocation in order to replace a single T-Band channel pair.[14] Also, spectrum availability is site-specific. Therefore, a more detailed system-by-system analysis of T-Band operations would be needed to confirm the actual adequacy of 700 MHZ band channel availability. The current analysis provides a rough order of magnitude perspective instead

If all these channels thought to be available were in fact available, the Boston, Chicago, Los Angeles, New York, and Philadelphia metro areas would still face a shortfall in the number of channels needed to re-accommodate their T-Band operations.[15] Dallas, Houston, Miami, Pittsburgh, San Francisco, and Houston might have sufficient channels to accommodate their displaced T-Band systems if all channels were available. NPSTC believes, based on interviews with user agencies and frequency advisors, that many of these "available" channels are already designated to support expansion of existing systems.[16]

3.6 700 MHz Broadband Spectrum

Public safety has 10+10 MHz of spectrum in the 700 MHz band specifically designated by Congress to support the deployment of a Nationwide Public Safety Broadband Network (NPSBN). An entity designated as the First Responder Network Authority (FirstNet) is charged with determining the

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[14] For example, channels may appear to be available in a given market, but may not actually be available at the specific location or locations needed in that market.

[15] These shortfalls could be partially addressed by the deployment of interoperable P25 Phase II trunked systems that operate in a 2 slot TDMA mode with an equivalent spectrum efficiency of one traffic path per 6.25 kHz. That would require the conversion of mostly conventional T-Band systems to trunking which could impact specialized operations such as fire ground communications which typically use conventional technology.

[16] NPSTC notes that a Working Group member indicated difficulty in finding 700 MHz channels available in the Houston area. However, given the relatively small number of T-Band channels used by public safety in the Houston area, NPSTC has not included that metro area as one where a spectrum shortfall exists, for purposes of this report. As noted in the report, all channel availability is location-specific and the NPSTC initiative did not attempt to analyze spectrum availability for a particular licensee.

design, deployment, operation, and maintenance of this public safety broadband network. FirstNet was created in legislation signed into law in February 2012 and in August 2012 the Board of FirstNet was named.

The technology chosen for the broadband network is called Long-Term Evolution (LTE) and is also being deployed in most commercial systems. Standards for LTE are defined by the Third Generation Partnership Project (3GPP). Standards work involves setting priorities on what features or aspects of the technology will be considered for standardization under what schedule. Given that LTE is a global standard, the 3GPP includes standards bodies from around the world that help define the priorities and schedule.[17] The LTE standard has been focused primarily on data, not voice. Even when commercial-grade LTE voice standards are defined, they are distinct from mission critical voice operations of the type currently supported in the T-Band spectrum. While 3GPP is aware of public safety requirements, as of the development of this report, a specific plan and timeline to define mission critical voice standards in 3GPP has not yet been created or approved. The following trade press report referenced standards activities with respect to public safety:

> "At its December [2012] workshop, the Third Generation Partnership Project (3GPP) Technical Specification Group (TSG) Service and System Aspects (SA) identified three key strategic areas for LTE Release 12. One of these areas was public safety, including proximity services (direct mode) and group communications (push to talk or PTT). **Mission critical voice was not added** to Release[12], but direct mode and PTT are two features essential to public safety."[18] [*Emphasis added*]

In February 2012, the U.S. Government Accountability Office (GAO) issued a report that underscored the tentative nature of mission critical voice operations on the planned broadband network. That report, entitled *Emergency Communications, Various Challenges Likely to Slow Implementation of a Public Safety Broadband Network*, noted the following:

> "Multiple federal entities are involved with planning a public safety broadband network and while such a network would likely enhance interoperability and increase data transfer rates, it would not support mission critical voice capabilities for years to come, perhaps even 10 years or more. A broadband network could enable emergency responders to access video and data applications that improve incident response. Yet because the technology standard for the proposed broadband network does not support mission critical voice capabilities, first responders will continue to rely on their current LMR systems for the foreseeable future. Thus, a broadband network would supplement, rather than replace, current public safety communication systems." [19]

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[17] The 3GPP member from the United States is the Alliance for Telecommunications Solutions (ATIS).

[18] http://www.pscr.gov/about_pscr/press/broadband/public_safety_makes_big_strides_in_lte_standards_process_012013-missioncritical_communications.pdf

[19] GAO Report, 12-343, February, 2012, summary page titled "What GAO Found."

Once broadband mission critical voice standards are finalized, the associated technology is developed and confirmed in the public safety environment, deployment to provide the requisite coverage is essential. Planning of the nationwide public safety broadband network is still expected to take some time and a deployment schedule has not been defined. Therefore, the timeline for the network to provide coverage comparable to that provided by today's T-Band systems is not yet known. The degree of required reliability and hardening, as well as operational management of the network in a given metro area, is also yet to be defined.

The use of broadband emissions reduces the coverage obtained from each transmitter site, compared to that of a typical land mobile site. The actual ratio varies by a number of factors related to terrain, type of coverage, and data rate required, etc. Those factors still need to be decided for the broadband network. The number of sites is expected to be greater for broadband but the magnitude of the increase is not yet known.

NPSTC fully supports the development of a robust broadband network that is designed and deployed to meet public safety requirements. Such a network will bring significant increased functionality in the form of high-speed data and video capacity not attainable on current public safety spectrum allocations and systems. That said, it is not clear yet when and if the broadband network would support mission critical voice operations at coverage and reliability levels comparable to that of today's T-Band land mobile networks. Furthermore, it is not clear how much capacity will be required to accommodate mission critical voice over broadband and whether the broadband network will have sufficient capacity for public safety's net communications requirement. Accordingly, public safety entities in the NPSTC T-Band Working Group concluded it is premature to rely on the 700 MHz nationwide public safety broadband network as a viable operational alternative and relocation home for critical voice operations now supported on the T-Band spectrum.

3.7 Spectrum Evaluation Conclusions

Analysis of the various potential spectrum options, compared to the current T-Band spectrum resources required, indicates that loss of the T-Band and forced relocation to other spectrum will present great challenges to public safety. Public safety T-Band licensees in the greater Boston, Chicago, Los Angeles, New York, Philadelphia, and San Francisco metro areas will face the most difficult challenge as T-Band usage in those markets is the greatest. NPSTC's analysis shows that T-Band usage is somewhat less concentrated in the Dallas, Washington DC, Houston, Miami, and Pittsburgh regions.

Of the potential alternative spectrum analyzed, VHF, UHF, and the 800 MHz band have practically no available channels. As discussed in section 3.6, positive FCC action on the EWA Petition for Rulemaking to add interstitial channels into the interleaved spectrum at 800 MHz could create additional channels for public safety and industrial/business use. NPSTC agrees the FCC should move the EWA petition to the next step, but notes that the resulting interstitial channels would not totally solve spectrum shortfalls resulting from a reallocation of the T-Band public safety spectrum.

Deployment of those interstitial channels would need to be geographically spaced a sufficient distance to avoid interference with existing operations on the current interleaved channels, except in cases where systems on the existing interleaved channels are already voluntarily operating with 12.5 kHz channels. Under existing FCC rules, licensees on current 800 MHz band interleaved channels are allowed to operate at 25 kHz efficiency and bandwidth.

The 700 MHz narrowband General Use spectrum not yet licensed is insufficient to compensate for loss of the T-Band public safety channels in the Boston, Chicago, Los Angeles, New York, and Philadelphia metro areas. Those areas would still face a shortfall of spectrum. Accommodation of any displaced public safety T-Band systems in San Francisco, Washington, DC, and Pittsburgh on 700 MHz General Use channels appears to be marginal. Based on the analysis, it appears that public safety T-Band users in the Dallas, Houston, and Miami metros may have sufficient spectrum if forced to move off of T-Band.

Further analysis on the availability of designated 700 MHz state channels might provide additional insight. However, even if all 96 of the 12.5 kHz state channel pairs were open, there would still be a spectrum shortfall in the Boston, Chicago, Los Angeles, New York, and Philadelphia metro areas. The wide-area approach to licensing these designated state channels provides little detailed information from FCC licensing information that can be analyzed.

As addressed in Section 3.6 above, the Working Group concluded that is premature to consider the 700 MHz broadband network being planned as a viable alternative home for mission critical voice operations supported by the T-Band spectrum.

In view of the above analysis of the bands available to public safety, NPSTC focused its cost analysis of the impact of the legislation on potentially relocating T-Band operations to the 700 MHz narrowband spectrum.

4. Relocation, Cost, Timing, and Process

4.1 Introduction

The cost associated with public safety's relocation out of the T-Band is of paramount importance. The Act requires that the FCC auction the T-Band spectrum and that the proceeds from the auction "cover relocation costs for the relocation of public safety entities from the T-Band spectrum."[20] Given the scarcity of state and local funding for such relocation it is critical to understand the cost associated with a complete transition out of the T-Band. This funding must provide the T-Band licensees with comparable facilities, thus maintaining their current capabilities. As a result, the T-Band Working Group established a Cost Task Group to estimate the cost to transition out of the T-Band.

[20] PL 112-96 Section 6103 Paragraph (b)

In order to assess the cost, we must understand the master plan to determine the expected scope of work and ultimate transition cost. The target band has a substantial impact on the cost of the transition. Based on the studies of the Working Group, the public safety narrowband 700 MHz spectrum represents the most potentially viable alternative for current T-Band operations. Therefore, the Cost Task Group assumed that all T-Band systems migrated to 700 MHz narrowband systems in its cost estimates.

For 800 MHz rebanding, the vast majority of subscriber devices could be reconfigured to access the target spectrum in the 800 MHz band. In contrast, a transition to 700 MHz requires all radios to be replaced.[21] In addition, a "domino effect" for network infrastructure would occur that would start from a replacement of the antennas, base stations, and perhaps also the core network components due to a 700 MHz move. This factor makes the T-Band transition far more complex than the 800 MHz rebanding transition which is still in progress.

The NPSTC T-Band questionnaire asked respondents for the estimated total investment of items that would need to be replaced if they left the T-Band. This can serve as a proxy for the total cost for transition, but the general nature of the question logically excluded some costs. Furthermore, the questionnaire only represented some 300 licensees. The results indicated that a total of $2.9 billion had been invested in "replacement" equipment. This partial response provides some indication of the magnitude of the expected costs.

Unfortunately, with roughly 1,000 licensees, NPSTC lacks the resources for a comprehensive analysis of the transition cost for each licensee. As a result, the Task Group determined that it should approximate the cost and make assumptions based on available data. The two pieces of information available to the Task Group are the FCC's ULS data and the NPSTC questionnaire results. These two sources of information allow reasonable accuracy for the purposes of addressing the rough order costs; however, they are inadequate to determine highly accurate cost estimations. A number of additional pieces of information would be required for each existing system to determine what would be required to provide each licensee with "comparable facilities" in 700 MHz. For example:

1. Does the system use satellite receivers? While the questionnaire collected such information, NPSTC only received responses from roughly 30 percent of the T-Band licensees. Therefore, how do we extrapolate the costs associated with transitioning a satellite receiver?
2. What other frequency bands does a current T-Band licensee need to be interoperable with after transition? Will all of their mutual aid partners also migrate to 700/800 MHz, or will some remain in UHF, and thereby require multiband radios for all in the region?

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[21] The Working Group expects that a very small minority has multiband (UHF and 700/800) radios that could operate on both the T-Band and 700 MHz.

3. Do the T-Band licensees also operate UHF (450-470 MHz) channels in their systems? If so, does the transitioned 700 MHz system require those additional channels? How many channels are included in this transition?
4. What type of radio is used in the T-Band? How many have encryption?
5. Is the system simulcast?

There are many other questions that are analyzed in this document to estimate the costs. Because the Task Group lacked the answers to these detailed questions for all licensees, it made logical assumptions to estimate the costs. Those assumptions are provided throughout this document. The Working Group, with membership of public safety professionals from across the county, tried to simplify the model to the greatest extent possible. Therefore, where the cost differential was not substantially impacted, assumptions that made the model less complex were chosen. For example, mobile and portable radios have different costs, but when the total costs are considered, the cost difference between a portable radio deployment (with all of its accessories) and a mobile deployment (with installation costs) was deemed to be negligible, and therefore, there was no effort to split costs by radio type.

4.2 Types of Systems

The ULS database lists approximately 1,000 public safety licensees in the T-Band. Of these licensees, 93 percent are designated as conventional and 7 percent are trunking systems. The questionnaire conducted by the Working Group showed that 133 of 172 respondents, or 77 percent, use conventional systems. Another, 34 respondents, or nearly 20 percent, use both conventional and trunked systems. Clearly, the vast majority of these T-Band licensees and the NPSTC respondents' systems are conventional. A common practice in the T-Band for these conventional systems is the use of satellite receivers.[22] The vast majority of all conventional systems in the T-Band are analog.

While the ULS database does not indicate if a system is voice or data, the NPSTC questionnaire indicated that the vast majority of the T-Band systems are voice only. Of 174 responses,[23] 135 (78 percent) indicated their systems were "voice only." The majority of the remaining systems are likely to be both voice and data. However, there are other uses of the T-Band by public safety. For example, paging and alerting systems operate in the band. And with no 700/800 MHz paging solutions, these systems would have to transition to the remaining UHF band (450-470 MHz). Unfortunately, neither the NPSTC questionnaire, nor the ULS database provided data on the quantity of paging systems. To simplify the model, all systems are assumed to be voice land mobile radio systems.

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[22] "Satellite" receivers in this context are additional land-based fixed receive sites beyond those already deployed at base transmitter locations.

[23] Note that a different number of questionnaire respondents responded to each question. In total, more than 300 responses were obtained. In this case, 172 responded to the question regarding whether the system was conventional or trunked, 174 responded to the question as to whether the system was voice, data, or both.

Due to the FCC freeze on T-Band activities in 2012 and the impending T-Band transition, existing T-Band licensees may be more likely to hold off on upgrades of their systems. As a result, the Working Group surmised that the existing systems are likely to be the same systems that must be transitioned in time to meet the law's requirements. Therefore, it is the current systems that will dictate "comparable systems" and will also determine the likelihood of replacement of the systems. Radio systems are seldom "standalone." As a result, a change in a radio system has implications on other supporting systems. These systems include:

- Computer Aided Dispatch (CAD): Some radio systems are interfaced with CAD systems to provide push-to-talk information, emergency triggers, etc.
- Logging Recorder: Public safety systems have voice logging recorders for evidentiary purposes. These recorders must integrate with the radio system to receive audio and talkgroup information (on trunking systems).
- Fire Station Alerting: Many fire station alerting systems leverage radio systems for delivery of audio and other communications.
- SCADA (Supervisory Control and Data Acquisition) Systems: Many land mobile radio systems support supervisory control and data acquisition systems.
- Vehicular Repeater Systems (VRS): These systems include back-to-back "radios" that provide coverage enhancements at an incident scene. Changes in frequency could impact the VRS system and require a replacement.
- Bi-Directional Amplifiers (BDAs): BDAs are generally unaffected by the content of an amplified signal, but they are highly impacted by a change in frequency. T-Band BDAs are particularly susceptible to frequency changes because they often have custom filters and duplexers for each licensee. The impact of BDAs is complicated by building codes requiring public safety coverage improvements borne by building owners. These costs must be addressed as part of the overall plan.
- Distributed Antenna Systems (DAS): Distributed antenna systems can include leaky coaxial cable, fiber to RF conversion electronics, antennas, and BDAs. Leaky cable can be "tuned" to specific frequencies but may not support the "target" band. Likewise antennas are often "narrowband" and support only the current band. These systems may require a wholesale change-out unlike broadband fiber optic and copper cables.
- Ancillary Systems: Air conditioning, generators, battery backup, alarm systems, and other systems supporting the central and remote equipment may be impacted by the transition.

4.3 Cost Model Overview

At a high level, the cost model is based on the scope of work of the transition itself. It identifies what needs to be replaced and the work performed in order to move public safety from its current T-Band systems to other bands. The model factors in the cost of each item and the quantity of items to arrive at the net cost per item. **Furthermore, public safety requires continuous operations, requiring a new system to be completed prior to the migration and further impacting**

costs. The aggregation of the item costs for a region results in the total transition cost for that region.

The model considers each unique licensee as having its own system. When a single licensee has licenses for both conventional and trunking systems, that licensee is considered to have two systems. The Cost Task Group did not know the makeup of these systems, and therefore, for each licensee, all conventional licenses assigned to the same licensee were assumed to be the same "system" and all trunking licenses were assumed to be the same "system" for a single licensee. The model calculates the transition cost for each system based on the number of channels, sites, repeaters, and mobiles (subscriber radios) that appear in the ULS database. In addition, several other regional costs are included in the model.

The model uses the numbers from the FCC ULS except where Working Group members had specific knowledge of the deployed assets. A more detailed inventory process would be required to enable greater refinement of the actual costs. The model envisions that this enhancement of the cost estimation would occur during a planning process. The following table provides the high-level groups of costs included in the model:

Table 4.1: High Level Cost Model Groups

Cost Group	Description	Calculation Methodology
System	System costs must account for centralized costs (e.g., core network hardware, software, overall project management, switching gear, installation, etc.).	Quantities equivalent to number of unique licensees in ULS per licensee. System quantities differ based on the size of the system (small, medium, large, and very large) and whether the existing system is conventional or trunked.
Site	Site costs are those associated with ancillary support systems to house the RF components. They include towers, shelters, microwave, and other costs. Sites may also require upgrade or replacement to reliably support the equipment.	Based on the number of transmitter sites in ULS per licensee. The site costs include additional coverage sites and sites requiring upgrade or replacement due to the dual system loading. The site costs factor both transmit/receive sites and receive only (known as satellite receive sites).
Repeater	Items associated with the Radio Frequency portion of the fixed infrastructure. This includes the base station, cables, combiners, receivers, and antennas.	Quantities based on the number of base stations in ULS per licensee. These quantities were added to repeaters associated with new coverage sites and other UHF channels. The cost of these items varies based on the quantity of base stations and whether they are trunking or conventional. Receivers associated with satellite receive sites were also added for conventional systems.
Mobile	The mobile cost includes typical functionality associated with the portable and vehicular radios. These costs vary substantially by the type or capabilities of each radio (trunking, multi-band, encrypted).	Quantities based on the number of mobiles in ULS per licensee. The quantities factor in the percentage of trunked versus conventional radios, multiband radios, encrypted radios, and the full costs associated with radio deployment including technician programming, training, and coordination.
Other	Other cost items such as vehicular repeaters, BDAs, spares, taxes, etc.	The methodology for each varies. The NPSTC questionnaire data provides quantities of vehicular repeaters and BDAs. Taxes varied per region and applied to taxable items. Spares were calculated based on items thought to be required for sustainable service.
Planning	Up-front activities to estimate the scope of work for the individual licensees to execute the transition. Includes equipment inventory, preliminary engineering and transition planning, vendor procurement, and other preliminary administrative functions.	For infrastructure elements, a flat 10 percent of the estimated transition cost is used. For subscriber devices, a flat $300 per radio is used based on metrics from the 800 MHz Transition Administrator.

In each case, the fully deployed cost is determined. For example, a portable radio requires engineering (template development), configuration (radio programming), coordination (shuttling of portable radio to/from the field), accessories (microphones, chargers, etc.), training (on a new or reconfigured radio), and project management for the successful deployment of a transitioned portable radio. Details regarding the models and the costs associated with each item and the quantity calculation methods are provided below.

But fundamentally, what must be replaced is the primary driver for the total scope of work and ultimately the cost. And the scope of the replacement is a function of the current equipment used by the T-Band licensee and the "target" system. Due to the complexities of a transition out of the band, the Working Group assumed that transition required parallel operations of a T-Band and "other band" system. Due to the nature of the equipment changes, the Working Group determined that both a T-Band and 700 MHz band system would need to operate simultaneously. The following table presents the high-level scope of work impacts of the various changes to a system as a result of transitioning from the T-Band; each factor has been considered in the cost modeling.

Table 4.2: High-Level Assumptions for T-Band Transition

Change	Triggered By	Scope of Work Impacts
T-Band to 700 or 800 MHz in general	Insufficient UHF spectrum requires move to 700 or 800 MHz bands.	Additional sites are required to match coverage. All band specific RF infrastructure must be replaced. All radios replaced. BDAs replaced. Vehicular repeaters replaced.
Simulcast Required	Maintaining the same spectrum requirements for each system while adding coverage sites that result from frequency shift.	Simulcast equipment will be required at every system (conventional and trunking) including core (e.g., comparators) and site (GPS and timing source) elements.
Analog Conventional to Digital Conventional	Forced by move to 700 MHz which is a digital only band.	Replacement of core network required. Change of a significant number of dispatch consoles required.
Conventional to Trunking	Forced due to lack of 6.25 MHz conventional standard P25 and need to move to 700 MHz and use of more than 6 channels at any one site.	Complete change of core and all RF systems. All radios must be trunking and mutual aid partners may need to support trunking in radios.
T-Band trunking to 700/800 MHz for trunking systems	Insufficient UHF spectrum, incompatibility between 700/800 MHz RF gear and existing core	All new core required. Includes switches, simulcast gear, voting, consoles, logging recorders, etc.
Migrate some (not all) mutual aid partners to 700/800 MHz	Insufficient spectrum for all public safety operators in 700/800 MHz	Multi-band radios required in some circumstances
Simultaneous Two Band Operations	The amount of time required to transition the infrastructure requires operations on both bands.	In addition to current T-Band equipment, a fully functional parallel system is required. This system must be fully tested before a transition can occur. The additional equipment can have additional impacts to the towers, HVAC, generator, battery, and ground space. As such, they may trigger upgrades to these supporting systems.

The following table presents the high level "scope of work" for the various types of systems considered in this analysis:

Table 4.3: Cost Model Scope of Work Factors

Existing T-Band System	Target System	Rational For Target System	Scope of Work
Analog[24] Conventional System	700 MHz Digital Conventional System with simulcast	Due to limited spectrum in other bands, 700 will be most viable alternative for some regions. Will require core change due to assumed digital conversion.	Replace: [25] • RF Electronics • Core Switch if applicable • Simulcast/voting • Microwave Backbone • Consoles • Logging Recorder • Add sites for coverage • Upgrade sites as needed
Trunking System	700 MHz TDMA Trunking System with simulcast	700 MHz narrowbanding triggers TDMA system	Replace: [26] • RF Electronics • Core Switch • Simulcast/voting • Microwave Backbone • Consoles • Logging Recorder • Add sites for coverage • Upgrade sites as needed

Multiple assumptions must be made regarding the subscriber devices due to the lack of information in ULS. The high-level plan for assessing the cost impacts of subscriber devices is as follows:

[24] For purposes of cost modeling, the Task Group assumed the existing T-Band conventional systems were analog.
[25] Due to change of RF system to digital, this will trigger an upstream replacement of these systems.
[26] Due to change of RF system (new RF systems incompatible with old core system likely on some systems) and the nature of trunking systems, all cores must be replaced. The lifecycle of most cores to support new RF sites is short, and therefore, given the likelihood that most cores will be older, few cores are anticipated to be able to support changed RF gear. However, it is anticipated that the microwave system can be reused.

Figure 4.4: High Level Subscriber Cost Allocations and Assumptions

System Type	Subscriber Type Assumption	Notes
Conventional	700/800 MHz Digital Conventional Regional assumptions (see chart below) were made for following characteristics: • Low-Tier vs. High-Tier percentage • Percentage requiring multiband capability • Percentage requiring trunking The percentage of high-tier conventional radios requiring encryption was defined nationwide at 40 percent	The Working Group believes that many of conventional systems use “low tier” subscribers costing less. Of the “high tier” radios, only a portion of those require interoperability via multiband. 40 percent of the high tier radios are thought to use encryption (LEAs)
Trunking	700/800 MHz Digital Trunking Radio Regional assumptions (see chart below) were made for following characteristics: • Low-Tier vs. High-Tier percentage • Percentage requiring multiband capability The percentage of high-tier trunking radios requiring encryption was defined nationwide at 40 percent.	While inexpensive trunking radios are available, the Working Group believes these “low-tier” trunked radios represent on average a smaller percentage than conventional systems. Unless otherwise stated, 100 percent of the high-tier radios were assumed and of those it was assumed that 20 percent require multiband interoperability and 40 percent require encryption.

The regional subscriber assumptions are based on the available knowledge of each region by Working Group members. For regions without any existing T-Band trunking systems, no trunking capability was added to the radios. The estimated cost of replacing each radio includes the costs associated with project management, coordination, programming, engineering, accessories, installation, and training. The regional assumptions are included in the detailed model description section of the document.

The model includes other data points that are outside the purview of the FCC and the ULS database. The following table indicates those costs and provides a high-level perspective on the source for the costs:

Table 4.5: Additional Transition Cost Assumption

tem	Source	Notes
BDAs	NPSTC Questionnaire – Regional	The questionnaire captured the quantity of BDAs for the respondents. Not all respondents populated the BDA information, and not all licensees responded, therefore the response represents a subset of the public safety BDAs in service. There is no known way to estimate the total BDAs, and therefore, the Working Group uses the subset of BDAs in the cost calculation.
Dispatch Consoles	ULS Channels (Proxy)	The Working Group estimates there is a high degree of correlation between the number of consoles and the total number of channels, therefore, a percentage of the number of channels (from ULS) is used as a proxy for consoles with a 1 to 5 ratio for larger systems and a 1 to 2 ratio for smaller systems. The Working Group determined that 50 percent of T-Band consoles would need to be replaced. The number of consoles was calculated based on the following formula: • For systems with less than 10 channels: Consoles = Channels x 50% x 50% • For systems with more than 10 channels: Consoles = Channels x 20% x 50%
Vehicular Repeaters	NPSTC Questionnaire – Regional	The questionnaire also collected VRS quantities for a subset of the total deployed in the T-Band. There is no known way to extrapolate the totals for all of public safety, and therefore, the direct regional quantities are added to the total cost per region.

The vast majority of the estimated cost items come from the FCC ULS database. The model assumes that the data represented in the ULS data accurately represents the currently deployed T-Band equipment for public safety. Further, the Working Group assumed that this currently deployed equipment would be in place just prior to the transition out of the T-Band and would represent the basis for "comparable facilities." And, as occurred in 800 MHz rebanding, the Working Group assumed that the federal government would fund transition out of the band with the same capabilities from a performance and features perspective.

Finally, the Working Group identified other costs that could also impact the net cost to transition public safety out of the T-Band. Due to a lack of time and the complexity of the issues, these costs were excluded but could dramatically increase the transition cost. These additional costs that are excluded from the model include:

- Subway Systems: Covering subway systems (stations and tunnels) is highly complex and costly. The cost will depend on the additional fiber optic, coaxial, and radiating cable needed in the tunnels and other factors. These costs could be substantial depending on the current facilities in each metro area.
- Transition Oversight: A program such as the T-Band transition would likely need substantial oversight at least equivalent to the role of the Transition Administrator for 800 MHz rebanding. This oversight could serve to help reduce costs and facilitate the process of the transition.
- Regional Interoperability Coordination: As with 800 MHz rebanding, regional interoperability would be required during the transition, and the program would fund such an effort.
- Additional VRS and BDAs: The NPSTC questionnaire only captured information for a fraction of the T-Band licensees. As a result, there are likely additional costs associated with additional VRS and BDA assets from those who did not respond.
- Other System Changes: The model assumes that existing transmit and receive sites can be "reused" in the new 700 MHz system. It may be necessary, due to site availability, frequency use, or other reasons, that these existing sites may not be usable in the new system. The additional costs associated with this factor are not included in the model.
- Multi-Band Interoperability: The T-Band licensees are likely to interoperate with other UHF licenses that will remain in the UHF band. While the model includes additional costs associated with multi-band radios for the T-Band licensees, the Working Group could not estimate the cost associated with those public safety agencies that will remain in UHF and need interoperability with transitioned former T-Band users.
- Other Ancillary Systems: Fire Station Alerting, SCADA, and other systems that may use the existing T-Band radio systems are likely impacted by a transition. As such, a transition to a different band would impact subscriber and infrastructure costs. Furthermore, such a transition could have downstream impacts to these systems and may require wholesale changes of these ancillary systems.

A detailed study would be required to better understand these additional costs and ensure that public safety could achieve 100 percent comparable facilities in the new band. The model envisions a planning process where the licensees would more comprehensively determine the cost of the transition.

4.4 Cost Model Results

The model results document that more than $6 billion will be needed to accommodate the transition. The Working Group divided the cost on a regional basis to allow for an understanding of the potential spectrum auction benefit versus the transition cost itself. The following table provides the cost breakdown by region for the major categories:

Table 4.6: Public Safety T-Band Transition Cost Summary (Millions of Dollars)

Region	Total Cost	System	Sites	Repeaters	Subscribers	Other[27]	Planning
Boston	$ 831.0	$ 165.8	$ 277.2	$ 126.3	$ 99.2	$ 90.5	$ 72.1
Chicago	$ 759.7	$ 90.6	$ 191.0	$ 164.0	$ 153.0	$ 104.6	$ 56.5
Dallas	$ 82.8	$ 20.0	$ 22.5	$ 7.8	$ 15.1	$ 10.8	$ 6.7
Houston	$ 11.4	$ 3.0	$ 4.1	$ 0.8	$ 1.0	$ 1.5	$ 0.9
Los Angeles	$ 857.3	$ 84.3	$ 161.1	$ 208.0	$ 231.7	$ 108.3	$ 63.9
Miami	$ 49.4	$ 12.3	$ 12.8	$ 5.9	$ 8.2	$ 6.1	$ 4.1
New York	$ 1,428.4	$ 262.3	$ 314.1	$ 239.2	$ 295.1	$ 188.9	$ 128.8
Philadelphia	$ 1,151.6	$ 200.4	$ 196.9	$ 173.5	$ 355.1	$ 137.7	$ 87.9
Pittsburgh	$ 203.4	$ 28.4	$ 45.3	$ 53.3	$ 34.8	$ 24.2	$ 17.5
San Francisco	$ 355.1	$ 73.1	$ 76.5	$ 44.5	$ 88.9	$ 44.2	$ 27.9
Washington, DC	$ 209.5	$ 27.7	$ 29.6	$ 28.6	$ 51.1	$ 58.8	$ 13.6
Total	**$ 5,939.7**	**$ 967.9**	**$ 1,331.1**	**$ 1,051.7**	**$ 1,333.2**	**$ 775.7**	**$ 480.1**

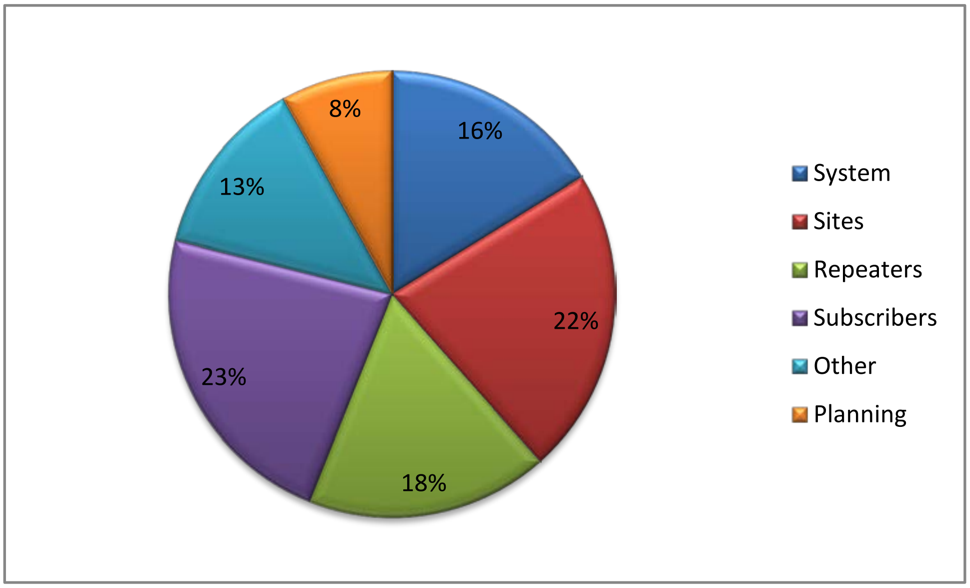
The table shows more than $5.9 billion in total T-Band relocation costs. Costs labeled as "other" include BDAs, dispatch consoles, spares, taxes, and VRS. As expected, the table shows that the cities with substantial T-Band use have substantial costs. New York and Philadelphia both cost in excess of $1 billion each to relocate. Boston, Chicago, and Los Angeles also have high transition

[27] Other cost items such as vehicular repeaters, BDAs, spares, taxes, etc.

costs due to the scope of the T-Band systems in those regions. However, some regions with limited public safety usage such as Houston, Miami, and Dallas cost less than $100 million to transition.

The chart below underscores the distribution of cost across all of the regions:

Figure 4.7: T-Band Transition Cost Breakdown



The chart highlights the primary contributors to the overall costs: the system, site, subscriber, and repeater costs. As a result of substantial work required at remote radio frequency (RF) sites and backhaul requirements, the site costs are the highest individual cost group at 29 percent. The BDAs, VRSs, and the dispatch consoles together account for $126 million of the nearly $6 billion, or two percent of the overall cost.

The program must fund planning activities for a T-Band transition. These planning funds will enable the licensees to more accurately establish their existing assets, establish contracts with vendors, and help negotiate agreements with the federal government for compensation for the transition. These funds must be granted to the licensees at the very beginning of the transition process. The planning costs estimated by the Working Group total nearly $500 million across all regions. The planning costs represent approximately 9 percent of the overall costs of the program.

It is also important to note that these figures do not include any contingency budget. These costs are high-level estimates. We have addressed excluded items that could increase the cost from tens of millions to hundreds of millions dollars. In addition, the Working Group may have overlooked significant costs associated with the transition. Likewise, it is also possible that the ULS data, the Working Group assumptions, and the per unit cost figures could be higher or lower than estimated. As a result, the actual cost could vary substantially from the estimated cost provided in this document. And, as 800 MHz rebanding has shown, additional costs will be exposed even after the planning phase is completed. The funding would need to ensure that public safety could successfully complete the transition process, and therefore, public safety will require a plan for a contingency budget to avoid stranded public safety systems.

4.5 Detailed Model Description

The following sections provide the detailed equations and costs associated with the cost model. The model consists of three components:

- ULS based "localized" costs,
- Questionnaire response based "regional" costs and,
- Nationwide costs.

The following sections provide the details associated with each aspect of the model. Appendix A provides detailed cost breakdowns for the individual unit costs associated with the equipment that must be upgraded or replaced according to the model.

4.5.1 ULS-Based Localized Costs

The model is predominately based on ULS based inputs. For purposes of the cost modeling, the group determined that each individual licensee represented one "system." A licensee was deemed to have multiple "systems" if it had both conventional and trunking licenses. If a unique licensee (i.e., the same licensee name) possesses multiple licenses, these licenses are aggregated and assumed to be part of one "system." The following variables describe the ULS based attributes in the model for each system:

- "ULS Channels": This is the total number of licensed frequency pairs for each "system."
- "ULS RF Sites": This is the total number of unique transmit sites in the ULS database for each "system."
- "ULS Repeaters": This is the total number of base stations for each "system."
- "ULS Mobiles": This is the total number of mobiles and portables assigned to the licenses for that licensee/system.

The following table depicts a sample of the output from the ULS database used in this analysis. Separate tables were created for trunking and conventional systems to simplify the model:

Table 4.7: Sample Output from the ULS Database Used for Analysis

Licensee / System	Channels	RF sites	Repeaters	Mobiles
Licensee A/System A	2	5	5	100
Licensee B/System B	5	4	9	40
Licensee C/System C	7	7	12	31
Licensee D/System D	7	2	4	60

The following sections provide the details on the costs associated with ULS based factors. They are broken up by:

- System Related Costs: Centralized and core costs associated with the transition from the T-Band. These costs are based on the type and scope of the system per row in the ULS database.
- -Site-Related Costs: Costs associated transmit and receive sites (e.g., towers and rooftops). These costs are based on the number of RF sites per system.
- Repeater-Related Costs: Costs associated with the quantity of repeaters.
- Mobile-Related Costs: Costs associated with the quantities of mobiles (includes portables).

4.5.1 System-Related Costs

The system costs focus on the "core" or "centralized" elements of each "system. Of course, the complexity of the system costs is a function of the type of existing T-Band system and the type of "target" system. The following table represents the logic for determining the system costs on a per system basis of all ULS licensees. Systems will be broken out in the ULS by conventional and trunking:

Table 4.8: Conventional vs. Trunking Cost Model Assumptions

Condition	System Scope	Percent Affected Systems
Conventional T-Band System with upgrade	• Implement new system core to support digital 700 MHz channels (including switch, simulcast gear, voting, consoles, logging recorder) • Includes budget for host facilities (e.g., UPS) to support additional equipment • Add gateway to T-Band System • PM • Engineering	100 percent of conventional systems are affected due to digital transition (note: consoles are treated separately and some are assumed to be retained)
Trunking T-Band System	• Implement new system core (including switch, simulcast gear, voting, consoles, logging recorder) • Includes budget for host facilities (e.g., UPS) to support additional equipment • Add gateway to T-Band System • PM] • Engineering	100 percent of existing T-Band systems are affected (note: consoles are treated separately and some are assumed to be retained)

The estimation for the system costs are broken up by the size of the system. The system cost estimate includes all items defined in the above chart. The size of the system is based on the number of repeaters listed within the ULS database. In reality, the costs associated with the core network depend on a variety of factors that are not available in the ULS. Therefore, the Working

Group established small, medium, large, and very large core "buckets." This allowed the Working Group to capture the larger scope of the larger cores as well as the perceived likelihood that the larger systems would have additional costly features. Fundamentally, the "core" costs include everything outside of site, repeater, and subscriber cost – those costs that are "centralized." The breakdown of the system size and their estimated cost is as follows:

Table 4.9: T-Band System Size Cost Model Assumptions

System Size	Repeater Size Range	Trunked Systems		Conventional Systems	
		Cost	Scope	Cost	Scope
Small System	0<x<7	$1,163,000	Core switch, gateway, Logging recorder, simulcast, and CAD Interface	$609,000	Logging recorder, gateway, and simulcast
Medium System	7<x<30	$1,436,000	Small system features plus encryption and operations and maintenance system (fault management)	$1,242,000	Small system features plus core switch, CAD Interface, O&M system
Large System	30<x<100	$2,757,000	Medium system plus geo-redundancy	$2,462,000	Medium system plus data, geo-redundancy
Very Large System	x>100	$8,200,000	Large system plus data (e.g., GPS), text, and ISSI interface.	$3,793,000	Large system data, text, and ISSI interface

The breakpoints occur based on the total quantity of repeaters for the transition system. Therefore, the "size" of the core costs are based on the additional repeaters that result from the additional 700 MHz sites and repeaters. For example, a medium-sized system is one with between 7 and 30 repeaters after the new coverage sites and their associated repeaters are added to the total. The detailed cost breakdown of the core/systems can be found in Appendix A. The model includes an additional 10 percent of the system costs outlined above to address planning costs.

4.5.3 Site Related Costs

Site-related costs include those associated with supporting facilities to the repeaters. This includes towers, shelters, HVAC, UPS, and other costs that cannot be directly linked to repeaters. Site costs are highly complex in that the transition triggers multiple potential costs. First, a transition from the T-Band to 700/800 MHz involves coverage differences that require additional sites. Those new sites could be new tower builds or site leases. Furthermore, the coverage differential is much more challenging to address for a system with only 1 site compared with 1 of 30 sites. Second, a transition that requires simultaneous operations of T-Band and 700/800 MHz systems requires that there is sufficient tower space, shelter space, HVAC capacity, and UPS capacity to support both systems during the transition. As many existing towers or supporting facilities are overloaded, this requirement could trigger upgrades or replacements to many facilities in the 11 markets. Third, the extensive use of receive only conventional sites creates complications in determining site count impacts. These sites (and their RF and backhaul equipment) are not included in the ULS database.

The database only includes transmit sites. As a result, costs associated with receive only or “satellite” receive sites must be determined via available sources.

The site contribution quantities are divided into the following categories:

- New Sites: New sites are those that are required beyond the existing sites. New sites may be added as capital builds (where public safety pays for the construction of new towers) or leased sites (where public safety leases existing towers). New sites are the result of:
  - Capital Sites: Sites where public safety must build all underlying facilities to support the repeater systems. This includes the tower, pad, shelter, backhaul, HVAC, UPS, and generators.
  - Leased Sites: Sites where the tower and pad exist, but public safety must add shelter, backhaul, HVAC, UPS, and generators (these items are not assumed to be shared).
  - It should be noted that these cost estimates do NOT include the land acquisition costs.
- Existing Sites: Existing sites are those that exist today. This includes sites that are transmit and receive (which are included in the ULS database) and receive only sites (which are not included in the ULS database). Existing sites are broken into two categories:
  - Refurbished Sites: Sites where the basic facilities are largely adequate, however, they require some level of “upgrade.” This includes structural reinforcements, HVAC upgrade, and possible UPS upgrade.
  - “As Is” Sites: Sites where the existing facilities can accommodate the transition. However, these sites will require structural analysis at a minimum.
- Additional Microwave: Today, public safety uses a combination of leased circuits and microwave to backhaul its traffic to the network core. The Working Group assumes that some temporary additional circuits can be leased to support the transition system. Additionally, where microwave systems support the current system, some of those systems can accommodate the additional temporary capacity. The Working Group assumes that 50 percent of all existing sites[28] require complete microwave system replacement. The Working Group further assumes that 100 percent of the new coverage sites require new microwave systems to minimize the operations costs associated with the transition.

The distribution between the various sites in the model is as follows:

- New Sites: 50 percent capital sites, 50 percent leased sites. It is important to note that these new sites will incur additional operational costs for T-Band licenses. Leased sites will incur additional long-term costs.

[28] The Working Group lacks information on the percentage of microwave system use versus leased circuits. We directionally assume 50 percent microwave use, and therefore, we assume that all of these microwave systems must be replaced. This is predominately due to the analog to digital transition for conventional systems. Conventional systems make up 90 percent of the transmit sites in the ULS database.

- Existing Sites: 60 percent; “As Is”, 40 percent refurbished sites.

It should be noted that across all RF sites, equipment required to support simulcast communications is included.

4.5.4 Receive Only Impact

Due to receive only sites involved in conventional networks, conventional and trunking systems must be treated separately regarding the number of sites. And in the case of conventional systems, the model considers receive only sites differently due to the reduced equipment level at receive only sites. As discussed earlier, there is no FCC ULS information regarding the quantity of receive sites. However, in the T-Band questionnaire, NPSTC did collect the quantity of T-Band receivers. The region by region summary is below:

Table 4.10: Satellite Receive Usage

Region	No. of Satellite. Receivers	No. of Base Stations	Satellite / Base Station
Boston	634	516	1.228682
Chicago	525	64	8.203125
Dallas	0	28	0
Houston	0	2	0
Los Angeles	1015	903	1.124031
Miami	1	11	0.090909
New York	832	1220	0.681967
Philadelphia	306	867	0.352941
Pittsburgh	86	41	2.097561
San Francisco	74	377	0.196286
Washington, DC	0	287	0
Overall	**3473**	**4316**	**0.80468**

The table shows that there is extensive satellite receiver use in Chicago and Pittsburgh and a high degree of use in Boston, LA, and New York. The remaining regions had limited satellite receiver use in comparison with base stations with no usage in Dallas, Washington, DC, and Houston. However, it is unclear if this use of satellite receivers will be consistent with T-Band licensees who did not respond to the questionnaire. In order to retain what seems to be regional trends on the use of satellite receivers, the model assumes that the multiplier associated between base stations and satellite receivers applies to additional receive only sites. In other words, in Chicago, there are an average of 8.2 receive only sites per transmit site; however, in DC, there are no receive only sites.

4.5.6 Coverage Impact

The difference in free space path loss is 20*log(f) resulting in 4.26 dB advantage of T-Band over 700 MHz coverage. Making up that differential is possible with additional sites. However, the number of additional sites is a more complicated matter. The Los Angeles Regional Interoperable Communications System (LA-RICS) estimates their larger system requires 25 percent additional sites. However, a single site system will have coverage holes open up in all directions. In that case, 20 percent additional sites results in only 0.2 sites which is insufficient to recover from the coverage holes. Instead, the model assumes that systems with a small number of sites, more new sites are required to provide comparable coverage.

The model used for new coverage sites is:

- ULS Sites = 1, New Sites =2
- ULS Sites >= 2, New Sites = .25 *ULS Sites (for each system the number of sites will be rounded up to the nearest integer)

The resulting table then represents the total quantities of the different types of sites for each region:

Table 4.11: Radio Site Cost Comparison

Site Category	Quantity	Cost Each
New Capital TX/RX[29] Sites	50% * New Sites (see above for formula)	$312,000
New Leased TX/RX Sites	50% * New Sites (see above for formula)	$52,000
Refurbished TX/RX Sites	50% * ULS Sites	$87,000
"As Is" TX/RX Sites	50% * ULS Sites	$10,000
New Microwave Sites (TX/RX)	100% * New Sites	$125,000 per link
Existing Microwave Sites (TX/RX)	50% * ULS Sites	$125,000 / Link
"As Is" Receive Only Sites	50% * ULS Sites * Regional Multiplier	$87,000
Refurbished Receive Only Sites	50% * ULS Sites * Regional Multiplier	$10,000
Simulcast Sites (TX/RX)	100% * (New Sites + ULS Sites)	$50,000

The model does not add coverage sites that might result from satellite receive sites

[29] TX/RX is an abbreviation of transmit/receive. It represents sites that have both a transmit (outbound to mobiles) and receive (inbound from mobiles) function as opposed to receive only (or satellite) sites. The model treats these site types separately.

4.5.7 Repeater-Related Costs

The repeater-related costs include those elements that can be easily linked to repeaters. This includes base stations (or trunking repeaters), satellite receivers, antennas, cables, and combiners. Because these elements are required for the new 700 MHz systems in parallel with the T-Band system, the model assumes that new cables (that might normally be able to be reusable at the new frequency) are required. Therefore, the full complement of RF components is required. And since new RF equipment is required at new coverage sites, these sites need a full complement of RF components. Importantly, the costs associated with repeaters are different depending on whether the equipment uses conventional or trunking repeaters. Additionally, because the 700 MHz band requires 6.25 kHz equivalent capability, any trunking system requires Time Division Multiple Access (TDMA) capable repeaters.

The following formal applies to conventional and trunking system repeater quantities:

Repeaters = ULS Repeaters + (New Sites * ULS Repeaters/ULS Sites)

This equation factors in the additional repeaters associated with the new sites at the same repeaters per site ratio as is currently available in ULS. The Working Group assumed that the existing T-Band systems are Frequency Division Multiple Access (FDMA), and therefore, a single talk path per channel. Due to the migration to TDMA for trunking systems, the total number of repeaters is reduced by 50 percent due to the double capacity available for each repeater.

The following formal applies to conventional systems satellite receiver[30] quantities:

Satellite Receivers = ULS Repeaters * Regional Multiplier

The following table then provides the formula associated with the repeater and satellite receiver costs:

Table 4.12: Repeater & Satellite Receiver Cost Model

Equipment Type	Quantity	Cost Each
TDMA Trunking Repeater	50%[31] (ULS Repeaters + (New Sites * ULS Repeaters/ULS Sites))	$64,000
Conventional Repeater	ULS Repeaters + (New Sites * ULS Repeaters/ULS Sites)	$50,000
Satellite Receiver	ULS Repeaters * Regional Multiplier	$35,000

[30] A satellite receiver is one which provides only the receive function (no transmit) at a particular site.
[31] In this case, the current trunking systems are presumed to be FDMA. The move to TDMA allows for 2 channels for every repeater, and therefore, the 700 MHz systems require half the repeaters.

Finally, the Working Group concluded that Dispatch Console quantities are correlated with number of channels. For both the trunking and conventional systems, it was estimated that 50 percent of the consoles across the region would be able to support the upgrade. Of those systems requiring new consoles it was estimated that for small systems with less than 10 channels they would require one console for every two channels. For systems with more than 10 channels it was estimated that one console would be required for every 5 channels.

4.5.8 Subscriber-Related Costs

The public safety user equipment undergoes substantial changes with regards to the transition. The scarcity of multiband subscriber devices in the T-Band currently means that the vast majority of the radios must be replaced. While a substantial percentage of the in-service radios are expected to be UHF (450-470 MHz) capable by the late 2010s, it was deemed by the Working Group that there is so little UHF spectrum available, that the most viable opportunity was in 700 MHz. As a result, the Working Group expects that all T-Band radios must be replaced with 700 MHz radios. The following table provides the breakdown of the subscriber devices:

Table 4.13: Subscriber Device Cost Model Assumptions

Type	Percent	Comments
High vs. Low Tier Radios		
Percentage of High-Tier Conventional Radios	50%[32]	High-Tier radios are capable of, encryption and multiband
Percentage of High-Tier Trunked Radios	100%	As per the feedback from the questionnaire and working group participants
Conventional vs. Trunking		
Percentage of Conventional Radios with Trunking	60%	60 percent of the High-Tier Conventional radios require interoperability with trunking systems.
Percentage Conventional Radios with Conventional Systems	40%	40 percent of the radios only need conventional capability
Single Band vs. Multiband		
Percentage of Multiband	Regional Values	Percentage of the High-Tier radios requiring ongoing interoperability with UHF band after migration to 700 MHz
Encryption		
Percentage of radios with Encryption	40%	Represents the expected total law enforcement percentage of all radios

[32] Fifty percent is the default value. If specific information regarding a region is known, that specific value is included in the model. See the table below for those details.

Regional Radio Assumptions

Regional	System	% of High-Tier Radios & Mobiles	Add Trunking to High-Tier Conventional Radio	Add Multi-Band to High-Tier Radio
Boston	Conventional	40%	0%	50%
Boston	Trunked			
Chicago	Conventional	100%	60%	50%
Chicago	Trunked	100%		50%
Dallas	Conventional	50%	60%	50%
Dallas	Trunked	100%		50%
DC	Conventional	50%	60%	50%
DC	Trunked	100%		50%
Houston	Conventional	50%	0%	50%
Houston	Trunked			
LA	Conventional	90%	60%	90%
LA	Trunked	100%		90%
Miami	Conventional	60%	0%	50%
Miami	Trunked			
NY	Conventional	20%	60%	20%
NY	Trunked	100%		20%
Philadelphia	Conventional	50%	60%	50%
Philadelphia	Trunked	100%		50%
Pittsburgh	Conventional	50%	0%	50%
Pittsburgh	Trunked			
San Fran	Conventional	50%	60%	50%
San Fran	Trunked	100%		50%

Conventional Radio Assumptions

Using Chicago as an example, the overall formulas for each type of device for conventional systems is as follows:

Type of Radio	Quantity Formula	Unit Cost	Notes
Low Tier Conventional Radio	ULS Mobiles * 0%	$1,500	60 percent of all conventional radios low-tier
High Tier Conventional Only Radio	ULS Mobiles * 100% * 40%	$4,175	100 percent high tier, and of those 40 percent only have conventional
High Tier Conventional Radio add Trunking	ULS Mobiles * 100% * 60%	$1,300	Of 100 percent high tier, 60 percent also have trunking
Additional Multi-band Capability	ULS Mobiles * 100% * 50%	$900	Of high tier radios, 50 percent are multiband
Additional Encryption Capability	ULS Mobiles * 100% * 40%	$800	Of high tier radios, 40 percent are encrypted

Trunking Radio Assumptions

Using Chicago as an example, the following table applies to trunking radios:

Type of Radio	Quantity Formula	Unit Cost	Notes
High Tier Radio with Trunking	ULS Mobiles * 100%	$5,475	100 percent high tier
Additional Multi-band Capability	ULS Mobiles * 100% * 50%	$900	Of high tier radios, 50 percent are multiband
Additional Encryption Capability	ULS Mobiles * 100% * 40%	$800	Of high tier radios, 40 percent are encrypted

4.6 Other Costs

Regional costs include those not easily attributable to the local systems. Regional costs include the following elements:

Table 4.14 BDA and Vehicle Repeater Cost Model

Item	Cost	Notes
Bi-Directional Amplifier	35,000	Includes donor and coverage antennas, cables, amplifier, installation, engineering, and project management.
Vehicle Repeater System	23,000	Includes repeater, mobile, antenna and cable installation, engineering, and project management.

4.6.1 Spares

Public safety generally keeps sufficient spare inventory in order to retain high service availability. As a result, the Working Group expected that these T-Band licensees will have spares that must be replaced to properly operate on 700 MHz systems. Ten percent is generally a good rule-of-thumb for sparing rates employed by public safety licensees. In order to simplify the model, the ten percent spare level was applied to 75 percent of the overall cost (outside of the planning costs). The spare costs were applied to the overall regional totals.

4.6.3 Taxes

Some members of the Working Group advised that in their area, even local governments are required to pay sales tax. The model includes taxes applied to non-labor items based on regional overall sales taxes. Seventy-five percent of the overall regional costs (outside of planning costs) were assumed to be taxable. The following taxes were applied to the overall regional cost.

Regional Values	Sales Tax
Boston	4.50%
Chicago	11.50%
Dallas	8.25%
DC	6.00%
Houston	8.25%
LA	9.00%
Miami	7.50%
NY	8.88%
Philadelphia	8.00%
Pittsburgh	8.00%
San Fran	8.75%

NPSTC is aware that the applicability of sales tax on purchases by state and local governments varies by state or jurisdiction. The total tax included from the model for public safety T-Band relocation is approximately $300 million. To the extent some local and state T-Band licensees are not required to pay sales taxes, a portion of that cost could be reduced accordingly.

4.7 Potential Changes in Cost Structure

A Working Group member pointed out that if an agency were ultimately required to transition from its individual T-Band system to a regionally operated trunked system in another band, changes in cost structure could occur. For example, some agencies that have an individual system have negotiated no-charge lease agreements with tower or building owners, which mean there is no associated line item in their budget. Moving to a regionally operated trunked system could translate to the need to include line items in the budget for costs that include factors for infrastructure maintenance. However, such costs, if applicable, are not predictable for the high-level analysis NPSTC conducted.

4.8 Timing Required to Plan and Implement Relocation

The Act presents multiple challenges associated with timing. Based on the complexity of relocation, the Working Group expects a T-Band transition to take longer than 800 MHz rebanding. It was in March 2002 that the FCC issued its first Notice of Proposed Rule Making (NPRM) for 800 MHz rebanding, 11 years ago. Rules were defined in an FCC decision issued in July 2004 and a rebanding schedule was approved by the FCC in March 2005.[33] Those decisions set forth a process and planned schedule for a multi-year process which has actually taken many years beyond the schedule originally adopted. Given that the Commission has recently released a Public Notice seeking comments on the T-Band, it may take upwards of one year before a NPRM could be released. And due to border issues, 800 MHz rebanding is not finished.

A program such as 800 MHz rebanding that was focused largely on subscriber device reprogramming and limited subscriber replacement provides a glimpse into the effort required for a T-Band transition. However, in this case, due to parallel systems operation, additional coverage sites, and, in most cases, replacement of all infrastructure and subscriber equipment, the program is far more complex and time consuming. For example, if an existing tower cannot support the dual-band load (both T-Band and 700 MHz), a new tower may be required. With that new tower are multiple steps. It can take months or years to simply secure approval to build the tower. The typical Land Mobile Radio system takes 3 to 5 years to construct, and, therefore, this additional time would be added to the 800 MHz rebanding duration.

The Act calls for the funding of the public safety relocation to come from the auction proceeds, not scheduled until 2019. As a result, there is substantial gap between the funding for relocation and when the relocation process should begin. The cost analysis above shows that $500 million is required for planning alone. And given the Working Group's expectation that T-Band relocation will take longer due to its complexities, the program should have commenced prior to 2009 in order to meet the 2023 deadline.

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[33] *See* Improving Public Safety Communications in the 800 MHz Band, *Report and Order*, WT Docket No. 02-55, 19FCC Rcd 14969 (2004) (*Report and Order*). *See also Supplemental Order and Order on Reconsideration*, WT Docket No. 02-55, 19 FCC Rcd 25120 (2004) (*Supplemental Order*); and Public Notice in WT Docket No. 02-55, DA 05-619, issued March 11, 2005.

5. Potential Auction Value

Section 6103 of Public law 112-96 indicates that proceeds from the auction of the public safety T-band spectrum will be made available to the Assistant Secretary of Commerce to make grants "…in such sums as necessary to cover relocation costs for the relocation of public safety entities from the T-Band spectrum." The law does not address whether there was any consideration given to a situation in which the T-Band auction proceeds would be insufficient to cover the relocation cost.

While there is no certainty in predicting future auction proceeds, the NPSTC T-Band Working Group has examined the spectrum environment potential auction bidders would face that would impact auction results. First, it is important to recognize that high-value spectrum auctions over the last several years most often involve spectrum for which bidders plan to deploy for broadband operations. For example, in one of the most recent major spectrum auctions, in March 2008 Verizon paid $4.7 billion for 22 MHz of spectrum in the 700 MHz upper C block that essentially provides a nationwide license. Verizon has subsequently deployed broadband LTE on an aggressive schedule and anticipates providing 4G Broadband service to match its 3G coverage footprint by mid 2013.[34] Similarly, AT&T purchased 700 MHz band spectrum in the auction and on the aftermarket and is also deploying broadband LTE. AT&T has indicated it will cover about 300 million people with its 4G LTE network by yearend of 2014.[35] At the time of the 700 MHz band auction in 2008, it was clear that the spectrum would be cleared of incumbent operations nationwide in June 2009 by legislation and subsequent FCC rules. Therefore investment could lead to broadband 4G deployments without undue delay.

In contrast, potential auction bidders of the T-Band spectrum (TV channels 14-20) would face a far different environment. While public safety systems required to be cleared under the legislation operate in the top eleven markets as discussed in Sections 1 and 2 of this report, the band also supports a large number of broadcast services throughout the country, as shown in the map below.[36]

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[34] See *Verizon to Complete its 4G LTE Buildout in Mid-2013*, BGR, November 8, 2012. http://bgr.com/2012/11/08/verizon-4g-lte-coverage-complete-mid-2013/

[35] See AT&T plots $14billion network buildout; Sprint nabs spectrum. ZDNet, November 7, 2012. http://www.zdnet.com/at-and-t-plots-14-billion-network-build-out-sprint-nabs-spectrum-7000007043/

[36] This map was publicly available on the Spectrum Bridge website. Spectrum Bridge is one of the database providers endorsed by the FCC to help protect TV and land mobile facilities from interference as TV White Space devices are deployed.

Public Law 112-96 that addresses public safety relocation and auction of the public safety T-band spectrum also includes separate unrelated sections addressing "incentive auctions" of broadcast spectrum. As noted by the FCC Notice or Proposed Rulemaking regarding incentive auctions involving broadcast spectrum, Congressional authority for such incentive auctions requires that they be voluntary:

> "Section 6402, codified at 47 U.S.C. § 309(j)(8)(G), authorizes the Commission to conduct incentive auctions in which licensees may **voluntarily** relinquish their spectrum usage rights in order to permit the assignment by auction of new initial licenses subject to flexible use service rules, in exchange for a portion of the resulting auction proceeds." [*emphasis added]*[37]

Therefore, Public Law 112-96 only mandates auction of the public safety T-Band spectrum, not the same spectrum in other areas used by the many broadcast stations shown on the above map. It is not practical to mix commercial broadband services with existing television services in the same spectrum, as evidenced by the necessary transition of TV operations out of TV channels 52-69 (698-806 MHz) to make way for both commercial and public safety operations in the 700 MHz band.

The following map depicts the select areas in the U.S. in which land mobile T-Band operations exists. Both public safety and industrial/business T-Band operations exists in these areas and under the law the T-Band spectrum used by public safety would be auctioned.

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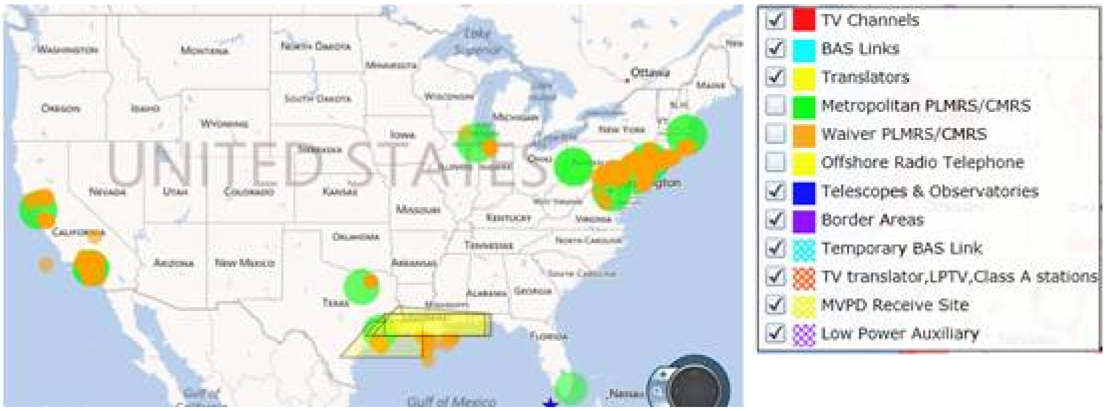
[37] Notice of Proposed Rulemaking, In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions, Docket NO. 12-268, released October 2, 2012, at paragraph 27.



These two foregoing maps together show that clearing public safety from the band does not result in a potentially attractive scenario for potential auction bidders, given the large number of licenses in the broadcast services that would remain throughout the U.S. even if public safety operations were relocated.

It is also important to note that broadcast operations exist even in some of the top 11 markets on T-band channels not allocated to public safety or industrial/business land mobile use. As addressed earlier in this report, only select TV channels within the T-Band are allocated for land mobile use in each of the 11 markets. Only 24 MHz of the 42 MHz of spectrum in TV channels 14-20 are allocated for land mobile in the Los Angeles market, with 18 MHz in the New York markets, and only a portion of that is public safety. In most of the 11 T-Band markets, only 12 MHz of the 42 MHz is allocated for land mobile and in several markets only 6 MHz is allocated. As in all T-Band markets only a portion of the land mobile T-Band spectrum is used by public safety and subject to the auction. Furthermore, as noted in Section 1 of this report, the portion of the T-Band spectrum considered to be "public safety" is designated on a land mobile channel-by-channel basis. Industrial/business channels and public safety channels are intermixed, so public safety spectrum is not contiguous.

The relatively limited geographic areas that would result from clearing public safety out of the T-Band, the lack of common spectrum availability in these 11 areas, and the lack of contiguous spectrum all would be expected to significantly reduce the attraction and resultant auction value of this spectrum for commercial broadband operations. Subscribers on such commercial systems would be limited to roaming on the specific segments of T-Band spectrum auctioned across no more than the 11 geographic areas. Nationwide roaming on the T-Band spectrum segments auctioned would not be feasible, given the significant number of broadcast operations that would remain in the band.

The reduced value of the T-Band spectrum that could be made available through an auction brings into serious question whether the auction proceeds even under the most optimistic projection, would be sufficient to cover the cost of public safety relocation from the band. NPSTC believes a significant amount of supplemental funding would be needed to relocate the public safety operations into some alternate spectrum with equivalent high reliability and comparable coverage as provided by the current T-Band land mobile operations.

6. Conclusions:

Based on the foregoing analysis, NPSTC draws the following conclusions:

- *The provisions of Section 6103 of Public Law 112-96 and the subsequent FCC freeze cause a major disruption to public safety agencies that rely heavily on T-Band.*
- *Analysis of public safety spectrum bands shows that at least 5 of the 11 metro areas do not have sufficient spectrum in any band to relocate their existing T-Band operations. These areas are the Boston, Chicago, Los Angeles, New York, and Philadelphia metros. The adequacy of relocation spectrum in three additional areas, San Francisco, Washington, D.C., and Pittsburgh is marginal.*
- *Even if spectrum could be located to support existing T-Band systems, the cost to move public safety operations in the 11 metro areas to new frequencies is estimated to at approximately $5.9 billion. This estimate excludes the cost to relocate industrial/business users, if necessary.*
- *Extensive TV broadcast operations throughout the country and industrial/business systems in 11 metro markets remain on T-Band channels even if public safety systems are relocated out of the band. Also, the T-Band frequencies used by public safety are not consistent across the metro areas and are not all contiguous, making the spectrum unattractive for commercial broadband use. These circumstances are unlikely to produce the auction revenue needed for public safety relocation.*
- *If TV and industrial/business were also required to move, that would require additional relocation funding, so the net auction revenue is still likely to be a negative value.*
- *As addressed in the report, it is not yet viable to rely on the planned nationwide public safety broadband network as a likely option to support mission critical voice operations that would be displaced from the T-Band. The law does not provide sufficient time for the necessary planning, purchasing, and installation activities that would be needed to migrate public safety agencies from their existing T-Band spectrum.*
- *Given the lack of alternative spectrum, cost of relocation, disruption to vital public safety services, and likelihood that the spectrum auction would not even cover relocation costs, NPSTC believes implementing the T-Band legislation is not feasible, provides no public interest benefit and the matter should be re-visited by Congress.*

Acknowledgement

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T-Band Working Group Co-Chairs:

Stu Overby Vice-Chair, NPSTC Spectrum Management Committee
Joe Ross Co-Chair, T-Band Working Group, Televate, LLC

T-Band Working Group Members:

Jennifer Adkins, EMR Consulting
Doug Aiken, IMSA NPSTC
Tom Alessi, Westchester NY DES
Christopher Ambrose, New York City Fire
Joseph Barros, New Bedford FD
Jamie Barnett, Potomac Institute
Brian Bassett, NorComm 911
Eric Bistline, Director, York County PA
Sandra Black, EMR Consulting
David Buchanan, NPSTC Committee Chair
Richard Carlson, Winnetka PD NORCOM
Gregory Chapeton, Yonkers NY Fire
Norman Coltri, RCC Consulting
Mark Crosby, Enterprise Wireless Alliance
Donald Denning, City of Boston
David Eierman, Motorola Solutions
Adam Epstein, Westchester, New York
Fred Frantz, Engility Corporation
Shaun Golden, Monmouth County NJ
Bob Gurss, APCO
Ralph Haller, NPSTC Chair
Steve Harte, New York City
James Hassett, NYPD
CJ Hijazi, Dailey-Wells Communications
Mike Horst, LA City Fire
Peter Johnson, Westchester NY
Daryl Jones, Telec Engineering Associates
Gary Kimmerle, Dailey-Wells Communications
Farohk Latiff, APCO
John Lenihan, LA County Fire|
Chris Lougee, ICOM America
Luis Lucas, NW Networks
Barry Luke, NPSTC

Steve Makky, APCO
Pat Mallon, LA RICS Project
Harlin McEwen, NPSTC
Felix Melendez, New York City
Richard Netinho, New Bedford PD
Rich Nowakowsk, RCN CONSULTING LLC
Steven Page, Pasadena CA
John Powell, NPSTC
Gerry Reardon, Boston Metro Fire
Rodger Ricciuti, Mt Lebanon FD, PA
Martin Ryczek, Chicago Police Department
Bette Rinehart, Motorola Solutions
Fred Sestito, NIJ NLECTC
Andy Seybold, Andrew Seybold, Inc.
Robert "Bob" Speidel, Harris
David Sweet, Dailey-Wells Communications
Alan Tilles, SRGP&E
David Troup, Greater Boston Police Council
Steve Verbil, Statewide OSET
Mike Volk, Westchester NY DES
Marilyn Ward, NPSTC Executive Director
David Warner, State of Virginia
Steve Weston, LA County Fire
Chris Wilson, Motorola Solutions
Donald Wright, Executive Director, ICIS

Appendix B: Detailed Cost Model Breakdowns

The following tables provide the detailed cost and scope information for many of the high-level costs in the model presented above. These costs are grouped below in System, Site, Repeater, Subscriber, and other costs. These costs do not include the up-front planning costs. These are assumed to be 10% of the transition cost for infrastructure and $300 per radio. Therefore, those costs are in addition to the unit costs listed below.

System Costs

The following table provides the detailed cost breakdown of the system costs by size and system type:

	Trunked Systems				Conventional Systems			
	Small	Medium	Large	Very Large	Small	Medium	Large	Very Large
Core Network Costs*	$614,000	$651,000	$1,052,000	$1,816,000	$313,000	$600,000	$1,146,000	$1,422,000
Simulcast/Voting	$154,000	$297,000	$698,000	$3,835,000	$85,000	$185,000	$ 321,000	$695,000
Gateway System**	$42,000	$ 55,000	$67,000	$ 219,000	$-	$42,000	$95,000	$110,000
Logging Recorder	$25,000	$ 40,000	$80,000	$ 160,000	$-	$40,000	$ 125,000	$175,000
Power Systems (Core only)	$40,000	$ 35,000	$170,000	$ 170,000	$40,000	$50,000	$ 150,000	$400,000
System Software Services	$25,000	$ 35,000	$70,000	$ 140,000	$40,000	$50,000	$75,000	$150,000
PM, Installation Core Components	$263,000	$323,000	$620,000	$1,860,000	$ 131,000	$275,000	$ 550,000	$841,000
Total	$1,163,00 0	$1,436,000	$ 2,757,000	$ 8,200,000	$ 609,000	$ 1,224,000	$2,462,000	$ 3,793,000

Site Costs

Table 1: New Capital Site Unit Cost (Transmit and Receive)

Item	Cost	Comment
Land Cost	TBD	Depends upon area $100-$400K
A and E	$20,000	Site Architecture and Engineering Service
Development	$25,000	Preparation of site
Tower (100')	$65,000	Depends upon part of Country/Wind Loading
Installation	$30,000	
Grounding systems	$3,000	
Building	$82,000	12X28X9 Shelter see attached
Batteries	$14,000	5-6 Hours of operation
Generator	$28,000	Output 60 KW LP or Diesel
Trenching	Included in site prep	
Fencing	$5,000	
Alarm system	$5,000	
Cameras	$10,000	Indoor and outdoor
Other	$25,000	
Total:	**$312,000**	**Plus cost of land!**

Table 2: New Leased Site Costs (Transmit and Receive)

Item	Capital Cost	Operations Cost (monthly)	Comment
Site Rent		$800	
Per Antenna on Tower		$400	
Electric		$200	Does NOT include LTE (would add $400/Month)
Batteries	$14,000		
Generator	$28,000		
Misc	$10,000		
Total Leased	**$52,000**	**$1,400**	

Table 3: Refurbished Sites Capital Cost (Transmit and Receive)

Item	Cost	Notes
Beef up tower	$30,000	
Batteries	$14,000	New Batteries for site
Generator	$28,000	New Generator
Misc	$15,000	
Total per site upgrade	**$87,000**	

Table 4: Microwave Costs For New and Upgrade Sites (Transmit and Receive)

Item	Cost	Notes
6' Dishes	$16,000	Space diversity
Wave guide	$25,000	
Radios	$50,000	Redundant (hot standby)
PM, Install, Engineering	$34,000	
Total	$125,000	Includes equipment for entire link (both ends) per remote RF site

Table 5: Simulcasting Equipment Cost Per Site (Transmit Sites)

Item	Cost	Notes
Simulcast equipment and services	$50,000	GPS, clock source and including all PM, install, other services

Repeater (Base Station) Related Costs

Table 6: Repeater and Satellite Receive Costs

Item	Cost	Notes
Conventional Repeater	$50,000	Includes conventional repeater, antennas, combiners, multicoupler, and cables with associated services. Per repeater/base station.
Trunked TDMA Repeater	$64,000	Includes TDMA trunking repeater, antennas, combiners, multicoupler, and cables with associated services. Per TDMA repeater (two channels per repeater)
Satellite Receiver (Receive Only)	$35,000	Includes antenna, receiver, cables, multicoupler and associated services

Mobile / Subscriber Device Costs

Table 7: Low-Tier Conventional Radios

Item	Cost	Notes
Portable Radio	$1,225	700 MHz public safety quality radio, low tier, low channel capacity
Accessories	$200	Include charger, speaker microphone, spare battery and case
Configuration	$75	Technician time for initial PM and programming
PM, Coordination,	$400	Code plug development, distribution of radios, inventory management, overall project management
Sub Total	**$1,900**	

Table 8: High-Tier Conventional Radios

Item	Cost	Notes
Portable Radio	$3,500	700 MHz public safety quality radio, high-tier, high channel capacity
Accessories	$600	Include charger, speaker microphone, spare battery and case
Configuration	$75	Technician time for initial PM and programming
PM, Coordination,	$400	Code plug development, distribution of radios, inventory management overall project management
Sub Total	**$4,175**	

Table 9: High-Tier Trunking Radios

Item	Cost	Notes
Portable Radio	$3500	700 MHz public safety quality radio, high tier, high channel capacity
Trunking	1300	P25 trunking software
Accessories	$600	Include charger, speaker microphone, spare battery and case
Configuration	$75	Technician time for programming
PM, Coordination,	$400	Code plug development, distribution of radios, inventory management overall project management
Sub Total	**$5475**	

Other Costs

The cost estimates or the trunked and conventional consoles is given below

Dispatch Consoles	Unit Price	Encryption (5% Unit Cost)	Installation (50% Unit Cost)	Unit Total	Notes
Trunked TDMA Dispatch Consoles	$ 40,000	$ 2,000	$ 21,000	$ 63,000	Includes Encryption, trunking capability, AMBE codec
Dispatch Consoles for Conventional Systems	$ 30,000	$ 1,500	$ 15,750	$ 47,250	