An Assessment of the Viability of Accommodating Wireless Broadband in the 1755 – 1850 MHz Band

U.S. Department of Commerce

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EXECUTIVE SUMMARY

The Department of Commerce's National Telecommunications and Information Administration (NTIA) led an interagency group to determine the viability of accommodating commercial wireless broadband in the 1755-1850 MHz band. While the analyses summarized in this report indicates there are a number of challenges to repurposing, NTIA concludes that it is possible to repurpose all 95 megahertz of the band. The challenges still to be met include the high cost and long timeline of the undertaking, estimated to be approximately $18 billion over 10 years, assuming relocation of most existing federal users, not including costs to incumbent systems in comparable destination bands.[1] However, the extent to which the spectrum can be made exclusively available to commercial interests requires further investigation, as some federal systems could remain in the band indefinitely. As a step toward meeting these challenges, NTIA believes that the agencies need to engage with industry to identify potential solutions, which could include partial clearing scenarios and a phased approach to commercial auctions and entry. NTIA also believes that spectrum sharing is a vital component of satisfying the growing demand for access to spectrum and that both federal and non-federal users will need to adopt innovative sharing techniques to accommodate this demand.

This analysis results from an eight-month evaluation process led by NTIA and engaging, via the Policy and Plans Steering Group (PPSG), the predominant federal agency users of this band.[2] Each federal agency analyzed and documented its ability to relocate systems, associated costs, and anticipated periods of transition. In conducting the analysis, NTIA and the federal agencies endeavored to protect critical federal operations from disruption and to reach comparable capability via other spectrum, commercial services, or means that do not utilize spectrum, where appropriate.

The analysis performed in this study surfaced the following challenges, which require satisfactory resolution:

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[1] Some systems will remain in the band indefinitely. To ensure maximum flexibility, Department of Defense (DOD) seeks to maintain the 1755-1850 MHz band for satellite tracking, telemetry, and commanding (TT&C) operations including, but not limited to, vehicle anomalies and emergencies. Further, testing and training for electronic warfare and some software defined radios will require continued operation within the band.

[2] The PPSG, an advisory group of senior-level federal officials, advises the Assistant Secretary for Communications and Information on spectrum policy and strategic plans and serves as a forum for issue resolution and harmonization across federal agencies. Federal agencies with operations in the 1755-1850 MHz band include the Department of Commerce (DOC), DOD, Department of Energy (DOE), Department of Health and Human Services (HHS), Department of Homeland Security (DHS), Department of the Interior (DOI), Department of Justice (DOJ), Department of Veterans Affairs (VA), Federal Aviation Administration (FAA), Department of Housing and Urban Development (HUD), National Aeronautics and Space Administration (NASA), Office of Personnel Management (OPM), U.S. Agency for International Development (USAID), U.S. Capitol Police (USCP), Department of the Treasury, and U.S. Postal Service (USPS).

- **Achieving Comparable Capability for Federal Systems:** NTIA and the Federal Communications Commission (FCC) will need to allocate comparable spectrum (unless federal agencies achieve comparable capabilities via alternate means) to accommodate federal operations currently performed in the 1755-1850 MHz band under any clearing scenario. These comparable spectrum allocations must provide federal agencies with primary regulatory status, while non-federal services currently licensed as primary or co-primary will maintain that status. Under the approach studied, the DOD has identified the 2025-2110 MHz band as the preferred option to relocate most of its operations, which is currently allocated to the commercial broadcast auxiliary service and federal space operations. In addition, DOD and NASA have identified the 5091-5250 MHz band as preferred for federal aeronautical mobile telemetry. Some agencies have identified the 1435-1525 MHz, 1675-1695 MHz, and 2200-2290 MHz bands as preferred for their video surveillance operations. Further analysis may reveal other ways to provide comparable capabilities at lower transition cost, opportunity cost, and/or complexity, such as improvements in spectrum efficiency or identification of other comparable destination bands.
- **Considering Incumbent Operations in any Spectrum Selected for Relocated Federal Operations:** The comparable spectrum bands identified by the federal agencies for relocation of their systems all have incumbent federal and/or non-federal operations. Any relocation proposal that utilizes these frequencies or any other frequency that achieves comparable capability will need to provide adequate protection for these uses. Arrangements, such as sharing, additional relocations, or other forms of accommodation would need to be developed where appropriate.
- **Supporting Federal Relocation Costs:** Current law requires that auction proceeds exceed expected federal relocation costs. Since federal relocation costs are expected to be high, any repurposing option needs to promote economic value while ensuring no loss of critical federal capabilities.[3]
- **Convening Stakeholder Planning Fora:** NTIA and the FCC will establish appropriate fora to encourage communications between federal agencies and industry. Working together early in the process will help in developing clear relocation, transition, and sharing plans. These are important to enable substantial availability of spectrum

[3] The recently enacted Middle Class Tax Relief and Job Creation Act of 2012 included some significant improvements to the Commercial Spectrum Enhancement Act (CSEA), such as providing required resources for planning before an auction, for sharing, and clarifications of activities that may be supported. These changes will provide greater certainty to the relocation process for federal agencies and commercial operators. Middle Class Tax Relief and Job Creation Act of 2012, Title VI of Pub. L. No. 112-96, 126 Stat. 156 (Feb. 22, 2012); *see also* Commercial Spectrum Enhancement Act, Title II of P.L. 108-494, 118 Stat. 3986, 3991 (codified at 47 U.S.C. §§ 923, 928).

with a high degree of certainty for commercial providers, while also ensuring critical federal operations are protected from disruption and that federal users will not be required to assume the responsibility of mitigating interference to commercial users during the transition period.

NTIA recognizes the significant challenges faced in repurposing the 1755-1850 MHz band, as they will affect the degree and timing of the relocation of federal systems. For example, the complexity of certain federal systems and the time required to redesign and modify those systems prevents the federal agencies from moving all of their operations from this band within the next ten years. Accordingly, certain federal operations would remain in the band past that point and these facilities or operations may need geographic exclusion zones.[4] Further, certain portions of the band or geographic areas may be cleared before others. As a result, the potential for interference from federal operations to the wireless broadband users exists during the transition period and it is necessary to establish clear regulatory mechanisms for sharing to ensure federal users are not required to assume the responsibility of mitigating such interference. Therefore, further analyses may be necessary to consider options such as enhanced coordination and sharing techniques, interference mitigation techniques, new technological solutions, and partial clearing of the federal systems in the band.

NTIA bases its conclusion on an analysis of repurposing the entire 95 megahertz and not just a portion of the spectrum.[5] In the agency-industry discussions that need to be convened, other options can be explored. Moreover, based on these discussions, the FCC could decide to auction portions of the spectrum at different times over the next ten years. However, those alternatives would need to maintain essential federal capabilities and recognize that certain federal systems operate across the entire band, possibly incurring the full cost of relocation in a scenario where the FCC would desire to clear federal systems from only a portion of the band. If these conditions can be resolved and NTIA formally recommends reallocation of this band, it will constitute a major step in achieving President Obama's goal of making 500 megahertz of federal and non-federal spectrum available for wireless broadband within ten years.

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[4] Several of the operations described in this report may require exclusion zones around some critical federal installations to protect incumbent federal operations from interference caused by wireless broadband operations. Additionally, mutually agreed upon rules will have to be established regarding the acceptance of interference on wireless broadband operations caused by incumbent federal operations. These arrangements will require future discussion between the affected federal agencies and the wireless industry.

[5] The FCC has stressed that the wireless industry is initially most interested in the 1755-1780 MHz portion of this band. The National Broadband Plan states pairing the Advanced Wireless Services (AWS)-3 band with spectrum from the 1755-1780 MHz band has the potential to bring benefits of a global equipment ecosystem to this band. *See* Connecting America: The National Broadband Plan (Chapter 5: Spectrum) (March 16, 2010) at 86, *available at* http://www.broadband.gov/plan/5-spectrum/.

Although the industry gained experience implementing commercial operations in federal spectrum during the transition of federal operations from the 1710-1755 MHz band, the 1755-1850 MHz band presents significantly greater challenges. The variety of operations and number of systems in the 1755-1850 MHz band, as well as the length of the transition of those operations to other spectrum, will present greater coordination complexity and will require commercial providers to operate in the presence of continuing and transitioning federal operations. Over 20 agencies utilize more than 3,100 individual frequency assignments in this band.[6] In turn, there simply are few bands to consider for repurposing and few comparable bands to which federal agencies can relocate their operations. Furthermore, relocating to other parts of the radio frequency spectrum means that many of the systems require redesign. During the 1710-1755 MHz band relocation effort, many federal agencies simply reduced their channels and moved their operations above 1755 MHz, but reallocation of the 1755-1850 MHz band would require much more significant actions and costs. At the same time, promising advances in commercial wireless technology suggest it may be possible for the wireless industry to design services to be more tolerant of interference with minimal degradation to quality of service. Industry's need for additional spectrum suggests the value of exploring "early entry" through sharing, which also optimizes transition paths and costs by leaving federal systems in place where possible.[7] However, sharing during the transition period and possibly thereafter will require establishment of clear regulatory mechanisms prior to any auction to ensure appropriate protection of federal operations and acknowledgement by industry of its status with respect to potential interference from federal operations. It will be critically important to develop a complete statement of what spectrum will be available, in what timeframes, and a composite picture of any geographic or other sharing constraints well in advance of any spectrum auctions.

Summary of Findings

For their major operations, affected federal agencies provided assessments of relocation feasibility from the 1755-1850 MHz band in ten years and determinations of whether their systems could transition out of the 1755-1780 MHz band in five years, the conditions under which relocation could be accomplished, and the costs associated with the corresponding relocation. The following paragraphs summarize those assessments. As noted above, further

[6] This represents frequency assignments authorized by NTIA and not the pieces of equipment associated with those assignments. In most cases, a single assignment may represent multiple pieces of radio equipment, and sometimes hundreds of systems.

[7] "Early entry" means the implementation of commercial systems prior to the date of relocation promised by the incumbent federal agencies. Early entry allows commercial entrants to begin implementation while coordinating protection of remaining federal operations and otherwise accepting the continued presence of those federal operations.

analyses may reveal other solutions to providing comparable capabilities than the bands described here.

Fixed Point-to-Point Microwave: DOE, DOD, DHS, DOI, DOC, and the FAA operate fixed microwave links to transmit data supporting operations such as energy grid control, border monitoring, seismic monitoring, and air traffic control. Fixed microwave systems are relatively easy to relocate, assuming favorable site conditions, because commercially available technology exists to re-establish these systems in other frequency bands. Accordingly, federal agencies can likely relocate all of their point-to-point fixed microwave systems from the 1755-1780 MHz band to the 4400-4490 MHz or 7125-8500 MHz band within five years and can relocate all of the microwave systems in the 1780-1850 MHz band within ten years.

Military Tactical Radio Relay: Tactical Radio Relay is a generic term for a class of transportable fixed microwave systems that support Army, Navy, and Marine Corps training at a number of sites and on tactical operational missions. Tactical Radio Relay systems often interoperate with other military systems.

DOD analysis determined that most Tactical Radio Relay systems can relocate from the entire 1755-1850 MHz band within ten years and transition out of the 1755-1780 MHz band within five years. The Army operates a type of system that can transition operations out of the 1755-1780 MHz band as soon as comparable access is available in the 2025-2110 MHz band. The Navy and Marine Corps, however, operate a type of system that will require continued access and protection to the full 1755-1850 MHz band at a small number of critical test and training locations until the replacement system redesign and deployment is complete in comparable bands. These relocated systems will need primary access in the 2025-2110 MHz and 2200-2290 MHz bands.[8]

Air Combat Training System: The Air Combat Training System provides, via ground-based and airborne components, real-time monitoring of air combat training including gun-scoring; no-drop bombing; evasion and intercept tactics, techniques, procedures; and electronic warfare. These operations occur at test and training ranges and other flight areas near Reserve and Air National Guard locations, including some civilian airports.

DOD determined that it can relocate its Air Combat Training System operations within ten years. DOD's preferred spectrum that provides sufficient comparable attributes to meet DOD's requirements is the 2025-2110 MHz band. Due to the wide bandwidth and requirements for multichannel operation, DOD indicates that it cannot transition this system out of the lower 25 megahertz (1755-1780 MHz) sooner than the ten-year timeframe nor can it establish

[8] Primary access in some cases requires the FCC to initiate a rulemaking to add a primary federal allocation to the U.S. Table of Frequency Allocations.

practical exclusion zones because of the extensive potential geographic impact from the high altitude operations. This is one of the challenges to a full 95 megahertz clearing scenario and a reason why alternative options that maintain this critical capability, while maximizing economic value, will likely need to be explored further with federal and non-federal stakeholders.

Precision Guided Munitions: Precision Guided Munitions provide critical tactical communications between launched weapons and controlling platforms, allowing for precise and effective targeting. DOD analysis determined that the Navy can vacate the 1755-1850 MHz band within ten years. DOD also determined that, as part of a transition out of the entire 1755-1850 MHz band, the Navy can compress its operations into the 1780-1850 MHz band within five years. The Air Force does not need to take any action since the Air Force plans to cease operations of PGM systems that use the 1755-1850 MHz band within five years.

Tracking, Telemetry, and Commanding: DOD satellites provide communications, navigation, surveillance, missile early warning, weather monitoring, and research and development support. Tracking, telemetry, and commanding uplinks in the 1755-1850 MHz band provide the sole means of sending commands for mission-related functions, positioning, and orbit maintenance of satellites. These uplinks are particularly critical for launch, early orbit, and correcting anomalous operations.

DOD determined that moving its Space Ground Link Subsystem (SGLS) from the 1755-1850 MHz band (L-band) within a ten-year timeframe would leave mission critical national security spacecraft without a means of control. Many existing and planned satellite systems will continue to operate well into the next decade, some potentially to 2045. However, DOD believes it can accommodate commercial broadband systems in the 1755-1780 MHz band within five years by establishing, around earth station sites, exclusion zones that prohibit commercial operations except where mechanisms have been put into place to ensure federal users are not required to assume the responsibility of mitigating interference. To reduce operations in the 1755-1850 MHz band, DOD proposes it would develop a satellite uplink capability in the 2025-2110 MHz band (S-band), install dual-band (L- and S-band) transponders on all future satellites, and modify earth stations to transmit in both bands. To mitigate the risk of losing unfettered spectrum access for satellite tracking, telemetry, and commanding due to uncertainty of spectrum access globally, DOD states it must indefinitely retain contingency access to the 1755-1850 MHz band for emergency situations involving satellites.

Aeronautical Mobile Telemetry: Aeronautical mobile telemetry systems operate from manned aircraft, unmanned vehicles, aerostats, missiles, or other platforms to provide real-time flight characteristics from the airborne vehicles to the ground, real-time video of cockpit or project information, real-time monitoring of flight research/test parameters, and real-time

command and control of the vehicle.[9] NASA determined that it can vacate its aeronautical mobile telemetry operations from the entire 1755-1850 MHz band in less than five years. Relocation to the 2025-2110 MHz and 5091-5150 MHz band requires a primary federal allocation for the aeronautical mobile service.[10]

DOD determined that it can relocate its aeronautical mobile telemetry systems within ten years and can accommodate commercial broadband systems in the 1755-1780 MHz band within five years. DOD will require continued access to the spectrum and protection for a number of test ranges until systems can be relocated to the 5150-5250 MHz band. In order to accommodate operations, DOD requires a primary federal allocation for the aeronautical mobile service in the 5150-5250 MHz band. DOD also determined it can relocate the Standard Missile Kinetic Warhead Data Link capability to the 1435-1525 MHz band in less than five years.

Video Surveillance: Under assignments throughout the 1755-1850 MHz band, federal agencies conduct electronic video surveillance operations, including mobile law enforcement, high-resolution (fixed and transportable) video data links, and land mobile robotic systems. All affected agencies report that they can relocate out of the 1755-1850 MHz band in ten years with required allocation changes. However, DHS, DOJ, and the Treasury state they need to retain up to 30 megahertz of contiguous spectrum for surveillance in the 1780-1850 MHz band pending the successful development of new technology and the availability of spectrum in the comparable bands. All agencies can vacate the 1755-1780 MHz band within five years.

Unmanned Aerial Systems: The use of unmanned aerial systems has grown significantly with deployment of more sophisticated payloads for expanded functions of electronic attack, communications relay, firefighting, science observation, and search and rescue.[11] The specific unmanned systems in this band are Small Unmanned Aerial Systems (SUAS), which are small enough to carry in a backpack or for a single person to launch and operate. Many of these systems require wide bandwidths.

DOD, DOI, and NASA determined that they can relocate their unmanned aerial systems within ten years and that the 2025-2110 MHz band is the most viable comparable spectrum for relocating the majority of these systems. Relocation of SUAS can permit accommodation of commercial broadband systems in the 1755-1780 MHz band within ten years with continued

[9] Aeronautical Mobile Telemetry includes all components of telemetry from air-to-air, air-to-ground, air-ground-air, and ground-ground mobile telemetry for tank field-testing.

[10] With regard to the 2025-2110 MHz band, NASA requires modification of footnote US346 to include 11 of its satellite earth stations to the current list of 12 (military) satellite control stations to allow operation on a co-equal primary basis with non-federal operations.

[11] In this report, the term unmanned aerial systems includes unmanned aerial vehicles that are also known as remotely piloted vehicles.

access and protection for DOD in the entire band at three high-density training areas until it completes transition to the 2025-2110 MHz band.

Other Systems: DOD has a number of other systems that rely on spectrum between 1755 MHz and 1850 MHz. DOD states it will need indefinite access to the 1755-1850 MHz band for electronic warfare (EW) training at specific sites, including the ability to develop, test, and train on electronic warfare systems that counter threat systems operating in the 1755-1850 MHz band; and as such, DOD requires a clear procedure ensuring priority access to this spectrum to perform testing and training. Additionally, DOD determined that its Software Defined Radio systems can accommodate commercial broadband systems, but it needs to maintain access and protection for software defined radio operations at 28 Infantry Brigade Combat Team training locations. Likewise, DOD also determined that as a transition to relocating its Tactical Targeting Networking Technology capability out of the 1755-1850 MHz band within ten years, it can accommodate commercial broadband systems in the 1755-1780 MHz band within five years.

Preliminary Summary of Cost Estimates

The table below summarizes the estimated cost to relocate federal operations out of the 1755-1850 MHz band. Federal agencies developed cost estimates to reflect a phased relocation scenario; namely an initial transition from the 1755-1780 MHz band within five years with the ultimate goal of relocating out of the entire 1755-1850 MHz band in ten years. A classified companion to this report documents the impacts, conditions, and costs for relocation of certain national security systems.[12] While the costs associated with relocating classified systems are captured in the costs provided in this document, this report does not list these systems or provide details on the conditions for relocation. Additionally, while the table presents only the ten-year estimates, this report also reflects estimates for the transitional phase where agencies provided them.

[12] Office of the Director of National Intelligence, Memorandum to NTIA (Aug. 31, 2011). (Not for Public Release)

Preliminary Estimated Cost to Relocate Federal Operations from the 1755-1850 MHz Band

Operation	Estimated Cost ($M)
Fixed Point-to-Point Microwave	186
Military Tactical Radio Relay	160
Air Combat Training System	4,500
Precision Guided Munitions	518
Tracking, Telemetry, and Commanding	2,350
Aeronautical Mobile Telemetry	3,140
Video Surveillance	5,097
Unmanned Aerial Systems	1,511
Other DOD Systems	364
Total ($M) [See Note]	**17,826**

Note: This total estimated cost to vacate the entire 1755-1850 MHz band includes the cost to relocate from the 1755-1780 MHz band; it does not include implementation and administration costs for DOD, which it estimates at $272M for vacating the 1755-1850 MHz band.

Repurposing 95 megahertz of spectrum at 1755-1850 MHz, combined with the 2010 recommendation in the Fast Track Report to reallocate 115 megahertz of spectrum to wireless broadband, would mean that the federal agencies have identified up to 40 percent of the spectrum needed to meet the President's goal of making 500 megahertz of spectrum available for wireless broadband by 2020.[13] However, NTIA recognizes that there are significant challenges to realizing the full potential of these repurposing efforts and looks forward to engaging with industry in a constructive dialogue to ensure protection of federal missions and to optimize economic value. To facilitate greater understanding of the challenges involved in any clearing of this band, NTIA recommends that the FCC and NTIA jointly sponsor an on-going forum to encourage communication between federal agencies and industry to discuss approaches to transition planning that will protect critical federal missions, while optimizing the economic value of the 1755-1850 MHz band. NTIA believes that a greater shared understanding of these challenges will promote better outcomes in any eventual relocation plan. Furthermore, the relocation of many operations will require close cooperation and coordination between government and industry. Such an approach will need to ensure spectrum access in support of critical federal missions, while minimizing the limitations on incoming industry operations.

[13] National Telecommunications and Information Administration, *An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, 4200-4220 MHz, and 4380-4400 MHz Bands* (Fast Track Evaluation) (Oct. 2010), *available at* http://www.ntia.doc.gov/report/2010/assessment-near-term-viability-accommodating-wireless-broadband-systems-1675-1710-mhz-17.

1. INTRODUCTION

Background

In June 2010, President Obama signed a memorandum calling for the Secretary of Commerce, working through the National Telecommunications and Information Administration (NTIA), in collaboration with the Federal Communications Commission (FCC), to make 500 megahertz of spectrum available for fixed and mobile wireless broadband in the next ten years.[14] Since the issuance of the Presidential Memorandum, NTIA has completed two initiatives in support of the 500 megahertz goal. NTIA developed a Ten-Year Plan and Timetable (Plan) with input from the Policy and Plans Steering Group (PPSG) that identified over 2,200 megahertz of federal and non-federal spectrum that might provide opportunities for wireless broadband use.[15]

NTIA and the federal agencies concurrently performed a Fast Track Evaluation of four spectrum bands by October 1, 2010 for the Office of Management and Budget (OMB), the National Economic Council, and the Office of Science and Technology Policy.[16] The goal of the Fast Track Evaluation was to determine whether spectrum in those bands could be made available for wireless broadband use within five years. NTIA selected the 1755-1780 MHz band for the Fast Track Evaluation because of the wireless industry's interest in the band and because the National Broadband Plan recommended this band be studied for possible pairing with the 2155-2180 MHz band.[17] However, NTIA did not make a recommendation concerning the 1755-1780 MHz band in its Fast Track Evaluation because it had insufficient time to analyze the full range of federal users and the diversity of federal uses in the band. Since this band is harmonized internationally for mobile operations, wireless equipment already exists, and the band provides propagation characteristics advantageous to mobile operations, it remained a priority for consideration pursuant to the Plan.

Of the spectrum bands identified in the Plan, NTIA selected and ranked six blocks of spectrum for priority consideration for repurposing to non-federal use for FCC-licensed wireless

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[14] Memorandum for the Heads of Executive Departments and Agencies, *Unleashing the Wireless Broadband Revolution* (Presidential Memorandum) (Jun. 28, 2010), 75 Fed. Reg. 38387 (July 1, 2010), *available at* http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution.

[15] National Telecommunications and Information Administration, *Plan and Timetable to Make Available 500 MHz of Spectrum for Wireless Broadband* (Nov. 15, 2010), *available at* http://www.ntia.doc.gov/reports/2010/TenYearPlan_11152010.pdf. Information regarding the PPSG and its member agencies is set forth *supra* note 2.

[16] Fast Track Evaluation, *supra* note 13. The Fast Track Evaluation recommended making the 1695-1710 MHz and 3550-3650 MHz bands available for wireless broadband use within five years.

[17] *Supra* note 5.

broadband systems.[18] On January 28, 2011, NTIA, in conjunction with the PPSG, selected 1755-1850 MHz as the first band designated for analysis.

Objective and Scope

The objective of this report is to assess the potential of the 1755-1850 MHz band to accommodate wireless broadband. NTIA invited federal agencies with operations in the band (listed below) to participate in the analysis. NTIA, via the PPSG, asked the federal agencies to analyze options, develop plans, and outline requirements for relocation of their federal systems out of the band while ensuring continuity of their critical operations. Final reports from the federal agencies provide timelines, estimated costs, and prerequisites that need to be satisfied to accommodate reallocation. An asterisk (*) denotes the agencies that provided input. This report summarizes their input.[19] Where possible, NTIA made these inputs available to the public on NTIA's website. Due to the detailed and sensitive nature of some of the inputs, NTIA cannot make all agency documents available to the public. In some cases, agencies supplied a separate version of their input for public release.

- Department of Commerce*
- Department of Defense*
    - Representing the Air Force, Army, Navy and Marine Corps
- Department of Energy*
- Department of Health and Human Services
- Department of Homeland Security*
- Department of Housing and Urban Development*
- Department of the Interior*
- Department of Justice*
- Department of the Treasury*
- Department of Veterans Affairs*

[18] National Telecommunications and Information Administration, *First Interim Progress Report on the Ten-Year Plan and Timetable* (April 2011), *available at* http://www.ntia.doc.gov/reports/2011/First_Interim_Progress_Report_04012011.pdf. The six bands selected for priority consideration are 1755-1850 MHz, 1695-1710 MHz, 406.1-420 MHz, 1370-1390 MHz, 4200-4400 MHz, and 3500-3650 MHz.

[19] See *Appendix A* for a list of referenced federal agency submissions. Releasable reports are available at http://www.ntia.doc.gov/category/spectrum-management.

- Federal Aviation Administration*
- National Aeronautics and Space Administration*
- Office of Personnel Management*
- U.S. Agency for International Development
- U.S. Capitol Police*
- U.S. Postal Service*

Approach

NTIA developed a plan for analyzing the 1755-1850 MHz band that required federal agencies to identify and evaluate alternative spectrum bands suitable to accommodate the relocation of and provide comparable capability for each type of agency system/operation in the 1755-1850 MHz band within ten years (hereafter referred to as comparable bands). To aid the federal agencies, NTIA suggested comparable bands for each application.

NTIA developed two relocation scenarios for purposes of analysis. The first scenario involved vacating the 1755-1850 MHz band in its entirety within ten years. The second scenario involved a phased transition from the 1755-1780 MHz band within five years with the ultimate goal of relocating out of the entire band in ten years. Since the majority of federal functions operate throughout the entire 1755-1850 MHz band to meet their missions, this approach investigated the conditions under which the 1755-1780 MHz band could be made available for commercial broadband use without negatively affecting incumbent operations in a shorter timeframe (e.g., within five years). However, in order to ensure a long-term approach to satisfying federal requirements and to take a significant step toward meeting the President's goal, NTIA did not pursue the evaluation of the 1755-1780 MHz band as an exclusive solution.

To conduct the analysis, agencies developed detailed technical and operational information for both the relocating systems and incumbents' systems in the comparable bands. The sheer number of possible combinations of agencies and agency applications in the 1755-1850 MHz band, multiple prospective comparable bands, and the incumbent services in those bands made the analysis complex.

As a result, NTIA and the PPSG needed to reduce to a manageable number the representative set of independent, detailed evaluations for comparison. To this end, NTIA implemented a two-step approach involving: (1) the *Comparable Band Prioritization*, which prioritized federal agency options for comparable relocation spectrum; and (2) a *Detailed Analysis of Priority Comparable Bands*, which analyzed trade-offs of the high priority bands. From an initial list of recommended comparable bands for 1755-1850 MHz band operations/system types, the affected agencies performed an initial analysis of alternatives

based on technical factors, impact to agency operations, relocation strategy, and gross time and cost estimates. The agencies considered each band's ability to accommodate a relocating operation in terms of the physics of the bands, spectrum availability, challenges in coordination of incumbent and new entrant operations, and the ability of the agencies and equipment designers to redesign equipment to operate in those bands. Each agency provided NTIA, in rank order, a prioritization of comparable bands for each 1755-1850 MHz band operation, supported by a rationale for each band's selection and ranking.

Evaluation of the comparable bands considered multiple operations; the physical environment; operational scenarios; refined timelines and cost estimates; and a relocation plan to relocate from the entire 1755-1850 MHz band within ten years, including any plans (e.g., phasing) to transition out of the 1755-1780 MHz band within five years where feasible. In addition, the relocating agency and the federal agencies operating in the proposed comparable spectrum jointly explored approaches that would ensure compatibility among their respective operations. The affected agencies specified any actions or conditions deemed necessary to ensure successful relocation. This type of effort is still required to appropriately address non-federal operations currently operating in the comparable bands.

The result of these detailed analyses provides the framework for transitioning federal operations from the 1755-1850 MHz band in its entirety to other comparable spectrum within ten years. Included is a schedule for transitioning out of the 1755-1780 MHz band within five years where feasible with the ultimate goal of relocating out of the entire band in ten years, corresponding cost estimates, and identification of the required regulatory actions and prerequisites.

2. 1755-1850 MHZ BAND OVERVIEW

Internationally, the 1755-1850 MHz band falls in the 1710-1930 MHz band allocated on a primary basis to the fixed and mobile services for all three International Telecommunication Union (ITU) Regions. Nationally, the 1755-1850 MHz band is allocated on an exclusive basis to the federal government for fixed and mobile services. The U. S. Government uses the entire 1755-1850 MHz band across the nation. Video surveillance operates on channels throughout the band under nationwide assignments and, therefore, may operate in any part of the band, at any location, at any time. Likewise, some systems such as the Air Combat Training System require access across the entire band to satisfy their mission. Footnote G42 of the National Table of Frequency Allocations provides for the co-equal accommodation of federal space command, control, and range and range-rate systems for earth station transmission in the

1761-1842 MHz band.[20] The following list represents the initial grouping of federal systems identified by NTIA as operating in the 1755-1850 MHz band.

- Fixed point-to-point microwave
- Military tactical radio relay
- Air combat training system
- Precision guided munitions
- Law enforcement mobile video surveillance applications
- High-resolution (fixed or transportable) video data links for surveillance
- Tracking, telemetry, and commanding for federal space systems
- Air-to-ground telemetry
- Land mobile robotic video functions (e.g., explosive ordnance disposal (EOD) and hazardous material investigations and disposals)
- Unmanned aerial systems (UAS), unmanned aerial vehicles (UAV), and remotely piloted vehicles (RPV)

This assessment addresses the 1755-1850 MHz band in two ways: the 1755-1780 MHz sub-band, and the entire 1755-1850 MHz band. As of September 2011, the Government Master File (GMF) listed 833 frequency assignments for federal stations in the 1755-1780 MHz band compared to 3,183 in the entire 1755-1850 MHz band.[21] Table 2-1 presents a distribution of the number of assignments by agency for each category of system. The number of assignments, authorized by NTIA, cannot be considered independently since many systems use the entire band, and the number of assignments does not represent the number of equipment items in use. In many cases, multiple pieces of radio equipment, and sometimes hundreds of devices, operate under a single frequency assignment. For example, nationwide assignments support video surveillance, for which thousands of functional devices may operate based on a single assignment. In this band, only the assignments for fixed point-to-point systems (about ten percent of the total) link single transmitter/receiver combinations. Figure 2-1 provides a pictorial representation of some of the major systems operating in the band.

[20] National Telecommunications and Information Administration, U.S. Department of Commerce, *Manual of Regulations and Procedures for Federal Radio Frequency Management* (May 2010 Revision of the January 2008 Edition) (NTIA Manual) at § 4.3.1.

[21] NTIA maintains the GMF, a master list of frequency assignments authorized for use by federal agencies.

Table 2-1. Number of Federal Frequency Assignments in the 1755-1850 MHz Band

AGENCY	Fixed Point-to-Point Microwave	Military Tactical Radio Relay	Air Combat Training Systems	Precision Guided Munitions	Law Enforcement Mobile Video Surveillance Applications	High-Resolution Video Surveillance (fixed or transportable)	Telemetry, Tracking, and Commanding for Federal Space Systems	Air-to-Ground Telemetry	Land Mobile Robotic Video Functions (e.g. EOD & Hazardous Waste Disposal, etc)	UAS, UAV, RPV	TOTAL
Air Force	12		273	1		2	220	186	61	45	800
USAID						1					1
Army	45	408	4			36		19	4	378	894
DHS	152				25						177
DOC	8						1				9
DOE	91								2		93
DOI	26				1	1					28
DOJ					7	75			7	6	95
FAA	8										8
HHS						1					1
HUD						6					6
Marine Corps	4	169								21	194
Navy	14	2	430	20			48	303	6	14	837
OPM						1					1
NASA								6		11	17
Treasury						10					10
USCP						5					5
USPS						3					3
VA						4					4
TOTAL	360	579	707	21	33	145	269	514	80	475	3183

Note: This table provides a snap shot of the recorded GMF assignments for federal agency operations in the 1755-1850 MHz band as of September 2011. While federal agencies generally provided inputs using these categories, agencies found slight disparities in the alignment of assignments to categories. Actual counts and alignment will also change because of future activities (e.g., pending assignment approvals, fielding of developmental systems, and planned future operations).

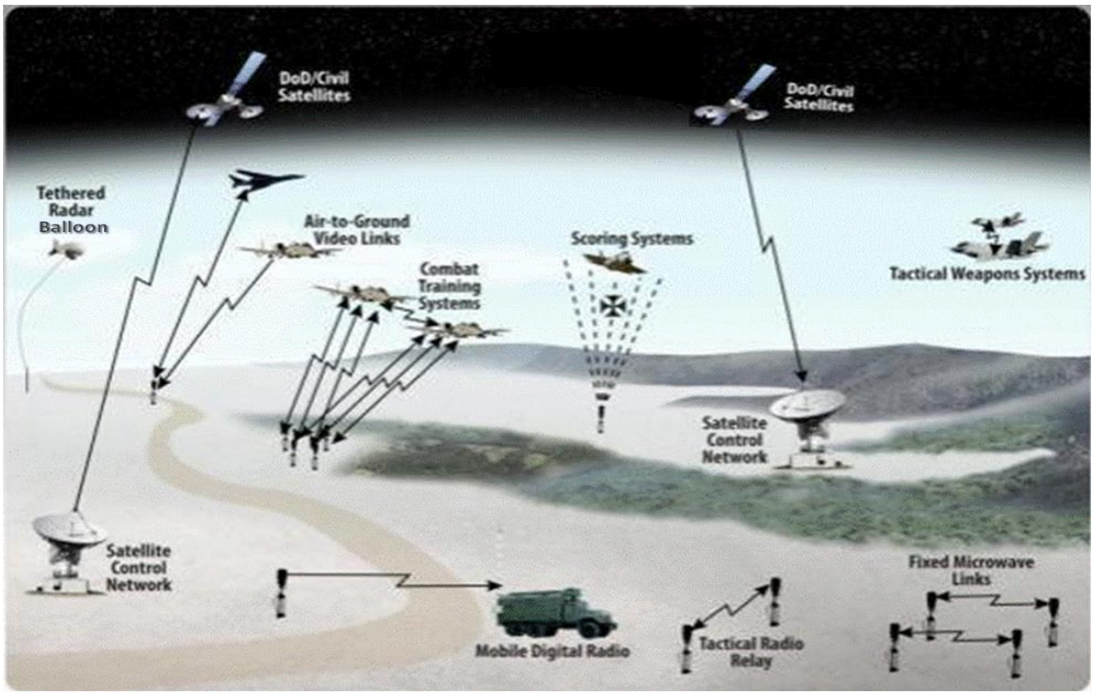

Figure 2-1. Pictorial Representation of Some Federal Systems in the 1755-1850 MHz Band

Table 2-2 provides an overview relating federal agencies with the operations they perform in the 1755-1850 MHz band**.** While federal agencies generally provided inputs using the initial nomenclature provided to them for operations in Table 2-1, there were slight disparities among some agency submissions. To reconcile these differences, NTIA adopted the naming convention shown in Table 2-2. Accordingly, Section 3 of this report documents comparable band considerations using the convention of Table 2-1, while the remainder of this section and Section 4 presents operations in accordance with Table 2-2.

Table 2-2. Federal Agencies with Operations in the 1755-1850 MHz Band

OPERATION	Federal Agencies currently operating in the 1755-1850 MHz band with this type of operation
Fixed Point-to-Point Microwave	**DHS, DOC, DOD, DOE, DOI, FAA**
Military Tactical Radio Relay	**DOD**
Air Combat Training System	**DOD**
Precision Guided Munitions	**DOD**
Tracking, Telemetry, and Commanding	**DOC, DOD**
Aeronautical Mobile Telemetry	**DOD, NASA**
Video Surveillance • **Law Enforcement Mobile** • **High Resolution Video Data Links** • **Land Robotics**	**USAID, DHS, DOD, DOE, DOI, DOJ, HHS, HUD, OPM, Treasury, USCP, USPS, VA**
Unmanned Aerial Systems[22]	**DOD, DOI**[23]**, DOJ, NASA**
Other Systems[24] • **EW Systems** • **SDR (e.g., JTRS)** • **TTNT**	**DOD**

The text that follows provides a general description of these operations. Appendix B provides additional details regarding specific systems including their locations and use.

[22] The UAS category includes UAVs, which are also known as RPVs. A UAV is defined as a pilotless aircraft remotely controlled or flown by a pilot, controller at a ground control station, by a pre-programmed flight plan, or dynamic automation system. The UAS term reflects that these complex systems include ground stations and other elements besides the actual air vehicles. *See also* http://www.theuav.com/.

[23] DOI is currently in the process of obtaining frequency assignments for their UAS from NTIA.

[24] DOD identified these additional systems in their detailed band analysis report.

Fixed Point-to-Point Microwave

Federal agencies use fixed point-to-point microwave systems for the transmission of voice, data, and/or video in support of law enforcement, military command and control, emergency preparedness and response, the national air space system, energy grid control, and resource management activities. These systems also support the distribution of meteorological data to a variety of users including the public. Fixed point-to-point microwave systems provide service where commercial options are either unavailable, too expensive, or do not provide the level of reliability required by federal users.

Military Tactical Radio Relay (TRR)

The DOD operates tactical communications systems that provide mid- to high-capacity digital information to battlefield commanders.

Army High-Capacity Line-of-Sight (HCLOS)

Army TRR systems provide wide area communications for Army tactical deployments at the battalion, brigade, and division levels. These systems, typically deployed up to 30-50 kilometers apart, provide high-throughput data communications from command and control traffic to intelligence imagery, logistics, medical, and morale and welfare support. The HCLOS system currently tunes to the 225-400 MHz and 1350-2690 MHz bands and provides a digital microwave backbone to link mid-level and lower-level battlefield commanders. The TRR systems operate like high-capacity cellular telephone systems with highly transportable base stations. The ability to set up, to establish a link to higher headquarters and subordinate units, and then to take the link down and to move it is key to the survivability of the headquarters units and supports the concept of maneuver warfare. Frequent field training is required to ensure that soldiers can quickly establish a network of tactical microwave links. The AN/GRC-245 is the Army's primary TRR system that will replace its legacy TRR systems (AN/GRC-226 and AN/VRC-99B).

Navy and Marine Corps Digital Wideband Transmission System (DWTS)

The DWTS provides a backbone digital communications capability supporting amphibious and ground combat operations. The DWTS supports command, control, and data transfer from the Marine Expeditionary Force level down to the regimental level and supports training and operations at a number of locations throughout the United States. The Marine Corps version of this system provides digital backbone services (voice, video, and data) for shore-to-shore and/or ship-to-shore communications links. This radio system is the only transmission media available to the Marine Corps with sufficient bandwidth to carry large quantities of critical data, such as maps, overlays, intelligence pictures, and other data to battlefield commanders. The Marine Corps currently employs three variants of the DWTS. Two

variants are limited to the tuning range between 1350 and 1850 MHz. The third tunes between 1350-2690 MHz, but is not compatible with the other two variants. The Navy has a ship-to-shore version of DWTS used for communications between Expeditionary Strike Group ships and Marine Corps units ashore, where most of the critical information flow is from the ship to the landing forces.[25] The Navy shipboard DWTS system tuning range is limited to 1350-1850 MHz.

Air Combat Training System (ACTS)

Air combat training involves air-to-air encounters and may include a network of ground stations monitoring the training activity. Aircraft relay data regarding the aircraft's flight parameters to ground stations. Ground stations also send information to aircraft. Training and status data communications link aircraft-to-aircraft and may be recorded on each aircraft. Training staff retrieve and analyze recorded data for training debriefings. The Tactical Combat Training System (TCTS)/P5 Combat Training System (P5 CTS) is a cooperative program between the Navy (TCTS) and Air Force (P5 CTS) that supports training aircrews via realistic warfighting scenarios using a single cooperative instrumented tactical aircrew training capability. It is the primary tool at virtually all air combat training ranges and supports every level of training from schools where pilots first learn to fly the aircraft they will take into battle to advanced-tactics training schools that hone combat skills. To ensure multi-national interoperability, Allied Forces perform training missions inside and outside of the United States. The TCTS has or will replace all other instrumented training systems currently utilized by the Navy.[26]

The P5 CTS is the primary Air Force ACTS in use today at Air Force training facilities, replacing the older Air Combat Maneuvering Instrumentation (ACMI) system. ACMI, and other unique systems, although older, remain in daily use at Nellis Air Force Base (AFB) in Nevada and Eielson AFB in Alaska.[27]

Precision Guided Munitions (PGM)

Precision guided munitions include weapons systems that employ communications between a launched weapon and a controlling platform allowing for precision delivery of the weapon's payload. These advanced systems are normally employed against high-value and hardened enemy targets. Tactical control links that support PGMs provide a decisive combat edge to U.S. forces. PGMs require regular testing and training by operational units to maintain

[25] DOD-2 at § 4.3.2.

[26] *Id. at* § 4.5.

[27] *Id.*

operational readiness and to update capabilities in response to new missions and threats. These activities are limited to test and training ranges in United States.[28]

Current PGMs affected by the potential reallocation of the 1755-1850 MHz band include the Air Force Air-to-Ground Missile (AGM)-130 and Guided Bomb Unit (GBU)-15 systems and a Navy PGM. In response to the reallocation of 1710-1755 MHz band, DOD compressed PGM control links so they operate in the 1755-1850 MHz band.[29]

Tracking, Telemetry, and Commanding (TT&C)

Satellites provide communications, navigation, surveillance, missile early warning and attack characterization, weather monitoring, and research and development. DOD uses the 1755-1850 MHz band for initial contact with newly launched satellites, early orbit checkout of those satellites, emergency access to spinning/tumbling satellites (anomaly resolution), and final disposal of satellites upon mission completion. This band also supports critical command and control; mission data retrieval; and on-orbit maneuvering of low and medium earth, highly elliptical, geosynchronous, and geostationary orbit satellites.[30]

Space Ground Link Subsystems

All DOD satellites rely on control provided by the Air Force Satellite Control Network (AFSCN), Naval Satellite Control Network (NSCN), Global Positioning System (GPS), or Defense Support Program (DSP)/Space Based Infrared System (SBIRS) networks. The Air Force SGLS is the primary component of this network, and provides TT&C functions with satellites that perform missile warning; navigation; military satellite communications (SATCOM); weather tracking and reporting; and intelligence, surveillance, and reconnaissance (ISR).[31] Table 2-3 provides a list of the satellite TT&C ground stations in the United States.

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[28] *Id.* at § 4.6.

[29] *Id.*

[30] Department of Defense, *Strategic Spectrum Plan* (DOD Strategic Spectrum Plan) (Feb. 2008) at § 3.16, *available at* http://www.ntia.doc.gov/files/ntia/publications/dod_strategic_spectrum_plan_nov2007.pdf.

[31] DOD-2 at § 4.7.

Table 2-3. Satellite TT&C Ground Stations

Antenna Location	State
Fairbanks (National Oceanic and Atmospheric Administration) (NOAA)	Alaska
Vandenberg AFB, Laguna Peak (Navy), Camp Parks	California
Buckley AFB, Schriever AFB	Colorado
Cape Canaveral Air Force Station	Florida
Joint Region Marianas	Guam
Kaena Point	Hawaii
Prospect Harbor (Navy)	Maine
Laurel, Blossom Point (Navy)	Maryland
New Boston Air Force Station	New Hampshire
Kirtland AFB	New Mexico
Joint Base San Antonio	Texas
Ft. Belvoir, Quantico	Virginia

The NSCN provides TT&C for the Ultra High Frequency (UHF) Follow-On (UFO), Fleet Satellite (FLTSAT), and Joint Milli-Arcsec Pathfinder Surveys systems with command uplinks in the 1755-1850 MHz band. These systems, however, have a projected end of life before 2022. The Mobile User Objective System (MUOS), scheduled to achieve initial operating capability in 2012 and full operational capability in 2017, will replace these systems with a network of four geosynchronous satellites and one in-orbit spare. MUOS satellites will provide communications between fixed and mobile terminals worldwide, using both broadband code division multiple access (CDMA) and legacy UHF transmissions. MUOS satellites will also provide radio frequency (RF) interference geolocation at UHF frequencies. The satellites will include transponders for receiving command uplinks from NSCN and AFSCN using the L-band (1755-1850 MHz), S-band (2-4 GHz), and Ka-band (26.5-40 GHz).

Other Space Operations and Space Telecommand Systems

The mission control station for GPS is located at Schriever AFB in Colorado. Dedicated earth stations provide command uplinks to GPS satellites in the 1755-1850 MHz band from Cape Canaveral, Kwajalein Island, Ascension Island, and Diego Garcia. A number of other facilities transmit on SGLS frequencies. Furthermore, the Air Force maintains transportable TT&C antenna systems to support launch, early orbit, anomaly resolution, and augmentation in the event of war and natural disasters.

Aeronautical Mobile Telemetry (AMT)

AMT systems support testing and evaluation of manned aircraft, unmanned aerial systems, missiles, or other ordnance devices to provide real-time flight characteristics data and video from airborne vehicles to the ground; real-time video of cockpit or project information; real-time monitoring of flight research/test parameters; and real-time command and control of vehicles.[32] DOD and NASA use the 1755-1850 MHz band for telemetry operations. DOD test and training ranges operate a complex system of telemetry tracking stations and control centers. Telemetry serves multiple purposes in the design and testing phases of aircraft and weapons system designs (i.e., safety, command and control, specification compliance, system performance, lethality). Flight test telemetry provides critical data on platform performance, enabling DOD to perform hazardous complex testing events using integrated scenarios. The Kinetic Warhead Data Link (KWDL) that is integral to the Aegis Ballistic Missile Defense (BMD) system is included within this category of operations because its data link to the tactical missile is used in both test and training exercises as well as in tactical BMD missions. The major DOD and NASA test and training ranges and centers include:

- Naval Air Systems Command (NAVAIR) Pacific Ranges, Naval Air Warfare Center-Weapons Division, China Lake and Pt. Mugu, California;
- Air Force Flight Test Center, Edwards AFB, California;
- National Training Center (NTC), Fort Irwin, California;
- Yuma Proving Ground (YPG), Yuma, Arizona;
- DOD Gulf Range (which encompasses most of Florida and large portions of Georgia, Alabama, Mississippi, and southeastern Louisiana);
- NAVAIR Atlantic Test Range, Naval Air Warfare Center-Aircraft Division, Patuxent River, Maryland;
- White Sands Missile Range (WSMR), White Sands, NM;
- Dryden Flight Research Center (DFRC), Edwards AFB, California;
- Langley Research Center (LaRC), Hampton, Virginia; and
- Wallops Flight Facility (WFF), Wallops, Virginia.[33]

[32] *Supra* note 9.

[33] DOD-2 at § 4.4; NASA-1.

Video Surveillance

The agencies analyzed three types of video surveillance systems: law enforcement mobile, high-resolution video (HRV) data links, and land robotic systems, described in the following subsections.

Law Enforcement Mobile

Federal agencies use the 1755-1850 MHz band to employ undercover low-power video surveillance devices during criminal investigations. NTIA has authorized many of these operations throughout the United States and its possessions (US&P) for protective operations and criminal investigations and therefore, the devices may operate in any part of the band, at any location, at any time. The video obtained during these investigations ensures rapid response support to undercover officers and agents and provides evidence essential to criminal investigations and court proceedings.

While many agencies perform surveillance activities using this spectrum, DOJ and DHS perform the majority of surveillance operations in this band. The DOD does not operate law enforcement mobile video surveillance systems in the 1755-1850 MHz band.[34]

High-Resolution Video (HRV or Hi-Rez) Data Links (fixed or transportable)

The federal agencies maintain and conduct authorized electronic video surveillance on multiple frequency assignments in the 1755-1850 MHz band to satisfy their law enforcement requirements. Missions, in most cases, require mobile or transportable surveillance equipment.[35] Therefore, devices must be lightweight, easily assembled, and concealable. They also must prevent electronic detection to ensure officer/agent safety.

Land Robotic Systems

Agencies operate land robotic video systems in real world situations and training exercises to maintain operational readiness. These systems, employed on robotic devices, reduce "risk to life" of personnel during explosive ordnance demolition or disposal and other uses. Explosive ordnance disposal operations use a video link between a remote-controlled robot and the command site to enable the operator to provide command and control for the robot and, at the same time, monitor the disposal operation. The 1755-1850 MHz band meets the high mobility and high-path reliability requirements for these systems.[36]

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[34] *Id.* at § 4.9.1.

[35] *Id.* at § 4.9.2.

[36] *Id.* at § 4.9.3.

Unmanned Aerial Systems

DOD performs command, control, and telemetry operations for a number of small to mid-sized UAS in the 1755-1850 MHz band. UAS transmit video and status data to the ground control system. Training and operational use of UAS has increased significantly over the past few years and agencies have designed several UAS platforms to enhance the expanded ISR functions.[37] UAS permit longer times over battlespace and support multiple missions and platform interfaces (i.e., air, space, sea, and ground platforms). Requirements for UAS continue to grow not only overseas but also in the United States to support increased operations and training.[38] In addition to military operations, other federal agencies use UAS for missions such as border patrol, science applications, and disaster relief.[39]

Other Systems

DOD has a number of other systems, described in the following subsections, which rely on spectrum between 1755 MHz and 1850 MHz.

Electronic Warfare Testing, Training, and Exercises

DOD employs EW systems to assure that friendly forces can use the spectrum to its full potential across the full range of military operations, while denying that use to enemies. The value of electronic warfare operations and training can be seen most clearly in current operations in Iraq and Afghanistan. Military forces have successfully trained and applied EW to disable the use of remote controlled improvised explosive devices.[40] The 1755-1850 MHz band provides the only opportunity to perform testing and for training of DOD personnel against threat systems in that band.

Software Defined Radio (SDR) Systems

SDR systems generate different waveforms and RF modulations of varying complexity through modifiable software and by the use of digital synthesis. Systems under various stages of development include the Joint Tactical Radio System (JTRS) man-pack radio and Multifunctional Information Distribution Systems (MIDS) for JTRS.[41] Appendix B provides further detail.

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[37] DOD-2 at § 4.8.

[38] *Id.*

[39] In some cases, this report addresses costs for these systems under other categories of operations (e.g., Hi-Rez video surveillance, telemetry).

[40] DOD-2 at § 4.10.1.

[41] *Id.* at § 4.10.2.

Tactical Targeting Networking Technology (TTNT)

TTNT provides an Internet Protocol-based, high-speed, dynamic ad hoc network designed to enable the U.S. military to quickly target moving and time critical targets. TTNT enables net-centric sensor technologies to correlate information among multiple platforms. The changing nature of warfare, in which real-time communication exchanges are paramount, makes TTNT an important element in conducting future military operations.[42]

3. AGENCY EVALUATIONS OF COMPARABLE BANDS

Comparable Band Prioritizations

To facilitate identification of comparable bands, NTIA, in coordination with the PPSG, developed an initial set of alternative bands for consideration. NTIA suggested the initial set of bands based on several factors including capability to support operations similar to those in the 1755-1850 MHz band, propagation characteristics, potential for frequency availability, and potential suitability for hosting multiple operations based on their current use and to provide a greater number of band options from which to choose. Appendix C provides an overview of operations that are currently in these bands. Table 3-1 identifies the comparable bands selected relative to their best match for federal operations and the factors taken into consideration when making the selections.

[42] *Id.* at § 4.10.3.

Table 3-1. Potential Comparable Spectrum Bands

Initial Categories of Systems	Potential Bands for Relocation		Factors Considered
Fixed Point-to-Point Microwave	4400-4950 MHz 7125-8500 MHz Wireline or Commercial	14.5-14.7145/ 15.1365-15.35 GHz Possibly higher (e.g., 25-27.5 GHz)	Equipment is available and there is adequate spectrum.
Military Tactical Radio Relay	1435-1525 MHz 2025-2110 MHz	2110-2165 MHz 2200-2310 MHz*	These bands minimize the need for modifications to equipment (e.g., existing equipment such as Mobile Subscriber Equipment and HCLOS tune up to 2690 MHz, so no equipment modifications are necessary).
Air Combat Training Systems	1350-1390 MHz 1435-1525 MHz 2025-2110 MHz	2200-2300 MHz* 2360-2395 MHz	Airborne operations can be accommodated or are already being performed in these bands; these bands have similar or better propagation characteristics; and coordination with aeronautical telemetry is possible.
Precision Guided Munitions	1350-1390 MHz 1435-1525 MHz 2025-2110 MHz	2200-2300 MHz* 2360-2395 MHz	Airborne operations can be accommodated or are already being performed in these bands; these bands have similar or better propagation characteristics; and coordination with aeronautical telemetry is possible.
Law Enforcement Mobile Video Surveillance Applications	225-328.6/ 335.4-380 MHz 420-450 MHz 902-928 MHz 1350-1390 MHz	1435-1525 MHz 1675-1695 MHz 2025-2110 MHz 2200-2300 MHz* 2360-2395 MHz	Equipment is available; and/or propagation characteristics are similar or better; and/or the incumbent radio services are similar to those in the 1755-1850 MHz band where successful sharing exists.
High-Resolution (fixed or transportable) Video Data Links for Surveillance	225-328.6/ 335.4-380 MHz 420-450 MHz 902-928 MHz 1350-1390 MHz	1435-1525 MHz 1675-1695 MHz 2025-2110 MHz 2200-2300 MHz* 2360-2395 MHz	Equipment is available; and/or propagation characteristics are similar or better; and/or the incumbent radio services are similar to those in the 1755-1850 MHz band where successful sharing exists.
Tracking, Telemetry, and Commanding for Federal Space Systems	2025-2110 MHz 7125-8500 MHz	20/30 GHz	Equipment is available and there is adequate spectrum.
Air-to-Ground Telemetry	1350-1390 MHz 1435-1525 MHz 2025-2110 MHz	2200-2300 MHz* 2360-2395 MHz	Airborne operations can be accommodated or are already being performed in these bands; these bands have similar or better propagation characteristics; and coordination with aeronautical telemetry is possible.
Land Mobile Robotic Video Functions	225-328.6/ 335.4-380 MHz 420-450 MHz 1350-1390 MHz 1435-1525 MHz	1675-1695 MHz 2025-2110 MHz 2200-2310 MHz* 2360-2395 MHz	Propagation characteristics are similar or better and the incumbent radio services are similar to those in the 1755-1850 MHz band where successful sharing exists.
UAS, UAV, RPV	225-328.6/ 335.4-380 MHz 2025-2110 MHz 2200-2300 MHz*	4400-4950 MHz 14.5-14.7145/ 15.1365-15.35 GHz	Although these bands are already used, they can also support the operations conducted in the 1755-1850 MHz band.

* The correct band for consideration is 2200-2290 MHz; however, because NTIA identified two different bands, 2200-2300 MHz and 2200-2310 MHz, in the initial list of candidate comparable bands, these bands are sometimes referenced throughout this report.

Following the approach described for the *Comparable Band Prioritization* process, federal agencies, using the information in Table 3-1, performed a comparable band prioritization analysis for each of their operations based on rough estimates regarding technical realization, operational compatibility, and the time and cost to relocate. Some federal agencies assessed bands that were not part of the initial list provided by NTIA because they thought the bands might offer potential. Table 3-2 presents the comparable bands ranked highest in priority by the federal agencies.[43]

[43] *See* DHS-1, DOC-1, DOD-1, DOE-1A, DOE-1B, DOI-1, DOJ-1, FAA-1, HUD-1, NASA-1, and Treasury-1. (See Appendix A *infra* for full citation.)

Table 3-2. Federal Agency Designation of Highest Priority Comparable Bands (in MHz)

Federal Agencies	Fixed Point-to-Point Microwave	Military TRR	ACT Systems	PGM Systems	Law Enforcement Mobile Video Surveillance	Hi-Rez Video Data Links	TT&C for Federal Space Systems	Air-to-Ground Telemetry	Land Mobile Robotics Video Functions	UAS, UAV, RPV
DHS	Possibly 7 GHz Band[44]				2200-2290	2200-2290				
DOC	Commercial Services									
DOD	7125-8500	2025-2110 2200-2310	2025-2110	2025-2110	2025-2110	2025-2110 2200-2290	2025-2110	5150-5250[45] 2025-2110 4940-4990[46]	2025-2110 2200-2300	2025-2110 2200-2300
DOE	4400-4940 7125-8500									
DOI	8000				2200-2300	2200-2300				
DOJ[47]					2200-2290	2200-2290				
FAA	7125-8500 4400-4940 2200-2300									
HUD					2200-2290	2200-2290				
NASA								4400-4940 5091-5250[48]		4400-4940[49]
Treasury					2200-2290	2200-2290				

Note: HHS, OPM, USAID, USCP, USPS, and VA did not designate their high priority comparable bands.

[44] The DHS evaluation stated that "[m]icrowave operations may possibly migrate to the 7 GHz range," but it did not address any bands above 2360-2395 MHz. See DHS-1 at 78.

[45] This band was submitted to NTIA/PPSG by DOD, and thus, NTIA added it to this analysis as a result of DOD's initial assessment.

[46] This band was submitted to NTIA/PPSG by DOD, and thus, NTIA added it to this analysis as a result of DOD's initial assessment.

[47] DOJ's fixed and transportable point-to-point microwave systems are included under Mobile Video Surveillance operations. Additionally, DOJ's UAS operations are incorporated with the Hi-Rez Video Data Link operations for this report.

[48] This band was added by NASA.

[49] While NASA operates UAVs and identified a prioritized band for them, for this report, NASA reported related costs under AMT.

Appendix D summarizes the rationale given by federal agencies in support of their band prioritizations. Not all agencies ranked all of the candidate bands. This occurred for several reasons, namely:

- Some agencies have opted to use commercial services;
- Some agencies, with fixed point-to-point operations, deemed the lower bands less suitable than the bands in the upper part of the radio spectrum; and
- Other agencies determined that some of the candidate bands could not effectively support their operations.

Notwithstanding these differences, each agency performed its *Detailed Analysis of Priority Comparable Bands*, investigating the feasibility of each of its preferred spectrum band(s) to support each of its operations. Figure 3-1 depicts the process for the detailed analysis.

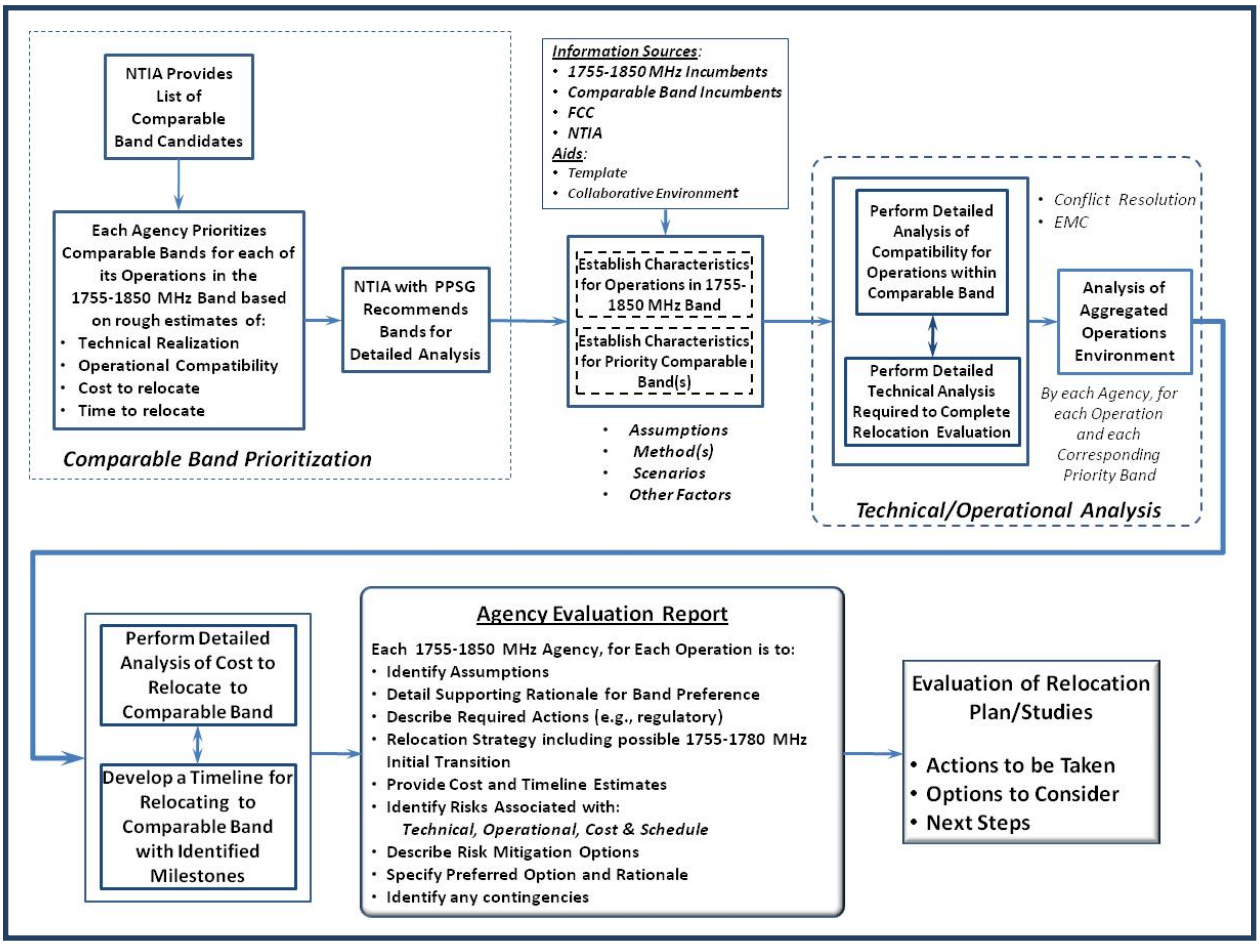

Figure 3-1. Evaluation Process for Detailed Analysis of Comparable Bands

Detailed Analysis of Priority Comparable Bands

NTIA provided the agencies a template for organizing their evaluations of potential comparable spectrum bands. The template recommended that agencies develop assumptions to bound their analysis, consider scenario-based approaches, and describe the methods used to support their evaluations. Moreover, NTIA encouraged the agencies to engage in a collaborative exchange of ideas with both their counterparts in the 1755-1850 MHz band and those agencies that are the current incumbents of the comparable bands.

The federal agencies first established characteristics of their operations in the 1755-1850 MHz band. Specifically, for each type of operation, each affected agency identified, by type, the systems it has in this band, the number of assignments by system type, and type of assignment by system (i.e., local, regional, or national). The agencies also developed brief descriptions of the types of operation in the band and, to the extent possible, a gross characterization of each system's frequency of use. In addition, they investigated the characteristics of their chosen priority comparable bands, including identification of the incumbents, the number of incumbent assignments, and the types of incumbent systems in those bands. The comparable bands studied have both incumbent federal and non-federal operations; and accordingly, agencies have not yet had the dialogue required with non-federal incumbents to consider all options for repurposing in detail.

Table 3-3 presents the final set of comparable bands that NTIA asked the affected federal agencies to consider in their detailed analysis of comparable bands. The table inter-relates each operation, the preferred bands for each operation, and the respective agency that made the selections. The table also includes bands that some federal agencies ruled out based on their initial assessments and additional bands, 1350-1390 MHz and 5091-5250 MHz, which NTIA added to increase the band options available to agencies.

Table 3-3. Comparable Bands for Detailed Analysis

Initial Categories of Systems / Frequency (MHz)	Fixed Point-to-Point Microwave	Military TRR	ACT S [c]	PGM [c]	Law Enforcement Mobile Video Surveillance	High-Resolution Video Data Links	TT&C	Air-to-Ground Telemetry	Land Mobile Robotics Video Functions	UAS, UAV, RPV
1350-1390									[DOD]	
1435-1525			[DOD]	[DOD]	Treasury DHS DOJ DOI	Treasury DHS DOJ DOI [DOD]		NASA [DOD]	DOJ [DOD]	NASA [DOD]
1675-1695					Treasury DHS DOJ[e] DOI	Treasury DHS DOJ[e] DOI [DOD]			[DOD]	
2025-2110		DOD	DOD	DOD		DOD	DOD [b]	DOD	DOD	DOD NASA
2200-2290 [d]		DOD	[DOD]	[DOD]	Treasury DHS DOJ DOI	Treasury DHS DOJ DOI [DOD]		[DOD]	DOD	DOD
2360-2395			[DOD]	[DOD]						
4400-4940								NASA DOD		NASA [DOD]
5091-5250								NASA DOD		NASA [DOD]
7125-8500	DHS DOE DOI DOD FAA [a]								DOE	
14.5-14.7145 GHz 15.1365-15.35 GHz	For shorter path length									

Table Notes:

a. The FAA did not specify a preferred band, however, the 7-8 GHz band is presumed to be their preferred band to relocate to given that the FAA has existing point-to-point microwave operations in that band.

b. DOD has indicated that 1755-1850 MHz band earth stations must be accommodated in the band; however, they are considering combining ground station locations and/or moving locations to rural areas

c. An option would be to consider reducing operating frequencies and/or channel bandwidth.

d. Various agencies considered the entire 2200-2300 MHz band as a option for analysis.

e. DOJ's fixed and transportable point-to-point microwave systems are included under Mobile Video Surveillance operations. Additionally, DOJ's UAS operations are incorporated with the Hi-Rez Video Data Link operations for this report.

[--] Indicates that the agency did not select that candidate band (either as its high, medium or low choice) as part of its submission.

Having completed the characterization process, the agencies then performed a detailed evaluation of the comparable band candidates based on technical feasibility and operational impact. Technical considerations included technology implications of relocating a "type of operation" or major system into a specific alternate spectrum band, such as:

- The limitations, if any, on the agency systems' performance anticipated in the new band attributable to technical or technology shortcomings (e.g., propagation loss, signal fading, path reliability);
- Technical solutions available to overcome such limitations (e.g., high gain antennas, higher power transmitter, new waveforms);
- The state of availability and maturity of the technology necessary to overcome the limitations;
- The mitigation options available to minimize or eliminate the limitations due to this band; and
- Identification of the preferred technical solution to overcome any performance limitations related to technology and the reasons for this preference.

Operational considerations included any limitations on performance imposed by the physics of the new bands, the presence of incumbents in the new band and the extent to which these limits affect mission effectiveness, such as:

- Determination of the alternate bands' electromagnetic effects (i.e., presence of incumbents, systems employed in band, number of assignments, location, time of operation, gross characterization of the system's frequency of use) that might limit the ability of the system under consideration to fulfill its mission;
- The extent to which any limitations impact mission effectiveness;
- Possible mitigation options available to minimize or eliminate the limitations;
- Identification of the preferred solution for overcoming the limitations on performance brought on by the operational environment and the reasons for this preference; and
- Supporting evidence that the relocating agency and the incumbent agency agree that the approach pursued will assure compatibility in the comparable band.[50]

[50] While NTIA's approach to the detailed analysis of comparable spectrum sought interagency discussions by incumbents in the comparable bands and potential relocating agencies, agencies were not able to analyze and reach agreement on specific bands in all cases in the time available. However, where multiple options remain open, NTIA believes that agencies will find a compatible operational approach among the band options.

Next, agencies developed refined cost estimates for relocation to the preferred comparable band(s) and associated timelines for relocation including milestones. Each agency conducted this analysis for each of its operations in the 1755-1850 MHz band and for each priority band preference. The analysis details each agency's plan to relocate out of the 1755-1850 MHz band in totality and includes the identification of any operations that can transition from the 1755-1780 MHz portion of the 1755-1850 MHz band in less than five years. Each agency also described constraints that may impede relocation (e.g., necessary allocation changes, international uncertainties) to a comparable band and proposed remedies.

The final report from each of the affected agencies includes:

- Identification of assumptions;
- Detail supporting their band preferences;
- Required actions (e.g., regulatory action) and other pre-conditions for relocation;
- Agency strategy for relocating from the 1755-1850 MHz band, including a possible early relocation from the 1755-1780 MHz band;
- Detailed cost and timeline estimates;
- Identification of the risks;
- Risk mitigation options; and
- The agency's preferred option(s) and supporting rationale.

4. FINDINGS

The federal agencies concluded their detailed evaluations by submitting reports to NTIA that describe their determinations regarding the relocation from the 1755-1850 MHz band in ten years, and whether they could transition out of the 1755-1780 MHz band in five years. Their reports also identified their preferred comparable bands for each operation; the conditions or assertions under which transition and the relocation out of the entire band could be accomplished; and estimates of associated costs.[51] Some agencies identified comparable bands for some operations that are different from those they prioritized highest in Table 3-2 or those identified by NTIA in Table 3-3 for detailed analysis. For several of the operations described in this report, exclusion zones around some critical installations will be required to

[51] *See* DHS-2, DHS-3, DOC-2, DOD-2, DOE-2, DOI-2, DOJ-1, FAA-2, HUD-1, OPM-1, NASA-2, Treasury-2, USCP-1, USPS-2, and VA-1. (See Appendix A *infra* for full citation.) DOD cost estimates are expressed in terms of "Then Year Dollars" and represent the amount of money needed when the expenditures are actually made during the acquisition process.

protect incumbent federal operations from interference from wireless broadband operations. Additionally, wireless broadband operations will be prohibited during the transition period in the areas where interference is expected from the incumbent federal operations, except where regulatory mechanisms are established that would enable them to accept interference without putting the onus of mitigation on the incumbent users. This will be the subject of future discussion with the wireless industry in order to establish the mechanisms that would enable commercial entrants to enter, during the transition, areas designated for exclusion, if they alter their operation in a way that protects the incumbent and to which the incumbent can agree.

The following presents the highlights, by operation, of the key aspects of the agencies' detailed analysis, as described in their reports. The cost estimates represent the two scenarios described in the approach; namely vacating the 1755-1850 MHz band in its entirety within ten years, and a phased transition from the 1755-1780 MHz band within five years with the ultimate goal of relocating out of the entire band in ten years. DOD did not provide cost estimates for vacating the 1755-1780 MHz sub-band for those operations that cannot fully transition out of the 1755-1780 MHz band in five years. In addition, while most agencies may have included implementation and administration costs for each operation in their five-year and ten-year estimates, DOD has provided a separate total cost, not pro-rated over their operations, for implementation and administration.

Fixed Point-to-Point Microwave

All affected agencies selected either the 4400-4490 MHz band or the 7125-8500 MHz band for relocation of their fixed point-to-point microwave operations within ten years. Four agencies, DHS, DOC, DOI and the FAA, can relocate all of their fixed point-to-point operations out of the 1755-1780 MHz band within five years.[52] DOD can transition a portion of its fixed point-to-point microwave systems currently operating in the 1755-1850 MHz band into the 7125-8500 MHz band within five years.[53] DOD also determined all of its systems could potentially vacate the entire band in less than 10 years, but will require funds as well as accelerated engineering analysis and procurement (land and equipment) since additional relay sites will be required to replace the existing connectivity with new systems operating in the higher frequency bands. DOE has stated that only the National Nuclear Security Administration (NNSA) can satisfy early relocation while the Bonneville Power Administration (BPA) and South Western Power Administration (SWPA) relocations can occur in ten years.[54] Based on experience in the 1710-1755 MHz band, NTIA does not see a clear reason for relocation of fixed

[52] See DHS-2 at 6-8; DOC-2; DOI-2 at 4; FAA-3.

[53] DOD-2 at § 6.1.1.1.1.

[54] DOE-2 at 2, 3-5.

systems taking longer than ten years. However, most of the systems that have exceeded their planned transition out of the 1710-1755 MHz band operate in remote areas and have not prevented wireless deployment.

The agencies' estimate the cost to transition out of the 1755-1780 MHz band in five years as $45.5 million and the cost to vacate the entire 1755-1850 MHz band as approximately $186 million. [55] Table 4-1 and Table 4-2 provide a summary of the agencies' findings for fixed point-to-point microwave operations.

Table 4-1. Fixed Point-to-Point Microwave: Evaluation Summary of the 1755-1850 MHz Band

Agency	Estimated Cost ($B)	Comparable Bands (MHz)	Estimated Timeline	Conditions/Assertions
DHS	0.019	7125-8500	5 Yrs.	None
DOC	0.000432	N/A	5 Yrs.	• Switching to Commercial Services
DOD	0.0423	7125-8500	10 Yrs.	• All Air Force fixed microwave systems can relocate to the 7125-8500 MHz band within 5 years. • Army could potentially vacate the entire band in less than 10 years, but this will require funds as well as accelerated engineering analysis and procurement (land and equipment) since additional relay sites will be needed to replace the existing connectivity with new systems operating at this higher frequency.
DOE	0.0762	4400-4490 7125-8500	5 – 10 Yrs.	None
DOI	0.045	4400-4490 or 7125-8500	10 Yrs.	• Transition times could extend to 10-15 years due to the complexity of this system and its missions.
FAA	0.0035	7125-8500	2 Yrs.	• This estimate is based on the expectation of receiving funds to relocate by August 2015.
Total ($B) = 0.186 (Preliminary)				

[55] DHS-2 at 9, Fig. 2, 3; DOD-2; DOI-2 at 4-5, §§ d, f; FAA-3.

Table 4-2. Fixed Point-to-Point Microwave: Evaluation Summary of the 1755-1780 MHz Sub-band

Agency	Estimated Cost ($B)	Comparable Bands (MHz)	Estimated Timeline	Conditions/Assertions
DHS	0.0054	7125-8500	5 Yrs.	None
DOC	0.0004	N/A	5 Yrs.	• Switching to Commercial Services
DOD	0.0145	7125-8500	5 Yrs.	• All Air Force fixed microwave systems can relocate to the 7125-8500 MHz band within 5 years. • Army can prioritize transitioning of its systems to the 7125-8500 MHz band to vacate the 1755-1780 MHz band within 5 years. • Requires accelerated engineering analysis and procurement (land and equipment) since additional relay sites will be needed to replace the existing connectivity with new systems operating at this higher frequency.
DOE	0.0208	7125-8500	5 Yrs.	National Nuclear Security Administration only
DOI	0.0009	4400-4490 or 7125-8500	5 Yrs.	• Funding is required immediately.
FAA	0.0035	7125-8500		• This estimate is based on the expectation of receiving funds to relocate by August 2015.
Total ($B) = 0.0455 (Preliminary)				

Military Tactical Radio Relay

DOD can vacate its TRR systems in the 1755-1850 MHz band within ten years. DOD also determined it can accommodate commercial broadband systems in the 1755-1780 MHz band within five years except for the Navy and Marine Corps, which will require exclusion zones at critical test and training locations.[56] Army, Navy, and Marine Corps all have requirements for TRR capabilities and will be able to tune around the 1755-1850 MHz band with the existing Army TRR systems and with required modifications to the Navy and Marine Corps TRR systems, initially focusing on getting access to the 2025-2110 MHz band as primary and the 2200-2290 MHz band as alternative spectrum.[57] The Army can transition TRR operations out of the 1755-1780 MHz band as soon as comparable primary access is available in the 2025-2110 MHz band

[56] DOD-2 at § 6.2.1.1.

[57] Once relocated from the 1755-1850 MHz band, DOD would no longer require the two protection areas at Yuma Proving Ground and Cherry Point Marine Corps Air Station (MCAS), which were established as a result of the 1710-1755 MHz relocation effort.

and access to the 2200-2290 MHz band is assured.[58] Coordination with incumbent federal operations will be necessary.

DOD estimates the cost to relocate TRR systems from the 1755-1850 MHz band within ten years, including the early transition of Army systems from the 1755-1780 MHz band within five years, as $160 million.[59] Navy and Marine Corps TRR systems cannot vacate the 1755-1780 MHz band within five years without an unacceptable operational impact and will require exclusion zones around bases at Bogue Field, North Carolina; Panama City, Florida; Marine Corps Base (MCB) Kaneohe Bay, Hawaii; MCB Camp Pendleton, California; and Apra Harbor, Guam. DOD estimates replacement in eight to ten years.[60] If congestion or other reasons prevent access to enough frequencies in the 2025-2110 MHz and 2200-2290 MHz bands, there may be a need for the Army HCLOS (AN/GRC-245) radio to operate within the 4400-4940 MHz band, which will require modification to the radio.[61] Table 4-3 provides a summary of DOD's findings for TRR systems.

[58] DOD-2 at § 6.2.1.1.

[59] *Id.* at § 6.2.4.

[60] *Id.* at §§ 6.2.1.1, F.1.4.

[61] *Id.* at §§ 6.2.3, 6.2.4.

Table 4-3. Tactical Radio Relay: Evaluation Summary

Agency	Estimated Cost ($B)	Comparable Bands (MHz)	Timeline	Conditions/Assertions
Preliminary Estimates for Relocating from the 1755-1850 MHz Band				
DOD	**0.16**	**Primary: 2025-2110 Alternate: 2200-2290**	**8-10 Yrs.**	• **TRR systems need to have primary access in the 2025-2110 MHz and 2200-2290 MHz bands at a minimum, which will require a primary federal fixed and mobile service allocation in the 2025-2110 MHz band.** • **Electronic News Gathering (ENG) would need to relocate to a different band or must operate on a non-interference basis (NIB).** • **If further analysis demonstrates the need to modify the Army HCLOS (AN/GRC-245) radio to operate within the 4400-4940 MHz band, the additional estimated cost is currently $253M.**
Preliminary Estimates for Relocating from the 1755-1780 MHz Sub-band				
DOD	**See Note**	**Primary: 2025-2110 Alternate: 2200-2290**	**Army: 5 Yrs. Navy/Marine Corps: 8-10 Yrs.**	• **TRR systems need to have primary access in the 2025-2110 MHz and 2200-2290 MHz bands at a minimum, which will require a primary federal fixed and mobile service allocation in the 2025-2110 MHz band.** • **ENG would need to relocate to a different band or must operate NIB.** • **Army HCLOS can vacate lower the 25 megahertz as soon as comparable spectrum is made available in the 2025-2110 MHz band. Army also needs to maintain adequate spectrum access in the 2200-2290 MHz band.** • **If further analysis demonstrates the need to modify the Army HCLOS (AN/GRC-245) radio to operate within the 4400-4940 MHz band, the additional estimated cost is currently $253M.** • **The Navy/Marine Corps DWTS cannot compress into the upper 70 megahertz (above 1780 MHz); exclusion zones are required until replacement system can be deployed into comparable spectrum within 8-10 years.**
Note: DOD analysis indicates that this system cannot vacate the lower 25 megahertz (1755-1780 MHz) within five years. Also, the system cannot compress to the upper 70 megahertz (1780-1850 MHz) due to significant impacts on operations and training. DOD did not determine cost estimates for solutions considered to be unfeasible or assess costs and operational impacts for remaining in the upper 70 megahertz for an indefinite period.				

Air Combat Training System

DOD determined that ACTS can vacate the 1755-1850 MHz band within ten years and that the 2025-2110 MHz band is the least problematic alternate spectrum for meeting DOD's air combat training requirements. The ACTS currently uses the entire 1755-1850 MHz band to provide critical support to combat flight training operations across numerous training ranges, and at all Active, Reserve and Guard bases where combat aircraft are stationed. ACTS cannot transition out of the 1755-1780 MHz band in five years or in less than ten years without

significant operational impacts at air combat training locations especially in the southeast and southwest regions of the United States.[62] DOD further concluded that implementing exclusion zones would not be practical as an interim solution since the emission coverage of the ACTS is pervasive. The compatibility of commercial mobile wireless systems and ACTS has not yet been examined. If ACTS is to be relocated, DOD states that it needs to have primary access in the 2025-2110 MHz band, which will require an aeronautical mobile service allocation and electronic news gathering (ENG) systems to be accommodated in a different band or must operate on a non-interference basis (NIB).[63] In general, NTIA expects the potential for electromagnetic compatibility concerns between ACTS and incumbent federal systems in the band as well as other potentially incoming federal systems to be low, and existing frequency management processes and practices (local and national) can continue to be used to limit or mitigate interference risks and to ensure that incumbent federal systems are protected. DOD estimates the cost to relocate ACTS from the 1755-1850 MHz band within ten years as $4.5 billion (B).[64] Table 4-4 summarizes DOD's findings.

Table 4-4. Air Combat Training Systems: Evaluation Summary

Agency	Estimated Cost ($B)	Comparable Bands (MHz)	Timeline	Conditions/Assertions
Preliminary Estimates for Relocating from the 1755-1850 MHz Band				
DOD	**4.5**	**2025-2110**	**10 Yrs.**	• **ACTS needs to have primary access in the 2025-2110 MHz band, which will require an aeronautical mobile service allocation.** • **ENG systems in the 2025-2110 MHz band would need to relocate to a different band or must operate NIB.** • **To implement relocation within the ten-year timeframe, Eglin AFB must be able to coordinate with ENG users on a local level to get clearance to conduct developmental and operational testing of the new ACTS system.** • **System redesign with a more efficient waveform is required.**
Preliminary Estimates for Relocating from the 1755-1780 MHz Sub-band				
DOD	**See Note**	**2025-2110**	**Not possible**	• **While DOD continues to evaluate the feasibility of compressing operations into the 1780-1850 MHz band, thus far it has not identified a solution that does not significantly degrade capability.**
Note: DOD did not determine cost estimates for solutions considered to be unfeasible or assess costs and operational impacts for remaining in the upper 70 megahertz for an indefinite period.				

[62] DOD-2 at § 6.5.

[63] *Id.*

[64] *Id.*

Precision Guided Munitions

DOD determined that it can relocate Navy's PGM capabilities into the 1435-1525 MHz band and vacate the 1755-1850 MHz band within ten years. DOD also determined that it can compress operations of Navy's PGMs within the 1780-1850 MHz band within five years as an interim step to relocation out of the entire band within 10 years. This will require a modification to the system to block access to channels below 1780 MHz. The Air Force PGM program does not need to take any action since the Air Force plans to cease operations of PGM systems that use the 1755-1850 MHz band.[65]

DOD estimates the cost to relocate PGMs from the 1755-1850 MHz band within ten years, including the early transition of systems from the 1755-1780 MHz band within five years, as $518 million.[66] Table 4-5 summarizes DOD's findings.

Table 4-5. Precision Guided Munitions: Evaluation Summary

Agency	Estimated Cost ($B)	Comparable Bands (MHz)	Timeline	Conditions/Assertions
Preliminary Estimates for Relocating from the 1755-1850 MHz Band				
DOD	**0.518**	**1435-1525**	**10 Yrs.**	• **Relocation requires modification to the data link to transition operations to the 1435-1525 MHz band and retrofit existing inventory of platforms (approx 500 missiles) within ten years.** • **Relocation requires software modification to block access to channels below 1780 MHz in the interim.**
Preliminary Estimates for Relocating from the 1755-1780 MHz Sub-band				
DOD	**See Note**	**None**	**5 Yrs.**	• **As an interim step to relocation, vacating the 1755-1780 MHz band, requires software modification to block access to channels below 1780 MHz.**
Note: DOD did not determine cost estimates for solutions considered to be unfeasible or assess costs and operational impacts for remaining in the upper 70 megahertz for an indefinite period.				

Tracking, Telemetry, and Commanding

DOD cannot transition SGLS out of the 1755-1850 MHz band (L-band) within ten years without abandoning control of mission-critical national security spacecraft. To reduce operations in the 1755-1850 MHz band, however, DOD will develop TT&C uplink capability in the S-band (2025-2110 MHz) by installing dual-band (L- and S-band) transponders on all future satellites and modifying ground terminals. DOD will require exclusion zones to support

[65] *Id.* at § 6.6.

[66] *Id*.

remaining L-band-only satellites.[67] To further reduce the impact of continued 1755-1850 MHz federal operations in the United States, DOD will consolidate and/or geographically relocate SGLS ground terminals and employ interference mitigation techniques to the extent practicable while preserving full operational capability.

DOD cannot transition SGLS out of the 1755-1780 MHz band (L-band) in the five-year timeframe without abandoning control of mission-critical national security spacecraft.[68] However, DOD believes it can accommodate commercial broadband systems in the 1755-1780 MHz band within five years by using exclusion zones around SGLS ground terminal sites used for L-band uplinks and taking other steps to mitigate interference.[69]

To mitigate the risk of losing unfettered access to spectrum for TT&C in the future due to the uncertainty of worldwide spectrum availability, DOD plans to maintain dual-band capability for TT&C operations, using the 1755-1850 MHz band on a contingency basis indefinitely. Dual-band capability reduces risk to critical missions by providing flexibility to choose an uplink band based on the local, regional, or national regulatory environment and interference issues arising from commercial encroachment and/or band sharing.

DOD estimates the cost to reduce TT&C operations in the 1755-1850 MHz band as $2.35 billion; though the transition will take considerably longer than ten years.[70] DOD also identified a need for $292 million to address tactics, techniques, procedures, and technical modifications within five years to reduce the size of exclusion zones to the most practical extent possible without impacting operations.[71] Table 4-6 summarizes DOD's findings.

[67] *Supra* note 4.

[68] DOD-2 at § 6.7.

[69] *Id.*

[70] *Id.*

[71] DOD-3.

Table 4-6. Tracking, Telemetry, and Commanding: Evaluation Summary

Agency	Estimated Cost ($B)	Comparable Bands (MHz)	Timeline	Conditions/Assertions
Preliminary Estimates for Relocating from the 1755-1850 MHz Band				
DOD	2.35	2025-2110 with 1755-1850 MHz capability	>> 10 Years	• Retain regulatory protection for SGLS's unfettered access to the 1755-1850 MHz band by establishing exclusion zones around DOD uplink sites. • ENG would need to relocate to a different band when the 2025-2110 MHz band becomes the primary uplink or they must operate NIB. • Retain access to the 1755-1850 MHz band on a contingency basis indefinitely in the context of the dual-band requirement. • Satellite systems cannot be relocated within 10 years and will require band sharing until 2045. Ground stations can be consolidated and geographically relocated away from large metropolitan areas to the extent practical within 12 years.
Preliminary Estimates for Relocating from the 1755-1780 MHz Sub-band				
DOD	0.292	2025-2110 with 1755-1850 MHz capability	>> 10 Years	• Retain regulatory protection for SGLS's unfettered access to the 1755-1850 MHz band by establishing exclusion zones around DOD uplink sites. • ENG would need to relocate to a different band once the 2025-2110 MHz band becomes the primary uplink or they must operate NIB. • Retain access to the 1755-1850 MHz band on a contingency basis indefinitely in the context of the dual-band requirement. • Costs reflect tactics, techniques, procedures, and technical modifications to reduce the size of exclusion zones to the most practical extent possible without impacting operations.

Aeronautical Mobile Telemetry

NASA determined that its AMT operations can vacate the 1755-1850 MHz band in five years. [72] The Wallops Flight Facility selected the 1435-1525 MHz and 2360-2395 MHz bands as appropriate comparable bands (other options are the 4400-4940 MHz and 5091-5250 MHz bands). The Langley Research Center selected the 4400-4940 MHz band, and Dryden Flight Research Center chose the bands 2025-2110 MHz, 4400-4940 MHz, and 5091-5150 MHz. Relocation of telecommand to the 2025-2110 MHz band requires a primary federal allocation for aeronautical mobile service (currently, there is only a non-federal mobile service

[72] NASA-2 at 3.

allocation).[73] Relocation of aeronautical telemetry to the 5091-5150 MHz band will require a primary federal allocation for aeronautical mobile service that allows aeronautical telemetry.[74]

DOD determined that its AMT systems can vacate the 1755-1850 MHz band within ten years. DOD also determined that the most viable alternate spectrum for DOD AMT is the 5150-5250 MHz band.

DOD also determined that it can accommodate commercial broadband systems in the 1755-1780 MHz band within five years. This will require DOD's continued access to and protection for test ranges served by the Western Area Frequency Coordinator (WAFC), the Atlantic Test Range at Naval Air Station (NAS) Patuxent River, and WSMR to allow continued use of the entire 1755-1850 MHz band until AMT systems can relocate to the 5150-5250 MHz band.[75] DOD also determined that it can relocate the Standard Missile Kinetic Warhead Data Link capability from the 1755-1850 MHz band to the 1435-1525 MHz band in less than five years.[76]

NASA estimates the cost to relocate NASA AMT operations from the 1755-1850 MHz band in five years is approximately $41 million.[77] If the Wallops Flight Facility is unable to relocate its systems to the specified primary bands and must choose either of their secondary bands, the total cost for relocation would increase by approximately $6 million.[78]

DOD estimates the cost to move KWDL out of the 1755-1850 MHz band in less than five years as $5.6 million and the cost to relocate DOD AMT systems from the 1755-1850 MHz band within ten years as $3.093 billion.[79] This includes the accommodation of wireless broadband in the 1755-1780 MHz sub-band within five years, except at the highly congested ranges requiring exclusion zones as described above.[80]

Table 4-7 and Table 4-8 provide a summary of findings for each agency for AMT.

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[73] *Supra* note 10.

[74] *Id.*

[75] DOD-2 at § 6.3. The test ranges served by WAFC include Vandenberg AFB, Edwards AFB, NAS China Lake, and NAS Pt. Mugu.

[76] *Id.* at § 6.4.

[77] NASA-2 at 3.

[78] *Id.* at 3, 7.

[79] DOD-2 at §§ 6.3, 6.4.

[80] *Id.* at § 6.3.

Table 4-7. Aeronautical Mobile Telemetry: Evaluation Summary of the 1755-1850 MHz Band

Agency	Estimated Cost ($B)	Comparable Bands (MHz)	Estimated Timeline	Conditions/Assertions

NASA[1]	0.0413	• Wallops Island 1435-1525/ 2360-2395
		• Langley 4400-4940
		• Dryden 2025-2110/ 4400-4940 5091-5150
			• Wallops Island: < 2 Yrs
			• Langley: <1 Yr.
			• Dryden: 3-5 Yrs.
				• Wallops Island:
				  • Secondary Band Selection (in order): 4400-4940 MHz band; 5091-5250 MHz band (Telemetry - Regulatory Action required).
				  • If unable to relocate to the specified primary bands and instead choose either of the secondary bands, the cost will increase significantly due to the need to purchase all new equipment. The estimated cost then would be in the neighborhood of $ 6M with a relocation timeframe of up to 24 months.
				• Dryden:
				  • Relocation of telecommand to the 2025-2110 MHz band would require regulatory action for a (federal) aeronautical mobile service allocation (currently there is a non-federal only primary mobile service allocation).
				  • The 5091-5150 MHz band will require regulatory action for a new aeronautical mobile service allocation that allows aeronautical telemetry.

DOD	3.0930	AMT Systems 5150-5250	10 Yrs.	• Changes to the National Table of Frequency Allocations are required to allow primary use of the 5150-5250 MHz band for AMT. • The 2025-2110 MHz band could be a viable alternate option, but would require that incumbent ENG systems relocate to other bands; sharing with ENG is not feasible.
	0.0056	Kinetic Warhead Data Link 1435-1525	5 Yrs.	• This band is the most viable option since modifications would be less extensive.
Total ($B) = 3.1399 (Preliminary)				

[1] This cost also includes estimates for NASA's UAS.

Table 4-8. Aeronautical Mobile Telemetry: Evaluation Summary of the 1755-1780 MHz Sub-band

Agency	Estimated Cost ($B)	Comparable Bands (MHz)	Estimated Timeline	Conditions/Assertions
NASA	N/A	N/A	N/A	•NASA has no operations in this sub-band.
DOD	See Note	AMT systems 5150-5250 Continued access to the 1755-1850 MHz band	5 Yrs. (Vacate exclusion zones in 10 Yrs.)	• Changes to the National Table of Frequency Allocations are required to allow primary use of the 5150-5250 MHz band for AMT. • The 2025-2110 MHz band could be a viable alternate option, but would require that incumbent ENG systems relocate to other bands; sharing with ENG is not feasible. • It is possible to accommodate wireless broadband in the 1755-1780 MHz band but requires exclusion zones at high-density test ranges, namely ranges served by the WAFC, WSMR, and NAS Patuxent River.
	0.0056	Kinetic Warhead Data Link Access to 1435-1525	5 Yrs.	• This band is the most viable option since modifications would be less extensive.
Total ($B) = 0.0056 (Preliminary)				

Note: DOD analysis indicates that this system cannot vacate the lower 25 megahertz (1755-1780 MHz) within five years. Also, the system cannot compress to the upper 70 megahertz (1780-1850 MHz) due to significant impacts on operations and training. DOD did not determine cost estimates for solutions considered to be unfeasible or assess costs and operational impacts for remaining in the upper 70 megahertz for an indefinite period.

Video Surveillance

Video surveillance operations are conducted by DHS, DOD, DOE, DOJ, DOI, HHS, HUD, OPM, Treasury, USAID, USCP, USPS, and the VA. All affected agencies can relocate out of the 1755-1850 MHz band in ten years or less; however, DHS, DOJ, and Treasury stated that they need to retain up to 30 megahertz of contiguous spectrum in the 1780-1850 MHz band pending the availability of technology and spectrum in the comparable bands they have selected.[81] Federal agencies selected various bands as being comparable for relocating these operations including 1435-1525 MHz, 1675-1695 MHz, 1780-1810 MHz, 2200-2290 MHz, 4400-4940 MHz, and 7125-8500 MHz.[82]

[81] DOJ-1 at 2; DHS-3; Treasury-2 at 1.

[82] DOJ will retain use of up to 30 megahertz of contiguous spectrum in the 1780-1850 MHz band, ideally between 1780-1810 MHz, pending successful relocation to either the 1435-1525 MHz or 1675-1695 MHz band.

NOAA and NASA have expressed concerns regarding the practicability of co-channel operations in the 1675-1695 MHz band of video surveillance operations with meteorological satellite systems and radiosonde equipment as well as the 1435-1525 MHz band with aeronautical mobile telemetry, which are current incumbents in this band. In addition, for those systems being relocated to the 2200-2290 MHz band, federal satellite receiving earth stations and aircraft telemetry receiving ground stations will require protection from incoming transmitters using appropriate coordination contours around its earth stations and telemetry sites.[83]

DHS, DOE, DOJ, Treasury, and USCP, under the assumption that auctions will occur in year 2014, have indicated that they can vacate the 1755-1780 MHz band on or before 2018.[84] DOI, HUD, OPM, and USPS can vacate the 1755-1780 MHz band in five years.[85] The VA states that it can vacate in less than seven years.[86]

DOD determined that it can vacate its high-resolution video surveillance systems from the 1755-1850 MHz band within ten years. DOD indicates that it believes that the most viable alternate spectrum to relocate HRV surveillance systems into is the 2025-2110 MHz band. Changes to the National Table of Frequency Allocations would be required to add mobile service to allow primary use of the 2025-2110 MHz band for video surveillance systems and ENG would need to relocate to a different band or must operate NIB.[87] DOD also determined that it can move DOD HRV surveillance systems out of 1755-1780 MHz band and into the 1780-1850 MHz band within five years, as a transitional step to vacating the entire band within ten years.

DOD determined that it can relocate its land mobile robotic video systems, also referred to as EOD systems, from the 1755-1850 MHz band within ten years and that the 4400-4940 MHz band offers the best opportunity for frequency relocation. DOD also determined that it can move EOD systems from the 1755-1780 MHz band into the 1780-1850 MHz band within five years, as a transitional step to vacating the entire band within ten years. [88]

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[83] NASA-2 at 5.

[84] DHS-2 at 7; DOE-2; DOJ-1 at 10; Treasury-2 at 3; USCP-1.

[85] DOI-2 at 6, 8; HUD-1 at 4; OPM-1 at 3; USPS-2 at 1.

[86] VA-1 at 3.

[87] DOD-2 at § 6.9.2.

[88] DOD-2 at § 6.9.3.

Cost estimates to relocate non-DOD video surveillance from the 1755-1850 MHz band within ten years is approximately $4.9 billion; this amount includes the cost for early transition of systems from 1755-1780 MHz within five years, which is estimated to be $2.5 billion.[89]

DOD estimates the cost to relocate HRV surveillance systems from the 1755-1850 MHz band within ten years, including the early transition of systems from the 1755-1780 MHz band within five years, as $55.3 million.[90]

DOD estimates its cost to relocate land mobile robotic systems from the 1755-1850 MHz band within ten years, including the early transition of systems from the 1755-1780 MHz band within five years, as $143 million.[91]

Table 4-9 and Table 4-10 provide a summary of findings for each agency for video surveillance systems.

Table 4-9. Video Surveillance: Evaluation Summary of the 1755-1850 MHz Band

Agency	Estimated Cost ($B)	Comparable Bands (MHz)	Estimated Timeline	Conditions/Assertions
DHS	**1.66**	**1675-1695 2200-2290 4400-4940**	**10 Yrs.** • **1755-1785 MHz: 4 Yrs. (2014-2017)** • **1805-1850 MHz: +3 Yrs. (2018-2020)** • **1780-1805 MHz: +3 Yrs. (2021-2022)**	• **Assumes that auctions occur in 2014** • **Development of technologies and devices to support of overall surveillance operation relocation will progress to align with transition schedule needs.** • **DHS will retain use of up to 30 megahertz of contiguous spectrum in the 1780-1850 MHz band pending availability of technology and alternate spectrum.** • **NTIA will expedite and support the assignment of digital channels in the 1675-1695 MHz, 1780-1850 MHz, and 2200-2290 MHz bands.** • **Regulatory criteria will support relocated operations into the 1675-1695 MHz band.** • **Regulatory and/or policy and/or legislative changes will be made to ensure adequate priority for surveillance operations in the selected bands.**

[89] DHS-2 at 8, 9; DOE-2; DOI-2 at 7, 8; DOJ-1 at 11; HUD-1 at 4; OPM-1 at 3; Treasury-2 at 3; USCP-1; USPS-2 at 1; VA-1 at 3.

[90] DOD-2 at § 6.9.2.

[91] DOD-2 at § 6.9.3.

Table 4-9. Video Surveillance: Evaluation Summary of the 1755-1850 MHz Band (Continued)

Agency	Estimated Cost ($B)	Comparable Bands (MHz)	Estimated Timeline	Conditions/Assertions
DOD	0.198	Hi-Resolution Video Surveillance: 2025-2110	7 Yrs.	• Changes would need to be made to the National Table of Frequency Allocations to add mobile service to allow primary use of the 2025-2110 MHz band for HRV surveillance systems. • ENG would need to relocate to a different band or must operate NIB.
		Land Robotic Systems: 4400-4940	5 Yrs.	• All systems can relocate with access to the 4400-4940 MHz band within five years. • System modification will be necessary in order to operate land mobile robotics in the 4400-4940 MHz band.
DOE	0.0004	7125-8500	3 Years	None
DOI	0.0014	2200-2290	Less than 1 Yr.	• Funds required immediately.
DOJ[1]	3.21	1435-1525 1675-1695 1780-1810 2200-2290 4400-4940 7125-8500	• 1755-1780 MHz: 5 Yrs. (2014-2018) • 1810-1850 MHz: +5 Yrs. (2019-2023)	• Assumes that auctions occur by 2014 • Technologies/devices, which provide equivalent or better service while making more efficient use of spectrum, must be available for procurement during the relocation timeframe. • DOJ will retain use of up to 30 megahertz of contiguous spectrum in the 1780-1850 MHz band, pending successful DOJ relocation to the 1435-1525 MHz and 1675-1695 MHz bands. • Regulatory and/or policy and/or legislative changes will be made to ensure co-primary status for surveillance operations in the destination band(s). • Results of interference testing in the field must show feasible co-existence for DOJ operations and other incumbent operations in destination bands. If not, then other comparable spectrum will be made available for DOJ, and/or incumbent and DOJ operations will be modified as appropriate to prevent interference.
HUD	0.0001	2200-2290	< 10 Yrs.	None
OPM	0.000075	2200-2290	1-2 Yrs.	None
Treasury	0.01996	2200-2290	Cease its operations in band in 5 years	• It is expected to take longer than five years to restore full capability.
USCP	0.000082	2025-2110 2360-2395	< 1 Yr	None
USPS	0.00658	2200-2290	5 Yrs.	None
VA	0.000090	2200-2290	< 7 Yrs.	None
Total[2] ($B) = 5.097 (Preliminary)				

[1] DOJ cost estimates for UAS are incorporated into their video surveillance estimate. Additionally, DOJ's estimate includes $ 43M in pre-auction costs for studies and research and development.
[2] USAID and HHS did not supply adequate operation or cost information and are therefore not included in this preliminary total.

Table 4-10. Video Surveillance: Evaluation Summary of the 1755-1780 MHz Sub-band

Agency	Estimated Cost ($B)	Comparable Bands (MHz)	Estimated Timeline	Conditions/Assertions
DHS	0.564	1675-1695 1785-1805 2200-2290 4400-4940	4 Yrs. (2014-2017)	• Assumes auctions occur in 2014
DOD	See Note[1]	Hi-Resolution Video Surveillance: 2025-2110	7 Yrs.	• Changes would need to be made to the National Table of Frequency Allocations to add mobile service to allow primary use of the 2025-2110 MHz band for HRV surveillance systems. • ENG would need to relocate to a different band or must operate on a NIB. • Any possible compressed operation of HRV within five years is only assessed as a transitional step to relocating the system to comparable spectrum within ten years.
	0.143	Land Robotic Systems:4400-4940	5 Yrs.	• All systems can relocate with access to the 4400-4940 MHz band within five years. • System modification will be necessary in order to operate in the 4400-4940 MHz band.
DOE	N/A	N/A	N/A	• Robotic video systems do not operate in this part of the band.
DOI	0.0014	2200-2290	1 Yr. or less	• Dependent on immediate spectrum relocation funds
DOJ[2]	1.773	1435-1525 1675-1695 1780-1810 2200-2290 4400-4940 7125-8500	5 Yrs. (2014-2018)	• Assumes auctions occur in 2014
HUD	0.0001	2200-2290	< 5 Yrs.	None
OPM	0.000075	2200-2290	1-2 Yrs.	• Dependent on the timeliness and availability of funding for replacement of current systems
Treasury	0.009981	2200-2290	5 Yrs.	• Regulatory and/or policy and/or legislative changes will be made to ensure co-primary status for surveillance operations in the destination bands.
USCP	0.000082	2025-2110 2360-2395	< 1 Yr	None
USPS	0.00658	2200-2290	5 Yrs.	None
VA	N/A	2200-2290	Not Possible	None
Total[3] ($B) = 2.498 (Preliminary)				

[1] DOD did not determine cost estimates for solutions considered to be unfeasible or assess costs and operational impacts for remaining in the upper 70 megahertz for an indefinite period.

[2] DOJ cost estimates for their UAS systems are incorporated into their video surveillance estimate. In addition, DOJ's estimate includes $43M in pre-auction costs for studies and research and development.

[3] USAID and HHS did not supply adequate operation or cost information and are therefore not included in this preliminary total.

Unmanned Aerial System

DOD operates several types of SUAS in the 1755-1850 MHz band. DOD determined that it can vacate the various SUAS from the 1755-1850 MHz band within ten years. The 2025-2110 MHz band is the most viable comparable spectrum for relocating the majority of SUAS and integrated video receiver capabilities.

DOD also determined that, as a transition to vacating SUAS and associated integrated capabilities out of the 1755-1850 MHz band within ten years, it can accommodate commercial broadband systems in the 1755-1780 MHz band within five years with exclusion zones for the entire 1755-1850 MHz band at three high-density training areas (Fort Irwin/NTC, Fort Polk/Joint Readiness Training Center (JRTC), and WSMR). This is required to mitigate any technical and operational impacts that result from limiting operations within the 1780-1850 MHz band.[92]

DOI, which acquired a number of SUAS from DOD, evaluated its capabilities in support of environmental, law enforcement, and firefighting missions. DOI concluded that it will relocate SUAS to the 2025-2110 MHz band following the DOD timeline (i.e., vacate within ten years). This activity will cost approximately $88 million.[93]

The estimated cost for DOD to relocate SUAS from the 1755-1850 MHz band within ten years is $1.423 billion.[94] It includes the early transition of systems from the 1755-1780 MHz band within five years except at the highly congested ranges requiring exclusion zones as described. Table 4-11 and Table 4-12 provide a summary of findings for each agency for UAS.

[92] DOD-2 at § 6.8.

[93] Relocation funding is contingent upon DOI obtaining operational frequency assignments for these systems.

[94] DOD-2 at § 6.8.

Table 4-11. Unmanned Aerial Systems: Evaluation Summary of the 1755-1850 MHz Band

Agency	Estimated Cost ($B)	Comparable Bands (MHz)	Estimated Timeline	Conditions/Assertions
DOD	**1.423**	**2025-2110**	**8 Yrs.**	• **Primary access in the 2025-2110 MHz band is required; will require a fixed and mobile service allocation in the band.** • **ENG would need to relocate to a different band or must operate NIB.** • **Exclusion zones can be eliminated within ten years, as soon as transition to the 2025-2110 MHz band is completed.**
DOI	**0.088**	**2025-2110**	**10 Yrs.**	• **DOI will proceed with their exit strategy along the timeline established by DOD. They will be utilizing DOD's SUAS Program Office developer's maintenance contracts to retrofit their UAVs.**
Total ($B) = 1.511 (Preliminary)				
Note: NASA reports its findings and costs related to UAS under AMT, while DOJ reports theirs under Video Surveillance. DOI is currently in the process of obtaining frequency assignments for their UAS.				

Table 4-12. Unmanned Aerial Systems: Evaluation Summary of the 1755-1780 MHz Sub-band

Agency	Estimated Cost ($B)	Comparable Bands (MHz)	Estimated Timeline	Conditions/Assertions
DOD	**See Note**	**2025-2110**	**Cannot transition out of the band within 5 years**	• **Primary access in the 2025-2110 MHz band is required; will require a fixed and mobile service allocation in the band.** • **ENG would need to relocate to a different band or must operate NIB.** • **Exclusion zones can be eliminated within ten years, as soon as transition to the 2025-2110 MHz band is completed.** • **It is possible to accommodate wireless broadband in the 1755-1780 MHz band but requires exclusion zones at high-density training areas (Ft. Polk, Ft. Irwin, WSMR) and Wasp III systems will need to be replaced.**
DOI	**N/A**	**N/A**	**N/A**	**N/A**
Total ($B) = N/A				
Note: DOD analysis indicates that this system cannot vacate the lower 25 megahertz (1755-1780 MHz) within five years. Also, the system cannot compress to the upper 70 megahertz (1780-1850 MHz) due to significant impacts on operations and training. DOD did not determine cost estimates for solutions considered to be unfeasible or assess costs and operational impacts for remaining in the upper 70 megahertz for an indefinite period.				

Other Systems

DOD has three other operations that require access to the 1755-1850 MHz band: EW testing, training, and exercises; SDR Systems; and TTNT. DOD evaluations of these operations are summarized below.

Electronic Warfare Testing, Training, and Exercises

DOD must retain the ability to develop, test, and train on EW systems that counter existing and emerging threat systems that operate within the 1755-1850 MHz band. Therefore, neither vacating EW capabilities out of the 1755-1850 MHz band in ten years, nor the 1755-1780 MHz band within five years is viable. However, DOD can continue EW operations in the 1755-1850 MHz band with some enhancements to existing coordination and EW operating procedures that would permit EW testing and training in and around DOD ranges, and other approved operating areas when required, and still allow commercial broadband service providers to meet their customer demands. There is no applicable relocation cost for EW systems.

Software Defined Radio Systems

DOD determined that it can accommodate commercial broadband systems in the 1755-1850 MHz band within five years. However, it requires six exclusion zones (NTC/Fort Irwin, California; JRTC/Fort Polk, Louisiana; WSMR/Fort Bliss, Texas; Fort Hood, Texas; Fort Bragg, North Carolina; and YPG) for JTRS Airborne, Maritime, and Fixed (AMF) operations and 22 additional exclusion zones (Camp McCall, North Carolina; Fort Drum, New York; Fort Stewart, Georgia; Fort Carson, Colorado; Pinnon Canyon, Colorado; Fort Riley, Kansas; Joint Base Lewis-McChord, Washington; Yakima Training Area, Washington; Fort Sill, Oklahoma; Fort Campbell, Kentucky; Pohakuloa Training Area, Hawaii (Big Island); Fort Wainwright, Arkansas; Fort Pickett, Virginia; Campy Shelby, Mississippi; Camp Atterbury, Indiana; Camp Grayling, Michigan; Camp Blanding, Florida; Orchard Park, Idaho; Camp Roberts, California; Camp Ripley, Minnesota; Camp Guernsey, Wyoming; and Fort Chaffee, Arkansas) for JTRS Handheld, Man-Pack, and Small-Form-Fit (HMS) operations at Infantry Brigade Combat Team training locations.[95] There is no applicable cost for SDR systems.

Tactical Targeting Networking Technology

DOD determined it can vacate its TTNT capability from the 1755-1850 MHz band within ten years and that the most viable alternative spectrum for TTNT is the 2025-2110 MHz band since the band is the closest alternative to the 1755-1850 MHz band and offers similar propagation attributes. To achieve this end, DOD indicated that TTNT will need to have primary access in the 2025-2110 MHz band, which will require a federal mobile service allocation.[96]

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[95] *Id.* at § 6.10.2.

[96] *Id.* at § 6.10.3.

DOD also determined that during the transition to relocating TTNT capability out of the 1755-1850 MHz band within ten years, it can accommodate commercial broadband systems in the 1755-1780 MHz band within five years.

The estimated cost to relocate TTNT from the 1755-1850 MHz band within ten years, including the early transition of systems from the 1755-1780 MHz band within five years, is $364 million.[97] Table 4-13 summarizes DOD's findings for these other systems with the first section addressing relocation from the entire 1755-1850 MHz band, and the second section addressing transitioning from only the 1755-1780 MHz sub-band.

Table 4-13. DOD's Other Systems: Evaluation Summary

DOD Operation	Estimated Cost ($B)	Comparable Bands (MHz)	Estimated Timeline	Conditions/Assertions
Preliminary Estimates for Relocating from the 1755-1850 MHz Band				

EW	**0**	**Will need to co-exist in the band**	**Will need to co-exist in the band**	• **DOD must maintain current assignments for existing threat systems and gain the ability to obtain new assignments for emerging threat systems that will be located and operated in and around DOD Test and Training ranges in direct support of EW testing and training, and at other approved operating areas when required.**
				• **Enhancements to existing coordination and EW operating procedures and processes will be required. Such as:**
				  • **Increasing DOD Range Electronic Attack (EA) routine jamming clearances from one year to two years.**
				  • **Reducing EA jamming clearance request processing time to less than 21 days from submission.**
				  • **Implementing new national level guidance/agreements to allow for EA clearance coordination at the local level.**

SDR	**0**	**N/A**	**10 Yrs.**	• **Exclusion zones will be required at 28 Active, Guard, and Reserve locations for JTRS HMS and AMF training.** • **Compression of operations into the 1780-1850 MHz band is technically feasible in low-density environments.**
TTNT	**0.364**	**2025-2110**	**8 Yrs.**	• **Platforms using TTNT will need to have primary access in the 2025-2110 MHz band, which will require a Federal mobile service allocation.**

[97] *Id.*

Table 4-13. DOD's Other Systems: Evaluation Summary (Continued)

DOD Operation	Estimated Cost ($B)	Comparable Bands (MHz)	Estimated Timeline	Conditions/Assertions
Preliminary Estimates for Relocating from the 1755-1780 MHz Sub-band				

EW	**0**	**N/A**	**Will need to co-exist in the band**	• **DOD must maintain current assignments for existing threat systems and gain the ability to obtain new assignments for emerging threat systems that will be located and operated in and around DOD Test and Training ranges in direct support of EW testing and training, and at other approved operating areas when required.**
				• **Enhancements to existing coordination and EW operating procedures and processes will be required. Such as:**
				  • **Increasing DOD Range EA routine jamming clearances from one year to two years.**
				  • **Reducing EA jamming clearance request processing time to less than 21 days from submission.**
				  • **Implementing new national level guidance/agreements to allow for EA clearance coordination at the local level.**

SDR	**0**	**N/A**	**5 Yrs.**	• **Exclusion zones will be required at 28 Active, Guard, and Reserve locations for JTRS HMS and AMF training.**
TTNT	**See Note**	**2025-2110**	**5 Yrs. Vacate in 10 Yrs.**	• **DOD has assessed any possible compressed operation within the 5 years only as a transition step to relocating the system to the comparable spectrum 2025-2110 MHz band within 10 years.** • **DOD can cease use of frequency hopping channels within the 1755-1780 MHz band; DOD has assessed such action only as a transition step to relocating the system to comparable spectrum within the 10 years.**

Note: DOD did not determine cost estimates for solutions considered to be unfeasible or assess costs and operational impacts for remaining in the upper 70 megahertz for an indefinite period.

NTIA relied on analysis performed by the various federal agencies regarding their systems and presented in their reports. Review of the agency evaluations indicates that it is feasible to make the 1755-1780 MHz band available for commercial broadband wireless in five years and the 1755-1850 MHz band in ten years subject to a number of significant conditions and challenges, as follows:

- Agencies operating law enforcement surveillance will move out of the 1755-1780 MHz band in five years by moving to digital technology above 1780 MHz. They will move out of half the remaining spectrum in ten years. They will move out of the entire band if they can successfully develop technology for another band.
- DOD states it requires access to the 2025-2110 MHz band on a primary basis to ensure comparable capability for many of their systems. This will require reallocation of the band to allow various federal operations and the development of solutions for the accommodation of incumbent broadcast auxiliary service (BAS) and other systems in the band.
- DOD cannot move its satellite TT&C uplinks from the 1755-1850 MHz band within the ten-year timeframe. Earth station sites will require exclusion zones until DOD can fully develop and implement a dual-band capability with primary status in the 2025-2110 MHz band. DOD plans to maintain dual-band capability indefinitely, including transmissions in the 1755-1850 MHz band on a contingency basis.
- Many other DOD operations such as TRR, UAS, and AMT require continued access and protection of various types and at various locations for ten years.
- DOD and NASA require an allocation for aeronautical telemetry at 5091-5250 MHz.
- DOD requires continued access to the 1755-1850 MHz band for EW systems.

Table 4-14 summarizes the conclusions reached by the agencies regarding the possibility of relocating out of the 1755-1850 MHz band.

Table 4-14. Agency Evaluations Aggregated by Operation/System

Operation	Relocating from the 1755-1850 MHz Band in Ten Years		Relocating from the 1755-1780 MHz Sub-band in Five Years	
	Est Cost ($B)	Prerequisites	Est Cost ($B)	Prerequisites
Fixed Point-to-Point Microwave	0.1864	• DOD requires access to adequate spectrum in the 7125-8500 MHz band. • All Air Force fixed microwave systems can relocate to the 7125-8500 MHz band within five years. • Army could potentially vacate entire band in less than ten years, but this will require funds as well as accelerated engineering analysis and procurement (land and equipment) since additional towers will be needed to address the reduction in the separation of the point-to-point communication links at this high frequency.	0.0455	• DOD requires access to adequate spectrum in the 7125-8500 MHz band. • All Air Force fixed microwave systems can relocate to the 7125-8500 MHz band within five years. • Army can prioritize transitioning of its systems to the 7125-8500 MHz band to vacate the 1755-1780 MHz band within five years. • For DOE only NNSA can transition in five years.
Military Tactical Radio Relay (TRR)	0.1600	• TRR systems need to have primary access in the 2025-2110 MHz and 2200-2290 MHz bands at a minimum, which will require a primary federal fixed and mobile service allocation in the 2025-2110 MHz band. • ENG would need to relocate to a different band or must operate NIB. • Navy and Marine Corps TRR systems cannot vacate the 1755-1780 MHz band within five years or ten years will require exclusion zones. • Satellite operations (space-to-Earth) in the 2200-2290 MHz band will need geographic separation or frequency separation from TRR operations, especially in the case of sensitive space research sites. • An additional $253M (TY$) is required if further analysis demonstrates the need to modify the Army HCLOS (AN/GRC-245) radio to operate within the 4400-4940 MHz band.	See Note 1	• TRR systems need to have primary access in the 2025-2110 MHz and 2200-2290 MHz bands at a minimum, which will require a primary federal fixed and mobile service allocation in the 2025-2110 MHz band. • ENG would need to relocate to a different band or must operate NIB. • Army HCLOS can vacate the lower 25 MHz as soon as comparable spectrum is made available in the 2025-2110 MHz band. Army also needs to maintain adequate spectrum access in the 2200-2290 MHz band. • Navy/Marine Corps DWTS cannot compress into upper 70 MHz; exclusion zones are required until replacement system can be deployed into comparable spectrum within eight to ten years.
Air Combat Training System (ACTS)	4.5000	• ACTS would need to have primary access in the 2025-2110 MHz band, which will require an aeronautical mobile service allocation. • ENG would need to relocate to a different band or must operate NIB. • To implement within the ten-year timeframe, Eglin AFB must be able to coordinate with ENG users on a local level to get clearance to conduct developmental and operational testing of the new ACTS system. • System redesign with a more efficient waveform is required.	See Note 1	• DOD continues to evaluate the feasibility of compressing operations into the 1780-1850 MHz band, but thus far DOD has not identified a solution that does not significantly degrade capability.
Precision Guided Munitions (PGM)	0.5180	• Access to the 1435-1525 MHz band is needed. • Modify data link to transition operations to the 1435-1525 MHz band and retrofit existing inventory of platforms (approx. 500 missiles) within ten years.	See Note 1	• A software modification to block access to channels below 1780 MHz can be employed within five years (similar to what was done to vacate the 1710-1755 MHz band). DOD has assessed such action only as a transition step to relocating the system to comparable spectrum within the ten years.

Table 4-14. Agency Evaluations Aggregated by Operation/System (Continued)

Operation	Relocating from the 1755-1850 MHz Band in Ten Years		Relocating from the 1755-1780 MHz Sub-band in Five Years s	
	Est Cost ($B)	Prerequisites	Est Cost ($B)	Prerequisites
Tracking, Telemetry, and Commanding (TT&C)	2.3500	• Retain regulatory protection for SGLS's unfettered access to 1755-1850 MHz band by establishing exclusion zones around DOD uplink sites. • ENG needs to relocate to a different band when the 2025-2110 MHz band becomes the primary uplink. • Retain access to the 1755-1850 MHz band on a contingency basis indefinitely in the context of the dual-band requirement. • Satellite systems cannot be relocated and will require band sharing until 2045, ground stations can be consolidated and geographically relocated away from large metropolitan areas within 12 years.	0.2920	• Retain regulatory protection for SGLS's unfettered access to 1755-1850 MHz band by establishing exclusion zones around DOD uplink sites. • ENG needs to relocate to a different band or operate NIB when the 2025-2110 MHz band becomes the primary uplink. • Retain access to the 1755-1850 MHz band on a contingency basis indefinitely in the context of the dual-band requirement. • Costs reflect tactics, techniques, procedures, and technical modifications to reduce exclusion zone size (most practical extent possible without affecting operations).
Aeronautical Mobile Telemetry (AMT)	3.1399	• Changes to the National Table of Frequency Allocations would be required to allow primary use of the 5091-5250 MHz band for AMT. • DOD and NASA relocation to the 2025-2110 MHz band would require regulatory action for a (federal) aeronautical mobile service allocation (currently there is a non-federal only primary mobile service allocation). • DOD requires access to 1435-1525 MHz band for Kinetic Warhead Data Link (KWDL).	0.0056 for KWDL Only See Note 1 for Other DOD Systems	• Accommodation of commercial broadband systems in the 1755-1780 MHz band within five years will require exclusion zones for test ranges served by the WAFC, WSMR, and NAS Patuxent River. • Changes to the National Table of Frequency Allocations would be required to allow primary use of the 5091-5250 MHz band for AMT. • DOD and NASA relocation to the 2025-2110 MHz band would require regulatory action for a (federal) aeronautical mobile service allocation (currently there is a non-federal only primary mobile service allocation).
Video Surveillance	5.0966	• DHS and DOJ will retain use of up to 30 megahertz of contiguous spectrum in the 1780-1850 MHz band pending availability of technology and successful DOJ relocation to comparable bands. • Regulatory and/or policy and/or legislative change will need to be made to ensure co-primary status for surveillance operations in the destination band(s). • ENG needs to relocate to a different band or operate NIB when the 2025-2110 MHz band becomes the primary uplink. • DOD requires access to 4400-4940 MHz band for Land Mobile Video Robotics and to the 2025-2110 MHz band for High Resolution Video surveillance. • Changes to the National Table of Frequency Allocations would be required to add mobile service to allow primary use of the 2025-2110 MHz, 1435-1525 MHz and 1675-1695 MHz bands for video surveillance systems.	2.4980	• Regulatory and/or policy and/or legislative change will need to be made to ensure co-primary status for surveillance operations in the destination band(s). • DOD requires access to 4400-4940 MHz band for Land Mobile Video Robotics and to the 2025-2110 MHz band for High Resolution Video (HRV) surveillance. • ENG needs to relocate to a different band or operate NIB when the 2025-2110 MHz band becomes the primary uplink. • It is possible for DOD to compress HVR operations into the 1780-1850 MHz band for short term; DOD has assessed such action only as a transition step to relocating the system to comparable spectrum within the ten years. • Changes to the National Table of Frequency Allocations would be required to add mobile service to allow primary use of the 2025-2110 MHz, 1435-1525 MHz and 1675-1695 MHz bands for video surveillance systems.

Table 4-14. Agency Evaluations Aggregated by Operation/System (Continued)

Operation	Relocating from the 1755-1850 MHz Band in Ten Years		Relocating from the 1755-1780 MHz Sub-band in Five Years s	
	Est Cost ($B)	Prerequisites	Est Cost ($B)	Prerequisites
Unmanned Aerial Systems (UAS)	1.5110	• SUAS need to have primary access in the 2025-2110 MHz band, which will require a fixed and mobile service allocation in the band. • ENG would need to relocate to a different band or must operate on a NIB. • Exclusion zones can be eliminated within ten years, as soon as transition to the 2025-2110 MHz band is completed. • DOJ will proceed with a UAS exit strategy, following DOD's lead for timelines and destination band if the 2025-2110 MHz band is determined to be feasible for domestic UAS operations. Note that DOJ initially selected the 1435-1525 MHz band as its preferred band. • DOJ cost estimates for UAS are included under video surveillance.	See Note 1	• DOD requires primary access in the 2025-2110 MHz band, which will require a fixed and mobile service allocation in the band. • ENG would need to relocate to a different band or must operate on a NIB. • Exclusion zones required at three high-density training areas Ft. Polk, Ft. Irwin, and White Sands Missile Range. • DOI will proceed with their exit strategy as the DOD timeline determines because they will be utilizing DOD SUAS Program Office developer's maintenance contracts to retrofit their UAVs. • DOJ will proceed with a UAS exit strategy, following DOD's lead for timelines and destination band if the 2025-2110 MHz band is determined to be feasible for domestic UAS operations. Note that DOJ initially selected the 1435-1525 MHz band as its preferred band. • DOJ cost estimates for UAS are included under video surveillance.
Electronic Warfare(EW) Testing, Training and Exercises	0.0000	• DOD must maintain current assignments for existing threat systems and gain the ability to obtain new assignments for emerging threat systems, that will be located and operated in and around DOD test and training ranges in direct support of EW testing and training, and at other approved operating areas when required. • Increase DOD Range Electronic Attack routine jamming clearances from one year to two years. • Reduce EA jamming clearance request processing time to less than 21 days from submission. Implement new national level guidance/agreements to allow for EA clearance coordination at the local level.	0.0000	• DOD must maintain current assignments for existing threat systems and gain the ability to obtain new assignments for emerging threat systems, that will be located and operated in and around DOD Test and Training ranges in direct support of EW testing and training, and at other approved operating areas when required. • Increase DOD Range EA routine jamming clearances from one year to two years. • Reduce EA jamming clearance request processing time to less than 21 days from submission. • Implement new national level guidance/agreements to allow for EA clearance coordination at the local level.
Software Defined Radio (SDR) Systems	0.0000	• Exclusion zones will be required at 28 Active, Guard, and Reserve locations for JTRS HMS and AMF training. • Compression of operations into the 1780-1850 MHz band is technically feasible in low-density environments.	0.0000	• Exclusion zones will be required at 28 Active, Guard, and Reserve locations for JTRS training. • Compression of operations into the 1780-1850 MHz band is technically feasible in low-density environments.
Tactical Targeting Networking Technology (TTNT)	0.3640	• Platforms using TTNT will need to have primary access in the 2025-2110 MHz band, which requires a federal mobile service allocation.	See Note 1	• DOD can cease use of frequency hopping channels within the 1755-1780 MHz band; DOD has assessed such action only as a transition step to relocating the system to comparable spectrum within the ten years.
Total Preliminary Estimate ($B) =	17.8259	See Note 2	2.8411	See Note 1 and Note 3 This total does not include the DOD costs for operations that cannot fully transition out of the 1755-1780 MHz band in five years.

Note 1: DOD analyses indicate that this system cannot vacate the lower 25 MHz (1755-1780 MHz) within five years. Also, the system cannot compress to the upper 70 MHz (1780-1850 MHz) due to significant impacts on operations and training. DOD did not conduct cost estimates on unfeasible solutions or assess remaining in the upper 70 MHz for an indefinite period.

Note 2: This is the total cost to vacate the entire 1755-1850 MHz band, and includes the cost to relocate from the 1755-1780 MHz band; it does not include implementation and administration costs for DOD, which they estimate at $ 0.272B for vacating the 1755-1850 MHz band. DOD-3.

Note 3: This value does not include implementation and administration costs for DOD, which it estimates at $ 0.186B to transition out of the 1755-1780 MHz band. DOD-3.

5. CONCLUSIONS/RECOMMENDATIONS

While the analyses summarized in this report indicate there are a number of challenges to repurposing, NTIA concludes that it is possible to repurpose all 95 megahertz of spectrum between 1755-1850 MHz. The following challenges require satisfactory resolution:

- NTIA and the FCC will need to allocate comparable spectrum (unless federal agencies achieve comparable capabilities via alternate means) to accommodate federal operations currently performed in the 1755-1850 MHz band under any clearing scenario. These comparable spectrum allocations must provide federal agencies with primary regulatory status. Under the approach studied in this report, the DOD identified the 2025-2110 MHz band, which is currently allocated to the commercial BAS and federal space operations, as its preferred option to relocate most of its operations. Other options, including the potential for co-primary sharing with incumbent BAS, should be studied further. In addition, DOD and NASA have identified the 5091-5250 MHz band as preferred for federal aeronautical mobile telemetry. Some agencies have identified the 1435-1525 MHz, 1675-1695 MHz, and 2200-2290 MHz bands as preferred for their video surveillance operations. Further analysis may reveal other ways to provide comparable capabilities at lower transition cost, opportunity cost, and/or complexity, such as improvements in spectrum efficiency or identification of other comparable destination bands.
- The comparable spectrum bands identified by the federal agencies for relocation of their systems all have incumbent federal and non-federal operations. Any relocation proposal that utilizes these frequencies or any other frequency that achieves comparable capability will need to consider these uses. Arrangements, such as sharing, additional relocations, or other forms of accommodation would need to be developed where appropriate.
- Current law requires that auction proceeds exceed expected federal relocation costs. Since federal relocation costs are expected to be high, any repurposing option needs to promote economic value while ensuring no loss of critical federal capabilities.[98]
- NTIA and the FCC will establish appropriate fora to encourage communications between federal agencies and industry during transition planning. Working together early in the process will help in developing clear relocation, transition, and sharing plans. These are important to enable substantial availability of spectrum with a high degree of certainty

[98] CSEA, *supra* note 5.

for commercial providers, while also ensuring critical federal operations are protected from disruption during the transition period.

NTIA recognizes the significant challenges faced in repurposing the 1755-1850 MHz band, as they will affect the degree and timing of the relocation of federal systems. As a step to overcome these challenges, NTIA believes that the agencies need to engage with industry to identify potential solutions, which could include partial clearing scenarios and a phased approach to commercial auctions and entry. As the potential for interference exists from federal operations to the wireless broadband users during the transition period, it is necessary to establish clear regulatory mechanisms for sharing to ensure federal users are not required to assume the responsibility of mitigating such interference. It will be critically important to develop a complete statement of what spectrum will be available, in what timeframes, and a composite picture of any geographic or other sharing constraints well in advance of any spectrum auctions.

NTIA proposes to work jointly with the FCC to sponsor an ongoing forum to encourage communications between federal agencies and industry to discuss the relevant technical and coordination issues, with the goal of identifying approaches that maintain critical federal missions and optimize the economic value of the 1755-1850 MHz band. Once the challenges are satisfactorily addressed, NTIA can make a formal recommendation to reallocate this spectrum. Repurposing the 1755-1850 MHz band will constitute a major step in achieving President Obama's goal of making 500 megahertz of federal and non-federal spectrum available for wireless broadband within ten years.

ACRONYMS AND ABBREVIATIONS

A/G/A TLM – Air-to-Ground-to-Air Telemetry

ACMI – Air Combat Maneuvering Instrumentation

ACTS – Air Combat Training System

AFB – Air Force Base

AFSCN – Air Force Satellite Control Network

AGM – Air-to-Ground Missile

AMF – Airborne, Maritime, and Fixed

AM(R)S – Aeronautical Mobile Route Service

AMT – Aeronautical Mobile Telemetry

ARNS – Aeronautical Radionavigation Service

ARTS – All-Purpose Remote Transport System

B – Billion

BAS – Broadcast Auxiliary Service

BPA – Bonneville Power Administration

BMD – Ballistic Missile Defense

CARS – Cable Antenna Relay Service

CDMA – Code Division Multiple Access

CDL – Common Data Link

CONUS – Continental United States

CSEA – Commercial Spectrum Enhancement Act

DFRC – Dryden Flight Research Center

DHS – U.S. Department of Homeland Security

DMSP – Defense Meteorological Satellite Program

DOC – U.S. Department of Commerce

DOD – U.S. Department of Defense

DOE – U.S. Department of Energy

DOI – U.S. Department of the Interior

DOJ – U.S. Department of Justice

DSP – Defense Support Program

DWTS – Digital Wideband Transmission System

EA – Electronic Attack

EESS – Earth Exploration-Satellite Service

EIRP – Effective Isotropic Radiated Power

EMI – Electromagnetic Interference

ENG – Electronic News Gathering

EOD – Explosive Ordnance Disposal

EW – Electronic Warfare

FAA – Federal Aviation Administration

FCC – Federal Communications Commission

FLTSAT – Fleet Satellite

FN – Footnote

FY – Fiscal Year

GBU – Guided Bomb Unit

GHz – Gigahertz

GMF – Government Master File

GMR – Ground Mobile Radio

GPS – Global Positioning System

HCLOS – High Capacity Line-of-Sight

HDR – High Data Rate

HHS – U.S. Department of Health and Human Services

Hi-Rez – High Resolution

HMS – Handheld, Man-Pack, and Small-Form-Fit

HRV – High Resolution Video

HRVDL – High Resolution Video Data Link

HUD – U.S. Department of Housing and Urban Development

ISM – Industrial, Scientific, Medical

ISR – Intelligence, Surveillance, and Reconnaissance

IED – Improvised Explosive Device

ITU – International Telecommunication Union

JTF-CS – Joint Task Force-Civil Support

JRTC – Joint Readiness Training Center

JTRS – Joint Tactical Radio System

KWDL – Kinetic Warhead Data Link

LaRC – Langley Research Center

LEMVS – Law Enforcement Mobile Video Surveillance

LEO&A – Launch, Early Orbit, and Anomaly Resolution

LMRV – Land Mobile Robotic Video

LOS – Line-of-Sight

M – Million

MCB – Marine Corps Base

METAIDS – Meteorological Aids

METSAT – Meteorological Satellite

MHz – Megahertz

MIDS – Multifunctional Information Distribution System

MLS – Microwave Landing System

MSS – Mobile-Satellite Service

MTRS – Man Transportable Robotic System

MUOS – Mobile User Objective System

N/A – Not Applicable

NAS – Naval Air Station

NASA – National Aeronautics and Space Administration

NATO – North Atlantic Treaty Organization

NAVAIR – Naval Air Systems Command

NAVSOC – Naval Satellite Operations Center

NGSO – Non-geostationary Satellite Orbit

NIB – Non-Interference Basis

NNSA – National Nuclear Security Administration

NOAA – National Oceanic and Atmospheric Administration

NSCN – Naval Satellite Control Network

NTC – National Training Center

NTIA – National Telecommunications and Information Administration

OMB – Office of Management and Budget

OPM – Office of Personnel Management

P5 CTS – P5 Combat Training System

PGM – Precision Guided Munitions

PPSG – Policy and Plans Steering Group

RCIED – Remote Controlled Improvised Explosive Device

RF – Radio Frequency

RONS – Remote Ordnance Neutralization System

ROVER – Remote Operations Video Enhanced Receiver

RPV – Remotely Piloted Vehicles

RTS – Remote Tracking Stations

SATCOM – Satellite Communications

SBIRS – Space-Based Infrared System

SDR – Software Defined Radio

SGLS – Space Ground Link Subsystem

SOCC – Satellite Operations Control Center

SOS – Space Operation Service

SRS – Space Research Service

SRW – Soldier Radio Waveform

SUAS – Small Unmanned Aerial Systems

SWPA – South Western Power Administration

TCTS – Tactical Combat Training System

TDRS – Tracking and Data Relay Satellite

TDRSS – Tracking and Data Relay Satellite System

TRR – Tactical Radio Relay

TT&C – Tracking, Telemetry, and Commanding

TTNT – Tactical Targeting Networking Technology

TY$ -- Then Year Dollars

UAS – Unmanned Aerial System

UAV – Unmanned Aerial Vehicle

UFO – UHF Follow-on

UGV – Unmanned Ground Vehicle

UHF – Ultra High Frequency

UK – United Kingdom

U-NII – Unlicensed National Information Infrastructure

USAID – U.S. Agency for International Development

USCG – U.S. Coast Guard

USCP – U.S. Capitol Police

US&P – United States and Possessions

USPS – U.S. Postal Service

VA – U.S. Department of Veterans Affairs

VHF – Very High Frequency

VIP – Very Important Person(s)

WAFC – Western Area Frequency Coordinator

WCS – Wireless Communications Service

WFF – Wallops Flight Facility

WIN-T – Warfighter Information Network-Tactical

WNW – Wideband Networking Waveform

WRC – World Radiocommunication Conference

WSMR – White Sands Missile Range

YPG – Yuma Proving Ground

Yrs. – Years

24/7 – 24 hours a day/seven days a week

LIST OF TABLES

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APPENDIX A

List of Referenced Federal Agency Inputs

The following is a list of federal agency inputs specifically referenced in this report. Several of the documents are not releasable or available to the public. Where possible, agencies provided redacted version, which are releasable. These are available at http://www.ntia.doc.gov/category/spectrum-management.

1. Federal Aviation Administration, *Comparable Band Analysis Template Information from Agencies FAA Comments* (FAA-1) (Jun. 2, 2011). (Not for Public Release)
2. Federal Aviation Administration, *FAA Phase Two Report of 1755-1850 MHz Transition and Comparable Bands* (FAA-2) (Sep. 8, 2011). (Not for Public Release)
3. Federal Aviation Administration, E-mail Rodney Murphy, *Phase 2 Report 1755-1850 MHz Draft* (FAA-3) (Sep. 15, 2011). (Not for Public Release)
4. National Aeronautics Space Administration, *NASA Response to NTIA re 1755-1850 MHz Comparable Bands* (NASA-1) (Apr. 1, 2011).
5. National Aeronautics Space Administration, *NASA Revised Phase III Response to NTIA (Revision 2), 1755-1850 MHz Relocation* (NASA-2) (Oct. 5, 2011).
6. United States Capitol Police, E-mail Kenneth Taylor, *USCP Transition Quote (Q-8109 USCP)* (USCP-1) (Oct. 20, 2011). (Not for Pubic Release)
7. United States Department of Commerce, National Oceanic and Atmospheric Administration, E-mail from Carmelo Rivera, *1750-1855 MHz Report -- Reference* (DOC-1) (Oct. 5, 2011).
8. United States Department of Defense, *Report on the Assessment of Alternate Spectrum Bands for the 1755-1850 MHz* (DOD-1) (Apr. 19, 2011). (Not for Public Release)
9. United States Department of Defense, *Spectrum Reallocation Feasibility Study, 1755-1850 MHz Band* (DOD-2) (Sep. 8, 2011). (Not for Public Release)
10. United States Department of Defense, *Summary of DOD Relocation Estimates* (DOD-3) (Sep. 29, 2011). (Not for Public Release)
11. United States Department of Energy, Bonneville Power Administration, *BPA Comparable Band Evaluation (1755-1850)* (DOE-1A) (Mar. 17, 2011). (Not for Public Release)
12. United States Department of Energy, Department Of Energy Response to 1755-1850 MHz Phase II Relocation Study (DOE-2) (Mar. 2, 2012). (Not for Public Release)
13. United States Department of Energy, National Nuclear Security Administration, *NNSA Comparable Band Evaluation (1755-1850)* (DOE-1B) (Mar. 17, 2011). (Not for Public Release)
14. United States Department of Homeland Security, *Summary Report,* 1755-1850 MHz, *Comparable Band Assessment* (DHS-1) (Mar. 30, 2011).

15. United States Department of Homeland Security, 1755-1850 MHz, *Comparable Band Assessment* (DHS-2) (Jul. 28, 2011).

16. United States Department of Homeland Security, E-mail from Edward Smith (CTR), *Info we discussed at the SWG* (DHS-3) (Sep. 9, 2011).

17. United States Department of Housing and Urban Development, *HUD-OIG Comparable Band Analysis – 1755-1850 MHz* (HUD-1) (Jul. 20, 2011).

18. United States Department of the Interior, *Department of the Interior 1755-1850 MHz Comparable Band Analysis Phase I – Summary Report* (DOI-1) (Apr. 7, 2011).

19. United States Department of the Interior, *Department of the Interior 1755-1850 MHz Comparable Band Analysis Phase III – Final Report* (DOI-2) (Sep. 9, 2011).

20. United States Department of Justice, *1755-1850 MHz Band Study, Phase II RFI Guidance/Feasibility Analysis* (DOJ-1) (Sep. 29, 2011). (Redacted Version)

21. United States Department of the Treasury, *Department of the Treasury, Comparable Band Analysis (1755-1850)* (Treasury-1) (Apr. 1, 2011).

22. United States Department of the Treasury, *Department of the Treasury, 1755-1850 MHz Relocation, Comparable Band, Phase III Report* (Treasury-2) (Sep. 21, 2011).

23. United States Department of Veterans Affairs, *Department of Veterans Affairs, Office of Spectrum Management, Comparable Band Analysis* (VA-1) (Sep. 22, 2011).

24. United States Office of Personnel Management, *U.S. Office of Personnel Management, Office of the Inspector General, Comparable Band Analysis* (OPM-1) (Jun. 30, 2011).

25. United States Postal Service, *USPS Summary Report, 1755-1850 MHz, Comparable Band Assessment, Phase I* (USPS-1) (Sep. 22, 2011).

26. United States Postal Service, *U.S. Postal Service Feasibility Analysis, 1755-1850 MHz, Phase II* (USPS-2) (Sep. 22, 2011).

APPENDIX B

Federal Agency Systems in the 1755-1850 MHz Band

Introduction

This section provides an in-depth description of the federal systems operating in the 1755-1850 MHz band.

Fixed Point-to-Point Microwave Systems

Fixed microwave networks provide backbone links for many federal agencies' voice, data, and/or video communications. These links provide service where commercial options are either unavailable, too expensive, or do not provide the reliability percentages required by federal mandate. These systems support voice, data, and/or video communications for law enforcement, military command and control networks, emergency preparedness and response, the national air space system, power generation and distribution, and resource management activities. In addition, fixed microwave links may provide data or video relay, timing distribution signals, and covert video surveillance for forensic investigations.[99]

The DOD uses fixed microwave relay systems in the band on military installations and test and training ranges for a variety of functions. These functions include providing general-purpose communications to remote areas; relaying radar data from remote ranges to control centers; transmitting video data from bombing and gunnery ranges; supporting command and control networks; and sending control data to tethered aerostat balloons, radar data from the tethered aerostat balloons to the ground control stations, and power grid and hydroelectric data.[100]

The Air Force uses the band for the ground infrastructure of the Air Combat Training Systems, which are located at Nellis AFB, Nevada and Eielson AFB, Alaska. The non-ACTS frequency assignments for the Air Force fixed point-to-point systems are associated either with local range instrumentation and data retrieval or with installation security. These systems are used at Nellis AFB, Nevada; Eielson AFB, Alaska; and Kirtland AFB, New Mexico.[101]

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[99] National Telecommunications and Information Administration, *The Potential of Accommodating Third Generation Mobile Systems in the 1710-1850 MHz Band: Federal Operations, Relocation Costs, and Operational Impacts, NTIA Special Publication 01-46* (NTIA 01-46) (March 2001) at 3-2, *available at* http://www.ntia.doc.gov/files/ntia/publications/3g33001.pdf.

[100] DOD-2 at § 4.2.

[101] DOD-2 at § E.7.

The Army operates long-haul communications links and air traffic control links at their Fort Rucker, Alabama and Ft. Campbell, Kentucky airfields.[102]

The Army Corps of Engineers uses this band for its fixed microwave radio systems providing backbone communications for the engineering districts in the continental United States. The Corps also uses this frequency band for various purposes such as operating remotely-controlled hydro-electric generating stations, communications support for emergency civilian relief, flood control and sensor telemetry, temporary communications in each district, and maintenance and traffic control of approximately 48,000 kilometers of inland waterways, including harbors, locks, and dams. The fixed microwave communications systems ensure the safety and integrity of the nation's waterways, help prevent catastrophes, and provide emergency civilian relief.[103]

The Navy operates fixed microwave radio systems in this frequency band at certain facilities to provide infrastructure connectivity. These systems support both one-way and two-way communications, depending on connectivity requirements. These fixed microwave radio systems provide cost-effective and reliable solutions for isolated facilities in remote areas.

The Department of Commerce's National Weather Service relays valuable meteorological data to a variety of users, including the public.

DHS uses this band to support security enforcement along the United States' Texas/Mexican Border. Several point-to-point microwave systems provide a critical link for the various communications and surveillance technologies used by DHS field personnel. These wireless systems route communications media, voice from tactical radios, video imagery from remote video surveillance systems, and data from ground sensors to the key decision makers in central command and communications centers. The systems operate on a continuous basis and provide itinerant video imaging and critical border operations information to the border patrol and law enforcement.[104]

The Department of the Interior system supports relaying seismic monitoring data. The seismic monitors collect and disseminate near real-time data used for emergency response to significant earthquakes, tsunami warning, detection of volcanic unrest, and public information.[105]

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[102] DOD-2 at § D.4.

[103] DOD Strategic Spectrum Plan, *supra* note 30, at 3-2.

[104] DHS-1 at 8.

[105] DOI-1 at 6.

The FAA uses fixed links to interconnect the nation's air traffic control facilities in support of aviation safety. FAA radar and air–to-ground radio facilities are frequently located in remote mountain areas to facilitate clear communications with commercial and military aircraft. These locations usually lack commercial communications access and require the FAA to use microwave radio systems.[106]

DOE uses this band for a wide-area network to supervise, control, and protect electric power transmission systems.[107] The system connects federal power marketing control facilities in the western half of the United States. The system can interconnect with the private sector for critical communications dealing with generating and distributing power. This critical infrastructure operates 24 hours a day/seven days a week. The microwave systems allow power system dispatchers to monitor the health and the amount of load on the energy grid, to be able to add or drop load, and to monitor generation. These microwave systems also allow protective relay and remedial action schemes to operate in order to prevent phase or ground faults from taking down the power grid, as well as preventing damage to power substation equipment and loss of life. This entire system works to ensure the western United States does not lose power. In addition, the microwave system also carries the very high frequency (VHF) land mobile radio system channels. The VHF mobile systems allow maintenance personnel to perform maintenance of the energy grid at Fort Chaffe and Pinnacle Peak in Arizona.[108]

Military Tactical Radio Relay Systems

The DOD operates tactical communications systems in the band that provide mid/high capacity digital information to the battlefield commanders. Tactical radio relay is a transportable fixed microwave system often deployed to multiple locations to interoperate with other systems for training exercises or operational missions.[109] DOD uses TRRs for the command and control of forces and high-capacity digital information to the battlefield.[110]

There are two TRR systems within the DOD. One is the Army's HCLOS and the second is the Navy and Marine Corps' DWTS. These tactical systems quickly establish microwave links in support of combat operations and maneuver warfare. TRRs provide the DOD with

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[106] FAA-1 at 1.

[107] National Telecommunications and Information Administration, *Federal Operations in the 1755-1780 MHz Band: The Potential for Accommodating Third Generation Mobile Systems Interim Report* (NTIA 2000 Interim Report) (Nov. 15, 2000) at 23, *available at* http://www.ntia.doc.gov/files/ntia/publications/imt2000.pdf.

[108] DOE-2 at 14.

[109] A "transportable station" is a station, which is transferred to various fixed locations, but is not intended to be used while in motion. NTIA Manual, *supra* note 20, at § 6.1.1.

[110] NTIA 2000 Interim Report, *supra* note 107, at 24.

transportable base stations and the capability of backhaul high-capacity voice and data communications.[111] These systems are described in more detail below.

Army HCLOS

The HCLOS radio (AN/GRC-245) is a multi-band, multi-mode, software-defined radio that allows the operating frequency and waveform to be selected in real-time to meet operational requirements of the digital battlefield. The HCLOS radio is a primary component of the Warfighter Information Network-Tactical (WIN-T) Increment-1. WIN-T includes network management tools, radios, routers and small, vehicle-mounted satellite dishes able to transmit signals via terrestrial and satellite from the company level up to division echelons. It also supports communication connectivity to vehicles on the move, to other command posts, and higher headquarters. The WIN-T Increment 2 will support the purchasing and fielding of 20 brigade-sized maneuver units.[112]

The HCLOS provides the Army with wide area communications for Army tactical deployments at the battalion, brigade, and division levels. The Army uses these systems for high-throughput data communications from command and control traffic to intelligence imagery, logistics, medical, and morale and welfare support. In addition, the Army's TRR systems deploy up to 30-50 km apart. These systems provide a digital microwave backbone to link mid-level and lower-level battlefield commanders. The TRR system operates like a high-capacity cellular telephone system with highly transportable base stations. The ability to set up, establish a link to higher headquarters and subordinate units, and then take down the link and move it to a new location is key to the survivability of the headquarters' units and supports the concept of maneuver warfare. Soldiers require frequent field training to ensure that they can quickly establish a network of tactical microwave links.[113]

The HCLOS radio system is expected to replace the AN/GRC-226(V)2 and AN/VRC-99B radios. The HCLOS radio operates in the 225-400 MHz and 1350-2690 MHz bands with increased spectral efficiency and higher data rates compared to the current radios.[114] This radio also requires a 50.125-megahertz minimum frequency separation between the site transmitter and receiver for a duplex link.[115] Table B-1 depicts major current and planned locations for Army operations.

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[111] DOD Strategic Spectrum Plan, *supra* note 30, at 38.

[112] DOD-2 at § D.1.

[113] *Id.* at § 4.3.1.

[114] United States Department of Defense IMT-2000 Technical Working Group Interim Report (DOD IMT 2000 Interim) (Oct 27, 20000) at 2-4, available at http://www.ntia.doc.gov/files/ntia/publications/dod_imt2k.pdf.

[115] *Id.* at 2-3.

Table B-1. Major HCLOS Locations in the United States

Location	State
Redstone Arsenal*, Fort Rucker*	Alabama
Fort Greely, Yukon Range, Joint Base Elmendorf-Richardson	Alaska
Fort Huachuca*, Yuma Proving Grounds*	Arizona
Camp Roberts*, Fort Hunter Liggett, Fort Irwin, Huntington Beach*	California
Fort Carson, Pinon Canyon	Colorado
Camp Blanding	Florida
Fort Benning*, Fort Gordon, Fort Stewart	Georgia
Kauai, Oahu, Pohakuloa	Hawaii
Camp Atterbury	Indiana
Iowa	Iowa
Fort Leavenworth*, Fort Riley	Kansas
Fort Campbell, Ft. Knox*	Kentucky
England Industrial Park, Fort Polk, JRTC (Fort Polk North)	Louisiana
Aberdeen Proving Ground*	Maryland
Camp Ripley, Faribault, Rosemount	Minnesota
Camp Shelby*	Mississippi
Fort Leonard Wood, Saint Joseph, Vichy Airfield	Missouri
Fort Bragg	North Carolina
McGregor, White Sands Missile Range	New Mexico
Fort Drum	New York
Ohio	Ohio
Fort Sill	Oklahoma
Letterkenny, Fort Indiantown GAP	Pennsylvania
Fort Jackson	South Carolina
Camp Mabry, Fort Bliss*, Fort Hood	Texas
Dugway Proving Ground*	Utah
Fort A. P. Hill, Joint Base Langley-Eustis*, Fort Lee*	Virginia
Joint Base Lewis-McChord, Yakima Firing Center	Washington
Fort McCoy, Two Rivers	Wisconsin
**indicates planned location*	

Navy and Marine Corps Digital Wideband Transmission System

The Navy and Marine Corps DWTS provides a backbone digital communications capability supporting amphibious and ground combat operations. DWTS is used by the U.S. Joint Forces Command to support the Joint Task Force-Civil Support (JTF-CS) in the event of a

weapon of mass destruction incident.[116] The mission of the JTF-CS is to provide support to a designated lead federal agency in the conduct of consequence management operations in response to a chemical, biological, radiological, nuclear, and high yield explosives incident or accident in the United States. Additionally, the Navy and Marine Corps use DWTS for other contingency operations within the United States to include disaster relief, national emergencies, and other DOD support requirements to civil authorities, as directed from the National Command Authority.[117] Table B-2 depicts major current and planned Marine Corps and Navy locations for DWTS operations.

Table B-2. Major DWTS Locations in the United States

Location	State
Yuma, Telegraph Pass*	Arizona
Bridgeport, Camp Pendleton, Twenty Nine Palms, Miramar, Point Mugu*, San Clemente Island*	California
Fort Carson*, Pinon Canyon*	Colorado
Apra Harbor	Guam
Kaneohe, Joint Base Pearl Harbor-Hickam	Hawaii
Sand Ridge, Fox Lake, Great Lakes	Illinois
Grissom	Indiana
Hawthorne	Nevada
Bogue Field, Camp Lejeune*, Elizabeth City*, Greensboro, Morehead City	North Carolina
Brooklyn	New York
Cincinnati	Ohio
Joint Base Charleston	South Carolina
Craney Island*, Midway Research Center*, Portsmouth*, St. Juliens Creek, Vacapes, Quantico	Virginia
* *indicates planned location*	

The DWTS supports command, control, and data transfer from the Marine Expeditionary Force level down to the regimental level. The Marine Corps DWTS provides digital backbone services (voice, video, and data) for shore-to-shore and/or ship-to-shore communications links. This is the Marine Corps' radio system with sufficient bandwidth to carry large quantities of critical data such as maps, overlays, intelligence pictures, and other data to the battlefield commanders. The Marine Corps currently employs three versions (A, B, and C). Versions A and B tune between 1350-1850 MHz. The C variant tunes between 1350-2690 MHz and is not compatible with the A and B variants. The Navy has a ship-to-shore version of DWTS that is a

[116] Department of Defense, *Investigation of the Feasibility of Accommodating the International Mobile Telecommunications (IMT) 2000 Within the 1755-1850 MHz Band* (DOD IMT 2000 Assessment)(Feb. 9, 2001) at C-3, *available at* http://www.ntia.doc.gov/files/ntia/publications/dodassessment.pdf.

[117] DOD Strategic Spectrum Plan, *supra* note 30, at 38.

LOS radio system used for communications between Expeditionary Strike Group ships and Marine Corps units ashore, where most of the critical information flow is from the ship to the landing. The Navy's shipboard DWTS tunes in the band 1350-1850 MHz and requires at least 62 megahertz of transmit/receive separation and twelve separate frequencies when communicating ship-to-shore.[118]

- **Marine Corps DWTS:** This radio uses the frequency bands 1350-1390 MHz, 1432-1435 MHz, and 1710-1850 MHz and requires a 62-megahertz minimum frequency separation between the site transmitter and receiver for a duplex link. The anticipated service life of the Marine Corps DWTS extends beyond the 2010 timeframe.[119]
- **Navy Shipboard DWTS:** This radio is essential for amphibious operations where most of the critical information flow is from the ship to the landing forces. The ship-based DTWS uses an omnidirectional antenna to communicate with other ships and shore-based radios. The radio requires a 50-megahertz minimum frequency separation between the site transmitter and receiver for ship-to-ship duplex links; however, ship-to-shore links must conform to the 62-megahertz separation requirements of the Marine Corps DWTS.[120]

Air Combat Training Systems

Current air combat training involves live air-to-air encounters and may include a network of ground stations monitoring the training activity. ACTS incorporates fixed and aeronautical mobile components. The aircraft relays flight parameter data to ground stations and the ground stations send information to the aircraft. In some cases, training and related ACTS data and communications involve only interaction between the aircraft, without the ground links. Training staff, subsequently, retrieve the recorded data for use in training debriefings. The Tactical Combat Training System/P5 Combat Training System is a cooperative program between the Navy (TCTS) and Air Force (P5 CTS) to procure a single instrumented tactical aircrew training capability. This system is replacing the Air Force's Aircrew Combat Maneuvering and Instrumentation system and the Navy and Marine Corps Tactical Aircrew Combat Training System. The TCTS/P5 CTS supports training aircrews using realistic warfighting scenarios. It is the primary tool at virtually all air combat training ranges and supports every level of training from initial schools where pilots first learn to fly the aircraft they will take into battle to advanced-tactics training schools that hone combat skills. The system provides real-time monitoring, tracking, and recording of training activities, which includes post-mission

[118] DOD-2 at§ 4.3.2.

[119] DOD IMT 2000 Assessment, *supra* note 116, at D-3.

[120] *Id.* at D-4.

reconstruction capabilities for pilots to receive accurate debriefing and critiques.[121] Allied Forces ensure cooperative capabilities by conducting joint training sorties. This joint training occurs inside and outside of the United States.[122]

The first major Air Force ACTS system to operate in the 1755-1850 MHz frequency band was the ACMI system developed in the 1970s. RF pods were mounted on combat aircraft, and training exercises took place over a ground infrastructure of master and remote stations that were connected to each other and could communicate with the aircraft as well. Master stations were typically associated with training and debriefing facilities. Air-to-ground transmissions were at the lower end of the band and ground-to-air in the upper end with the master and remote stations using frequencies in the middle of the band. Aircraft were "tethered" to the ground infrastructure and time, space, and position information was obtained by multi-lateralization. The Navy and Marine Corps used a similar system referred to as the Tactical Aircrew Combat Training System. Almost all the Air Force, Navy, and Marine Corps training facilities have migrated to newer systems. The major exception to this is Eielson AFB in Alaska, which has special system requirements. Nellis AFB also has a unique system known as the Nellis Air Combat Training System.[123]

Air Combat Training System and Tactical Combat Training System

The DOD uses these systems for daily proficiency training and as the final readiness training prior to deployment to combat areas around the world. ACTS and TCTS provide, during exercises and training, real-time monitoring of aircraft combat operations and maneuvering, such as gun-scoring, no-drop bombing training, evasion and intercept tactics, and electronic warfare. Most systems are composed of the ground-based tactical instrumentation subsystem (ground-to-air) and the aircraft instrumentation subsystem (air-to-ground) mounted internally or via a pod on the aircraft. The two-way data link between these two subsystems is the only means by which they interact and allow the overall system to function.

The air-to-air frequencies must be separated by at least 11 megahertz and adjacent range facilities must be separated by at least five megahertz. Operating altitudes may be as high as 60,000 feet, with normal operations occurring up to 40,000 feet.

ACTS and TCTS support every level of training a pilot receives from first learning to fly to advanced tactics. They operate at all test and training ranges, as well as at other bases,

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[121] DOD Strategic Spectrum Plan, *supra* note 30, at 38.

[122] DOD-2 at § 4.5.

[123] *Id.* at § E.3.

including Reserve and National Guard locations that may include civilian airports.[124] U.S. Allied Forces use identical frequencies and the same equipment.

P5 Combat Training System

The P5 Combat Training System is the principal Air Force Air Combat Training System in use today. Additional P5 CTS capabilities include real-time monitoring and control of aircraft during large and joint force, and small unit training, while being able to record events for post-mission debrief and analysis. Other P5 CTS capabilities include:

- real-time kill notification/verification;
- system security initiatives to protect classified aircraft and armament systems information;
- integration of electronics;
- air-to-ground weapon simulations; and
- threat simulations.

The P5 CTS also includes ground system integration, location specific architecture, internal pod replacement subsystems, and integration of new operational flight programs.

Mission lengths and frequencies may vary from facility to facility depending on the using unit and the training mission underway. Additional factors affecting mission length and frequency include local quiet hour regulations, airspace agreements with the FAA, and overall range operations. There are nominally 32 operational areas in the US&P that include Air Force, Navy, and Marine Corps usage.[125] A listing of major current and planned operational areas is included in Table B-3. The Air Force P5 CTS units operate on discrete frequencies in the 1755-1850 MHz band at the following Air Force training facilities listed in Table B-3.

[124] NTIA 2000 Interim Report, *supra* note 107, at 25.

[125] DOD-2 at § E.3.

Table B-3. Major U.S. Navy and U.S. Air Force Air Combat Training System Deployment Locations

Location	State
Aircraft, Big Delta, Caribou, Central Remote 2, Central Remote 3, Central Remote 4, Central Remote 5, Central Remote 6, Central Master, Chena Hot Springs, Circle Hot Springs, Delta Junction, Donnelly Dome, Eielson AFB, Joint Base Elmendorf-Richardson*, Far Mountain, Fox Remote 2, Hill 3265, Hill 3285, Hill 3320, Hill 4415, Hill 4797, Hill 5105, Hill 5575, Hill 6502, Hill 824, Glacier Mountain, North Remote 1, North Remote 2, North Remote 3, North Remote 4, North Remote 5, North Master, Paxon, Remote 1, Sheep Creek, Sleetmute, Snowy Peak, Sparrevohn, South Remote 1, South Remote 2, South Remote 3, South Remote 5, South Remote 7, South Remote 9, South Master, Stony Master 2, Stony Master 4, Stony Master 5, Stony Master 7, Stony Master 8, Stony Master, Taylor Mountain, West Remote 1, West Remote 2, West Remote 3, West Remote 4, West Master, Woodchopper Creek, Yukon Range	Alaska
Aircraft, Aztec, Childs Mountain, Crater Mountain, Granite Mountain, Growler Mountain, Luke, Mohawk, Sierra Pinta, Baker Peaks, Barry Goldwater Range/Range Management Office, Barry Goldwater Range Moving Sands, EW Site 23, Yuma	Arizona
LANT, Central Ocean, East Ocean, East Tower, North Ocean, Ocean Tower, Ocean Tower R9, Platform M1, Platform M2, Tower R1, Tower R3, Tower R3R9, Tower R4, Tower R 5, Tower R6, Tower R7, Tower R8, South Ocean	Atlantic Ocean (LANT)
Aircraft, Edwards*, El Centro, Fort Irwin*, LeMoore, Miramar, Chia, China Lake, Quartz Peak, Spring Hill	California
Aircraft, Carrabelle, Homestead, Eglin, Key West/Key West NAS, St. George Island, Telogia, Tyndall AFB, Wewahitchka, Avon Park, Marco Island, Pine Castle, Umatilla	Florida
Savannah, Shellman Bluff	Georgia
Guam	Guam
Aircraft, Platform, South Master Ocean Tower, Towers, Ocean Towers-South Gulf	Gulf of Mexico
Pacific Missile Range Facility (PMRF) (Pacific)	Hawaii (Kauai)
Mountain Home	Idaho
Barksdale AFB, Pearson Ridge	Louisiana
Patuxent River	Maryland
Alpena	Michigan
Gulfport, South CRTC Tower, North CRTC Range, Camp Shelby*	Mississippi

Location	State
Great Falls	Montana
Angel Peak, Aysees Peak, Badger Mountain, Belted Peak, Cedar Peak, Cedar Ridge, Cherry Stem, Fallon NAS*, Highland Peak, Mount Ella, Mount Irish, Nellis AFB, Nellis Test Range, Nevada Test and Training Range, Pahranagat, Pintwater, Reveille, Reveille Ridge, Stonewall Mountain, Timber Mountain, Timber Ridge, West Master, Bald Mountain Monitor, Balt Mountain Toiyabee, Brown Knob, Buffalo Mountain, Bunker Hill, Carson Sink, Cocoon Mountain, Cold Springs, Copper Mountain, Desert Mountain, Dixie Hot Springs, Dixie Valleys, Dixie Valley North, Eastgate, Edwards Creek Valley, Elephant Head, Fairview Peak, Hickerson Summit, Horse Mountain, Hot Springs Mountain, Ione, Job Peak, Mesa, Monitor, Mount Anna, Mount Augusta, Mount Callahan, Mount Moses, NAS Fallon, New Pass, North Dixie Valley, North Edwards Creek, North Sand Springs Range, North Stillwater Range, Paradise Peak, Railroad Pass, South Dixie Valley, Shoshone Creek, Slate Mountain, Toiyabe, White Rock Canyon	Nevada
Seymour Johnson AFB, Atlantic Field, Bodie, Bogue Field, Center Tower, Cherry Point MCAS, Croatan, Dare County Range, East Tower, Engelhard Tower, Hobucken, Holly Ridge, Kill Devil Hills, Lola, Long Curve Tower, Merrimon, Morehead City, New River, North Tower, Ocracoke, Onslow, Palmetto B Tower, Pea Island, Piney Island, Starling, South Tower, Swan Quarter	North Carolina
Portland ANG*	Oregon
Beaufort MCAS*, Joint Base Charleston, Myrtle Beach, Shaw AFB*, Sullivan Island*	South Carolina
Hill AFB	Utah
Joint Base Langley-Eustis, Oceana NAS	Virginia
Hardwood, Volk Field	Wisconsin
**indicates planned location*	

Tactical Combat Training System

The Navy and Marine Corp's TCTS consists of various types of Participant Subsystems (PS). The PS includes Airborne Subsystem pods and Internal Subsystems carried onboard or inside numerous Navy, Marine Corps, and Air Force fixed wing and rotary platforms, as well as various Ground Subsystem components designed to receive this information via RF communication and to interface with other training range system infrastructure, such as the electronic warfare server system. TCTS merges all of this information into one comprehensive real-time operating picture and includes post mission reconstruction capabilities so that crews can receive accurate debriefing and critique of their mission, thereby maximizing the benefit of the training activities.[126]

TCTS was designed to operate in two modes. In the live monitor mode, communication is received by remote range units located throughout the range ground system infrastructure and passed to a fixed ground system for recording and display. In the rangeless or autonomous mode, the airborne participants transmit aircraft and weapons information via communication amongst themselves and data collected is recorded to a data recording device , and then downloaded post-flight. This rangeless capability makes system operation and emission possible worldwide.[127] The Navy TCTS operates on discrete frequencies in the band.

Precision Guided Munitions

PGMs operate in this band to communicate between a launched weapon and a controlling platform, allowing for precise targeting. PGMs provide the capability to attack single military targets with one aircraft or one standoff weapon with greater probability of success than by flying waves of aircraft dropping conventional, unguided bombs. PGMs increase aircrew survivability by allowing the launch of weapons outside of enemy's anti-air system threat envelope, thereby significantly decreasing aircrew vulnerability. The Air Force and the Navy both use PGMs that carry television cameras or infrared sensors, and GPS receivers, which provide operators the ability to attack targets in all weather conditions, day or night. Weapon operators require access to a video and a command link frequency throughout the mission; including ground, pre-launch, post take-off, and post-launch weapon flight operations. Training operations require use of the frequencies for two hours at a time.[128] Figure B-1 provides a map of the contours of nominal radio line-of-sight distances surrounding many of the operational training areas for PGMs within the United States.

[126] DOD-2 at § F.3.

[127] *Id.*

[128] *Id.* at § F.4.

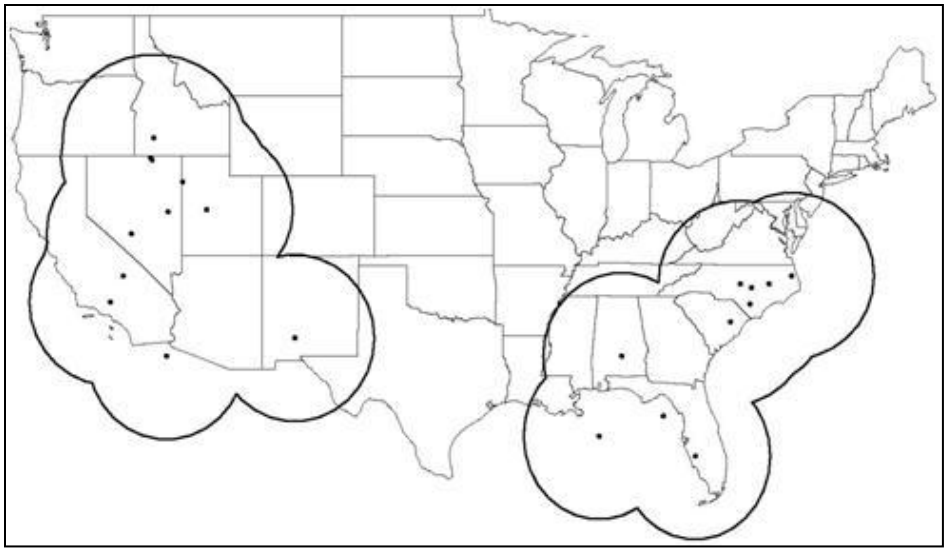

Figure B-1. Line-of-Sight Distances from PGM Operational Areas

Air Force Air-to-Ground Missile-130 (AGM-130) and Guided Bomb Unit-15 (GBU-15)

The Air Force uses PGMs to attack fixed, high-value, and hardened enemy targets.[129] These 2,000-pound class weapons are launched from tactical aircraft from either low or high altitude, at ranges from five to more than 30 nautical miles. Weapon control data-link systems provide operators with the ability to control the precision guided weapons. Video from the weapon's seeker apparatus is transmitted to a weapon systems officer who manually identifies the target, via a command frequency, and controls the bomb to the designated impact point. The AGM-130 provides a longer range, compared to the GBU-15, because its flight is assisted by use of a rocket motor. Both AXQ-14 and ZSW-1 data-link systems associated with these munitions use multiple frequencies within the 1755-1850 MHz band for both video and command links. The AXQ-14 and ZSW-1 weapon control pods carried on the centerline station on the aircraft, receive the weapon video for display, and transmit weapon guidance signals through the command link.

Navy Precision Guided Munitions

The Navy PGM operating in the 1755 – 1850 MHz band is a highly survivable, air-to-surface man-in-the-loop guided missile system. Its usage within United States and Possessions is limited to testing and training.[130] It is an upgrade to the fielded inventory of Navy PGM missiles. A pod on the aircraft provides terminal control for the Navy PGM. The pod provides

[129] NTIA 01-46, *supra* note 99, at 3-22, 3-23.

[130] DOD-2 at § F.4.

commands to the Navy PGM missile via an RF data link, allowing the weapon to be directed remotely to a target by the launch aircraft or a remotely stationed controlling aircraft.

Video Surveillance

To satisfy their congressionally mandated law enforcement requirements, federal agencies maintain and conduct authorized electronic video surveillance operations on multiple frequency assignments in the band. Thirteen federal agencies (DOD, DOE, DOI, DOJ, DHS, HHS, HUD, OPM, Treasury, USAID, USCP, USPS and VA) hold all of the frequency assignments for video surveillance.

Federal agencies performing law enforcement functions operate mobile, fixed, and high-definition video surveillance systems in this band throughout the United States. These systems provide the agencies with the capability of enhancing law enforcement by providing measures for agent safety, protective service, criminal investigation, and crime detection and prevention functions. Video surveillance operations are typically covert in nature and occur both indoors and outdoors.

Agencies operate three types of video surveillance systems: law enforcement mobile, high-resolution video surveillance (fixed and transportable), and land robotic systems.

Law Enforcement Mobile

Federal law enforcement agencies use the 1755-1850 MHz band to employ undercover low-power video surveillance devices during criminal investigations. These devices are authorized throughout the US&P for agent safety, protective operations, and criminal investigations. The video footage obtained during these investigations is critical for providing rapid response support to undercover officers and agents and used as evidence during criminal trials and procedures. These systems may operate in any part of the band, at any location, at any time.

DHS operates a nationwide system of portable and mobile video surveillance devices used in the investigation of criminal activities and the protection of national leaders, visiting heads of state and government, designated sites and National Special Security Events. These systems incorporate multiple transmitters and receivers that collect, transport, and store video and audio evidentiary and intelligence information. The nature of the operations requires that the devices be highly concealable, portable, and capable of short notice deployment.

DOJ operates a nationwide system of portable and mobile video surveillance devices used in the investigation of terrorist and criminal activities in addition to supporting joint protective operations during major national events. These systems incorporate multiple transmitters and receivers that collect, transport, and store video and audio evidentiary and intelligence information. The nature of the operations requires that the devices be highly

concealable, portable, and be capable of short notice deployment. They are typically secured from both physical and electronic detection in order to ensure mission integrity and officer/agent safety. The video surveillance activities include primary evidence and intelligence collection, management and control of data and information from various surveillance and data backhaul platforms, manned and unmanned aircraft, and remotely controlled robotic devices.[131]

DOI operates a nationwide system of portable and mobile video surveillance devices supporting U.S. Fish and Wildlife Service, Office of Law Enforcement Services, operations throughout US&P. The video surveillance system is comprised of portable and mobile video devices for the collection of evidence and information during law enforcement operations in support of criminal investigations and Secretarial, Executive staff and other Very Important Person(s) (VIP) protection details.[132]

High-Resolution Video Data Links (fixed or transportable)

The DOD and other federal agencies maintain and conduct authorized electronic video surveillance operations on multiple frequency assignments in the band. Mission requirements, in most cases, necessitate that surveillance equipment be highly mobile or transportable (although some equipment operates from fixed sites) and therefore must be lightweight and easily assembled; must be concealable because they are used for law-enforcement activities; and must be secured from both physical and electronic detection in order to ensure officer/agent safety.

The DOD, specifically the Air Force and Army, use the band for area surveillance using HRV systems. HRV are point-to-point data communications systems designed to meet Army and National Guard requirements for highly capable, multi-role helicopter missions that range from homeland security and medical evacuation to drug interdiction, support, and logistics operations. HRVs are typically used at active duty installations and National Guard and Reserve locations throughout the United States; however, during periods of national emergency and other significant events, HRV systems can be required to support operations anywhere within the US&P. This type of service supports critical missions and must be protected when considering comparable spectrum.[133]

The Army currently uses multiple HRV systems including the TactiLink Eagle and the VTX-40 systems. The TactiLink Eagle system is a good representative system in this category because it is expected to be the most widely used aerial HRV. The Army contracted for

[131] *See generally* DOJ-1 at 12-14.

[132] DOI-2 at § 5a.

[133] DOD-2 at § D.5.

procurement of over 200 of these video systems.[134] It has both an airborne and a ground component associated with its operation. The Army plans to install the airborne component on the UH-72A Lakota helicopter.[135]

This system creates the ability to conduct a real-time aerial survey of bridges, roads, and structures immediately after a natural disaster to assess damage and direct relief operations from a remote command center. Army National Guard security and support battalions are able to support Operation Jump Start by patrolling along the Texas border and to provide full motion video to ground reaction elements for immediate intercept and streaming of full motion video to distant command posts over the Internet. Military Intelligence C3 Analysis Teams receive real-time full motion information and imagery from airborne forward-looking infrared cameras.[136]

The Air Force also operates multiple HRV systems that include the ANG Dragoon system, the Sniper/LITENING Advanced Targeting pod, and the Remotely Operated Video Enhanced Receiver (ROVER) family of systems. The Dragoon system is a high-resolution video data link providing full motion video in the 1755-1850 MHz band. ANG RC-26B aircraft carry the system onboard to provide aerial surveillance and reconnaissance for law enforcement agencies. The Sniper/LITENING Advanced Targeting Pod is an advanced electro-optical targeting system mounted in a single, lightweight pod, which may be configured for multiple types of fighter aircraft. A video downlink provides the capability to transmit pod-generated video with embedded symbology to a ROVER ground station receiver. The ROVER family of systems includes capabilities to transmit and receive data and full motion video. Systems within this family were initially receive-only, but have been enhanced to include transmit functions.

DOI uses aeronautical mobile video surveillance transmitters located on rotor blade aircraft to provide real-time video surveillance downlinks to federal agencies' Command Posts for video surveillance, mission management, law enforcement, homeland security, search and rescue, and medical evacuation operations within the National Capitol Region. This aviation asset has also deployed to support National Emergency Response situations (e.g., U.S. Park Police deployed the video surveillance equipment to Louisiana to provide emergency response support during Hurricane Katrina relief operations).[137]

Treasury utilizes this band for covert/body-worn and "pole cam" audio and video surveillance as a method of collecting evidence during administrative and/or criminal

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[134] *Id.*

[135] *Id.*

[136] *Id.*

[137] DOI-1 at § 4a.

investigations. These systems are primarily mounted on outdoor light posts and electrical poles, installed covertly in offices and cubicles, or worn by undercover agents and/or cooperating witnesses (body worn). Treasury may deploy video surveillance systems "anytime, anywhere," gathering evidence for investigations. Systems may be operational for a specific event, typically a few hours, or may be employed to survey and record activity at a business over several weeks or months. [138]

High-capacity fixed point-to-point systems support most of DOJ's surveillance operations. They transmit video and voice data at locations across the United States. The fixed systems also receive data from the transportable systems to backhaul and route the data to a distant command location. DOJ also operates transportable surveillance operations. The devices for these type operations are highly concealable, portable, and/or rapidly deployable assets. Transportable operations involve a device with limited or pre-tuned channel selection capability designed to support low profile, undercover, covert operations. These devices transmit video information within the 1755-1850 MHz band from a transportable device via a one-way communications link to an established fixed collection point (if available), or associated transportable collection platform. Transportable operations support the standard digitized video capture using an eight-megahertz bandwidth; however, the 17-22 MHz bandwidth supports DOJ's high definition analog video capture and robotic-based platforms.[139]

DOJ supports missions under current "fixed" authorizations that are typically longer in duration (days/weeks/months), and 24/7 in nature, but can routinely change based on real-time dynamic operational requirements. As the core architecture changes within each operating area, the specific application of 1755-1850 MHz dependent devices may also change in accordance with the aggregate ability to apply other in-band and associated out-of-band devices to support overall data capture, routing, backhaul, and recording/storage capabilities. Although DOJ can operate all 1755-1850 MHz spectrum dependent devices independently or in association with other peripheral devices within the overall network, the radio signature(s) produced from these devices is no different from that already identified in the previous transportable and point-to-point discussions.

USAID, HHS, HUD, OPM, USCP, USPS, and VA conduct video surveillance during administrative and criminal investigations. These systems are primarily mounted on outdoor light posts and electrical poles; or worn by undercover agents and/or cooperating witnesses. USAID, HHS, and HUD operate throughout the United States. OPM, USPS, and the VA accomplish their operations in the US&P. The USCP operates video surveillance specifically in Washington, District of Columbia.

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[138] Treasury-1 at 1.

[139] *See generally* DOJ-1 at 12-14.

Land Robotic Systems

Normally, federal agencies employ these systems using communications links in the 1755-1850 MHz band to engage in law enforcement activities or to perform as "first responders" in support of EOD and hazardous material (Hazmat) disposal (e.g., chemical, biological, nuclear, etc.). The military services are typically the ones responsible for EOD and Hazmat disposal and use land robotic video systems for both live operations and training exercises. The EOD operation entails a video link from a remote-controlled robot to the command site to enable the operator to provide command and control for the robot and, at the same time, disable or disarm and/or monitor the ordnance or bomb disposal operation. Land robotic video systems are part of the mobile service. The 1755-1850 MHz band meets the high mobility and high path reliability requirements for these systems.

The following paragraphs describe typical robotic systems.

All-Purpose Remote Transport System (ARTS)

ARTS provides for wireless remote control operation in hazardous environments. The primary use is for EOD operations and the primary user is the Air Force.[140] In addition to the disposal of unexploded ordnance, other ARTS functions include force protection, fire-fighting, and hazardous/toxic waste cleanup. ARTS operation consists of robot-controller links at distances up to about 4000 feet. The frequency range authorized for this system is 1760.5-1833.5 MHz; however, relocation to another frequency band is under consideration.[141] A typical radius for EOD operation for these locations is between 5 to 10 kilometers. The transmitter nomenclature is the Tron-Tek TT-1812TAFS. Table B-4 provides the major current and planned Air Force training areas used for EOD operations; however, special security situations may require operations anywhere within the US&P.

[140] DOD-2 at § E.10.

[141] *Id.*

Table B-4. Locations of EOD Operations within the United States

Location	State
Little Rock AFB	Arkansas
Luke AFB	Arizona
Edwards AFB, Travis AFB	California
Eglin AFB, Hurlbert Field AFB, Patrick AFB, Tyndall AFB	Florida
Moody AFB	Georgia
Joint Region Marianas	Guam
Joint Base Pearl Harbor-Hickam	Hawaii
Mountain Home AFB	Idaho
McConnell AFB	Kansas
Barksdale AFB	Louisiana
Joint Base Andrews	Maryland
Malmstrom AFB	Montana
Pope Army Air Field, Seymour Johnson AFB	North Carolina
Joint Base McGuire-Dix-Lakehurst	New Jersey
Holloman AFB, Kirtland AFB*, White Sands Missile Range*	New Mexico
Nellis AFB	Nevada
Joint Base Charleston	South Carolina
Joint Base San Antonio, Dyess AFB	Texas
Hill AFB	Utah
Joint Base Langley-Eustis	Virginia
South Royalton	Vermont
Joint Base Lewis-McChord	Washington
F.E. Warren AFB	Wyoming
**indicates planned location*	

Remote Ordnance Neutralization System (RONS)

The RONS is currently used at several Air Force and Navy/Marine Corps bases. The nomenclature is SEMCO VT40 and the MS-30001/F.[142] The video link from the robot to the ground station operates in the 1755-1850 MHz band, however, some RONS have a capability for a video link in a second frequency band, such as 2200-2290 MHz. The control link from the RONS operator to the robot typically operates in another frequency band such as VHF, UHF, or L-band (1427-1435 MHz). The Air Force will retire RONS and transfer them to federal and local bomb squads with fiscal year (FY) 2012 being the target timeframe.[143] The Navy RONS operations occur at China Lake, California. The Navy and Marine Corps use this system for both emergency and testing/training purposes. Frequency scheduling is required via the China Lake

[142] *Id.*

[143] *Id.*

Frequency Management Office for testing/training operations, however, this does not apply for emergency operations.

Excavator

The Excavator is a one-of-a-kind converted John Deere backhoe that is remotely controlled to aid in the effort to access, recover, and disposal of dud-fired and unexploded ordnance used by the Air Force. It is capable of recovering live ordnance, safe explosives, and hazards. Eglin AFB personnel developed the system for test range operations. The Excavator uses two radio systems, one each for data and video subsystems. The remote control system uses the AACOM AT-2700V for the video link and the AACOM AT-4801L for the data link.[144]

Talon III Mk2 Man Transportable Robotic System (MTRS)

The Air Force, Army, National Guard, and the Navy/Marine Corps use the Talon III Mk2 MTRS. (See Figure B-2) It is controlled through either a radio link or a fiber optic line from a portable or wearable operator control unit that provides continuous data and video feedback for precise vehicle positioning. The L-band radio link consists of the VML-2000 transmitter on the robot and the VRX-500 receiver at the robot operator control station. The robot is a modified version of the commercial EOD ROBOT and can operate under the most adverse conditions to overcome almost any terrain. The EOD ROBOT is a small, tracked, military robot designed for missions ranging from reconnaissance to combat.

The Mk2 MTRS robotic vehicle communication system, called the MTRS C-BOX, consists of video and data radios dedicated to the transmission of low latency video and telemetry data from the robotic vehicle to the operator control unit where it is received and displayed to the operator via a video receiver and data transceiver. It receives video from the robotic vehicle and transmits command and control data from the operator back to the robotic vehicle.[145]

Figure B-2. Talon IIIB Robot

[144] *Id.*

[145] *Id*. at § F.7.

The Talon IIIB Mk 2 MTRS is a 115- to 140-lb system that provides soldiers the ability to identify improvised explosive devices (IEDs) visually from a range safe enough so that the operator has a minimal likelihood of injury. In addition to spotting and identifying stand-alone IEDs, the system, with its extension arm and cameras, microphone and loudspeaker, provides the ability to detect and identify vehicle-borne IEDs. It also has a gripper attached to the control arm that supports EOD and IED operations.

The payload and sensor options for the Talon include multiple cameras (color, black and white, infrared, thermal, zero light); a two-stage arm; gripper manipulators; pan/tilt; two-way communications; nuclear, biological, and chemical sensors; radiation sensors; unexploded ordnance/countermine detection sensors; grenade and smoke placing modules; breaching tools; communications equipment; and distracters and disrupters.[146]

The video radio operates in the 1700-1850 MHz frequency band although DOD is looking at options to move the robot from the 1755-1850 MHz frequency band.[147] The Talon IIIB is in the process of being migrated to the Talon IV, which operates in the 4400-4940 MHz band because of in-band electromagnetic interference within the 1755-1850 MHz band. Approximately one-half of the robotic systems have been converted to another band. The present inventory includes 1,439 systems fielded with a total objective of 2,338 systems by FY2013. The Talon MTRS is one of the larger unmanned ground vehicle (UGV) platforms and is one of the most-frequently-used systems. The Talon IIIB MTRS has already started the migration process into the Talon IV (although all systems have not yet completely migrated), so therefore it was chosen as the representative system for UGVs.[148] The Talon MTRS is used for training purposes at numerous Army, Army Reserve, Army National Guard, Air Force, Navy, and Marine Corps locations throughout the US&P. Special security situations may require operations anywhere within the US&P.

M160

The Army uses the M160 (See Figure B-3). The M160 (formally called the MV-4B) is a mechanical, antipersonnel mine clearing system providing standoff protection to the operator. The M160 uses a chain flail and hammers to defeat antipersonnel mines mechanically. This system has been procured by the Army to meet the robotic combat support system requirements necessary to provide current mine-clearing capability. Approximately 65 M160 systems have been fielded to-date, and are deployed in the Global War on Terrorism to perform countermine operations and route clearance missions. Functional control of the mine-

[146] *Id*. at § D.6.

[147] *Id*. at § F.7.

[148] *Id*. at § D.6.

clearing vehicle is typically performed using visual observation even though a video link in the 1755-1850 MHz band is available (though seldom used). The Robotic System Joint Program Office is investigating a radio-change to a more suitable frequency band as identified in the Spectrum Supportability Risk Assessment. Figure B-3 shows the M160. The current quantities are 120 radios for 65 robotic systems.[149]

Figure B-3. M160 Robot

The training of personnel for EOD/Hazmat disposal operation is by robotic video surveillance systems and in specific designated training areas. In a typical EOD/Hazmat disposal scenario, the use of a two-way radio communication links allows for real-time command and control of the robot while a stream of video signals from the surveillance device traverse the other RF link to the command and control post.

Other federal agencies, such as the DOJ, use remotely controlled vehicles or robots with onboard video links and sensors for hazardous materials identification, bomb disarmament, neutralization, and/or disposal, explosives detection, and law enforcement video. The video link operates in the 1755-1850 MHz band. The remotely controlled vehicle's return path uses other frequency bands and transmits the command and control, voice, and/or telemetry. These missions occur with little to no notice of operational location, duration, or time of operations. The criticality associated with these operations requires nationwide access, availability, and authority to operate 24 hours a day/seven days a week.

The DOJ operates more intricate surveillance and robotic-based transportable operations. These devices require two-way communications for real-time device control and management. Similar to the transportable surveillance operations discussed above, the video component of the operation is one-way within the band, while the device receives the command, control, voice, and/or telemetry signal using various out-of-band signaling methods.[150]

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[149] *Id*. at § D.6.

[150] DOJ-1 at 12.

DOE has two assignments within the 1755-1850 MHz band that support the deployment of robots in response to emergency situations involving hazardous material that are too risky to compromise the safety of personnel. The land robotic video systems are primarily used for live operations and training, but may serve other functions as required. The robots provide a one-way LOS video link to observe and assess critical situations.

Telemetry, Tracking, and Commanding

DOD operates satellites orbiting the Earth in a geostationary satellite orbit or a non-geostationary satellite orbit (NGSO) to provide communications, navigation, surveillance, missile early warning and attack characterization, weather monitoring, and research and development. The critical nature of the Air Force and Navy Satellite Control Network (SCN) supports these satellites to achieve proper orbit, initialize for operations, maintain orbit and configuration, perform emergency recovery operations following on-orbit failures, and for disposal operations at end-of-life. Satellites are controlled to maintain proper orbit, and must be commanded to perform certain functions. This is the control function. The satellite controller must know the location of the satellite to determine its present orbit. This is called the tracking function. The operators also need to know the "health" of the satellites, so a telemetry link sends back to the ground station information relating to the status of all platform functions such as electrical, stabilization, temperature, and propulsion systems onboard the satellite. This is the telemetry function. The combination of these functions for satellite control is termed TT&C. The uplink TT&C function operates in the 1761-1842 MHz band for military satellites. The associated downlink for these satellites is in the 2200-2290 MHz band.[151]

DOD and DOC have assignments in the 1755-1850 MHz band for space operations with the DOD being the primary user. DOD uses the band for initial contact with newly launched satellites, early orbit checkout of those satellites, emergency access to spinning/tumbling satellites (anomaly resolution) and final disposition of satellites upon mission completion. This band is also vital for command and control, mission data retrieval, and on-orbit maneuvering of low and medium earth, highly elliptical, and geostationary orbit satellites.[152]

The 1761-1842 MHz band segment supports the TT&C for the DOD satellites, in addition to the North Atlantic Treaty Organization (NATO), United Kingdom (UK) military satellites, and various space and ballistic missile test programs. TT&C supports automatic space vehicle acquisition and tracking, ranging, reception and recording of vehicle telemetry data, and transmissions of commands to the space vehicle. The TT&C subsystem monitors and controls all of the other systems on the spacecraft, transmits the status of those systems to the control

[151] NTIA 01-46, *supra* note 99, at 3-11.

[152] DOD Strategic Spectrum Plan, *supra* note 30, at 37.

segment on the ground, and receives and processes instructions from the control segment. Telemetry is the data collected by sensors throughout the satellite that determine the status of various system components, including transmitters and antennas. This information is then transmitted to the ground segment. Telemetry also includes data on the operation and status of the satellite's payload. For example, on a communications satellite, telemetry would include data on power output of transponders, pointing direction of antennas, and antenna and transponder switch configurations. Tracking involves determining a satellite's position, altitude, and other orbital parameters. Many satellites carry a beacon that transmits a signal to help ground-tracking receivers locate the satellite. Onboard sensors, such as star trackers, horizon scanners, and inertial navigation sensors provide other tracking data. Tracking information is essential to determine a satellite's orbital parameters to predict accurately the satellite's future position. In this way, the satellite's orbital position can be adjusted so that it will be in its proper position at the proper time.[153]

Commanding is the act of controlling a satellite. Commanding a satellite is accomplished by sending signals to it that initiate an action or change the configuration in some way. Commands may be executed by the satellite immediately upon receipt or stored for later execution. Some commands are part of onboard software that allows the satellite to execute certain functions autonomously when a predefined condition exists. Commands may direct the thrusters to fire to change the orbit, or may reconfigure the payload to meet the needs of users. The major system operating in this band segment that supports the TT&C functions is the Space Ground Link Subsystem. The band plan for SGLS comprises 20 discrete channels within the 1761-1842 MHz band segment beginning at 1763.721 MHz and ending with 1839.795 MHz. Each channel is 4.004 megahertz wide. Although most TT&C operations are provided by fixed sites, the Air Force also uses transportable SGLS-compatible earth stations to provide additional coverage during launches, early orbit operations, anomaly resolution, and critical orbit insertion maneuvers. These transportable stations are moved as necessary to accomplish the mission. It is not possible to change the TT&C frequencies for satellites that have already been launched. While it may be possible to change the frequencies of satellites that are yet to be launched, this would be expensive, time consuming, and could impact scheduled launch dates of critical national space assets, thus affecting the government's ability to meet satellite replacement requirements. In addition to supporting TT&C for military satellites, the 1761-1842 MHz band segment supports TT&C for the cooperative DOE/DOD Proliferation Detection Technology Program. This program will demonstrate advanced system technologies for remotely monitoring nuclear facilities and for identifying and characterizing undeclared and clandestine nuclear facilities. Although this program is directed at nuclear

[153] NTIA 01-46, *supra* note 99, at 3-11, 3-12.

proliferation monitoring, the technology could potentially serve a variety of other national security and civilian needs. The civilian and commercial communities also derive significant benefit from GPS, in which the 1761-1842 MHz band controls and supports. The operation of U.S. satellite control facilities internationally is authorized by specific host nation agreements in those countries in which the SGLS-compatible stations are deployed. The lack of spectrum support for continued satellite control operations in the 1761-1842 MHz band would have implications for U.S. allies as well, since both NATO and the UK depend on satellite control stations operating in the 1761-1842 MHz band to provide military spacecraft TT&C support for the NATO SATCOM IV and the UK SKYNET satellites, respectively.[154]

Air Force Satellite Control Network

The Air Force is the designated service responsible for platform control of most DOD satellites. The AFSCN is operated and maintained by the Air Force Space Command's 50th Space Wing at Schriever AFB, Colorado.

The AFSCN provides support for the operation, control, and maintenance of a variety of DOD and some non-DOD satellites. This involves continual execution of the tasks involved in TT&C. In addition, the AFSCN provides pre-launch simulation, launch support, disposal and critical orbit insertion/early orbit support while satellites are in initial or transfer orbits and require maneuvering to their final orbit. The AFSCN provides tracking data to help maintain the catalog of space objects and distributes various data such as satellite ephemeris, almanacs, and other information.

The AFSCN consists of satellite control centers, tracking stations, and test facilities located around the world. Satellite Operations Centers are located at Schriever AFB, Colorado, and Vandenberg AFB, California. These centers are staffed around the clock and are responsible for the command and control of their assigned satellite systems. The control centers are linked to remote tracking stations (RTSs) around the world. The RTSs provide the link between the satellite being controlled and the control center. A similar relationship exists for dedicated networks. RTSs around the world are needed to maintain frequent communications with the satellite. Without RTSs, the control centers would only be able to contact a satellite when it came into the control center's view. Some satellites, especially those in geostationary orbits, never come within view of their control center (most control centers do not have antenna capabilities to communicate directly with satellites in this band). Space vehicle checkout facilities are used to test launch vehicles and satellite platforms to ensure that the onboard systems operate within specifications.[155]

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[154] *Id.* at 3-12.

[155] *Id.* at 3-12, 3-13.

Remote Tracking Stations (RTS)

Each RTS performs essential mission operations on a 24/7 basis. The AFSCN performs approximately 550 satellite contacts per day. The operations are driven by the requirements to support U.S. national security space operations, as well as by NATO, and the UK. Each RTS has one to four antennas used for transmitting in the 1761-1842 MHz band. During major maintenance or antenna replacement, transportable assets are deployed to the RTS sites to ensure continuity of operations. The antennas used are typically 60, 46, and 33 feet (18, 14, and 10 meters) in diameter. Transmitters operating between 250 and 7,000 watts, depending on the required mission operation, support them. Filters are employed to limit out-of-band radiation. The antennas may be pointed low on the horizon to communicate with low-altitude satellites, which have very short visibility times. Low-angle radiation will also occur at Vandenberg AFB, California and Cape Canaveral AFS, Florida to conduct open loop checkout of satellites on launch pads and to verify communications links prior to launch. For other satellite contacts, the antennas are typically pointed at higher elevation angles. The infrastructure at each RTS has evolved over the last 40 years and is extensive and sophisticated with regard to facility power, emergency power, and connectivity to commercial terrestrial communications. For the most part, the RTSs are located on U.S. military or host nation military/government facilities. RTSs are located as follows:

- Vandenberg Tracking Station, Vandenberg AFB, California
- New Hampshire Tracking Station, New Boston AFS, New Hampshire
- Thule Tracking Station, Thule Air Base, Greenland
- Guam Tracking Station, Andersen AFB, Guam
- Hawaii Tracking Station, Kaena Point, Oahu, Hawaii
- Colorado Tracking Station, Schriever AFB, Colorado
- Oakhanger Telemetry and Command Station, Borden, Hampshire, England
- Diego Garcia Tracking Station, British Indian Ocean Territory, Diego Garcia
- Eastern Vehicle Checkout Facility, Cape Canaveral AFS, Florida

The AFSCN control node sites are at Schriever and Vandenberg AFBs. Cape Canaveral AFS includes a data-link terminal antenna, which provides test and checkout communications function using SGLS.[156]

Other Transmitting Sites

Other than the AFSCN stations, certain satellites are controlled through dedicated sites to support specific programs. Typical examples of these sites follow. The Defense Meteorological Satellite Program (DMSP) has a dedicated network operated by the Suitland

[156] *Id.* at 3-13, 3-14.

Satellite Operations Control Center (SOCC) in Suitland, Maryland. The SOCC performs all primary TT&C functions for the DMSP by AFSCN assets. The SOCC has a back-up facility at Schriever AFB, Colorado. The GPS has a Mission Control Center at Schriever AFB operated by the Air Force Space Command, 50th Space Wing, 2nd Satellite Operations Squadron. There are also dedicated GPS monitoring stations at Ascension Island, Diego Garcia, Kwajalein, and Cape Canaveral tracking stations.[157] In addition to the AFSCN, the GMF lists the following facilities that are authorized to transmit on SGLS frequencies:

- Blossom Point, Maryland
- Laurel, Maryland
- Buckley AFB, Colorado
- Fairbanks (NOAA), Alaska
- Joint Base San Antonio, Texas
- Kirtland AFB, New Mexico
- Fort Belvoir, Virginia
- Quantico, Virginia
- Camp Parks, California

The additional sites operated by the Navy are:

- Prospect Harbor, Maine
- Laguna Peak, California

Further, the Air Force also has transportable tracking facilities that are relocated worldwide to satisfy immediate requirements for TT&C, such as anomaly resolution, that cannot be accomplished at the fixed facilities.[158] Figure B-4 shows the locations of SGLS-compatible uplink stations in the United States.

[157] *Id.* at 3-15.

[158] *Id.* at 3-14, 3-15.

Figure B-4. Satellite Control Network Sites

Space Ground Link Subsystems

All DOD satellites rely on control afforded by the AFSCN, Naval Satellite Operations Center (NAVSOC), GPS, and DSP/SBIRS networks. The Air Force SGLS is the primary component of this network, and provides TT&C functions with satellites that are used for missile warning, navigation, military SATCOM, weather tracking and reporting, and ISR.

The NAVSOC SGLS antennas operating on the NSCN provide uplink and downlink communications, which are required to conduct satellite operations of the UFO and FLTSAT constellations. UFO and FLTSAT satellites provide narrowband SATCOM support to joint warfighters.

Other Space Operations and Space Telecommand Systems

There are times where NASA and the Air Force operate a joint satellite; either NASA earth stations or SGLS earth stations, or both, could operate these space stations.

GPS provides navigation data to civilian and military users. The mission control station is located at Schriever AFB, Colorado. In addition, there are dedicated monitoring stations located around the world at Ascension Island, Diego Garcia, Kwajalein, Cape Canaveral and Hawaii. These monitoring stations passively track the satellites and accumulate navigation signals.[159] There are a number of other facilities authorized to transmit on SGLS frequencies, and the Air Force maintains transportable TT&C antenna systems to support launch, early orbit, anomaly resolution, and augmentation in the event of war and natural disasters.

[159] NTIA 2000 Interim Report, *supra* note 107, at 20.

Aeronautical Mobile Telemetry

AMT supports weapons system testing and evaluation. These systems operate from manned aircraft, unmanned aerial vehicles, aerostats, missiles or other ordnance devices to provide real-time flight characteristics data and video from the airborne vehicles to the ground, real-time video of cockpit or project information, real-time monitoring of flight research/test parameters, and real-time command and control of the vehicle, including flight termination.

Test and Training Range AMT

DOD test and training ranges operate a complex system of telemetry tracking stations and control centers that use telemetry as a tool to test and evaluate existing and proposed weapons systems (i.e., munitions, missiles, rockets, space vehicles, and UAS). DOD telemetry serves multiple purposes in the design and testing phases of weapons systems (i.e., safety, command and control, specification compliance, system performance, and lethality). Flight test telemetry provides critical data on platform performance, enabling the DOD to perform hazardous complex testing events, using integrated scenarios. Airborne telemetry supports all phases of a systems development from conceptual design, initial development, milestone completion, and production testing of munitions, missiles, rockets, space vehicles, and UAS. Major DOD Test and Training Range locations are located in the southwestern part of the United States, including: Naval Air Weapons Center-Weapons Division, China Lake and Point Mugu, California; the Air Force Flight Test Center, Edwards AFB, California; the NTC, Fort Irwin, California; the YPG, Yuma, Arizona; the DOD Gulf Range (which encompasses most Florida and large portions of Georgia, Alabama, Mississippi, and southeastern Louisiana); the Atlantic Test Range, Naval Air Warfare Center-Aircraft Division, Patuxent River, Maryland; and WSMR, White Sands, New Mexico.

Standard Missile-3 Block IIA Kinetic Warhead Data Link

The STANDARD Missile (SM)-3 Block (Blk) IIA is a ship- and land-based Aegis BMD system that intercepts incoming ballistic missiles in the exo-atmospheric phase of their flight. The DOD operates the KWDL as an integral element of the tactical SM-3 Blk IIA system. The KWDL is a low-probability-of-loss/low-probability-of-detection radio link. It provides target object map updates from the Aegis BMD ship to the kinetic warhead (KW) during the guidance phase and kill assessment imagery from the KW back to the ship via the SM-3 third stage. The KWDL is active during the exo-atmospheric portion of the SM-3 trajectory (greater than 100 kilometers), when the KW is ejected from the third stage of the missile. This two-way data link is currently designed to operate in the 1755-1850 MHz band. The KWDL consists of two identical half-duplex transceivers: one is located in the missile guidance section and the other is in the KW. The system includes arrays of directional antennas and associated switching networks in both the guidance section and KW. The KWDL will be used in both test and training exercises and in

tactical BMD missions. Test and training activities will be conducted primarily on ranges in the pacific and broad ocean area. A test complex capable of launching SM-3 Blk IIA missiles is being constructed at the Pacific Missile Range Facility in Kauai, Hawaii. Tactical sea-based operations will include navigable waters worldwide; land-based sites are planned for Europe, with potential applications in other countries.[160]

Missile Testing Operations

The 1755-1850 MHz frequency range is a part of the spectrum that the Navy chose for AMT in support of various missiles/weapons tests and evaluations to allow greater flexibility with multiple range users. The frequencies used for tests and evaluations are between 1756-1780 MHz frequency range. However, use of specific frequencies for the AMT operation is subject to the WAFC's and Mid-Atlantic Area Frequency Coordinator's approval or local base frequency coordinators. A typical test altitude is between 5,000 to 10,000 feet. However, 50,000 feet must be considered to protect civil aviation. For this particular altitude, mandatory scheduling is required with the Integrated Frequency De-confliction System. Major Navy areas of operation are in California, Florida, and Maryland.

The Marine Corps has an AMT requirement for target acquisition. The system deployed on Yuma, Arizona is for miss distance indicator (for missile distance tracking). The system uses a narrower bandwidth of 1 megahertz and the same power of 1 watt as the Navy's system.

Balloon-Air-to-Ground Operation

NASA operates high altitude scientific balloons in this band. NASA's Balloon Program provides platforms for scientific and technological investigations. These investigations include fundamental scientific discoveries that contribute to understanding the Earth, the solar system, and the universe. Scientific balloons also provide a platform for the demonstration of new instrument and spacecraft technologies. The Wallops Flight Facility operates NASA's balloon missions from launch sites in Palestine, Texas and Fort Sumner, New Mexico. These balloons routinely soar above 100,000 to 150,000 feet.[161] They are supported by telemetry receive sites at the launch site locations, as well as, by a telemetry receive site in Winslow, Arizona. Balloon operations vary in their time and frequency of use. Shorter missions may last between two hours to three days and may occur 15 to 20 times per year. Longer duration missions, lasting up to several weeks, may occur several times (two to four) times per year. Finally, extended duration missions, up to 100 days, may occur once or twice per year.[162]

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[160] DOD-2 at § G.1.

[161] NASA-1 at 2.

[162] *Id.* at 2, 3.

The Navy operates a tethered aerostat (balloon) to tests the integration of the VRC-99B radio with the aerostat to extend radio communication range between a control node ashore and an unmanned surface vehicle afloat in Elizabeth City, North Carolina.

NASA Flight Test Research

NASA requires access to aeronautical telemetry frequency allocations for links between in-flight experimental aerospace vehicles and ground systems for real-time data information from test vehicles to the ground, video of cockpit or project information, and command and control of the vehicle, including flight termination. Telemetry is used for the real time monitoring of flight research/test parameters that are necessary in order to minimize the risk to the pilot and aircraft during the performance of maneuvers intended to push the flight envelope of test vehicles.[163]

The DRFC, LaRC, and WFF perform NASA's flight test and research operations. Operations vary in both scope and time. Aircraft, which include models, may fly at altitudes from a few feet up to altitudes of approximately 5000 feet and ranges may extend from an immediate location out to a range of several hundred miles. Missions might last from minutes, to hours, and/or days. The frequency of missions is dependent upon scheduling with competing missions at the test centers.[164]

Unmanned Aerial Systems

The increased use of the UAS is due to its improved surveillance capabilities, ability to carry payloads (cameras, weapons, sensors, and communications equipment), and expanded functions of electronic attack, surveillance, communications relay, firefighting, science observation, and search and rescue.[165] These systems require the use of large amounts of bandwidth and DOD forecasts a significant upsurge in spectrum requirements for these systems in all bands currently supporting UAS including the 1755-1850 MHz band.[166] These systems can use up to 16 megahertz of spectrum for video applications. DOD, DOI, DOJ and NASA operate UAS in the 1755-1850 MHz band at a number of different locations throughout the United States.[167]

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[163] NASA-1 at 2.

[164] *Id.*

[165] DOD-2 § 4.8.

[166] DOD Strategic Spectrum Plan, *supra* note 30, at 89, 90.

[167] NASA reports costs related to UAS under AMT, while DOJ reports theirs under Video Surveillance. DOI is currently in the process of obtaining frequency assignments for their UAS.

DOD uses a number of UAS that operate in this band. UAS transmit video and status data to the Ground Control System using both analog video and data on subcarriers and more advanced digital technology. Due to their increased use, several UAS platforms have been designed to enhance the expanded ISR mission functions. UAS are categorized as long-range, medium, or short-range and support multiple missions and platform interfaces with other air, space, sea, and ground platforms. Additionally, in March 2010, the Secretary of Defense directed the military services to expand UAS training at U.S. training facilities. There is a continued requirement for UAS growth not only overseas but also in the United States to support increased operations and training. UAS support military operations as well as homeland security and other federal agency missions. New small UAS (SUAS) in the design and development phase will help support increased operational requirements. DOD SUAS operations will occur at all major testing, training, and IBCT locations, to include the following high-utilization areas: NTC/Ft. Irwin, CA; JRTC/Ft. Polk, LA; WSMR, NM/Ft Bliss, TX; and Eglin AFB, FL.

DOI's Dragon Eye is a SUAS that allows for backpack transport. It is used primarily for their natural resource core mission areas. Those missions involve numerous scientific and conservation applications to manage and protect the United States natural resources as outlined below.

- Environmental Mission:
    - Ecosystem, pollution, wildlife, and glacier or ice cap monitoring
    - Fishery control
    - Water resource observation and forecasting
    - Oil spill detection and control
    - Aerial mineral exploitation
    - Terrain mapping
    - Natural disaster impact and relief
    - Contamination measurements
    - Volcanic observation
    - Climate change research
- Law Enforcement:
    - Information gathering for investigative or evidence
    - Aerial crime scene inspection
    - Counter drug and anti-terrorism operations
    - Persistent LE surveillance
    - Traffic observation or law enforcement
    - Critical infrastructure protection
    - Search and rescue operations and monitoring

- Fire Fighting:
    - Fire monitoring
    - Fire investigation
    - Early warning systems

In addition, the rangelands are remote and DOI's Bureau of Land Management is required to monitor millions of acres of rangeland. The use of UAVs provides fast and repeated deployment for managing rangeland health and ecosystem change assessment and mapping vegetation or soils at very high resolution.[168]

The Pointer, Aqua Puma, Raven, Desert Hawk, Swiper, and Wasp SUAS are small, lightweight, man-portable, hand-launched remote monitoring and surveillance systems. They transmit real-time images and their video links operate in the 1755-1850 MHz band. The SUAS provides "over the hill" view reconnaissance to the operator. In addition, these systems can be flown autonomously or via remote control. However, SUAS have very limited operating range (100 to 300 feet and less than ten-kilometer radius) and flight duration (approximately 90 minutes).

- The Pointer is equipped with a nose-mounted camera in a fixed place and must be pointed at a target in order for the camera to see it. It has the capability for air pollution sensing, in addition to chemical weapons and land mine detection.[169] The DOD uses this SUAS.
- The Aqua Puma is a high wing monoplane with an electrically driven pusher propeller operated by the Navy and optimized for water landing operations.[170] It can track stationary and moving targets.
- DOD uses the Raven for training and real-world operations for ISR. In addition, DOI uses this UAS for its mission described above. It is a downsized version of the Pointer UAS because it carries the same navigation systems, control equipment, and payloads. However, the payloads include three different cameras. One camera, the electro-optical camera, can be mounted on the nose or on the side. The second and third cameras are infrared cameras, which are mounted inside the nose, and on either side of the aircraft.[171] This SUAS flies on autopilot to a near-hover landing and drops to the ground. It also provides real-time, up-to-date, over-the-horizon view of the area being surveyed in detail, day or night.

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[168] DOI-2 at 8-9.

[169] DOD Strategic Spectrum Plan, *supra* note 30, at 39, 40.

[170] *See generally* http://www.flightglobal.com/directory/detail.aspx?aircraftcategory=UAV.

[171] DOI-2 at 8-9.

- DOD uses the Desert Hawk for perimeter base protection. Like the Aqua Puma, it also uses an electric motor driven pusher propeller. A backpack or suitcase transports this SUAS. The payloads are interchangeable allowing for easy exchange and quick deployment. It is quiet providing covert operation through low aural signature and observability.
- The Swiper is designed for affordability and disposability while still providing good aerial surveillance capabilities. This SUAS can be flown manually, semi-manually, or automatically with just one operator. Its payload consists of stabilizing and targeting information, a pan and tilt color or low light camera, and a fixed infrared thermal camera. The Swiper is used for ISR, damage assessment, catastrophe relief, and situational awareness. [172]
- The Wasp III is a hand-launched, recoverable flying-wing SUAS, which uses synthetic materials that act both as a battery and as main wing structure. It is easily recoverable with horizontal landings on land or water. The SUAS can fly for 30-45 min, and is equipped with a GPS-based navigation system for fully autonomous missions. It can also be manually flown via the same remote control equipment used by other AeroVironment mini-UA, e.g., Raven and Puma. The Wasp's payload consists of forward and side-looking miniature EO and IR video cameras.[173]

The DOD operates the Remote Operations Video Enhanced Receiver (ROVER). It uses a satellite data link to acquire video from overhead aircraft from any military UAS and retransmits it to ground troops. Other terminals, such as manned aircraft, view the UAS video product through the ROVER's real-time full motion video capability enhancing air-ground coordination.

The DOI uses the T-Hawk III unmanned micro air vehicle. It provides real-time situation awareness that protects lives and property in critical situations. The lightweight and portable T-Hawk features quick ten-minute deployment, vertical take-off and landing, interchangeable payloads with day and night time cameras, and minimal training to fly. T-Hawk supports advanced ISR with real-time video documentation, day or night. The all-weather T-Hawk III increases situational awareness with a unique hover and stare capability and autonomous flight with dynamic re-tasking and manual intervention.

The FBI has been operating Unmanned Aerial Systems (UAS) for several years – they use these systems for all types of investigations and the demand for this technology is increasing. The UAS provide a unique video surveillance platform that augments other fixed wing and helicopter surveillance capabilities. For some aerial surveillance operations, unmanned aerial

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[172] *See generally* http://emmenaerospace.com/nswiper.html.

[173] DOD-2 at § E.5.

assets are more appropriate than manned assets due to their cost effectiveness, extended duration, and suitability for use over water and rural areas.

NASA operates UAS for conducting airborne remote sensing and scientific observations. These operations may involve development and calibration of sensors, or collection of data to support NASA Earth science programs concerned with the measurement of environmental parameters.[174]

Other RF Systems

The operations of a number of additional DOD systems rely on spectrum between 1755 and 1850 MHz. These systems include:

Electronic Warfare Testing, Training, and Exercises

EW is the struggle for control of the electromagnetic spectrum, to assure that friendly forces can use the spectrum to their full potential across the full range of military operations, while denying that use to enemies. U.S. military success depends on unfettered access to the spectrum to enable electronic equipment such as radars, communication links, computer networks, and sensors to work. The value of electronic warfare operations and training can be seen most clearly in current operations in Iraq and Afghanistan. U.S. forces have successfully trained and applied electronic warfare to disable Remote Controlled Improvised Explosive Device (RCIED) attacks. These successes continue today and the DOD expects requirements into the foreseeable future.[175]

EW testing, training, and exercises in the 1755-1850 MHz band include operations that exploit data transfer, including commercial communication systems and networks that are employed to simulate operational threat environments. Global System for Mobile Communications systems and networks are critical to training Army elements in the development and evaluation of counter-IED and tactical communications exploitation prior to deployment. This training system is essential for maintaining the operational readiness of Brigade Combat Teams. The systems have historical precedence of operating in nonfederal spectrum and are coordinated with the FCC and local commercial service providers to ensure compatibility. These systems are limited to U.S. Army test and training ranges.[176]

The Department of the Navy employs hundreds of aircraft with dedicated electronic attack suites (i.e., EA-6Bs and EA-18Gs) used to protect aircraft strike groups and ship battle groups from a variety of threats. This includes Navy and Marine units. Operations and training

[174] Costs related to the UAS belonging to NASA are reported under AMT in this report.

[175] DOD-2 at § 4.10.1.

[176] *Id.*

are conducted at DOD EW/EA ranges across the United States. Additionally, the Navy and Marine Corps have a continuing requirement to perform EW development testing and training on Naval Expeditionary Warfare Counter RCIED EW open-air test ranges in the 1755-1850 MHz band.[177]

The Air Force performs a limited amount of EA/EW training in the 1755-1850 MHz band. Training operations take place and are generally associated with Weapons Officer training school activities. Training operations in this frequency band are intermittent and coordinated.[178]

Software Defined Radio Systems

SDR systems are capable of generating different waveforms and RF modulations of varying complexity through modifiable software and by the use of digital synthesis. Systems under various stages of development include the Joint Tactical Radio System man-pack radio and the Multifunctional Information Distribution Systems for JTRS.[179]

Joint Tactical Radio Systems

JTRS represents a family of multi-band/multi-mode SDRs, designed to provide communications within the 2 MHz to 2 GHz frequency range. JTRS operates with new advanced waveforms that have enhanced performance capabilities in both military and civilian frequency bands. The JTRS Wideband Networking Waveform (WNW), the Soldier Radio Waveform (SRW), and the TTNT waveform are capable of operating in the 225-400 MHz, 1350-1390 MHz, and 1755-1850 MHz frequency bands. The Joint Enterprise Network Manager software product enables control of the new networks. Many variants of JTRS exist and will be used by all three services. DOD projects JTRS operations to occur at all major testing, training, and IBCT locations, most of which are shown in Table B-5. DOD targets the JTRS waveforms operating in the 1755-1850 MHz band for operational use in FY 2013. The WNW will be used with the JTRS Ground Mobile Radio (GMR) and the AMF equipment. The SRW will be used on the JTRS HMS, GMR, and AMF equipment. In addition, a critical aspect to consider regarding SDR operations is that the airborne and terrestrial ISR and communications relay capabilities must be available for training, testing and system development.[180]

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[177] *Id.*

[178] *Id.*

[179] *Id.* at § 4.10.2.

[180] *Id.*

Table B-5. Major Locations of JTRS Operations within the United States

Location	State
Fort Wainwright	Alaska
Yuma Proving Ground	Arizona
Ft Chaffee	Arkansas
Camp Roberts	California
NTC/Fort Irwin	California
Fort Carson	Colorado
Pinon Canyon	Colorado
Camp Blanding	Florida
Fort Stewart	Georgia
Pohakuloa Training Area (PTA)	Hawaii (Big Island)
Orchard Park	Idaho
Camp Atterbury	Indiana
Fort Riley	Kansas
Fort Campbell	Kentucky
JRTC/Fort Polk	Louisiana
Camp Grayling	Michigan
Camp Ripley	Minnesota
Camp Shelby	Mississippi
WSMR	New Mexico
Fort Drum	New York
Fort Bragg/Camp McCall	North Carolina
Fort Sill	Oklahoma
Fort Bliss	Texas
Fort Hood	Texas
Fort Pickett	Virginia
Joint Base Lewis-McChord	Washington
Yakima Training Area	Washington
Camp Guernsey	Wyoming

JTRS Man-Pack Radio

The man-pack radio is a tactical radio system that operates from 30 MHz to 2 GHz, and includes another networking waveform capable of operating in the 225-400 MHz, 1350-1390 MHz, and 1755-1850 MHz frequency bands. It also includes an option for ROVER IV and V L-band receive capability. In the current configuration, access to spectrum above 2 GHz is not achievable without significant engineering modifications.[181]

[181] *Id.*

Multifunctional Information Distribution System for JTRS

MIDS for JTRS radios, which are part of the JTRS family of radios, include the TTNT waveform. The Air Force is also supporting TTNT waveform development, but has not made a final decision on the Joint Aerial Layer-Tactical Edge waveform they will employ. The Air Force identified potential platforms for TTNT in FY 2008, but they are not actively preparing for TTNT integration on their MIDS-equipped combat aircraft. However, the Navy plans to use the MIDS-J radio in their combat aircraft as the host for the TTNT waveform.[182]

Tactical Targeting Networking Technology

TTNT is the high throughput, low-latency solution for addressing the sensor-to-shooter link and providing other real-time information. TTNT is an Internet Protocol-based, high-speed, dynamic ad hoc network designed to enable the U.S. military to quickly target moving and time-critical targets. TTNT enables net-centric sensor technologies to correlate information among multiple platforms, precisely locating time-critical targets. The changing nature of warfare, where real time communication exchanges are paramount, makes TTNT an important element in conducting future military operations.[183] Current frequency assignments span three sub-bands: 1350-1392 MHz (three channels), 1435-1518 MHz (six channels), 1755-1850 MHz (seven channels).

[182] *Id.* at § 4.10.3.

[183] *Id.* at § F.9.

APPENDIX C

Current Federal Operations in the Comparable Bands

Introduction

This appendix provides an overview of the comparable bands to include the allocations, authorized services, and operations. The information contained in the table originates from the Federal Spectrum Use Summary 30MHz-3000 GHz, June 21, 2010 available at http://ntia.doc.gov/files/ntia/Spectrum_Use_Summary_Master-06212010.pdf.

Frequency Band	Operations
225-328.6 MHz	DOD operates communication systems in this band that are used for tactical and training operations. They also operate radar systems in this band on a non-interference basis. The Department of Transportation Federal Highway Administration uses this band for Intelligent Transportation Systems. NASA uses this band for radio beacons onboard missiles to aid in payload recovery. The Army conducts research, development, test and evaluation of equipment in this band. This band is preserved for military operations by NATO and within the individual NATO member countries. The military nature of this band has also been maintained by certain allied and friendly nations outside the NATO alliance such as Australia, Israel, New Zealand, and Saudi Arabia; and by the European Cooperation Partner nations and the Partners for Peace nations. It is vital to the DOD and the U. S. Coast Guard (USCG) operations due to its excellent propagation characteristics. The DOD and the USCG use this band for air-to-ground and air-to-air radio communication systems for the control of military aircraft, including unmanned aircraft. The DOD and NASA use this band for airborne communications networks via multichannel radio relay systems. Air-to-air and air-to-ground modes are used. The DOD's use includes a major tactical radio communications system providing anti-jam, secure, frequency-hopping communications. The system is used for tactical air-to-air, air-to-ground, and ground-to-air communications, including interoperability communications among Air Force, Navy, Army, and NATO units. Over 60,000 radios have been manufactured for this system. The USCG uses this band for tactical operations such as ship-to-air and ship-to-ship clear and secure voice communications. It also uses the band for data link communications. The FAA uses this band for aeronautical communication systems for the air traffic control of military aircraft.

225-328.6 MHz continued	DOD operates training center instrumentation systems in this band that are used for data links connecting battle simulation systems on participants platforms (airborne, shipborne, or surface) to central data processing facilities, in addition to operating communication systems for air and sea rescues and telemetry systems for rocket testing programs. DOE uses this band for testing of equipment that remotely monitors declared nuclear facilities, and identifies and characterizes undeclared and clandestine nuclear facilities in support of the limited test ban treaty. NASA uses this band for voice communication related to Space Shuttle operations and air-ground-air communication for flight research. NASA also uses this band for space operations communications during Extravehicular Activity (EVA) at the International Space Station (ISS). The military agencies and the USCG use this band for operational tactical and strategic communications via mobile-satellite systems, especially using small terminals. The system consists of a constellation of eight satellites providing coverage over most of the world, providing communications channels for tactical and strategic forces on land, ships, submarines, and aircraft. The satellite downlinks are in the 243.855-269.95 MHz band with the corresponding uplinks in the 292.85-317.325 MHz band. The USCG uses six channels on DOD satellites. Over 18,000 satellite earth terminals have been deployed. The Navy uses this band for the next generation UHF satellites, termed the Multiple User Objective System (MUOS). The MUOS satellites will provide global communications to all DOD dispersed forces using various terminal devices such as handhelds, laptops, and personal communications units. The National Science Foundation uses this band for radio astronomy research via spectral line and continuum observations, including the hyperfine transition from the cosmologically significant deuterium atom.

Frequency Band	Operations
335.4-399.9 MHz	This band is a critical military radio communications band that has been preserved for military operations by NATO; and within the individual NATO member countries. The military nature of this band has also been maintained by certain allied and friendly nations outside the NATO alliance such as Australia, Israel, New Zealand, and Saudi Arabia; and by the European Cooperation Partner nations and the Partners for Peace nations. It is vital to military and Coast Guard operations due to its excellent propagation characteristics. The DOD and the USCG use this band for air-to-ground and air-to-air radio communication systems for the control of military aircraft, including unmanned aircraft. The DOD and NASA use this band for airborne communications networks via multichannel radio relay systems. Air-to-air and air-to-ground modes are used. DOD uses this band for a major tactical radio communications system providing anti-jam, secure, frequency-hopping radio communications. The system is used for tactical air-to-air, air-to-ground, and ground-to-air communications, including interoperability communications among Air Force, Navy, Army, and NATO units. Over 60,000 radios have been manufactured for this system. The FAA uses this band for aeronautical communication systems for the air traffic control of military aircraft. The USCG uses this band for tactical operations such as ship-to-air and ship-to-ship clear and secure voice communications. It also uses this band for data link communications. NASA uses this band for voice communication related to Space Shuttle operations and air-ground-air communication for flight research. DOD uses selected portions of the 380-399.9 MHz band for trunked land mobile radio communications networks, primarily for non-tactical applications such as military base security.

Frequency Band	Operations
420-450 MHz	The Air Force, Army, Navy, and DHS operate ground-based, shipborne, and airborne long-range surveillance radars in this band. These radar systems are used for national security by providing the early warning defense and protection of the borders. The DOD also operates the Enhanced Position Location System (EPLRS), a major tactical system used to provide critical position location information for ground and air forces. The military agencies have deployed thousands of EPLRS units. The Air Force uses the 449.775-450.25 MHz band for the space telecommand of small experimental satellites called nanosats. The DOD operates foliage penetration search and surveillance radars in this band. NOAA uses 449 MHz for the Wind Profiler Radar network that monitors and provides warnings of severe weather conditions through the measurement of wind speed and direction at various altitudes. NASA and DOD use this band for telemetry and telecommand systems. Operations also include test range safety via the command control and flight termination of launched vehicles. NASA uses the 432-438 MHz band for active remote sensing using synthetic aperture radar measurements over rain forests and polar ice regions. In addition, NASA uses this band for communication between the surface of Mars and spacecraft in orbit around Mars. The USCG uses 433 megahertz for radio frequency identification (RFID) for container tracking.
902-928 MHz	The Navy operates air search and surveillance radar systems onboard ships and aircraft carriers in this band. Propagation characteristics make the band ideal for the detection of fast-moving seaborne targets. DOD uses this band for tracking radar systems for aeronautical flight-testing, to monitor the position of missiles, drones, and manned aircraft, and for security via perimeter protection systems used for intrusion detection. NOAA operates the Wind Profiler Radar network that monitors and provides warnings of severe weather conditions through the measurement of wind speed and direction at various altitudes. The Coast Guard uses this band for radio frequency identification (RFID) for Container Tracking and port security.

Frequency Band	Operations
1350-1390 MHz	The FAA and the Air Force operate the Joint Surveillance System, fixed site, and transportable long-range air surveillance and safety-of-flight en-route air traffic control radar systems in this band. These radar systems are used for air-defense, missile defense, drug interdiction, and air-traffic control. They identify and track all aircraft, both commercial and federal. The DOD operates transportable radars in this band that are used for tracking and locating rocket, artillery, and mortar fire. The National Science Foundation performs radio astronomy observations of redshifted hydrogen spectral lines. NASA uses this band for the passive remote sensing of ocean salinity and soil moisture content. The Navy operates shipborne radars in this band for the detection, tracking, identification, threat evaluation, and weapons engagement of high-speed, small cross-section targets. The military agencies use this band to control unmanned vehicles and for fixed and mobile communications links, including tactical systems. GPS satellites use the frequency range, 1381.05 MHz ± 5 megahertz to relay data on the detection of nuclear bursts.
1435-1525 MHz	DOD and the NASA operate aeronautical mobile telemetry systems in this band for flight-testing of manned and unmanned aircraft, missiles, and space vehicles, and associated communications such as range safety, chase aircraft, and weather data.

Frequency Band	Operations
1675-1700 MHz	NOAA operates the Geostationary Operational Environmental Satellite (GOES) and non-geostationary, polar-orbiting meteorological satellites (POES). NOAA, DOD, NASA, and various federal/non-federal entities operate earth stations used to receive environmental research and weather data transmitted from these satellites. These satellites transmit data to four primary receiving NOAA earth stations in the United States, (Fairbanks, Alaska; Wallops Island, Virginia; Suitland, Maryland; Greenbelt, Maryland) for data processing at specific sites. These earth stations transmit the processed data back to the satellites and to federal/non-federal receiving earth stations. The data is used daily in the generation of weather reports that are broadcast over television and radio stations throughout the country. Various federal/non-federal earth stations also receive raw data from the NOAA meteorological satellites and process this data for their own weather related uses. NOAA, DOD, DOE, and NASA use the 1675-1683 MHz band to operate radiosonde systems in the Meteorological Aids service. Radiosondes are expendable buoys, free-floating balloons, equipped with transmitters and antennas that provide near real-time environmental data. The data from these radiosondes is used to provide warnings and forecasts of weather events such as tornados, tsunamis, and tropical cyclones. These systems perform measurements of the atmospheric pressure, temperature, and relative humidity. The wind speed and direction is determined using RF direction finding measuring the azimuth and elevation angle of the radiosonde with respect to the receiving antenna. Radiosondes are launched from 87 sites located throughout the United States and its possessions at a rate of twice per day. Transmission of data from radiosondes typically lasts for duration of two-three hours of data transmission.

Frequency Band	Operations
2025-2110 MHz	NASA operates their primary telecommand communications used for the control of their spacecraft and those associated with foreign space agency missions in this band. These operations employ uplinks direct from earth stations and forward links via the Tracking and Data Relay Satellite System (TDRSS), which provides links between low earth orbiting spacecraft and earth stations. NASA uses the same spectrum for multiple near space missions. NASA and NOAA command the GOES meteorological satellite system. The GOES system provides important imagery and atmospheric soundings to the National Weather Service (NWS) for their routine use and during periods of severe weather outbreaks when the information is furnished as frequently as once every 8 minutes. The imager and sounder measurements provide meteorological, environmental, and climate data used by the NWS, other federal agencies, and member nations of the World Meteorological Organization. The U.S. National Meteorological Satellite System is composed of two elements consisting of Polar Orbiting Environment Satellite (POES) and the GOES systems. The POES series satellites are polar orbiting and are able to collect global data on a daily basis for a variety of land, ocean, and atmospheric applications. Data from the POES satellites supports a broad range of environmental monitoring applications including weather analysis and forecasting, climate research and prediction, global sea surface temperature measurements, atmospheric soundings of temperature and humidity, ocean dynamics research, volcanic eruption monitoring, forest fire detection, global vegetation analysis, research, search and rescue, and many other applications. The National Polar Orbiting Environment Satellite System (NPOESS) is the follow-on polar weather satellite system replacing the POES and the Defense Meteorological Satellite Program and the Earth Observing System in a converged program. The NPOESS system will collect and disseminate data to a variety of users worldwide. This band is also the primary command and control band for U.S. civil space programs. Systems that use this band include the TDRSS, the Space Shuttle, the Hubble Space Telescope, and the International Space Station, all operated by NASA. DOD is pursuing dual band satellites that will operate in this band and over the range 1761-1842 MHz.

Frequency Band	Operations
2200-2290 MHz	DOD and NASA receive tracking, telemetry, and control data communications to control their spacecraft and those of other nations. These agencies operate systems for space research and Earth exploration services that communicate from earth stations and return links via the TDRSS to provide data links between low earth orbiting spacecraft and earth stations. NASA re-uses many of the same frequency bands for its near space missions; and re-uses other bands for their deep space missions. Federal agencies use this band for terrestrial telemetering operations for aircraft, sounding rocket, and missile flight-testing. NASA and NOAA use this band to command and control the GOES and polar-orbiting meteorological satellites. DOE's Western Area Power Administration (WAPA) uses this band for point-to-point microwave relay communications to support their hydroelectric power grid system in a number of western states. DOJ, DHS, and other federal agencies operate a nationwide system of portable and mobile video surveillance devices used in the investigation of terrorist and criminal activities in addition to supporting joint operations during major national events. These systems incorporate multiple transmitters and receivers that collect, transport, and store video and audio evidentiary and intelligence information. The nature of the operations requires that the devices be highly concealable, portable, and be capable of short notice deployment. The video surveillance activities include primary evidence and intelligence collection, management and control of data and information from various surveillance platforms, unmanned aircraft, remotely controlled robotic devices, MESH networking, and point-to-point data backhaul.

Frequency Band	Operations
2290-2300 MHz	NASA operates the Deep Space Network (DSN) in this band. The DSN is an international network of antennas and associated receivers used for interplanetary spacecraft missions and radio and radar astronomy observations for the exploration of the solar system and the universe. The DSN also supports selected Earth orbiting missions and currently consists of three deep-space communications facilities placed approximately 120 degrees apart around the world at Goldstone, California, near Madrid Spain, and near Canberra, Australia. The strategic placement permits constant observation of spacecraft as the Earth rotates, and helps to make the DSN the largest and most sensitive scientific telecommunications system in the world. The antennas and data delivery systems make it possible to acquire telemetry data from spacecraft transmit commands to spacecraft; track spacecraft position and velocity; perform very-long-baseline interferometry observations; measure variations in radio waves for radio science experiments; gather science data; and monitor and control the performance of the network. NASA operates, as part of its DSN system, the tracking and command of deep space probes Voyager 1 (Jupiter and beyond), Voyager 2 (Jupiter, Saturn, and beyond), and Galileo (Jupiter).
2360-2390 MHz	The DOD and NASA operate aeronautical mobile telemetry systems in this band used for the flight-testing of manned and unmanned aircraft, missiles, space vehicles, and associated communications such as range safety, chase aircraft, and weather data. The National Science Foundation operates a radar in Arecibo, Puerto Rico to explore the surface of planets, explore other solar system bodies and to detect Near Earth Objects. The Arecibo radar transmits and receives in the 2370-2390 MHz band.
2390-2395 MHz	The federal agencies use this band for experimental research development testing and evaluation programs.
4400-4500 MHz	DOD operates tactical systems used for point-to-point line-of-sight and troposcatter communications. NASA uses this band for development of unmanned aerial vehicle video downlinks. DOJ and other agencies use this band for some specific surveillance operations, as well as MESH networking, and point-to-point backhaul to centralized capture, processing, and /or storage based activities.

Frequency Band	Operations
4500-4800 MHz	DOD operates tactical systems in this band for line-of-sight and over-the-horizon troposcatter communications and for data and video communications links for the Pioneer, Shadow, and Camcopter Unmanned Aerial Systems (UASs). The primary mission of the UAS's is to relay information gathered by sensors onboard the UAVs to the ground control stations and to control the UAS operations. DOD also operates land-based and maritime tactical data links and drone command and control systems in this band. NOAA operates microwave radiometry systems from aircraft to measure ocean wide speed and rain characteristics in hurricanes and storms. The federal agencies use this band for multi-channel and wideband point-to-point microwave communication systems. The National Science Foundation uses this band for radio astronomy research via continuum observations to study the brightness distributions of both galactic and extragalactic objects such as ionized hydrogen clouds and supernova remnants. NASA uses this band for high performance aircraft video downlinks. DOJ and other agencies use this band for some specific surveillance operations, as well as MESH networking, and point-to-point backhaul to centralized capture, processing, and/or storage based activities.
4800-4940 MHz	DOD operates tactical systems in this band that are used for line-of-sight and over-the-horizon troposcatter communications, land-based and maritime tactical data links, and drone command and control systems. The federal agencies use this band for multi-channel and wideband point-to-point microwave communications systems. The National Science Foundation uses this band for radio astronomy research via continuum observations to study the brightness distributions of both galactic and extragalactic objects such as ionized hydrogen clouds and supernova remnants. DOJ and other agencies use this band for some specific surveillance operations, as well as MESH networking, and point-to-point backhaul to centralized capture, processing, airborne relay, and/or storage based activities.

Frequency Band	Operations
5030-5250 MHz	DOD and FAA use the 5030-5091 MHz band for the Microwave Landing System, an all-weather precision landing system that must be protected from interference, although there are no plans for additional installations. The FAA is considering implementing an Airport Network and Location Equipment (ANLE) system in the 5091-5150 MHz band. The ANLE is a high-integrity, high-data-rate wireless local area network (WLAN) for the airport area, with terminals on the ground and on taxiing aircraft. NASA uses this band on a non-interference basis for active sensor systems used in joint programs with the Centre National d'Etudes Spatiales (CNES) for space-based observations and measurements of surface topography and ocean wave height. The FAA has designated this band as a possible expansion band for the Microwave Landing System, an all-weather precision landing system used at civilian and military airports.
7125-8500 MHz	The federal agencies use this band for fixed point-to-point microwave communication systems for national and military test range communications, and the remote transmission of radar video and other data for functions such as weather, vessel traffic control in harbor areas, and hydroelectric grid power management. This includes the FAA's use of this band for fixed point-to-point microwave communications networks to connect remote long-range aeronautical radionavigation radars to air traffic control centers. NASA and NOAA use the 6425-7250 MHz band for passive sensing of the Earth from space using microwave radiometers to obtain measurements of sea surface temperature, which is a key component in weather forecasting and climatological studies. This band is used in conjunction with passive sensing bands around 10.6, 18.7, 23.8 and 36 GHz to obtain several important climatological parameters. The federal agencies use 7145-8500 MHz band for fixed point-to-point microwave communication systems for national and military test range communications, and the remote transmission of radar video and other data for functions such as weather, vessel traffic control in harbor areas, and hydroelectric grid power management. This includes the FAA use of this band for fixed point-to-point microwave communications networks to connect remote long-range aeronautical radionavigation radars to air traffic control centers.

Frequency Band	Operations
7125-8500 MHz continued	NASA operates a Deep Space Network that provides tracking, ranging, and command uplinks to deep space probes Voyager 1 (Jupiter and beyond), Voyager 2 (Jupiter, Saturn, and beyond), Galileo (Jupiter), Near Earth Asteroid Rendezvous (NEAR), Dawn (Asteroids), New Horizons (Pluto), Cassini (Saturn), Phoenix (Mars), Mars Odyssey (Mars), Messenger (Mercury), and others. NASA uses the 7190-7235 MHz band for tracking, ranging, and command uplinks for various programs such as the Summer Undergraduate Research Fellowship Satellites I and II. NOAA plans to use 7190-7235 MHz, 7235-7250 MHz, and 7250-8025 MHz bands for data uplinks to its GOES. DOD operates the Defense Satellite Communications Systems series of geostationary satellites in 7250-8400 MHz band. They provide federal agencies with secure jam-resistant communications for applications including command and control, crisis management, intelligence, early warning detection, and diplomatic communications. The military agencies operate the Wideband Gapfiller Satellite in this band. The Air Force uses the 7550-7750 MHz, 7900-8400 MHz bands for the space tracking and telecommand of communications satellites. NOAA uses the 7750-7850 MHz and 8025-8215 MHz bands for data downlinks for some of its non-geostationary satellites. NOAA also uses the 8025-8400 MHz band for the downlink transmissions of wideband data from spaceborne sensors. NASA uses the 8025-8400MHz band for space-to-ground communications supporting Earth exploration-satellite systems. In addition, NASA uses the 8400-8450 and 8450-8500 MHz band to receive downlink information from deep space and near Earth orbiting space research spacecraft, respectively. The DOJ uses this band for point-to-point data backhaul to centralized capture, processing, and/or storage based activities to augment surveillance activities performed in other bands.

Frequency Band	Operations
14.5-14.7145 GHz	Federal agencies use this band for fixed point-to-point microwave relay communications for voice, data, and video and for airborne downlink data transmissions. DOD operates fixed, mobile, and maritime mobile air-to-air and air-to-ground data links in this band via a common data link. The transmissions are in both directions. NASA uses this band for spacecraft communications downlinks involving space research, for TDRSS to provide communications to the space shuttle and other spacecraft, and for the single access uplinks. The National Science Foundation uses this band for the radio astronomy research of various spectral-lines, including the research of the formaldehyde line and quasars.
15.1365-15.35 GHz	Federal agencies use this band for fixed point-to-point microwave relay communications for voice, data, and video, for airborne downlink data transmissions, and mobile air-to-air and air-to-ground data links. The National Science Foundation uses this band for the radio astronomy research of various spectral-lines, including the research of the formaldehyde line and quasars. NASA uses this band for spacecraft communications downlinks involving space research and for TDRSS to provide communications to the space shuttle and other spacecraft. This band is also used for the single access uplinks. NASA uses the 15.2-15.4 GHz band for passive sensing of the Earth using microwave radiometers to obtain water vapor and rain rate data.
25.0-27.5 GHz	The National Science Foundation uses this band for the radio astronomy research of various spectral-lines and continuum measurements. NASA uses this band for its TDRSS to provide communications to other spacecraft, specifically the 25.25-27.5 GHz band is used to provide return links to Earth-orbiting spacecraft. NASA uses the 25.5-27.5 MHz band for broadband data communications from spaceborne sensors. Federal agencies use the 25.5-27 GHz for fixed and mobile microwave point-to-point communications links for voice, data, and video at various government facilities and laboratories, test ranges, and air traffic control facilities.

APPENDIX D

Agency Rationale for Comparable Band Priorities

Introduction

This appendix summarizes the rationale provided by DHS, DOJ, NASA, and DOD in their initial band prioritization reports. During their detailed band analysis, the federal agencies gave further consideration to some of the bands ruled out initially. Additional bands (i.e., 1350-1390 MHz, 5091-5250 MHz and 4400-4940 MHz) were also included in the detailed analysis to increase the band options.

Department of Homeland Security

Video Surveillance		Department of Homeland Security
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
225-328.6 MHz	Low	The lower operating frequency band raises technical concerns with required antenna size for small devices, the impacts of Doppler shift and RF channel parameters on digital modulation, the increase in man-made noise, and the lack of available devices.
335.4-380 MHz	Low	
420-450 MHz	Low	
902-928 MHz	Low	This frequency band raises technical concerns with the required antenna size for small devices, the impacts of RF channel parameters on digital modulation, and the lack of available devices.
1350-1390 MHz	Low	The frequency band presents some potential issues with the antenna size of some devices. The reduction in available bandwidth would require development of devices capable of providing comparable video quality and reliability in reduced bandwidth. The vendor community is currently developing technologies toward this goal but has not yet validated any technology. In addition, the potential interference from radar systems currently operating in the band would need to be addressed through a technology development currently not offered in the video devices or some other mechanism.
1435-1525 MHz	Med	The frequency band presents potential since there is similar available bandwidth; however, the extent of radio telemetry systems and the potential impact to and from telemetry systems, including non-federal telemetry, needs to be evaluated in more detail.
1675-1695 MHz	Med	The frequency band presents potential for migration of some of the operations. The major challenge would be the required reduction in channel bandwidth to provide comparable video quality and reliability in the reduced total bandwidth. The vendor community is currently developing technologies toward this goal but has not yet validated any technology. In addition, the potential interference from surveillance systems migrating into the band to radiosonde or satellite receivers would need to be addressed through technology development that is not currently offered in the video devices or some other mechanism.
2025-2110 MHz	Med	The frequency band presents potential for migration. The major challenge would be the need to more fully understand the potential for interference from incumbent systems assigned by the FCC and if required to develop and deploy intelligent interference avoidance systems or some other mechanism.
2110-2165 MHz	Not Evaluated for this Operation	
2200-2300 MHz	High	The frequency band is currently used on a limited basis so devices are available. The major challenge would be the possible reduction in channel bandwidth to accommodate an additional 21 channels with the current eight presently operating in the band. Comparable video quality and reliability in the reduced total bandwidth would be required. The vendor community is currently developing technologies toward this goal but they have not yet validated any technology. In addition, the potential interference from systems migrating into the band would also need to be addressed through technology development or some other mechanism
2360-2395 MHz	Med	The frequency band presents potential for migration of some of the operations. The major challenge would be the reduction in channel bandwidth required to provide comparable video quality and reliability in the reduced total bandwidth. In addition, the potential interference from systems currently in and migrating to the band would need to be addressed through technology development or some other mechanism.
4400-4940 MHz	Not Evaluated for this Operation	
7125-8500 MHz		
7900-8400 MHz		
14.5-14.7145 GHz		
15.1365-15.35 GHz		
25.0-27.5 GHz		

Department of Justice

Video Surveillance		Department of Justice
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
225-328.6 MHz	Non-select	These bands are too low in frequency to efficiently/effectively support "miniaturized" low-profile operations.
335.4-380 MHz		
420-450 MHz		
902-928 MHz		
1350-1390 MHz	Low	This band is essentially too low in frequency to efficiently and effectively support "miniaturized" low-profile operations. There is only 40 megahertz of bandwidth available and it is currently congested with highly incompatible primary radar surveillance activities.
1435-1525 MHz	Med	The available bandwidth of this band is attractive; however, the increased signal wavelength presents issues to the efficient and effective support of "miniaturized" low-profile operations. To utilize the band fully for an expansive deployment would require product development to address the physical constraints of the band. In addition, the sharing with aeronautical telemetry activities will need detailed analysis to ensure they do not prohibit deployment of significant quantities of US&P based systems. These evaluations need to include practical operational avoidance measures to ensure sharing is both feasible and manageable.
1675-1695 MHz	Med	This band demonstrates potential due to technical strengths associated with system design capabilities, but functionally will be a challenge due to very limited bandwidth and congestion/incompatibility with incumbent satellite and radiosonde operations. Some practical operational avoidance measures appear feasible/manageable.
2025-2110 MHz	Med	This band presents potential for migration; however, a major challenge would be the need to more fully understand the potential for interference from incumbent systems assigned by the FCC. It may be required to develop and deploy intelligent interference avoidance systems or some other mechanism.
2110-2165 MHz	Not evaluated for this operation	
2200-2300 MHz	High	This band demonstrates potential due to technical strengths associated with system design capabilities, ready availability of proven/supportable technology, and presence of similar operations already resident within the band. Problematic issues include current congestion within the band, which would lead to net loss of capabilities, potential aggravated congestion with influx of new users, the band's potential for future auctioning, and protection that can be afforded to new/existing authorized users in the band.
2360-2395 MHz	Med	This band demonstrates potential due to technical strengths associated with system design capabilities, but functionally it is very problematic due to very limited bandwidth and congestion/incompatibility with pervasive aeronautical telemetry operations throughout the band.
4400-4940 MHz	Not evaluated for this operation	
7125-8500 MHz		
7900-8400 MHz		
14.5-14.7145 GHz		
15.1365-15.35 GHz		
25.0-27.5 GHz		

National Aeronautics and Space Administration

Aeronautical Mobile Telemetry (AMT)	National Aeronautics And Space Administration	
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
225-328.6 MHz	Not Evaluated for this Operation	
335.4-380 MHz		
420-450 MHz		
902-928 MHz		
1350-1390 MHz	Low	This band is ranked low because of the lack of commercial off-the-shelf airborne telemetry transmitters and receivers. There is only 40 megahertz of spectrum available and there is heavy radar use in the band. Although there is an existing mobile service allocation, Footnote (FN) G27 to the U.S. Table of Allocation limits it to military use. This band is also allocated to fixed and radiolocation service including primary aeronautical radionavigation service (ARNS) (5.334) and secondary space research (SRS)/earth exploration satellite service (EESS) (passive) (5.339). Adding airborne telemetry transmission in this band is not ideal due to a desire to protect radio astronomy (US342). Additionally, it cannot be used for NASA's balloon program due to the proximity of the Fort Sumner launch range to a very large array antenna in Socorro, New Mexico.
1435-1525 MHz	Med	Commercial off-the-shelf airborne telemetry transmitters and receivers are available and this band is already being used by NASA for flight test telemetry and balloon data communications. Unfortunately, this band is already heavily used for aeronautical telemetry and it will be very difficult to support additional traffic. Extremely heavy use for testing at Edwards AFB eliminates use by the Dryden Flight Research Center, but it might be useful for the Wallops Flight Facility balloon program and Langley Research Center research programs.
1675-1695 MHz	Not Evaluated for this Operation	
2025-2110 MHz	Med	There are no commercial off-the-shelf airborne telemetry transmitters and receivers available. Although there is an existing mobile allocation, it is for non-federal use only. FN US393 allows some federal mobile service (no aeronautical mobile), but only to military on a secondary basis. This band is already heavily used by NASA satellite uplinks and forward links, hence there will be constraints on protecting telemetry ground station receivers and airborne telecommand receivers from high-power satellite NASA earth station uplinks and protecting new DOD uplinks and TDRS forward links from mobile operations.
2110-2165 MHz	Not Evaluated for this Operation	
2200-2300 MHz	Low	Commercial off-the-shelf airborne telemetry transmitters and receivers are available. However, this band is already heavily used and it would be extremely difficult to support additional traffic. There are already other primary allocations besides mobile (e.g., space operation service (SOS)/EESS/SRS) and fixed in this band already. It is heavily used by NASA satellite downlink receive sites and return links, hence there would be constraints on protecting earth station receivers from airborne telemetry transmissions and protecting TDRS return links from mobile operations.
2360-2395 MHz	Med	Commercial off-the-shelf airborne telemetry transmitters and receivers are available. NASA is already using this band for balloon/sounding rocket telemetry. Primary allocations are currently limited to mobile (limited to aeronautical telemetry and telecommand US276) and radiolocation. The band is already heavily used for aeronautical telemetry and it would be extremely difficult to support additional traffic.

AMT		National Aeronautics And Space Administration
Comparable Bands	**Rank**	**Rationale for Band Ranking**
4400-4940 MHz	High	There is some limited availability of commercial off-the-shelf airborne telemetry transmitters and receivers in this band. Some manufacturers are beginning to offer equipment, but it is more expensive than in other bands. Currently, there is a U.S. primary allocation for government mobile; however, it does not include aeronautical mobile telemetry. This would be a new band for aeronautical mobile telemetry if the United States adopts the WRC-2007 aeronautical mobile service international allocation, FN 5.440A, but there are constraints imposed on aeronautical telemetry use. FN 5.440A under ITU Res 416 (WRC07) places certain effective isotropic radiated power (EIRP) limits on the aircraft transmissions.
5091-5250 MHz[184]	High	There is limited availability of commercial off-the-shelf airborne telemetry transmitters and receivers. The use of 5 GHz telemetry links will require higher power transmitters for a given line-of-sight range due to higher propagation losses. There is no current U.S. aeronautical mobile telemetry allocation. This would be a new band for aeronautical telemetry if the United States adopts the WRC-2007 aeronautical mobile service international allocation, FN 5.444B, but there are constraints imposed on aeronautical telemetry use. FN 5.444B under ITU Res 418 (WRC07) places certain power flux-density and EIRP limits on the aircraft transmissions to protect fixed satellite service satellite receivers and ARNS/aeronautical mobile (R) service (AM(R)S) receivers. FN 5.444B also allows AM(R)S in the band for airport surface WiMax communications systems and aeronautical security transmissions which will require coordination with airborne telemetry users operating near airports. The 5091-5150 MHz band is also allocated to the fixed-satellite service (Earth-to-space) on a primary basis (FN 5.444A) for NGSO mobile satellite service (MSS) feeder links which would constrain the number of airborne telemetry transmitters (and telecommand transmitters) so as not to interfere with satellite receivers. There is no international Region 2 allocation for aeronautical telemetry, but ITU Res 418 governs allocation elsewhere. FCC Rules permit Unlicensed National Information Infrastructure (U-NII) devices at 5150-5250 MHz.
5925-6700 MHz[185]	Low	Commercial off-the-shelf airborne telemetry transmitters and receivers are not available. The use of 6 GHz telemetry links will require higher power transmitters for a given LOS range due to higher propagation losses. There is no U.S. aeronautical mobile telemetry allocation. This would be a new band for aeronautical telemetry if the United States adopts the WRC-2007 aeronautical mobile service international allocation, FN 5.457C, but there are constraints imposed on aeronautical telemetry use. FN 5.457C under ITU Res 416 (WRC07) places certain EIRP limits on the aircraft transmissions. This band is also allocated for fixed satellite (Earth-to-satellite) and fixed services and is heavily used by commercial entities in the United States.
7125-8500 MHz	Not Evaluated for this Operation	
7900-8400 MHz		
14.5-14.7145 GHz		
15.1365-15.35 GHz		
25.0-27.5 GHz		

[184] NASA assessed this band, although it was not included in the bands NTIA asked the agencies to evaluate.

[185] NASA assessed this band, although it was not included in the bands NTIA asked the agencies to evaluate.

UAS/UAV/RPV[186]		National Aeronautics And Space Administration
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
225-328.6 MHz	Med	Commercial off-the-shelf airborne telemetry transmitters and ground telemetry receivers are available for the 215-320 MHz portion of the band. Large antennas are required for high data rate (HDR) aeronautical telemetry and video requirements. This band is channelized to narrowband and mobile service is currently limited to military services (FN G27) making it already heavily used for military voice/data communications. The range 242.95-243.05 MHz must be avoided since it is an emergency band for Search and Rescue/emergency position-indicating radio beacons/emergency locator transmitters. This band is also allocated to fixed service (limited to military by FN G27) so it is also likely heavily used for military fixed voice/data communications and mobile satellite in 235-322 MHz band (for military use only via FN G100) which could constrain airborne telemetry transmitters to protect MSS earth station receivers. Airborne telemetry transmission is not ideal in the 322-328.6 MHz portion of this band due to a desire to protect radio astronomy (FN US342). It may be useful for narrowband command and control.
335.4-380 MHz	Med	Commercial off-the-shelf airborne telemetry transmitters and receivers are not available. Large antennas are required for HDR telemetry and video. This band is also already channelized to narrowband.
420-450 MHz 902-928 MHz	Not Evaluated for this Operation	
1350-1390 MHz	Low	Commercial off-the-shelf airborne telemetry transmitters and receivers are not available. There is only 40 megahertz available and it already contains heavy radar use. There is an existing mobile service allocation, but FN G27 limits it to military use. This band is also allocated to fixed service and radiolocation service including primary ARNS (5.334) and secondary SRS/EESS (passive)(5.339). Airborne telemetry transmission is also not ideal in this band due to a desire to protect radio astronomy (FN US342).
1435-1525 MHz	Med	Commercial off-the-shelf telemetry transmitters and receivers are available. This band is already being used by NASA (14 assignments) for flight test telemetry and balloon data communications. There is currently an exclusive allocation for mobile (aeronautical telemetry and associated telecommand) and the band is already heavily used. It would be extremely difficult to support additional traffic. Extremely heavy use for testing at Edwards AFB already eliminates use by DFRC, although it might be useful for the WFF balloon program and LaRC research programs.
1675-1695 MHz	Low	Commercial off-the-shelf airborne telemetry transmitters and receivers are not available. This is a meteorological aids (METAIDS)/meteorological satellite (METSAT) downlink band and appears to be lightly used by other agencies including NASA. Currently there is no mobile service allocation. Airborne telemetry transmissions would be constrained by the need to protect METSAT/METAIDS ground station receivers and also radio astronomy in the adjacent band (US211). There is only 20 megahertz available making it not very useful for wideband channels.

[186] The evaluation of these bands for this type of operation includes an assessment of their potential to provide comparable spectrum for both air-to-ground telemetry and ground-to-air telecommand.

UAS/UAV/RPV		National Aeronautics And Space Administration
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
2025-2110 MHz	Med	Commercial off-the-shelf airborne telemetry transmitters and receivers are not available. There is an existing mobile allocation, but it is for non-federal only. FN US393 allows some federal mobile service (no aeronautical mobile) but only to military on a secondary basis and only at six military sites. The band also allocated to fixed (non-federal only) and to SOS/EESS/SRS (Earth-satellite) (satellite-satellite) federal only use. It is already used heavily by NASA satellite uplinks and forward links, hence there would be constraints on protecting telemetry ground station receivers and airborne telecommand receivers from high-power satellite NASA earth station uplinks and protecting new DOD uplinks and TDRS forward links from mobile operations. It may be useful for command and control.
2110-2165 MHz	Not Evaluated for this Operation	
2200-2300 MHz	Low	Commercial off-the-shelf telemetry transmitters and receivers are available. NASA is already using it for balloon/sounding rocket telemetry. The current primary allocation is limited to mobile (limited to aeronautical telemetry and telecommand US276) and radiolocation. This band is already heavily used for aeronautical telemetry and it would be extremely difficult to support additional traffic.
2360-2395 MHz	Med	Commercial off-the-shelf telemetry transmitters and receivers are available. NASA is already using it for balloon/sounding rocket telemetry. The current primary allocation is limited to mobile (limited to aeronautical telemetry and telecommand US276) and radiolocation. This band is already heavily used for aeronautical telemetry and it would be extremely difficult to support additional traffic.
4400-4940 MHz	High	There is some limited availability of commercial off-the-shelf airborne telemetry transmitters and receivers. Some manufacturers are beginning to offer equipment, but it is more expensive than L-band/S-band equipment. The use of 5 GHz telemetry links will require higher power transmitters for a given LOS range due to higher propagation losses. The current U.S. primary allocation is for federal mobile; however, there is no current U.S. aeronautical mobile telemetry allocation. This would be a new band for aeronautical telemetry if the United States adopts the WRC-2007 aeronautical mobile service international allocation, FN 5.440A, but there are constraints imposed on aeronautical telemetry use. FN 5.440A under ITU Res 416 (WRC07) only allows transmissions from aircraft in the air-to-ground direction (i.e., no telecommand/uplinks in the band). Resolution 416 also places certain EIRP limits on aircraft transmissions. The existing mobile service allocation could be used for telecommand.

UAS/UAV/RPV		National Aeronautics And Space Administration
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
5091-5250 MHz	Med	There is some limited availability of commercial off-the-shelf airborne telemetry transmitters and receivers. Some manufacturers are beginning to offer equipment, but it is more expensive than L-band/S-band equipment. The use of 5 GHz telemetry links will require higher power transmitters for a given LOS range due to higher propagation losses. There is no current U.S. aeronautical mobile telemetry allocation. This would be a new band for aeronautical telemetry if the United States adopts the WRC-2007 aeronautical mobile service international allocation, FN 5.444B, but there are constraints imposed on aeronautical telemetry use. FN 5.444B under ITU Resolution 418 (WRC07) only allows transmissions from aircraft in the air-to-ground direction (i.e., no telecommand/uplinks in the band). Resolution 418 also places certain PFD and EIRP limits on the aircraft transmissions to protect FSS satellite receivers and ARNS/AM(R)S receivers. FN 5.444B also allows AM(R)S in the band for airport surface WiMax communication systems and aeronautical security transmissions which will require coordination with airborne telemetry users operating near airports. This band is also allocated to ARNS (Microwave Landing System (MLS)) (FN 5.444) and AMS(R)S (FN 5.367); however, there is no longer MLS in the United States and currently no AMS(R)S systems. The 5091-5150 MHz band is also allocated to the FSS (Earth-to-space) on a primary basis (FN 5.444A) for NGSO MSS feeder links which would constrain the number of airborne telemetry transmitters (and telecommand transmitters) so as not to interfere with mobile satellite receivers. There is no international Region 2 allocation for aeronautical telemetry, but ITU Res 418 governs the allocation elsewhere. FCC Rules permit U-NII devices at 5150-5250 MHz.
5925-6700 MHz	Low	Commercial off-the-shelf airborne telemetry transmitters and receivers are not available. The use of 6 GHz telemetry links will require higher power transmitters for a given LOS range due to higher propagation losses. There is currently no U.S. aeronautical mobile telemetry allocation. This would be a new band for aeronautical telemetry if the United States adopts the WRC-2007 aeronautical mobile service international allocation, FN 5.457C, but there are constraints imposed on aeronautical telemetry use. FN 5.457C under ITU Res 416 (WRC07) only allows transmissions from aircraft in the air-to-ground direction (i.e., no telecommand/uplinks in the band). Resolution 416 also places certain EIRP limits on the aircraft transmissions. This band is also allocated for FSS (Earth-to-Satellite) and fixed service and is heavily used by commercial entities in the United States.
7125-8500 MHz	Not Evaluated for this Operation	
7900-8400 MHz		
14.5-14.7145 GHz		
15.1365-15.35 GHz		
25.0-27.5 GHz		

Department of Defense

Fixed Point-to-Point Microwave Systems	Department of Defense	
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
225-328.6 MHz	Not Evaluated for this Operation	
335.4-380 MHz		
420-450 MHz		
902-928 MHz		
1350-1390 MHz		
1435-1525 MHz		
1675-1695 MHz		
2025-2110 MHz		
2110-2165 MHz		
2200-2300 MHz		
2360-2395 MHz		
4400-4940 MHz	Low	This band is already saturated with incumbent stakeholders. Although properly allocated, DOD asserts that this band would be better suited for mobile DOD assets including new AMT applications. Continued access to the 4400-4940 MHz band by transportable microwave systems is also crucial. Moreover, the WRC-07 outcomes support access in this band for federal/military AMT, further saturating the band and making the reality of getting spectrum support for relocating systems difficult.
7125-8500 MHz	High	This band is the only candidate band deemed suitable for DOD fixed point-to-point systems. Although the band is at a significantly higher frequency than the 1755-1850 MHz band and will result in some reduced path lengths, the band is successfully used by many other federal agencies for similar systems and DOD does not expect major obstacles to moving most fixed systems to this band. Transportable microwave systems will likely need to consider a lower frequency band allocated for fixed systems.
7900-8400 MHz	Not Evaluated for this Operation	
14.5-14.7145 GHz	Low	The increased infrastructure costs necessary to support operations in this band were deemed prohibitive. Since propagation path loss increases with frequency, path links must necessarily shorten and therefore additional sites will be required to support existing connectivity requirements, thereby increasing costs.
15.1365-15.35 GHz		
25.0-27.5 GHz		

Tactical Radio Relay (TRR)	Department of Defense	
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
225-328.6 MHz	Not Evaluated for this Operation	
335.4-380 MHz		
420-450 MHz		
902-928 MHz		
1350-1390 MHz		
1435-1525 MHz	Low	This band is used extensively for federal and non-federal AMT operations nationwide and is specifically used for safety of flight range testing operations. Band saturation is already severe, especially in areas where flight testing is performed; consequently close coordination and strict scheduling are required. In fact, WRC-07 agenda item 1.5 was established because of the congestion in the current AMT bands and it is expected that AMT bandwidth increases will continue for the foreseeable future, i.e., the need for more spectrum access will increase. Costly flight test programs are accomplished only through day, night, and weekend operations due to crowding. These programs could be critically impacted by the addition of TRRs. The extremely large RF footprint of the AMT service makes de-confliction with TRR very difficult. DOD acknowledges that it currently operates TRR in the 1755-1850 MHz band under similar conditions; however, in this band the additional co-primary AMT operations by the non-federal community make coordination unmanageable.
1675-1695 MHz	Not Evaluated for this Operation	
2025-2110 MHz	High	While this band has a primary allocation for non-federal fixed and mobile, this band is deemed the best candidate for TRR systems with respect to physics (allowing good propagation and high throughput). Some TRR systems currently tune through this band, while other TRR systems would need to be replaced in order to provide tuning capabilities for this band. The prevalence of TRR systems among the Army, Navy, and Marine Corps at many locations across the country would make sharing the band with the current incumbent broadcast auxiliary service (BAS), electronic news gathering (ENG), cable antenna relay service (CARS), and TV auxiliary services impractical. These incumbent services would have to be moved to another band in order for this band to successfully support DOD TRR operations.
2110-2165 MHz	Low	This band is a non-federal band that was recently (2006) auctioned for Advanced Wireless Service-1 licenses. This band is not a viable candidate for DOD TRR systems.
2200-2290 MHz	High	Some TRR systems currently tune through this band and have frequency authorizations, while other TRR systems would need to be replaced in order to have tuning capabilities for this band. This band is considered a lower priority band to assess for support of DOD TRR operations, but a potential candidate to support areas where the existing space operations ground sites would not be impacted. The prevalence of TRR systems among the Army, Navy, and Marine Corps at many locations across the country could make sharing the band with incumbent telemetry and space operations users a challenge.
2290-2300 MHz	High	This band should be assessed in conjunction with access to the 2200-2290 MHz band. Relocation into this band would be subject to the same

Tactical Radio Relay (TRR)		Department of Defense
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
		challenges as relocation into the 2200-2290 MHz band.
2300-2305 MHz	Low	The FCC recently (Aug. 3, 2010) amended the rules for the Wireless Communications Services (WCS) in the 2.3 GHz band to permit mobile broadband services. Furthermore, amateur radio operators use this band for long distance, narrow-band communication, which could be highly susceptible to TRR interference. Finally, the NTIA and the FCC would have to initiate a rulemaking action to accommodate federal fixed and mobile users in this band, an action that is highly unlikely due to the recent decision to permit WCS in this band. (Note: this band is currently not allocated for federal use.)
2305-2310 MHz	Low	In addition to WCS being a primary user, this band also has multiple other non-federal allocations (fixed, mobile, and radiolocation). All these services would be incompatible with TRR operations. This band also is authorized for Part 15 devices, which could introduce interference to/from TRR. (Note: this band is currently not allocated for federal use.)
2360-2395 MHz	Not evaluated for this operation	
4400-4940 MHz		
7125-8500 MHz		
7900-8400 MHz		
14.5-14.7145 GHz		
15.1365-15.35 GHz		
25.0-27.5 GHz		

Air Combat Training Systems (ACTS)	Department of Defense	
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
225-328.6 MHz	Not Evaluated for this Operation	
335.4-380 MHz		
420-450 MHz		
902-928 MHz		
1350-1390 MHz	Low	ACTS systems are airborne and sharing with high power, large bandwidth, upward looking, long-range air route surveillance radars would be impractical. These high power operations would be highly incompatible with the lower power mobile ACTS. While radars in this band are primarily in fixed locations, usable geographic regions where radar coverage is not required are limited. Further, the 1370-1390 MHz portion of this band is still on the list of high-priority bands NTIA is considering for commercial wireless broadband.
1435-1525 MHz	Low	This band extensively used for federal and non-federal AMT operations nationwide and is specifically used for range flight-testing operations. Band saturation is already severe especially in areas where flight testing is performed; consequently, close coordination and strict scheduling are required. In fact, WRC-07 agenda item 1.5 was established because of the congestion in the current AMT bands and it is expected that AMT bandwidth increases will continue for the foreseeable future, i.e., the need for more spectrum access will increase. Costly flight test programs are accomplished only through day, night, and weekend operations due to crowding. These programs could be critically impacted by the addition of further airborne systems such as ACTS. DOD acknowledges that it currently operates ACTS in the 1755-1850 MHz band under similar conditions; however, in this band the additional co-primary AMT operations by the non-federal community makes coordination untenable.
1675-1695 MHz	Not Evaluated for this Operation	
2025-2110 MHz	High	While this band has a primary allocation for non-federal fixed and mobile, it is a suitable candidate for ACTS systems with respect to physics and is therefore deemed the only suitable band for potential relocation. The prevalence and large RF footprint of ACTS systems at many locations across the country (29 ranges) would make sharing the band with the current incumbent BAS, ENG, CARS and TV auxiliary services impractical. The incumbent BAS, ENG, CARS, and TV auxiliary services would have to be moved to another band in order for this band to successfully support DOD ACTS operations. This band has very good propagation characteristics to support ACTS mission requirements that currently operate in the 1755-1850 MHz band.
2110-2165 MHz	Not Evaluated for this Operation	
2200-2300 MHz	Low	Sharing the band with incumbent telemetry and space operations would be impractical. Geographical coverage for ACTS would be significantly and unacceptably constrained due to 24/7/365 operations by fixed systems with large high-gain antennas as well as transportable earth stations that may be deployed throughout the United States in support of space-based platform downlinks for TT&C of space assets. The band is heavily used by NASA satellite downlink receive sites (there are 18 receive sites in the United States including Guam) and TDRS return links (total 233 NASA assignments). There would be constraints on protecting earth station receivers and TDRS return links from airborne transmissions with the large RF footprint from the ACTS operations.

Air Combat Training Systems (ACTS)		Department of Defense
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
2360-2395 MHz	Low	This band is only 35 megahertz wide and used extensively for federal and non-federal AMT operations nationwide. Band saturation is already severe especially in areas where flight testing is performed; subsequently close coordination and strict scheduling are required. Costly flight test programs could be critically impacted by the addition of ACTS. WRC-07 agenda item 1.5 was established to combat congestion in the current AMT bands and AMT increased bandwidth requirements will continue to exacerbate the situation.
4400-4940 MHz	Not Evaluated for this Operation	
7125-8500 MHz		
7900-8400 MHz		
14.5-14.7145 GHz		
15.1365-15.35 GHz		
25.0-27.5 GHz		

Precision Guided Munitions (PGM)		Department of Defense
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
225-328.6 MHz	Not Evaluated for this Operation	
335.4-380 MHz		
420-450 MHz		
902-928 MHz		
1350-1390 MHz	Low	PGM systems are airborne and sharing with high power/high bandwidth long-range air route surveillance radars would be impractical. These high power operations would be highly incompatible with the lower power PGM Systems. While radars in this band are primarily in fixed locations, usable geographic regions where radar coverage is not required are limited. Further, the 1370-1390 MHz portion of this band is still on the list of high-priority bands NTIA is considering for commercial wireless broadband.
1435-1525 MHz	Low	This band is extensively used for federal and non-federal AMT operations nationwide and is specifically used for range flight-testing operations. Band saturation is already severe especially in areas where flight testing is performed; consequently close coordination and strict scheduling are required. In fact, WRC-07 agenda item 1.5 was established because of the congestion in the current AMT bands and AMT bandwidth increases will continue for the foreseeable future, i.e., the need for more spectrum access will increase. Costly flight test programs are accomplished only through day, night, and weekend operations due to crowding. These programs could be critically impacted by the addition of further airborne systems such as PGMs. DOD acknowledges that it currently operates PGMs in the 1755-1850 MHz band under similar conditions; however, in this band the additional co-primary AMT operations by the non-federal community make coordination untenable.
1675-1695 MHz	Not Evaluated for this Operation	
2025-2110 MHz	High	The 2025-2110 MHz band was the only candidate band deemed suitable to support of DOD PGM operations. This band has acceptable propagation characteristics to support PGM mission requirements that currently operate in the 1755-1850 MHz band. The use of PGM systems by the Air Force and Navy at locations across the country would make sharing the band with the current incumbent BAS, ENG, CARS and TV auxiliary services impractical. These services would have to be moved to another band in order for this band to successfully support DOD PGM operations.
2110-2165 MHz	Not Evaluated for this Operation	
2200-2300 MHz	Low	Sharing the band with incumbent telemetry and space operations would be impractical. Geographical coverage for Air Force and Navy PGMs would be significantly and unacceptably constrained due to 24/7/365 operations by fixed systems with large high-gain antennas as well as transportable earth stations that may be deployed throughout the United States in support of space-based platform downlinks for TT&C of space assets. The band is also heavily used by NASA satellite downlink receive sites (there are 18 receive sites in the United States including Guam) and TDRS return links (total 233 NASA assignments). There would be constraints on protecting earth station receivers and TDRS return links from airborne transmissions with the large RF footprint from the PGM operations.
2360-2395 MHz	Low	This band is only 35 megahertz wide and is used extensively for federal and

Precision Guided Munitions (PGM)		Department of Defense
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
		non-federal AMT operations nationwide. Band saturation is already severe, especially in areas where flight testing is performed; subsequently close coordination and strict scheduling are required. Costly flight test programs could be critically impacted by the addition of PGMS. WRC-07 agenda item 1.5 was established to combat congestion in the current AMT bands and AMT increased bandwidth requirements will continue to exacerbate the situation.
4400-4940 MHz	Not Evaluated for this Operation	
7125-8500 MHz		
7900-8400 MHz		
14.5-14.7145 GHz		
15.1365-15.35 GHz		
25.0-27.5 GHz		

Law Enforcement Mobile Video Surveillance (LEMVS)		Department of Defense
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
225-328.6 MHz 335.4-380 MHz	Low	The DOD and other federal agencies with critical interoperability missions have long standing extensive Continental U.S. (CONUS)-wide usage in this band. The band is intensely managed and highly organized, using a developed allotment plan of primarily narrowband channels, reflecting the diverse needs of both military and federal agency requirements including but not limited to training, tactics, air traffic control, unmanned systems, installation infrastructure, command and control, range operations, satellite, and many other requirements. Obtaining assignments for adding LEMVS operations into this band would be nearly impossible. A count of current assignments equals 8,017 records (a single record can support hundreds to thousands of individual transmitters and receivers). A record count alone does not provide an accurate indication of the magnitude of spectrum demand nor the intensity of spectrum use that occurs in this band due to its dynamic support to highly mobile applications where user devices may be handheld, airborne, satellite, or shipborne and where the inventory is in the many thousands.
420-450 MHz	Low	This band is allocated in the United States to radiolocation on a primary basis and would require reallocation to the fixed and mobile service. Since such a reallocation would open the band to other fixed and mobile assets, band congestion would increase, resulting in increased potential for electromagnetic interference (EMI). Moreover, DOD has critical radiolocation assets in this band, which must be protected for the national defense.
902-928 MHz	Low	This band is allocated for federal radiolocation (radars), but the band is actually used by a myriad of fixed and mobile radio systems. This band also includes an allocation to industrial, scientific, and medical (ISM) applications, and therefore has become heavily used for unlicensed Part 15 devices.
1350-1390 MHz	Low	LEMVS are mobile; sharing with high power/high bandwidth long-range air route surveillance radars would be impractical. Introduction of LEMVS into the band would be met with staunch resistance by incumbent users. Although radars in this band are primarily in fixed locations, geographic regions without the potential for mutual EMI would be minimal. Further, the 1370-1390 MHz portion of this band is still on the list of high-priority bands NTIA is considering for commercial wireless broadband.

Law Enforcement Mobile Video Surveillance (LEMVS)		Department of Defense
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
1435-1525 MHz	Low	This band is used extensively for federal and non-federal AMT operations nationwide and is specifically used for range flight-testing operations. Band saturation is already severe especially in areas where flight-testing is performed; consequently, close coordination and strict scheduling are required. Scheduling has become a necessity of cooperative agreement between test ranges with similar missions that often must accept trade-offs in time or spectrum in order to accomplish operational requirements. In fact, WRC-07 agenda item 1.5 was established due to the congestion in the current AMT bands and AMT bandwidth increases will continue into the near future, i.e., the need for more spectrum access will increase. Costly flight test programs are accomplished only through day, night, and weekend operations due to crowding. These programs could be critically impacted by the addition of LEMVS. The extremely large RF footprint of the AMT service makes deconfliction with LEMVS very difficult. DOD acknowledges that it currently operates LEMVS in the 1755-1850 MHz band under similar conditions; however, the additional co-primary AMT operations by the non-federal community make coordination untenable.
1675-1695 MHz	Low	This band is only 20 megahertz wide and allocated to the meteorological aids (radiosonde) and satellite service and not suitable to accommodate displaced LEMVS systems. Current meteorological based assignments more than cover the already limited spectrum within the band. This situation is additionally aggravated by the high altitude profiles associated with radiosonde operations. Radiosondes currently operate in the eight megahertz from 1675-1683 MHz, are launched twice daily from 87 National Weather Service launch sites across the country (plus numerous other military, commercial, and private facilities), achieve altitudes of up to 33,000 meters, and average 2.5 hours of flight time per operation. Interference issues are not anticipated from downlink meteorological-satellite transmissions. However, the establishment and integrity of protection zones around primary earth station receivers will be extremely problematic for LEMVS systems. Given that FN US211 requires that operators in this band “take all practical steps” to protect the radio astronomy service in adjacent bands, operational restrictions are likely. NTIA has already recommended the adjacent spectrum at 1695-1710 MHz for commercial wireless broadband. Moreover, this band is on the NTIA’s list for potentially being repurposed to commercial broadband users.
2025-2110 MHz	High	While this band has a primary allocation for non-federal fixed and mobile, the band is considered the best candidate for LEMVS systems with respect to physics. The use of LEMVS systems by the military services at locations across the country would make sharing the band with the current incumbent BAS, ENG, CARS and TV auxiliary services difficult, but may be possible. This band has excellent propagation and other characteristics needed to support LEMVS mission requirements that currently operate in the 1755-1850 MHz band.
2110-2165 MHz	Not Evaluated for this Operation	

Law Enforcement Mobile Video Surveillance (LEMVS)		Department of Defense
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
2200-2290 MHz	Low	Sharing the band with incumbent telemetry and space operations would be impractical. Geographical coverage requirements for LEMVS would be significantly and unacceptably constrained due to 24/7/365 operations required by multiple mobile earth stations as well as fixed systems deployed throughout the United States in support of space-based platform downlinks for TT&C of space assets.
2290-2300 MHz	Low	The potential use of LEMVS systems at locations across the country would make sharing the band with the current incumbent Deep Space Research users difficult and subject to challenging coordination.
2360-2395 MHz	Low	This band is used extensively for federal and non-federal AMT operations nationwide and is specifically used for range flight-testing operations. Band saturation is already severe, especially in areas where flight testing is performed; consequently close coordination and strict scheduling are required. Scheduling has become a necessity of cooperative agreement between test ranges with similar missions that often must accept trade-offs in time or spectrum in order to accomplish operational requirements. In fact, WRC-07 agenda item 1.5 was established because of the congestion in the current AMT bands and AMT bandwidth increases will continue into the near future, i.e., the need for more spectrum access will increase. Costly flight test programs are accomplished only through day, night, and weekend operations due to crowding. These programs could be critically impacted by the addition of LEMVS. The extremely large RF footprint of the AMT service makes deconfliction very difficult. DOD acknowledges that it currently operates LEMVS in the 1755-1850 MHz band under similar conditions; however, in this band the additional co-primary AMT operations by the non-federal community make coordination untenable.
4400-4940 MHz	Not Evaluated for this Operation	
7125-8500 MHz		
7900-8400 MHz		
14.5-14.7145 GHz		
15.1365-15.35 GHz		
25.0-27.5 GHz		

High Resolution Video Data Link (HRVDL)		Department of Defense
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
225-328.6 MHz 335.4-380 MHz	Low	The DOD and other federal agencies with critical interoperability missions have long-standing extensive CONUS-wide usage in this band. The band is intensely managed and highly organized, using a developed allotment plan of primarily narrowband channels, reflecting the diverse needs of both military and federal agency requirements including but not limited to training, tactics, air traffic control, unmanned systems, installation infrastructure, command and control, range operations, satellite, and many other requirements. Obtaining assignments for adding HRVDL operations into this band would be nearly impossible. A count of current assignments equals 8,017 records. A record count alone does not provide an accurate indication of the magnitude of spectrum demand nor the intensity of spectrum use that occurs in this band due to its dynamic support to highly mobile applications where user devices may be handheld, airborne, satellite, or shipborne and where the inventory is in the many thousands.
420-450 MHz	Low	This band is allocated in the United States to radiolocation on a primary basis and would require reallocation to the fixed and mobile service. Since such a reallocation would open the band to other fixed and mobile assets, band congestion would increase resulting in increased potential for EMI. Moreover, DOD has critical radiolocation assets in this band which must be protected for the national defense
902-928 MHz	Low	This band is allocated for federal radiolocation (radars), but the band is actually used by a myriad of fixed and mobile radio systems. This band also includes an allocation to non-federal ISM applications, and therefore has become heavily used by unlicensed Part 15 devices.
1350-1390 MHz	Low	HRVDLs are mobile; sharing with high power/high bandwidth long-range air route surveillance radars would be impractical. These high power operations would be highly incompatible with the lower power HRVDLs. Introduction of HRVDLs into the band would be met with staunch resistance by incumbent users. Although radars in this band are primarily in fixed locations, geographic regions without the potential for mutual EMI would be minimal. Further, the 1370-1390 MHz portion of this band is still on the list of hi-priority bands NTIA is considering for commercial wireless broadband.

High Resolution Video Data Link (HRVDL)		Department of Defense
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
1435-1525 MHz	Low	This band is used extensively for federal and non-federal AMT operations nationwide. Band saturation is already severe especially in areas where flight testing is performed; consequently, close coordination and strict scheduling are required. Scheduling has become a necessity of cooperative agreement between test ranges with similar missions that often must accept trade-offs in time or spectrum in order to accomplish operational requirements. In fact, WRC-07 agenda item 1.5 was established because of the congestion in the current AMT bands. Costly flight test programs could be critically impacted by the addition of HRVDLs; however, the greater impact is expected to be degradation to the HRVDLs operations. This would be due to the high operating altitudes associated with typical aeronautical telemetry platforms, which create an extremely large RF footprint over the ground and would prohibit the operation of terrestrial based systems on similar frequencies. DOD acknowledges that it currently operates HRVDLs in the 1755-1850 MHz band under similar conditions; however, in this band the additional co-primary AMT operations by the non-federal community make coordination untenable.
1675-1695 MHz	Low	This band is only 20 megahertz wide and allocated to the meteorological aids (radiosonde) and satellite service and is not suitable to accommodate displaced HRVDL systems. Current meteorological based assignments more than cover the already limited spectrum within the band. This situation is additionally aggravated by the high altitude profiles associated with radiosonde operations. Radiosondes currently operate in the eight megahertz from 1675-1683 MHz, are launched twice daily from 87 National Weather Service launch sites across the country (plus numerous other military, commercial, and private facilities), achieve altitudes of up to 33,000 meters, and average 2.5 hours of flight time per operation. Interference issues are not anticipated from downlink meteorological-satellite transmissions. However, the establishment and integrity of protection zones around primary earth station receivers will be extremely problematic for HRVDL systems. Given that FN US211 requires that operators in this band "take all practical steps" to protect the radio astronomy service in adjacent bands, operational restrictions are likely. NTIA has already recommended the adjacent spectrum at 1695-1710 MHz for commercial wireless broadband. Moreover, this band is on the NTIA's list for potentially being repurposed to commercial broadband users.
2025-2110 MHz	High	While this band has a primary allocation for non-federal fixed and mobile, the band is considered the best candidate for HRVDLs systems with respect to physics. The use of HRVDL systems by the military services at locations across the country would make sharing the band with the current incumbent ENG, CARS and TV auxiliary services difficult, but may be possible. This band has excellent propagation and other characteristics to support HRVDL mission requirements that currently operate in the 1755-1850 MHz band.
2110-2165 MHz	Not Evaluated for this Operation	

High Resolution Video Data Link (HRVDL)		Department of Defense
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
2200-2290 MHz	High	While ubiquitous operations of DOD HRVDLs are inevitable, these systems are low power and ground-based. Electromagnetic compatibly analysis may indicate that with coordination with existing space operations, sharing may be possible.
2290-2300 MHz	Low	The potential use of HRVDL systems at locations across the country would make sharing the band with the current incumbent deep space research users difficult and subject to challenging coordination.
2360-2395 MHz	Low	This band is only 35 megahertz and is extensively used for federal and non-federal AMT operations nationwide and is specifically used for range flight-testing operations. Band saturation is already severe especially in areas where flight testing is performed; consequently close coordination and strict scheduling are required. In fact, WRC-07 agenda item 1.5 was established because of the congestion in the current AMT bands and AMT bandwidth increases will continue into the near future, i.e., the need for more spectrum access will increase. Costly flight test programs are accomplished only through day, night, and weekend operations due to crowding. HRVDLs could critically impact these programs – mainly due to the expected degradation to the HRVDL operations resulting from interference from the AMT. Because of the extremely large RF footprints of the AMT service, deconfliction becomes very difficult. DOD acknowledges that it currently operates HRVDLs in the 1755-1850 MHz band under similar conditions; however, in this band the additional co-primary AMT operations by the non-federal community make coordination untenable.
4400-4940 MHz	Not Evaluated for this Operation	
7125-8500 MHz		
7900-8400 MHz		
14.5-14.7145 GHz		
15.1365-15.35 GHz		
25.0-27.5 GHz		

Tracking, Telemetry, and Commanding (TT&C)	Department of Defense	
Comparable Band Candidate	**Ranking**	**Rationale for band Ranking**
225-328.6 MHz	Not Evaluated for this Operation	
335.4-380 MHz		
420-450 MHz		
902-928 MHz		
1350-1390 MHz		
1435-1525 MHz		
1675-1695 MHz		
2025-2110 MHz	High	This band has propagation characteristics similar to the 1755-1850 MHz band, is properly allocated, and is therefore the primary candidate available for relocation assessment. The mission of the SGLS is to support TT&C functions for spacecraft during the launch, early orbit, and anomaly resolution (LEO&A) phases for DOD and other agencies' assets. Connectivity with the spacecraft is required without fail for any orientation of the spacecraft. The vagaries of spacecraft orientation require the use of an omni-directional antenna onboard the spacecraft and subsequently the use of frequency bands with propagation characteristics similar to that of the 1755-1850 MHz band.
2110-2165 MHz	Not Evaluated for this Operation	
2200-2300 MHz		
2360-2395 MHz		
4400-4940 MHz		
7125-8500 MHz	Low	While this band has the proper allocation for use in supporting the TT&C function for DOD and other federal spacecraft, the physics associated with this band are not conducive to supporting the LEO&A aspects of space flight, an essential element of the SGLS mission. A number of DOD spacecraft use this band as a "mission" band and some have a TT&C capability in this band, but the band is unable to support the critical LEO&A functions.
7900-8400 MHz	Not Evaluated for this Operation	
14.5-14.7145 GHz		
15.1365-15.35 GHz		
25.0-27.5 GHz		
30/20[187] GHz	Low	See rationale for 7900-8500 MHz above.

[187] DOD assessed this band, although it was not included in the bands NTIA asked the agencies to evaluate.

Aeronautical Mobile Telemetry (AMT)		Department of Defense
Comparable Band Candidate	**Ranking**	**Rationale for band Ranking**
225-328.6 MHz	Not Evaluated for this Operation	
335.4-380 MHz		
420-450 MHz		
902-928 MHz		
1350-1390 MHz	Low	Air-to-Ground-to-Air Telemetry (A/G/A TLM) systems are airborne and sharing with high power/high bandwidth long-range air route surveillance radars would be impractical. These high power operations would be highly incompatible with the lower power A/G/A TLM systems. While radars in this band are primarily in fixed locations, usable geographic regions where radar coverage is not required are non-existent. Further, the 1370-1390 MHz portion of this band is still on the list of high-priority bands NTIA is considering for commercial wireless broadband.
1435-1525 MHz	Low	This band is extensively used for federal and non-federal AMT operations nationwide and is specifically used for safety of flight range testing operations. Band saturation is already severe especially in areas where flight testing is performed; consequently close coordination and strict scheduling are required. Scheduling has become a necessity of cooperative agreement between test ranges with similar missions that often must accept trade-offs in time or spectrum in order to accomplish operational requirements. In fact, WRC-07 agenda item 1.5 was established because of the congestion in the current AMT bands and AMT bandwidth increases will continue into the near future, i.e., the need for more spectrum access will increase. Costly flight test programs are accomplished only through day, night, and weekend operations due to crowding. The addition of more AMT operations could critically impact these programs.
1675-1695 MHz	Not Evaluated for this Operation	
2025-2110 MHz	High	While this band has a primary allocation for non-federal fixed and mobile, it is a suitable candidate for AMT systems with respect to physics and is therefore deemed the only suitable band for potential relocation. The prevalence and large RF footprint of AMT systems at many locations across the country would make sharing the band with the current incumbent BAS, ENG, CARS and TV auxiliary services impractical. The incumbent BAS, ENG, CARS, and TV auxiliary services would have to be moved to another band in order for this band to successfully support DOD AMT operations. This band has very good propagation characteristics to support AMT mission requirements that currently operate in the 1755-1850 MHz band.
2110-2165 MHz	Not Evaluated for this Operation	

Aeronautical Mobile Telemetry (AMT)		Department of Defense
2200-2300 MHz	Low	The introduction of Air Force, Army, Navy, and Marine Corps A/G/A TLM systems at many range locations across the country would make sharing this band with the current incumbent telemetry and space operations users impractical. Geographical coverage for A/G/A TLM systems would be significantly constrained due to 24/7/365 operations by fixed systems with large high-gain antennas as well as transportable earth stations that may be deployed throughout the United States in support of space-based platform downlinks for TT&C of space assets. The band is heavily used by NASA satellite downlink receive sites (there are 18 receive sites in the United States including Guam) and TDRS return links (233 NASA assignments). There would be constraints on protecting earth station receivers and TDRS return links from airborne telemetry transmissions.
2360-2395 MHz	Low	This band is only 35 megahertz wide and is used extensively for federal and non-federal AMT operations nationwide. Band saturation is already severe especially in areas where flight testing is performed; subsequently close coordination and strict scheduling are required. Costly flight test programs could be critically impacted by the addition of more AMT operations. WRC-07 agenda item 1.5 was established to combat congestion in the current AMT bands and AMT increased bandwidth requirements will continue to exacerbate the situation.
4400-4940 MHz	High	Studies evaluated for WRC-07 showed that A/G/A TLM specifically could share with systems that currently operate in the band today. Relocation of A/G/A TLM operations into this higher frequency band will alleviate some of the spectrum crowding pressure on lower frequency bands.
5150 - 5250[188] MHz	High	Studies evaluated for WRC-07 showed that A/G/A TLM specifically could share with systems that currently operate in the band today. Relocation of A/G/A TLM operations into this higher frequency band will alleviate some of the spectrum crowding pressure on lower frequency bands.
7125-8500 MHz	Not Evaluated for this Operation	
7900-8400 MHz		
14.5-14.7145 GHz		
15.1365-15.35 GHz		
25.0-27.5 GHz		

[188] DOD assessed this band, although it was not included in the bands NTIA asked the agencies to evaluate.

Land Mobile Robotic Video (LMRV) Functions		Department of Defense
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
225-328.6 MHz 335.4-380 MHz	Low	The DOD and other federal agencies with critical interoperability missions have long-standing extensive CONUS-wide usage in this band. The band is intensely managed and highly organized, using a developed allotment plan of primarily narrowband channels, reflecting the diverse needs of both military and federal agency requirements including but not limited to training, tactics, air traffic control, unmanned systems, installation infrastructure, command and control, range operations, satellite, and many other requirements. Obtaining assignments for adding LMRV operations into this band would be nearly impossible. A count of current assignments equals 8,017 records. A record count alone does not provide an accurate indication of the magnitude of spectrum demand nor the intensity of spectrum use that occurs in this band due to its dynamic support to highly mobile applications where user devices may be handheld, airborne, satellite, or shipborne and where the inventory is in the many thousands.
420-450 MHz	Low	This band is allocated in the United States to radiolocation on a primary basis and would require reallocation to the fixed and mobile service. Since such a reallocation would open the band to other fixed and mobile assets, band congestion would increase resulting in increased potential for EMI. Moreover, DOD has critical radiolocation assets in this band, which must be protected.
902-928 MHz	Not Evaluated for this Operation	
1350-1390 MHz	Low	Sharing LMRV systems with high power/high bandwidth long-range air route surveillance radars would be impractical. These high power operations would be highly incompatible with the lower power LMRV systems. Introduction of these systems into the band would be met with staunch resistance by incumbent users. Although radars in this band are primarily in fixed locations, geographic regions without the potential for mutual EMI would be minimal. Further, the 1370-1390 MHz portion of this band is still on the list of high-priority bands NTIA is considering for commercial wireless broadband (ranked #4).
1435-1525 MHz	Low	This band is extensively used for federal and non-federal AMT operations nationwide. Band saturation is already severe especially in areas where flight testing is performed; consequently close coordination and strict scheduling are required. In fact, WRC-07 agenda item 1.5 was established because of the congestion in the current AMT bands. Costly flight test programs could be critically impacted by the addition of LMRV operations; however, the greater impact is expected to be degradation of LMRV operations. This would be due to the high operating altitudes associated with typical aeronautical telemetry platforms, which create an extremely large RF footprint over the ground and would prohibit the operation of terrestrial based systems on similar frequencies. DOD acknowledges that it currently operates LMRV in the 1755-1850 MHz band under similar conditions; however, in this band the additional co-primary AMT operations by the non-federal community make coordination untenable.

Land Mobile Robotic Video (LMRV) Functions		Department of Defense
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
1675-1695 MHz	Low	This band is only 20 megahertz wide and allocated to the meteorological aids (radiosonde) and satellite service and is not suitable to accommodate displaced LMRV operations. Current meteorological based assignments more than cover the already limited spectrum within the band. This situation is additionally aggravated by the high altitude profiles associated with radiosonde operations. Radiosondes currently operate in the eight megahertz from 1675-1683 MHz, are launched twice daily from 87 National Weather Service launch sites across the country (plus numerous other military, commercial, and private facilities), achieve altitudes of up to 33,000 meters, and average 2.5 hours of flight time per operation. Interference issues are not anticipated from downlink meteorological satellite transmissions. However, the establishment and integrity of protection zones around primary earth station receivers will be extremely problematic for LMRV systems. Given that FN US211 requires that operators in this band "take all practical steps" to protect the radio astronomy service in adjacent bands, operational restrictions are likely. NTIA has already recommended the adjacent spectrum at 1695-1710 MHz for commercial wireless broadband. Moreover, this band is on the NTIA's list for potentially being repurposed to commercial broadband users.
2025-2110 MHz	High	While this band has a primary allocation for non-federal fixed and mobile, the band is considered the best candidate for LMRV systems with respect to physics. The use of LMRV systems by the military services at locations across the country would make sharing the band with the current incumbent ENG, CARS and TV auxiliary services difficult, but may be possible. This band has excellent propagation and other characteristics to support LMRV mission requirements that currently operate in the 1755-1850 MHz band.
2110-2165 MHz	Not Evaluated for this Operation	
2200-2290 MHz	High	This band is considered a lower priority band to assess for support of LMRV operations, but it is a potential candidate to support areas where the existing space operations ground sites would not be impacted, though incumbent telemetry operations will make coordination challenging.
2290-2300 MHz	High	This band should be assessed in conjunction with access to the 2200-2290 MHz band; relocation into this band would be subject to the same challenges as relocation into the 2200-2290 MHz band.
2300-2305 MHz	Low	This band does not have a federal allocation, but it does have an amateur allocation. The FCC recently (Aug. 3, 2010) amended the rules for the WCS in the 2.3 GHz band to permit mobile broadband services. Furthermore, amateur radio operators use this band for long distance, narrow-band communication, which could be highly susceptible to LMRV interference. Finally, the NTIA and the FCC would have to initiate a rulemaking action to accommodate federal fixed and mobile users in this band, an action that is highly unlikely.
2305-2310 MHz[189]	Low	This band does not have a federal allocation and it does have multiple non-federal allocations (fixed, mobile, and radiolocation). WCS are a primary user of this band. If this service stays in the band, it would be incompatible with LMRV operations. This band also is authorized for Part 15 devices, which could be a source of interference to LMRV systems.

[189] DOD assessed this band, although it was not included in the bands NTIA asked the agencies to evaluate.

Land Mobile Robotic Video (LMRV) Functions		Department of Defense
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
2360-2395 MHz[190]	Low	This band is only 35 megahertz and is extensively used for federal and non-federal AMT operations nationwide and is specifically used for range flight-testing operations. Band saturation is already severe especially in areas where flight testing is performed; consequently close coordination and strict scheduling are required. In fact, WRC-07 agenda item 1.5 was established because of the congestion in the current AMT bands and it's expected that AMT bandwidth increases will continue into the near future, i.e., the need for more spectrum access will increase. Costly flight test programs are accomplished only through day, night, and weekend operations due to crowding. These programs could be critically impacted by the addition of LMRV – mainly due to the expected degradation to the LMRV operations resulting from interference from the AMT. Because of the extremely large RF footprints of the AMT service, deconfliction becomes very difficult. DOD acknowledges that it currently operates LMRV in the 1755-1850 MHz band under similar conditions; however, in this band the additional co-primary AMT operations by the non-federal community make coordination untenable.
4400-4940 MHz	Not Evaluated for this Operation	
7125-8500 MHz		
7900-8400 MHz		
14.5-14.7145 GHz		
15.1365-15.35 GHz		
25.0-27.5 GHz		

[190] DOD assessed this band, although it was not included in the bands NTIA asked the agencies to evaluate.

Unmanned Aerial Systems (UAS)	Department of Defense	
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
225-328.6 MHz	Low	The DOD and other federal agencies with critical interoperability missions have long-standing extensive CONUS-wide usage in this band. The band is intensely managed and highly organized, using a developed allotment plan of primarily narrowband channels, reflecting the diverse needs of both military and federal agency requirements including but not limited to training, tactics, air traffic control, unmanned systems, installation infrastructure, command and control, range operations, satellite, and many other requirements. Obtaining assignments for adding UAS, UAV, RPV operations into this band would be nearly impossible. A count of current assignments equals 8,017 records. A record count alone does not provide an accurate indication of the magnitude of spectrum demand nor the intensity of spectrum use that occurs in this band due to its dynamic support to highly mobile applications where user devices may be handheld, airborne, satellite, or shipborne and where the inventory is in the many thousands.
335.4-380 MHz		
420-450 MHz	Not Evaluated for this Operation	
902-928 MHz		
1350-1390 MHz		
1435-1525 MHz		
1675-1695 MHz		
2025-2110 MHz	High	While this band has a primary allocation for non-federal fixed and mobile, the band is considered the best candidate for UAS-UAV-RPV systems with respect to physics. The use of UAS-UAV-RPV systems by the Air Force, Army, Marine Corps and Navy at locations across the country would make sharing the band with the current incumbent ENG, CARS and TV auxiliary services impractical. If the current FCC database on commercial and private licenses is reviewed, there are already 7,187 licenses resident within the band. This situation is particularly aggravated given the current degree of direct assignment overlaps already present within assignment databases, and average assignment bandwidth requirements identified for these records. The incumbent BAS, ENG, CARS, and TV auxiliary services would have to be moved to another band in order for this band to successfully support DOD UAS-UAV-RPV operations. This band has excellent propagation and other characteristics to support UAS-UAV-RPV mission requirements that currently operate in the 1755-1850 MHz band.
2110-2165 MHz	Not Evaluated for this Operation	
2200-2290 MHz	High	While the DOD asserts that relocation into this band should be analyzed, ubiquitous operations of DOD UAS-UAV-RPV assets will likely make sharing the band with the current incumbent telemetry and space operations difficult and subject to extensive coordination. Significant geographical coverage would likely not be achievable due to 24/7/365 operations at multiple mobile earth stations and fixed systems with high-gain antennas used throughout the United States in support of space based platform downlink for TT&C of space assets.
2291-2300 MHz	High	This band should be assessed in conjunction with access to the 2200-2290 MHz band; relocation into this band would be subject to the same challenges as relocation into the 2200-2290 MHz band.
2360-2395 MHz	Not Evaluated for this Operation	

Unmanned Aerial Systems (UAS)	Department of Defense	
Comparable Bands	**Ranking**	**Rationale for Band Ranking**
4400-4940 MHz	Low	During WRC-07, the federal/military AMT community was successful in gaining access to the band for both federal/military and non-federal AMT operations to meet exponentially increasing test range AMT requirements, which will undoubtedly make the band much more crowded, especially when the band is expanded to allow non-federal AMT operations. Relocating UAS, UAV, RPV operations in this band is expected to prove difficult and getting a frequency assignment in the band could be almost impossible. Current incumbent users include telemetry, existing UAS operations, naval tactical data links, point-to-point microwave links; research and testing; land mobile radios; air-to-ground-to-air operations, and other uses. To combat crowding in the band, NTIA recently approved a channel plan; however, wideband airborne and mobile operations were exempted, including UAS operations and AMT.
7125-8500 MHz	Not evaluated for this operation	
7900-8400 MHz		
14.5-14.7145 GHz	Low	The DOD UAS-UAV-RPV systems are in many cases small physical platforms and have significant restrictions with respect to component size, weight, power requirements, and other limitations. Communications and control systems must be able to support platform operations during dynamic aircraft movements. In addition, DOD policy mandates that military ISR systems operate in this band using the Common Data Link (CDL). The band is already congested with a multitude of fixed and mobile users. It is nearly impossible to support wideband CDL UAS operations in this band due to the number of fixed microwave links already present; adding more will only worsen the situation. NTIA and DOD recently established rules including computer models to allow enhanced coordination and sharing among current and future users; however, the difficulties are deemed excessive. UAS-UAV-RPV systems are essentially unable to be adequately supported by bands above 3 GHz.
15.1365-15.35 GHz	Low	The DOD UAS-UAV-RPV systems are in many cases small physical platforms and have significant restrictions with respect to component size, weight, power requirements, and other limitations. Communications and control systems must be able to support platform operations during dynamic aircraft movements. Also, DOD policy mandates that military ISR systems operate in this band using the CDL. The band is already congested with a multitude of fixed and mobile users. It is nearly impossible to support wideband CDL UAS operations in this band due to the number of fixed microwave links already present; adding more will only worsen the situation. NTIA and DOD recently established rules including computer models to allow enhanced coordination and sharing amongst current and future users; however, difficulties are deemed excessive. UAS-UAV-RPV systems are essentially unable to be adequately supported by bands above 3 GHz.
25.0-27.5 GHz	Not evaluated for this operation	