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Report to the Ranking Minority Member, Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate

August 2001

DEFENSE SPECTRUM MANAGEMENT

More Analysis Needed to Support Spectrum Use Decisions for the 1755-1850 MHz Band

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Abbreviations

BBA	Balanced Budget Act
CTIA	Cellular Telecommunications and Internet Association
DMSP	Defense Meteorological Satellite Program
DOD	Department of Defense
DSB	Defense Science Board
DSCS	Defense Satellite Communications System
DSP	Defense Support Program
FCC	Federal Communications Commission
FFRDC	Federally Funded Research and Development Center
GPS	Global Positioning System
IMT-2000	International Mobile Telecommunications-2000
ITFS	Instructional Television Fixed Service
ITU	International Telecommunication Union
JTCTS	Joint Tactical Air Combat Training System
MDS	Multipoint Distribution Service
MMDS	Multichannel Multipoint Distribution Service
MSE	Mobile Subscriber Equipment
NATO	North Atlantic Treaty Organization
NDAA	National Defense Authorization Act
NTIA	National Telecommunication and Information Administration
OBRA	Omnibus Budget Reconciliation Act
PSD	Power Spectral Density
WARC	World Administrative Radio Conference
WRC	World Radiocommunication Conference

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Accountability * Integrity * Reliability

United States General Accounting Office
Washington, DC 20548

August 20, 2001

The Honorable James Inhofe
Ranking Minority Member
Subcommittee on Readiness and
Management Support
Committee on Armed Services
United States Senate

Dear Senator Inhofe:

The use of commercial mobile wireless communications, such as personal communications services and cell phones, has been escalating worldwide over the radio frequency spectrum.[1] This spectrum is a scarce and finite resource, which serves ever increasing and competing public and private uses. The federal government has supported commercial services by making spectrum available as these services developed over the years. Some representatives of the commercial mobile radio service industry claim additional spectrum is needed to support advanced communications systems, called third generation systems. Other members of the industry question the need for, or feasibility of providing, large amounts of additional spectrum to meet industry requirements. These members point to the need for increased efficiency in the use of spectrum through new technologies. Third generation systems are being developed to provide mobile voice, high-speed data, and Internet capabilities and are expected to contribute significantly to the economic well-being of the United States.

Access to the radio frequency spectrum is also critically important to federal, state, and local governments for national security, public safety, and other governmental functions. Specifically, while the national interest in a broad sense may be served by a robust commercial mobile wireless system, national security also requires that the federal government be able to meet its unique communications requirements to support domestic training and worldwide military operations. Thus, determining the proper

[1] Electromagnetic radiation is the propagation of energy that travels through space in the form of waves. The radio frequency spectrum is the portion of electromagnetic spectrum that carries radio waves. Frequency is the number of waves traveling by a given point per unit of time, in cycles per second, or hertz. Radio frequency is usually measured in thousands of hertz or kilohertz (kHz), millions of hertz or megahertz (MHz), and billions of hertz or gigahertz (GHz).

use of a limited amount of spectrum, today and in the future, is a challenging and complex task due to competing industry and governmental demands.

In response to a presidential memorandum released in October of 2000, the Department of Commerce issued a plan to select spectrum for potential use by third generation wireless systems in the United States. This plan designated the National Telecommunication and Information Administration (NTIA) to study the 1755 to 1850 MHz band. Within the United States, this band is allocated exclusively to the federal government, particularly for defense purposes, such as space systems, mobile tactical communications, and combat training.

To assist the NTIA, the Department of Defense (DOD) issued a report in February 2001, which focuses primarily on spectrum sharing and relocation issues in the United States. The report also describes potential operational impacts and estimates the costs DOD would incur from future reallocation of this spectrum to private sector users. DOD concluded that vacating the band could not be accomplished for space systems until at least 2017, and for most DOD non-space systems until at least 2010. The report notes that DOD could face significant operational restrictions in any frequency-sharing situation. In addition, the preliminary results of DOD's analysis indicate that comparable spectrum, which is operationally suitable, may not be available for the relocation of the DOD systems. NTIA's final report in March 2001 incorporated DOD's study results and concluded that unrestricted sharing of the 1755 to 1850 MHz band is not feasible and any other sharing option would require considerable coordination. Further, the report notes that issues involving the availability of comparable spectrum, reimbursement, and the time required for federal entities to either modify or replace equipment would need to be addressed before a decision could be made whether federal users could share or vacate a band of spectrum.

Because of the importance of this issue to private and public interests in the United States, you asked us to assess DOD's study of the 1755 to 1850 MHz band and determine whether the study provides a sound basis for decisions about the reallocation of this spectrum. As part of this assessment, we reviewed and analyzed an industry consortium report that reached different conclusions on space operations than the DOD study.[2] We also reviewed a separate ongoing Air Force analysis that has similar conclusions on space operations to the DOD study.[3] We did not review the Department of Commerce or the Federal Communications Commission (FCC) report or each agency's process to identify and select additional spectrum for third generation wireless systems.

Results in Brief

Spectrum decisions based on either the DOD or the industry study of the 1755 to 1850 MHz band would be premature at this time. Neither study contains adequate information to make reallocation decisions.[4] In particular, we found that neither the DOD model nor the industry model is mature enough to calculate spectrum interference to satellites, and, therefore, cannot support a near-term decision. DOD recognized in its report that additional analyses are needed to assess the impacts of any reallocation or sharing decision. A third model to calculate this interference, developed by the Air Force, shows promise but is still under development.[5] All three studies used different assumptions because there is no single agreed upon methodology or model today to estimate potential spectrum interference from third generation wireless systems.

[2] Report of the Industry Association Group on Identification of Spectrum for 3G Services, an attachment to comments to the Federal Communications Commission's notice of proposed rulemaking on 3G submitted by the Industry Association Group. The Industry Association Group is composed of the Cellular Telecommunications and Internet Association, the Telecommunications Industry Association, and the Personal Communications Industry Association.

[3] The Air Force study is being prepared by the Aerospace Corporation, a federally funded research and development center (FFRDC). These centers are sponsored by government agencies, but are privately administered by universities and other nonprofit corporations to ensure objectivity and independence. Aerospace Corporation's primary customer is the Space and Missile Systems Center of the Air Force Materiel Command. The primary responsibility of Aerospace Corporation is to ensure the mission success of national security space programs.

[4] Potential spectrum interference with DOD satellite operations is discussed later in the report, and appendixes I and II are devoted to this issue. This focus is the result of a lack of time for us to conduct similar analyses on other DOD systems and does not mean that problems are not present in other major tactical radio, air combat training, and precision guided munitions systems.

[5] Aerospace Corporation reviewed the DOD and industry studies as a starting point and is making changes in methodology as it deems appropriate. The Corporation will incorporate these changes into future work.

If the current schedule to auction spectrum is maintained, the federal government will make decisions affecting national security without knowing the full extent of the risks it faces or steps available to reduce those risks. While the DOD study provides preliminary information about DOD systems and operational requirements, it does not contain information on critical considerations, which are necessary for decisions on DOD's ability to vacate the entire band or share all or part of the band with industry. According to DOD officials, the following considerations (1) were outside the scope of its study or (2) were not included in its study because of a compressed time schedule and the lack of information on alternative spectrum and development of third generation systems.

- First, additional technical and operational analysis is required to determine the impact of third generation systems on military operations. Without the proper technical and operational analyses, DOD risks a reduction in military preparedness or a degradation of systems in the 1755 to 1850 MHz band that support mission capabilities. Specifically, DOD faces an unknown risk of operational degradation to its satellite operations that could include actual loss of control of its satellites and an undetermined risk to the warfighter.

- Second, because additional analysis is required to estimate costs, DOD risks not receiving a fair reimbursement value for the costs the agency incurs to vacate or share the 1755 to 1850 MHz band. The DOD cost estimate is potentially understated by billions of dollars because the Department did not include satellite replacement costs.

- Third, because the DOD report did not fully consider the Department's future communication requirements, the Department risks losing spectrum that may be needed for national security. DOD's future warfare plans assume unimpeded communications are readily available to deployed forces.

- Fourth, DOD's study process lacked adequate programmatic, budgetary, technical, and scheduling guidance for command and operational units. Without this guidance, command and operational units were unsure which program or technical alternatives to include in the study.

- Finally, DOD did not include in its study the potential impacts of U.S. spectrum reallocation decisions on international agreements and overseas military operations. Reallocation of U.S. spectrum could have a negative impact, such as loss of existing regulatory protection, on these agreements and operations.

This report contains recommendations to the Secretary of Defense and the Secretary of Commerce concerning actions needed to complete the analysis of the impacts from a potential spectrum reallocation of the 1755 to 1850 MHz band. In commenting on a draft of this report, DOD, FCC, and the Department of Commerce agreed with our findings and recommendations. The National Security Council provided only technical comments.

Background

Wireless technologies have become a valuable asset to improve communications efficiency and reduce costs for industries and governments around the world. The first generation of wireless technology, analog cell phones, is still used in many areas of the country. The second generation of wireless technology added digital “personal communications services,” such as voice mail, text messaging, and access to the World Wide Web. The second generation is growing at an extraordinary rate and is an essential part of the way the world does business. Today, industry is also developing a third generation of personal communications, which are expected to give consumers mobile, high data rate, high-quality multi-media services.

The most technically suitable spectrum for mobile communications, public and private, is below three gigahertz. This band of spectrum is the best match for special spectrum propagation characteristics (such as distance, capacity, and reliability) required by DOD, other federal agencies, and commercial wireless firms. As a result, this spectrum is the subject of much competition among the different users. This competition presents major spectrum management issues for decisions by governmental organizations within the United States and by international organizations composed of sovereign nations.

FCC and NTIA manage the radio spectrum in the United States. NTIA is the executive branch agency principally responsible for developing and articulating domestic and international telecommunications policy for the executive branch. NTIA is also responsible for managing the federal government’s use of the radio spectrum. FCC, an independent agency of the federal government, has authority over commercial spectrum use, as well as the use of spectrum by state and local governments. NTIA and FCC manage the spectrum through a system of frequency allocations, allotments, and assignments.[6]

Previously, Congress directed the reallocation of spectrum from federal to private sector use under title VI of the Omnibus Budget Reconciliation Act of 1993 (OBRA 93)[7] and later expanded the reallocation of spectrum under title III of the Balanced Budget Act of 1997 (BBA 97).[8] Under these laws, NTIA identified a total of 255 MHz for reallocation.[9]

Because radio waves transcend national borders and the number of global services has been increasing, international coordination of spectrum is a critical component of the spectrum allocation process. The radiocommunication conferences of the International Telecommunication Union (ITU)[10] are the principal mechanisms for international spectrum allocation via treaties. At the 2000 World Radiocommunicaton Conference (WRC-2000), the ITU discussed spectrum and regulatory issues for advanced mobile applications, including third generation services. According to NTIA officials, the WRC-2000 and the ITU 1992 World Administrative Radio Conference (WARC-92) identified a total of 749

[6] The entire radio spectrum is divided into blocks, or bands, that are allocated for broad categories of radio services, such as fixed, mobile, broadcasting, or satellite services. FCC establishes rules that further define the particular types of use that are permitted within each allocation. For example, a frequency band that is allocated to the mobile service may be designated in the FCC rules for particular users such as business users, public safety users, or cellular users. Allotments may be made within certain services, such as TV broadcasting, where particular channels are provided in each geographic area. Assignment refers to the final subdivision of the spectrum in which a party gets an assignment or license to operate a radio transmitter on a specific channel or group of channels at a particular location under specific conditions.

[7] P.L. 103-66, Aug. 10, 1993.

[8] P.L. 105-33, Aug. 5, 1997.

[9] Eight MHz of spectrum was subsequently reclaimed per congressional direction. See section 1062 of the National Defense Authorization Act for Fiscal Year 2000 (NDAA-2000) (P.L. 106-65, Oct. 5, 1999). OBRA 93 required FCC to gradually allocate and assign frequencies over the course of 10 years. The reallocation of the majority of the 235 MHz identified under that act is still underway. BBA 97 imposed a stricter deadline for NTIA to identify for reallocation and FCC to reallocate, auction, and assign licenses by September 2002 for the additional 20 MHz of federal spectrum.

[10] The International Telecommunication Union is a United Nations specialized agency. The federal government considers the ITU the principal competent and appropriate international organization for the purpose of formulating international treaties and understandings regarding certain telecommunications matters.

MHz[11] of spectrum for use by sovereign countries wishing to implement IMT-2000 (also known as third generation mobile wireless), including the 1755 to 1850 MHz band.[12] The United States agreed that it would study these bands domestically. Because of the significance of the services in this band of spectrum, the United States did not commit to providing additional spectrum for third generation systems.

Subsequent to WRC-2000, the President issued an executive memorandum on October 13, 2000, that outlined a policy to encourage cooperation among FCC, NTIA, other federal agencies, and the private sector to determine if additional spectrum could be made available for third generation wireless systems. In addition, the memorandum specified that incumbent users of spectrum be treated equitably, taking national security and public safety into account. The memorandum directed the Secretary of Commerce to work cooperatively with FCC to develop a plan to select spectrum for third generation wireless systems and to issue an interim report on the current spectrum uses and the potential for reallocation or sharing of the bands identified at WRC-2000. The plan established spectrum sharing and relocation options to be studied for implementation in the years 2003, 2006, and 2010. FCC, in conjunction with NTIA, was expected to identify spectrum by July 2001, and auction licenses to competing applicants by September 30, 2002.

Under the plan, NTIA studied the 1755 to 1850 MHz band and the FCC studied the 2500 to 2690 MHz band.[13] Within the United States, the 1755 to 1850 MHz band is allocated on an exclusive basis to the federal government for fixed and mobile services and satellite control. DOD is the

[11] According to NTIA, WARC-92 identified 1885 to 2025 and 2110 to 2200 MHz and WRC-2000 identified 806 to 960 MHz, 1710 to 1885 MHz, and 2500 to 2690 MHz.

[12] According to NTIA officials, WRC-2000 indicated that identification of these bands does not preclude the use of these bands by any services to which they are allocated and does not establish priority for third generation systems in the radio regulations. A DOD official said "identification" of spectrum for third generation mobile wireless systems does not create a treaty obligation on each party to a treaty to use particular spectrum for third generation systems.

[13] The 1755 to 1850 MHz band is a federal government band used primarily for fixed point to point microwave, air and ground mobile uses, and space operations. In the United States, the 2500 to 2690 MHz band is currently used by the Instructional Television Fixed Service (ITFS), Multipoint Distribution Service (MDS), and Multichannel Multipoint Distribution Service (MMDS).

predominant user, although 13 other federal agencies operate extensive fixed and mobile systems in this band throughout the United States.

To support NTIA's efforts to study the 1755 to 1850 MHz band, DOD issued a final report in February 2001. The report was prepared for DOD by the Office of Spectrum Analysis and Management, which is part of the Defense Information Systems Agency. In addition, responsibility for assisting in the development of cost estimates associated with implementing study results was assigned to the Department's Cost Analysis Improvement Group.[14] The study addressed whether the Department could share or vacate this band.

The Office of Spectrum Analysis and Management grouped military systems into five major categories. These categories included satellite operations, tactical radio relay, air combat training, weapons data links, and miscellaneous systems. Next, technical analyses were conducted to calculate the effects of potential spectrum interference between proposed commercial (third generation) and major military systems.[15] For example, DOD calculated the potential interference between selected DOD satellite ground stations and anticipated third generation wireless systems (mobile and fixed-base stations). DOD also calculated the potential interference from third generation wireless systems on DOD satellite operations. In another example of technical analysis, DOD selected two air combat training ranges, which were considered representative of all training areas in the United States, for analysis of potential spectrum interference. Finally, the military commands and the operational communities responsible for each major category of systems used the results of the technical analysis to estimate the extent of any operational impacts on their missions. Then, acquisition program officers provided cost estimates for the options of sharing or vacating the band.

DOD's spectrum report concluded that loss of access to spectrum, above and beyond the spectrum already transferred as a result of OBRA 93 and BBA 97, would jeopardize DOD's ability to execute its mission. Specifically, DOD concluded that it is unable to totally vacate the 1755 to 1850 MHz band until at least 2017 for space systems and at least 2010 for

[14] The Cost Analysis Improvement Group provides overall DOD guidance for accuracy of DOD cost analyses used in program acquisition decisions.

[15] DOD officials said their analysis incorporated expected performance characteristics of third generation mobile wireless systems derived from published sources and coordinated with NTIA and FCC.

non-space systems. DOD also found that full band sharing is not feasible. However, DOD said that the compressed schedule, initiated by the presidential memorandum and the Department of Commerce's plan, did not provide time for a thorough analysis and review of these complex issues.

NTIA issued a spectrum report on March 30, 2001.[16] Based in part on the DOD report, NTIA found that the unrestricted sharing of the 1755 to 1850 MHz band is not feasible and that any other sharing option would require considerable coordination between industry and DOD before third generation systems can be operated along with federal systems. Specifically, NTIA stated that there are several issues that must be resolved before any spectrum can be made available for reallocation in the 1755 to 1850 MHz band. These include reimbursement issues[17] and the assurance of availability of comparable spectrum if DOD must surrender spectrum in this band.[18]

On June 26, 2001, the Chairman of FCC wrote to the Secretary of Commerce stating that additional time is necessary to allow the Commission and the executive branch to complete evaluations of the various options available for advanced wireless services. FCC sought additional time to identify and schedule the auction of spectrum for third generation wireless services. FCC stated in its letter that it wanted to work with the executive branch and appropriate congressional committees to come up with a revised allocation plan and auction timetable for third

[16] NTIA's final report examined the potential for accommodating third generation mobile wireless systems in the broader 1710 to 1850 MHz band.

[17] The Strom Thurmond National Defense Authorization Act for the Fiscal Year 1999 (NDAA-99) (P.L. 105-251, Oct. 17, 1998) authorized federal entities to accept compensation payments when they relocate or modify their frequency use to accommodate non-federal users of the spectrum. These reimbursement provisions would be applicable to any spectrum that is or would be reallocated in the 1755 to 1850 MHz band. Both NTIA and FCC have issued notices of proposed rulemaking that address reimbursement provisions.

[18] The National Defense Authorization Act for Fiscal Year 2000 (NDAA-2000) (P.L. 106-65, Oct. 5, 1999) specified a number of conditions that have to be met if spectrum in which DOD is the primary user is surrendered. This act requires that NTIA, in consultation with FCC, identify and make available to DOD for its primary use, if necessary, an alternate band(s) of frequency as a replacement for the band surrendered. Further, if such bands of frequency are to be surrendered, the Secretaries of Defense and Commerce and the Chairman of the Joint Chiefs of Staff must jointly certify to relevant congressional committees that such alternative band(s) provide comparable technical characteristics to restore essential military capability.

generation systems that will allow completion of necessary work. In a July 19, 2001, letter responding to the FCC request, the Secretary of Commerce directed NTIA to work with FCC to develop a new plan for the selection of spectrum for third generation mobile wireless systems. The Secretary asked that this work be coordinated with appropriate executive branch entities, such as the National Security Council, the National Economic Council, the Office of Management and Budget, and DOD. He also encouraged participants in this process to consider ways to achieve flexibility with respect to the statutory auction dates if flexibility is needed to implement the new plan. For example, the 1710 to 1755 MHz band that is being considered for third generation purposes is under a statutory deadline for the auction of licenses by September 2002.[19]

Additional Analysis Is Required for Spectrum Decisions

DOD's February 2001 study does not provide a basis for decisions about reallocation of spectrum in the 1755 to 1850 MHz band. The study was constrained by lack of adequate guidance and by inadequate time and information. Thus, major considerations either were not addressed or were not adequately addressed in the final report. These considerations include complete technical and operational analyses of anticipated spectrum interference; cost estimates supporting DOD reimbursement claims, spectrum requirements supporting future military operations; programmatic, budgeting, and schedule decisions needed to guide analyses of alternatives; and potential impacts of U.S. reallocation decisions upon international agreements and operations. As a result, DOD's analysis was limited in its ability to adequately describe and document potential technical, operational, and cost impacts should the Department be required to vacate the 1755 to 1850 MHz band or to share it with commercial users.

In addition, neither the industry analysis nor the Air Force analysis of potential spectrum interference to DOD satellite systems provides an adequate basis for decisions about reallocation of the 1755 to 1850 MHz band from governmental to nongovernmental uses. The findings of both analyses, along with DOD's analysis of satellite interference, are not reliable or complete.

[19] Section 3007 of P.L. 105-33 provides that the Commission shall conduct the competitive bidding in such a manner as to ensure that all proceeds are deposited not later than September 30, 2002.

Importance of Analyzing DOD's Spectrum Needs and Requirements

Before making reallocation decisions with a significant impact on national security and the economic welfare of the nation, the federal government should approach the alternatives with knowledge gained from a sound and complete analysis. Given an adequate amount of time, information, and guidance, a study of DOD's spectrum needs and requirements could reduce operational and cost risks presented by critical spectrum reallocation decisions. The alternatives considered for making radio frequencies available to industry include DOD vacating the entire spectrum band or sharing all or part of the spectrum band with industry.

DOD based its analysis of potential operational and cost impacts on the premise that it could not accept any degradation of current mission capability from a complete or partial reallocation of its spectrum to other users. DOD also stated in its report that unrestricted sharing of the entire band with third generation mobile systems would place unacceptable operational restrictions on both DOD and commercial users of the band. These factors caused DOD to establish critical conditions that it believes must be met before it vacates or shares the 1755 to 1850 MHz band. These conditions include (1) alternative spectrum must be provided comparable to what the Department loses; (2) cost reimbursement must be timely as required under current law; (3) the Department must receive the same regulatory protection in any new spectrum as it now enjoys in the 1755 to 1850 MHz band; (4) defense systems must receive timely certification to operate in any new spectrum band; and (5) new commercial users in the 1755 to 1850 MHz band must be prohibited from interfering with DOD's legacy systems while they migrate into their new spectrum. The Department concluded in its report that these conditions could not be met in the short term and that it must have continued access to the 1755 to 1850 MHz band until at least the year 2017 for satellite systems and until approximately 2010 for other systems.

In its June 26, 2001, letter to NTIA, the Chairman of the FCC stated that the entire federal government faces a challenging set of issues in addressing how best to make available sufficient U.S. spectrum for advanced wireless services and that the public interest would be best served by additional time for informed consideration of these issues. DOD's February 2001 report also recognizes that additional analyses are needed to fully assess operational impacts and develop estimates of costs resulting from any spectrum reallocation or sharing.

Based on our experience and previous work on spectrum management issues,[20] we believe an analysis of spectrum reallocation affecting DOD would be more comprehensive if it included the following considerations:

- Additional technical and operational analyses to more completely reveal the impact of third generation wireless systems on military systems and any potential operational degradation of DOD systems.
- Additional analysis to estimate the cost of vacating or sharing the frequency band and the level of reimbursement.
- Identification of the expanding future communication requirements to allow DOD to include those requirements necessary for the envisioned warfare strategies, which rely heavily on wireless communications.
- Appropriate programmatic, budgeting, schedule, and technical guidance to the services and units conducting the analyses of the individual systems to define the scope and breadth of the analysis and prepare an accurate assessment of operational and cost impacts.
- Consideration of the impact of reallocation decisions on international agreements and operations. A national spectrum strategy could give DOD, FCC, and NTIA a guiding framework for decisions affecting training operations with allies, overseas deployments, and international treaty obligations. Spectrum reallocation impacts all of these areas.

Additional Technical and Operational Analyses Are Required for Spectrum Use Decisions

Due to time and information constraints on DOD's initial technical and operational analyses, further study is required in these areas. For example, the DOD report predicts interference to satellite operations from third generation wireless systems by the year 2006 and states that this interference could impede command and control of DOD satellites, especially low-earth orbit satellites. However, officials from the telecommunications industry have a different view. An industry analysis states that interference from third generation mobile wireless systems to DOD satellite receivers will be at acceptable levels and that sharing between these systems and DOD satellites is possible without any efforts to mitigate interference levels from the commercial systems. Our review of

[20] *Defense Communications: Federal Frequency Spectrum Sale Could Impair Military Operations* (GAO/NSIAD-97-131, June 17, 1997).

the DOD and industry reports, as described below, however, found that the two parties used different assumptions to calculate the extent of potential interference and the impact this interference will have on satellites. [21]

A third view of the potential interference from the commercial systems on DOD satellites is being developed by the Aerospace Corporation, a federally funded research and development center, for the Air Force. Aerospace officials said they are using many of the same assumptions industry used in its analysis but that they are also using techniques and assumptions not included in either the DOD or industry analysis. These officials told us that their results to date confirm the DOD position that third generation mobile wireless in the 1755 to 1850 MHz band could interfere with DOD operation of its satellites. However, Aerospace officials said they disagree with DOD on which satellites will be affected. According to these officials, the satellites affected by spectrum interference from third generation mobile wireless systems will be medium-earth orbit (20,000 kilometers) and high-earth orbit (36,000 kilometers) satellites, not the satellites in low-earth orbit as forecasted by DOD. When we spoke to Aerospace officials, they were starting to assess the effects of spectrum interference on the operations of specific types of satellites. These operational analyses are important for understanding the full effect of potential spectrum interference on satellite performance. For example, our review of Aerospace data suggests that estimated interference levels from third generation mobile wireless systems are high enough to adversely affect successful contact with the Global Positioning System (GPS).[22]

Each analysis led to a different conclusion because, while certain general engineering principles apply to estimating spectrum interference, no single methodology or model exists today to estimate potential spectrum interference to DOD satellite operations from third generation mobile wireless systems. As a result, each party used different methodologies and assumptions. In addition, our preliminary analysis of the DOD and

[21] See also appendix I.

[22] GPS provides worldwide navigation and timing data to both military and civilian users. The civilian market is estimated at approximately $10 billion dollars annually.

industry analyses indicates that questionable assumptions,[23] inadequate information, and a compressed schedule negatively impacted their analyses. One questionable assumption that was used in DOD and industry analyses was the assumption that cities would generate most of the spectrum interference to satellites and that contribution from suburban areas would be marginal. DOD officials said that including interference from suburban and rural areas or along interstate highways increases the projected amount of interference from third generation systems on the satellites. They said this interference could be severe enough to disrupt the command links to many satellites. However, DOD officials did not have time to revise their published analysis to incorporate this new information. Aerospace officials said they included an estimate for suburban and rural interference that neither industry nor DOD recognized in their reports.

With respect to inadequate information, all three analyses lacked essential information from industry about its plans for building and deploying third generation systems. The lack of good information about future industry plans for geographic coverage and density of third generation mobile wireless systems creates a very high level of uncertainty about the levels of energy from these systems that can cause interference with satellite operations and lessens the reliability of all three estimates. NTIA officials said this information was requested from industry representatives during a series of government-led industry outreach meetings between November 2000 and February 2001. NTIA officials said, however, that industry representatives refused to provide such information because it is proprietary and could not be shared with competitors. In addition, as we describe in appendix I, DOD may have significantly underestimated potential interference to control of its satellites because it incorrectly estimated the size of cities in its population database.

Another example of an incomplete technical and operational analysis is the DOD assessment of third generation systems on airborne, precision guided weapons training programs. These training programs use radio spectrum for data links between the aircraft and the air launched weapons within both the 1710 to 1755 and 1755 to 1850 MHz bands. The 1710 to 1755 MHz band was designated for reallocation from federal governmental to non-governmental use pursuant to congressional direction, but federal

[23] We analyzed the DOD and industry models to the point that we could replicate their estimates of the level of spectrum interference generated by the worldwide build-out of third generation systems. We reviewed the Air Force's model but did not attempt to replicate its findings.

operations can continue in the band within 16 protected zones.[24] According to NTIA officials, these sites were initially established by NTIA to protect DOD ground and air training functions.[25] However, in its March 2001 report, NTIA proposed, among other options, eliminating the 16 protection zones and relocating all systems in the 1710 to 1755 MHz band to the 1755 to 1850 MHz band or a higher band. According to NTIA, this proposal was necessary because no other solution was available to share the 1710 to 1755 MHz band with industry. The NTIA report noted that this proposal was not in the FCC and Commerce plan to identify spectrum for potential reallocation and had not been evaluated by DOD. Therefore, NTIA did not know how this proposal would affect DOD operations. DOD had not completed a review of this proposal at the time of our review.

The Air Force identified concerns to us about loss of spectrum in either band. Air Force officials said the frequencies in the 1710 to 1755 MHz and the 1755 to 1850 MHz bands operate as a pair,[26] and loss of either frequency would adversely affect the training operations in the other frequency. For example, Air Force officials told us the existing 16 protection zones in the 1710 to 1755 MHz band are already too small in land area to simulate realistic combat conditions, but eliminating them entirely would stop all operationally realistic training at these sites. In addition, an Air Force official stated that many training missions now flown on low level training routes over most of the continental United States would be severely degraded if further spectrum is lost in either band.

However, Air Force officials said that no new spectrum has been selected for training on precision guided weapons and that the total cost and operational impact of changing frequency bands have not been fully assessed. These officials stated that, at this time, any studies or analyses have been based on numerous assumptions and, thus, study results are preliminary. The cost of changing frequency bands could be substantial. Recognizing that these are preliminary estimates, Air Force officials believe that loss of spectrum in either band and moving to a higher band

[24] The Federal Power Administrations and public safety fixed links will also be protected.

[25] FCC disagreed with NTIA. According to FCC technical comments, Air Force operations were not identified to remain in this spectrum. FCC said retaining such operations would have a detrimental impact on any significant use of the spectrum for nongovernmental operations.

[26] Frequencies in both bands are used for the same missions.

could cost up to $580 million in new equipment development and take up to 10 years to complete.

Air Force and Navy officials managing precision guided weapons programs also cited lack of time and information as the main reasons for their inability to perform a detailed analysis. For example, these officials stated that they did not have adequate time to receive input from training bases and obtain technical information from the commercial providers of the weapons systems to determine the feasibility of band sharing or segmentation. DOD also said that it could not determine the amount of new engineering work required for the communications components of the weapons without knowledge of a new operating band.

The problems of a compressed time schedule and a lack of information make it difficult for federal agencies to reach a reasonable decision about reallocation of the 1755 to 1850 MHz band to nongovernmental uses. For example, a decision to exclude third generation mobile systems from this band because of potential interference to satellite or other operations could mean economic loss to industry. On the other hand, allowing these systems into the 1755 to 1850 MHz band when in fact they could interfere with satellite or training operations could mean a reduction in military preparedness, degradation of satellite performance, or even loss of satellites in orbit.

Additional DOD Work Required to Estimate Costs

We found that DOD—within time constraints, extensive programmatic uncertainty, and available guidance—produced reasonable cost estimates for the assumptions used in the studies. The cost estimates in DOD's report range from at least $2.8 billion to relocate major defense communications systems from segments of the band to in excess of $4.3 billion to fully vacate the band. However, the Department's cost estimates are incomplete because of program, budget, and technical uncertainties and could be underestimated by billions of dollars.

The DOD report acknowledges that its cost estimates are preliminary and states that they are not conclusive. According to the report, all of the cost estimates are sensitive to many complex technical and budgetary unknowns. For example, the report notes that implementation of interference mitigation measures can greatly enhance opportunities for spectrum sharing, but employing any of these techniques would require a new cost assessment that could dramatically alter the cost estimates in the report. In addition, Air Force officials told us they did not determine the cost of replacing entire satellite systems to make room for third generation mobile wireless systems before the year 2017. The DOD report states that the 1755 to 1850 MHz band is used to control over 120 satellites in orbit and that loss of this band before the year 2017 means it could no longer control satellites in orbit and would have to replace them. According to Air Force officials, they assumed continued access to the band for the life of existing satellites.[27] They said satellite systems, including spacecraft and related ground infrastructure, costing billions of dollars, would become useless if DOD were forced to vacate the 1755 to 1850 MHz band before the year 2017. While replacing these satellite systems would cost billions of dollars, Air Force officials also questioned whether industrial base or launch facilities exist to build and launch significant numbers of new satellites before the year 2017. The total system costs of these satellite systems suggest that the replacement costs would be significant.[28] For example, DOD estimates total GPS program costs at $18.4 billion over a 43-year period–fiscal years 1974 through 2016.[29] In a second example, the Defense Meteorological Satellite Program (DMSP) has a total program cost estimate through the year 2012 of $2.4 billion.[30] Therefore, the cost estimates could increase significantly if DOD is forced to vacate the 1755 to 1850 MHz band before 2017 and had to replace existing satellites before the end of their normal life cycle.[31]

Finally, DOD cost estimates on vacating the 1755 to 1850 MHz band cannot be completed until the alternative spectrum for DOD is identified. To date, NTIA has not been able to identify alternative and comparable spectrum available for federal use to replace the 1755 to 1850 MHz band. DOD's report states that relocation costs could vary depending upon the bands selected as replacements for lost spectrum in the 1755 to 1850 MHz band.

[27] Air Force officials assumed that all satellites launched after the year 2010 would be capable of using the Unified S- band (2025 to 2110 MHz band). However, as of June 2001 Air Force officials told us no decision had been made to move to this band.

[28] The Acting Assistant Secretary of Defense for Command, Control, Communications, and Intelligence testified on July 31, 2001, before Congress that the more than 120 satellites represent a cumulative investment of about $100 billion.

[29] The GPS system is totally DOD funded, about $9.0 billion has been invested to date and about $9.4 billion is planned to be invested.

[30] The DMSP system is totally DOD funded and provides weather information primarily for the military.

[31] The National Security Council said that if relocation costs were incurred because of international developments, the federal government may not be entitled to full reimbursement.

A change in spectrum bands for weapons data links, for example, could require either an extensive engineering redesign of antennas and other radio equipment on both weapons and the aircraft delivering the weapons or essentially a new major systems development program – depending on the new spectrum band selected. In another example, changes to frequencies used by existing satellites awaiting launch could delay the launch by years in order to develop and manufacture key components for the new frequencies.

Without complete cost estimates for the reallocation of spectrum, the Department cannot ensure that it is receiving a fair reimbursement value for the costs the Department incurs to vacate or share the 1755 to 1850 MHz band. Ultimately, if the Department is not fully reimbursed for the costs of reallocation, the government would be responsible for the funds needed to ensure that national defense is not degraded.

Future Military Spectrum Requirements Not Considered

DOD's report does not describe future spectrum requirements necessary to meet the Department's growing communications needs. The Defense Science Board's (DSB) November 2000 study on spectrum issues concluded that the Department's need for spectrum is escalating rapidly as "information superior" forces become a reality and deploy.[32] DSB said wireless communication is particularly critical for the type of geographically dispersed warfare contemplated in future concepts of the individual services, such as the Marine Expeditionary Forces.[33] The Board's study stated that the Department requires a proactive, needs-based strategy supported by detailed knowledge of DOD's spectrum requirements. DSB recommended the Department expand an ongoing internal requirements study into an inventory of current and future defense spectrum needs linked to military capabilities.

The Department's spectrum report acknowledged that it is highly likely that new defense requirements for this band and other military spectrum bands will arise. However, the DOD spectrum report does not discuss future spectrum requirements in any depth and does not attempt to

[32] Joint Vision 2010 establishes the DOD warfighting vision and defines "information superiority" as the key enabler of the operational concepts of Joint Vision 2010.

[33] A Marine Expeditionary Force is a warfighting arm of the Marine Corps that is composed of about 45,000 personnel from a Marine division, various support activities, and a Marine aircraft wing.

quantify the requirements for the new systems. A Joint Chiefs of Staff official said that an analysis of future requirements was outside the scope of the report. After the report was issued, DOD provided us general forecast information about fixed and mobile spectrum requirements. This information projected an increase in mobile spectrum requirements, below 3 gigahertz, of 92 percent by the year 2005; fixed requirements increasing by 60 percent by the year 2007; as well as more than 600 MHz of spectrum for training by the year 2005. According to the information provided, any sharing arrangement with third generation mobile wireless users in the 1755 to 1850 MHz band may not be workable in the longterm, unless DOD freezes its spectrum requirements in this band.

We recognize that DOD's requirements are likely to change as new systems, technologies, and strategies are developed for the nation's future warfighting force. However without a better understanding of future requirements, DOD increases its risk of losing access to bands of spectrum necessary for future mission needs.

DOD Analysis Requires Additional Programmatic, Budgeting, and Schedule Guidance

We also found that key programmatic, budgeting, and schedule decisions had not been provided to appropriate command and operational units to help prepare DOD operational and cost estimates. These decisions are necessary to guide the Department's analyses of alternative courses of action to either share the spectrum or vacate the spectrum band.

For example, Army Mobile Subscriber Equipment (MSE) program officials were uncertain about how band sharing would be accomplished for operational and cost analyses. Because of this uncertainty and the time constraints to complete the study, they chose a general, high-level approach that did not consider important factors with operational and cost implications in their assessment of the MSE program.[34] Under this high-level approach, the Army did not include the operational and cost impacts of relocating reserve units to accommodate training requirements or costs at individual bases to implement band sharing. In addition, the Army based its analysis on the assumption that the accelerated development and production of the High Capacity Line of Sight radio would replace the MSE radio. However, Army assumptions about accelerating production of the replacement radio have not been approved in the DOD budget and would require additional funding and

[34] The MSE system consists of line of sight trunk radios linking switching centers.

reprogramming of funds to earlier years. In addition, replacing the MSE radio with a new radio may not solve the Army's tactical radio communication problems should DOD have to share the 1755 to 1850 MHz band with third generation mobile wireless users.

In another example of inadequate program and budget guidance, the Joint Program Office for the Joint Tactical Air Combat Training System (JTCTS) based its operational analysis on a plan to accelerate development and fielding of that system,[35] but Navy and Air Force sponsors of JTCTS had not formally reviewed or approved this accelerated plan. In July 2001, DOD officials told us the contract for this program had been cancelled because of schedule and performance problems. According to these officials, no schedule has been approved for a new program, and any equipment from a new program could not be fielded until at least the year 2014.

Without programmatic, budgetary, and scheduling guidance, command and operational units risk uncertainty when assessing alternatives and making assumptions in their analyses. Thus, the resulting operational and cost estimates will also be uncertain.

Reallocation Effects on International Agreements and Overseas Operations Not Described

The DOD report does not recognize or discuss planned development of commercial wireless systems in other countries. Instead, it focuses on potential operational degradation that may be caused by sharing the 1755 to 1850 MHz band with commercial wireless systems in the continental United States. The services may need to operate on the same frequencies overseas as they train on in the United States, and spectrum allocation decisions in foreign nations could prevent the United States from using these frequencies in other countries. According to a Joint Chiefs of Staff official, the Joint Staff has produced several documents advocating greater flexibility through the use of multiple frequencies in new defense systems for overseas operations. However, the official said an analysis of overseas operations was outside the scope of the DOD report.

Omission of any discussion of foreign spectrum developments creates an unrecognized risk for DOD overseas operations, particularly DOD's

[35] JTCTS is the next generation of aircrew training systems displaying weapon and aircraft information in real-time. It is intended to support "rangeless" training that current systems cannot support.

control of its satellites. The International Telecommunication Union has identified the 1710 to 1885 MHz band as one of several bands for possible use by third generation mobile wireless systems worldwide. Overseas development in this band over the long term by current second generation commercial wireless systems or future development of this band by third generation wireless systems could result in spectrum interference with U.S. satellites.[36] Thus, DOD may have problems in the future controlling its medium- to higher-earth orbit satellites from ground stations in the United States because spectrum interference from overseas development of commercial wireless systems in this band could be visible to these satellites.[37] This interference could occur even if the United States does not allow commercial use of the 1755 to 1850 MHz band in this country.

Unilateral reallocation of the 1755 to 1850 MHz band by the United States could also have a potential negative impact on U.S. international spectrum agreements and overseas military operations. For example, DOD provides communications support to Great Britain and the North Atlantic Treaty Organization (NATO) within the 1755 to 1850 MHz band in the United States. Further, military air combat training systems in this same band are used by allied nations during training in the United States. The National Telecommunication and Information Administration Organization Act, as amended,[38] requires, among other things, that NTIA, before acting on a petition for relocation, determine that any proposed use of spectrum frequency to which a federal entity will be relocated is consistent with obligations undertaken by the United States in international agreements, national security and public safety interests. Also, the proposed use must be suitable for the technical characteristics of the band.

The November 2000 DSB study noted that the United States does not have a national spectrum strategy that addresses international issues. The Board said that international spectrum usage by DOD is governed by treaty, status of forces agreements,[39] and other arrangements with allied

[36] NTIA officials said the ITU identified several other bands for potential third generation wireless use but that such identification does not preclude use of any of these bands by any services to which they are now allocated and that no priority is accorded to third generation wireless systems in the radio regulations.

[37] NTIA officials expect deployment overseas will not occur first in the 1710 to 1885 MHz band but in other bands recently auctioned throughout the world.

[38] 47 U.S.C. sec. 923(g)(2)(D).

[39] Status of forces agreements and other arrangements govern interactions of U.S. forces deployed overseas with foreign governments.

nations. The Board also recognized that other nations are asserting their sovereign rights to manage their own spectrum, complicating deployments of U.S. forces abroad. The Board recommended that the National Security Council develop a national strategy given the increasing domestic and international private sector demand for spectrum and the importance of spectrum to national security. NTIA officials told us that federal agencies requiring spectrum in other countries must work directly with foreign countries because NTIA does not have responsibility or authority to develop plans for federal use of foreign spectrum. For example, they said DOD must press its strategic plans in NATO via country-to-country alliances and develop international support for its requirements at international radio conferences.

In the United States, there is a national allocation table wherein some 45 radiocommunication services are allocated spectrum. According to NTIA, the allocation table and existing spectrum management processes constitute a basic U.S. strategic spectrum plan, which covers all cases of spectrum use. However, the national allocation table only reflects the current landscape of spectrum use and does not provide a framework to guide spectrum decisions into the future.

The Chairman of the FCC has also expressed support for overall improvement of spectrum planning through a more coherent, nationally harmonized spectrum policy. He said FCC is trying to improve overarching coordination of the many existing policies within the Commission, but critical spectrum is also controlled by other parts of the federal government, each with its own area of responsibility. He said the administration and Congress both play critical roles in allocating scarce spectrum resources to the highest and best uses.

Conclusions

Original plans for identifying spectrum to support third generation mobile wireless systems by July 30, 2001, and to auction licenses by September 30, 2002, were premature. We agree with FCC and the Department of Commerce that delaying the identification of spectrum and the auction of licenses for third generation wireless systems could serve the public interest. Adequate information is not currently available to fully identify and address the uncertainties and risks of reallocation. Thus, DOD and the federal government could make decisions affecting national security without knowing the full extent of risks they face or the steps available to reduce those risks.

Extending the current schedule for identification and auction of licenses for this portion of the spectrum would allow DOD to complete technical and operational assessments and to consider future spectrum requirements of DOD systems. In addition, a delay would allow the federal government and DOD to further consider the adequacy of existing national spectrum strategies affecting international agreements and DOD overseas military operations, to modify these strategies as necessary, and to incorporate these strategies into a DOD long-range spectrum plan. Also, identifying potential alternative bands of spectrum would provide DOD with needed information to complete its technical, operational, and cost assessments. Including relevant national and DOD strategies into spectrum reallocation decisions would allow a more informed decision that balances national security interests and private interests. These strategies could also guide detailed studies that develop adequate measures to reallocate that spectrum and develop detailed cost estimates before any auction is scheduled.

Recommendations for Executive Action

To more accurately assess the potential impacts to DOD if the 1755 to 1850 MHz band is selected for third generation systems in the United States, we recommend that the Secretary of Defense

- complete a system-by-system analysis to determine existing and future spectrum needs and requirements of systems in the 1755 to 1850 MHz band;
- prepare a long-range spectrum plan and make programmatic decisions necessary to carry out that plan; and
- complete the technical, operational, and cost assessments of satellite systems in the 1755 to 1850 MHz band and review and complete assessments of other systems as necessary.

To provide DOD with adequate time and guidance to complete its plans and analysis, we recommend that the Secretary of Commerce

- incorporate a sufficient amount of time into the new NTIA plan to select spectrum for third generation mobile wireless systems to address the issues discussed in this report, specifically with respect to satellite operations;
- direct NTIA, in conjunction with FCC, to identify comparable alternative spectrum for use by the DOD systems before a decision is made to

reallocate the 1755 to 1850 MHz band, should such an action be contemplated; and

- coordinate with appropriate executive branch agencies to review existing national spectrum management plans and policies, and, if necessary, to establish a clearly defined national spectrum strategy reflecting DOD requirements for international agreements and spectrum requirements to operate overseas.

Agency Comments and Our Evaluation

In commenting on a draft of this report, DOD, FCC, and the Department of Commerce agreed with our findings and recommendations. All three agencies and the National Security Council also provided technical comments to ensure completeness and accuracy, and to provide clarity and balance. These comments were reviewed and incorporated into our report as necessary.

We also clarified our recommendation that the Secretary of Commerce identify alternative spectrum for DOD use before any reallocation decision. We included DOD's suggestion that NTIA work in conjunction with FCC to identify possible nongovernmental spectrum for DOD use.

DOD, the Department of Commerce, and FCC comments are reprinted in appendixes III, IV, and V, respectively.

Scope and Methodology

To determine whether the DOD process to define defense spectrum needs in the 1755 to 1850 MHz band experienced material constraints and whether the final analysis and findings of the DOD report are complete or need further work, we reviewed the Department’s data collections plans and visited selected field locations, commands, and program offices to review implementation of these plans. We also discussed data collection issues and related cost issues with officials from the Office of the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence; the Joint Chiefs of Staff Communications Division; the Office of Spectrum Analysis and Management; and individual service spectrum management offices. In addition, we reviewed findings and supporting material in the Department’s February 2001 spectrum report. We reviewed selected issues within the Department’s technical analysis and a separate technical analysis prepared by a communications industry working group. We also met with DOD and industry officials responsible for preparing these technical analyses to obtain further information and to discuss our findings on these issues. We reviewed material presented by Aerospace officials and conducted a telephone conference with those officials.

(See appendix II for details of our analysis.) In addition, we met with NTIA and FCC officials to discuss proposed rulemaking actions on spectrum related issues.

We conducted our work from November 2000 through June 2001 in accordance with generally accepted auditing standards.

We are sending copies of this report to appropriate congressional committees. We are also sending this report to the Secretary of Defense, the Secretary of the Air Force, the Secretary of the Army, the Secretary of the Navy, the Secretary of Commerce, the Chairman of the Federal Communications Commission, and the National Security Council. We will make copies available to others upon request. The report will also be available on our homepage at http://www.gao.gov.

If you or your staff have any questions concerning this report, please call me on (202) 512-4841 or Charles Rey on (202) 512-4174. Other major contributors to this report were Rahul Gupta, Arthur Fine, Robert Hadley, Judy Lasley, Gary Middleton, Keith Rhodes, Joseph Rizzo, Jay Tallon, and Dr. Hai Tran.

Sincerely yours,

Allen Li
Director
Acquisition and Sourcing Management

Appendix I: Spectrum Interference From Third Generation Systems to DOD Satellites

While certain general engineering principles apply to any estimation of spectrum interference, no single agreed-upon methodology or model exists today to estimate potential interference to Department of Defense (DOD) satellite operations from third generation mobile wireless systems. DOD satellite operations control more than 120 satellites and their payloads, including launch and early orbit operations, transmission of mission data, on-orbit operations, and emergency and end-of-life operations. These satellites provide for missile warning, navigation, military communications, weather, and other defense missions. Specific satellites controlled or served by DOD include (1) the Global Positioning System, which provides navigational data and precise time transfer capability to military and civilian users worldwide and (2) the Defense Satellite Communications System, which provides essential command and control communications. DOD controls these satellites through a set of common and dedicated Air Force Space Command and Navy satellite control sites both inside and outside the United States. This control is exercised through the Space Ground Link Subsystem of the Air Force Satellite Control Network or through other dedicated (mission specific) satellite control networks. Agencies and other government users served include the National Command Authority, DOD, Combatant Commanders, the Federal Aviation Administration, and National Aeronautics and Space Administration. Because some DOD satellites-most notably the Global Position System-broadcast information on an unrestricted basis, DOD satellite control also supports civil and commercial interests.

Developing a standard methodology to estimate potential spectrum interference to DOD satellite operations from third generation mobile wireless systems is particularly challenging because key assumptions must be made not only about the technical characteristics of mobile wireless systems to be fielded many years in the future, but also about the extent to which these systems will be deployed worldwide in urban, suburban, and rural environments. Unlike other DOD systems, satellites are unique in that they may be exposed to the aggregate level of interference emanating from significant portions of the globe. Moreover, because some DOD satellites may need to operate within the 1755 to 1850 MHz band until at least 2017 (and perhaps as late as 2030), interference estimates must consider the extent of third generation mobile wireless systems (IMT-2000) build-out over the next several decades. We reviewed, in detail, two models–a DOD model and an industry model–that took different approaches to estimating the level of interference DOD satellites could experience from this worldwide build-out. The level of interference predicted by these two models differed significantly. We also performed a limited review of a third Air Force model being developed by the

Aerospace Corporation, a federally funded research and development center. The Aerospace Corporation is developing its model in support of the Air Force's Space and Missile Systems Center and Air Force Space Command to better understand why the DOD and industry models produced such different results and to attempt to develop a trusted and credible interference model to generate results that all stakeholders can agree upon and that can be adopted as the standard in support of key decisions.[1]

Summary

We found that neither the DOD nor industry model is fully mature and that they differ strikingly from one another in many of their key assumptions. In our opinion, neither model is mature enough to support a near-term decision by the United States regarding whether DOD satellites can share spectrum with third generation mobile wireless systems, and both incorporate questionable assumptions that drastically influence their predicted level of spectrum interference. Moreover, because IMT-2000 will be a worldwide system and because the International Telecommunication Union has identified the 1710 to1855 MHz band (among other bands) for use by countries wishing to implement IMT-2000, some degree of spectrum sharing could become unavoidable regardless of any reallocation decisions made within the United States. If the aggregate level of the non-U.S. interference in the 1755 to 1850 MHz band proves to be significant, DOD satellites could be adversely affected by overseas deployment of IMT-2000.

As a result of this uncertainty, DOD faces an unquantified risk of operational degradation to its satellite operations if a decision is made to allow industry into the 1755 to 1850 MHz band in the United States before more accurate information is available upon which to base a decision. However, DOD may face such a risk irrespective of that decision due to overseas build-out of IMT-2000.

[1] We analyzed the DOD and industry models to the point that we could reproduce their estimates of the level of spectrum interference generated by the worldwide build-out of third generation systems. We reviewed the Air Force model but did not attempt to replicate its findings.

Different Analytical Approaches

DOD and industry studies do not agree about how to predict the level of potential interference to satellite receivers from the worldwide build-out of third generation wireless systems or about the effect of this interference on satellite operations. DOD predicts interference levels significant enough to affect satellite operations by the year 2006, particularly for low-earth-orbit satellites. Industry, on the other hand, predicts interference levels that are too low to adversely affect DOD satellite operations until at least the year 2015 and perhaps never. The Air Force model incorporates features more closely aligned with industry's methods. However, the Air Force model's worst-case results for operating under nominal conditions agree with the DOD report's overall conclusion that third generation wireless systems present potential interference problems to DOD satellites. The Air Force model's analysis suggests, however, that interference is much less likely to occur with low earth-orbit satellites (as DOD had concluded) than with medium and high earth-orbit satellites. For example, the Air Force model's analysis suggests that, under certain modeling conditions, the Air Force may experience difficulty communicating effectively with Global Positioning System and Defense Support Program satellites because of interference from the build-out of third generation systems.

A number of key data elements are necessary to finalize estimates of potential third generation wireless systems interference to DOD satellite operations. First, the locations and sizes of the geographic areas most likely to be served by the mobile wireless industry must be properly estimated, and translated into an estimate of the number of third generation base stations needed to serve each geographic area. Second, the amount of power needed by each base station to communicate with mobile units within its area of coverage (typically referred to as a mobile wireless base station's "cell") must be calculated. Third, the fraction of that power that will reach the satellite must be estimated. In addition, assuming some level of consensus can be reached regarding the best assumptions and methodology for predicting the level of interference at satellite orbital altitudes from the worldwide build-out of third generation wireless systems, the operational impact of this interference on DOD's ability to communicate with particular types of satellites from specific satellite control sites (both within and outside the United States) under specific operating conditions would need to be fully analyzed and presented to key decisionmakers before reasonable decisions can be made.

Third Generation Mobile Wireless Base Station Coverage Areas

While they disagree on the specifics of the interference estimates, both DOD and industry agree that low-power mobile stations are much less likely to cause significant interference with DOD satellite operations. However, they disagree about the potential interference to satellite operations from much higher-powered base stations. Each base station services a cell of a given size-up to about 10 kilometers in radius (or 314 square kilometers), although smaller base stations are more likely to be used within dense urban environments. Both DOD and industry agree that the first step in determining the interference generated by IMT-2000 base stations is to estimate the area of each geographic region likely to be served by third generation mobile wireless systems. However, neither DOD nor industry was able to locate a comprehensive database of the actual areas (geographic dimensions) of the world's population centers. The only information readily available to both was the geographic location and population of the world's largest urban centers-generally those with a population of 100,000 or more. Thus, both DOD and industry used the population of each urban center to estimate how much land area that population lives on. Those area estimates were then used to determine the interference contribution from base stations within that area. DOD's approach did not explicitly estimate the number of base stations required to service a given area. Rather, DOD assumed that the power radiated per unit area from IMT-2000 base stations would be a constant derived from reports and recommendations of the International Telecommunication Union, and then multiplied this constant by the estimated size of each urban area to determine the power radiated from that area. Industry's methodology used their estimated size of each service area to calculate the number of maximum-sized (10 kilometer radius) base stations that would be needed both to service that area, and to serve as an "upper bound" on the estimate of total power radiating from that area if smaller, more numerous base stations were used.

The first problem we identified is that both the DOD and industry models are likely to have significantly underestimated the total number and size of areas (urban, suburban, and rural) that are potential markets for third generation systems. This problem exists, in part, because no standard definitions exist of the most likely market areas for third generation mobile wireless systems. The International Telecommunication Union identified potential uses of third generation systems for urban, suburban, and rural markets, but detailed forecasts of IMT-2000 build-out are not available. Thus, both models are based on incomplete and inconsistent databases as a source to calculate the number of urban centers and other potential areas for service delivery.

For example, DOD used a database of 2,763 urban centers worldwide, of which approximately 320 were urban centers within the United States.[2] Industry used a database of 3,312 urban centers worldwide, of which approximately 209 were urban centers within the United States. However, both of the databases included only capitals and urban centers with populations over 100,000. The databases excluded many urban centers below 100,000, as well as suburban and rural areas. The Air Force model uses the same database of 2,763 urban centers used by DOD. However, the Air Force's model also includes an estimate of rural geographic areas that could be served by third generation systems. The Air Force is working to improve the overall quality of its population database. A 1990 U.S. Census Bureau report indicates that, within the United States, there are 224 urbanized areas[3] with a population of more than 100,000, and 396 urbanized areas with a population of more than 50,000; many of the additional 172 urbanized areas with a population between 50,000 and 100,000 are not included in any of the three models.

The population estimates for both the DOD and industry models are also incomplete because they do not include any estimate of population growth. The Air Force's model includes an estimation of the population growth based on population databases from 2 different years. DOD estimates the lifetime of a number of satellites may extend until 2017 and beyond, and perhaps until as late as the year 2030. Another indicator that service areas may be significantly underestimated is the FCC report on broadband (high data rate) use in the United States. This report documents high speed Internet access in 59 percent of the postal zip codes in the United States; according to the report, 91 percent of the U.S. population is in these zip code areas. We believe it is reasonable to expect that these counties would be candidates for third generation systems.

The second problem is that the DOD and industry models used different equations to estimate the geographic area covered by their urban centers. Both models analyzed 1990-era census data for a number of urban centers whose areas are known to estimate the size of the rest of urban centers in their databases. However, each model used different coefficients to

[2] Best estimate based on urban center locations; the database of urban centers used by DOD was not coded by country. Moreover, the origins of this database were not well documented.

[3] The United States' urbanized areas are defined by the U.S. Census Bureau. Each consists of at least one central city or place and its urban fringe.

calculate urban center size from population. Industry urban center sizes were bigger than DOD urban center sizes, but the Air Force model estimates urban center sizes are bigger than either DOD or industry estimates. In addition, DOD used only three urban centers in the United States, and five urban centers outside the United States, to obtain an average and appears to have used incorrect numbers for urban center size for two of the three U.S. urban centers. Thus, DOD calculated an average urban center size of 144.2 square kilometers per 1 million of population. Using 1990 U.S. census data, we calculated an average size for the 396 urbanized areas of about 1,000 square kilometers per one million people, or about seven times as much area for a population of the same size.

DOD recognizes that its database may significantly underestimate potential interference coming from rural and interstate highway base stations and smaller urban areas that will likely be served by third generation systems. According to DOD officials, their preliminary calculations suggest that even partial coverage of rural U.S. interstate highways alone will result in the deployment of thousands of additional high-power base stations. The industry model did not include any estimate for rural interference. The Air Force's model included estimates of interference from urban, suburban, and rural areas. According to Aerospace Corporation representatives, results from this model showed that significant interference came from rural areas.

Power Requirements for Each Base Station

Once the number of base stations is determined, the next required data element is how much power each base station must use to service mobile stations within its cell. DOD and industry disagree markedly in their estimate of power radiating from the area covered by an individual 10-kilometer radius cell served by a single base station. Industry placed an effective upper bounds of 30 watts of power for this 314 square kilometer area.[4] Using this set of assumptions, DOD's ITU-based method for calculating power from this 314 square kilometer area would be about 2,600 watts of power, or nearly 100 times as much power. As noted above, DOD's analysis did not explicitly label this area as the service area of a large base station. The Air Force's model calculated the level of power required to service a geographic area, taking into consideration the propagation model suitable to a particular area. Their results showed that

[4] Based on IMT-2000 technology over a 200 kHz bandwidth.

power radiating from an urban area would be significantly greater than predicted by industry, but considerably less than predicted by DOD.

According to Aerospace Corporation representatives, the Air Force's model uses a higher power level than industry because their investigation of second generation wireless systems suggests that power loss from each base station is higher in urban areas than industry assumed. Buildings in urban areas significantly lower distance covered by base stations. Industry assumed that the power radiated from IMT-2000 base stations would be proportional to the square of the base station cell's radius irrespective of the propagation environment. For example, a 314 square kilometer rural area, served by a single 10-kilometer base station, would radiate essentially the same amount of power as an urban area of the same size, served by 100 1-kilometer base stations. According to Aerospace Corporation representatives, the Air Force's model relies upon calculations of the specific distances that a base station could complete a call to a mobile unit, resulting in significantly higher estimate of power levels required of urban base stations within each area served by those base stations.

Base Station Power Radiated Into Space

The third required data element is a calculation of the amount of power from all base stations that reaches the satellites. Power from third generation systems reaching a DOD satellite is the sum of contributions from all of the base stations in view of that satellite at any given moment in time, and that contribution is the power each station generates times the fraction of the amount of that power that arrives in space at the satellite's orbital altitude. After attempting to determine the number of base stations and the power level required by urban base stations, the next issue is to determine how much of the power generated by each base station actually reaches DOD satellites. The International Telecommunication Union provides little guidance for estimating interference from IMT-2000 ground base stations to satellite operations.

The answer to this issue depends on two factors: (1) the way in which a base station's antenna concentrates the power it transmits in certain preferred directions (generally referred to as the antenna's gain pattern), and (2) how much power radiated by a base station's antenna is lost to atmospheric and other environmental effects before reaching orbital altitude. DOD assumed that each base station's antenna radiates power isotropically–that is, equally in all directions, but that 90 percent of this power would be lost due to environmental factors. Industry, on the other hand, employed an antenna gain pattern that assumes that the power radiated from a base station would be greatest at low elevation angles (directed just below the horizon), and that only a small fraction of the base station's power would be directed toward satellites that are not at or near the horizon. Industry further assumed that, at low elevation angles, 90 percent of the base station's power transmitted in that direction would be lost to the environment, but that most or all of the power radiated at high elevation angles would reach space. However, as noted above, overall the power radiated at high elevation angles represents a very small portion of the base station's radiated power. For intermediate elevation angles, industry assumed that power loss would fall between these two values – 0 and 90 percent. The Air Force's model employed the same antenna gain pattern as industry, but assumed that, other than at very low elevation angles, only a small fraction of this power would be lost to the environment before reaching space. As noted earlier, the Air Force's model still found potential problems from third generation wireless systems to satellite operations.

Calculating power levels reaching satellites is also difficult because data do not exist today to prepare a baseline, which can be compared to power levels projected for third generation systems. Commercial systems now operate in the 1755 to 1850 MHz band overseas, and DOD has military systems operating in this band within the United States and overseas. However, DOD officials said they have no data on existing second generation system base stations and deployment patterns. DOD officials told us that no interference has been experienced to date with satellite operations because overseas mobile unit densities on a given satellite control channel are much lower than those expected for third generation systems.

Operational Impact of Potential Interference

Assuming some consensus can be reached regarding how much power from IMT-2000 systems is likely to reach orbital altitudes, agreement would still be required on how this level of interference is likely to affect satellite operations. This analysis is complicated by the fact that, under any modeling assumptions, IMT-2000 interference is likely to vary greatly over the orbital "shell" at a given latitude, particularly for low-earth orbits. Moreover, each type of satellite can be affected differently by interference from third generation wireless systems because (1) any specific type of satellite can follow a different orbit, (2) the technical characteristics of satellites are different, and (3) each type of satellite has different abilities to respond to DOD commands in the presence of interference because the mission of each satellite type is different.

Neither DOD nor industry attempted a technical or an operational analysis on each satellite to determine how specific satellites can be affected by third generation interference from specific satellite control sites.[5] Instead, they both assumed a standard response irrespective of specific satellite characteristics. However, DOD does acknowledge that parameters that can affect its ability to communicate vary from satellite to satellite. As a result, accurate and complete information is not available to determine if operational workarounds can be planned to avoid loss of control or degraded satellite operations.

The Air Force's model suggests potential interference problems from third generation base stations for DOD satellites. The Air Force model's results were, in fact, close to the DOD results, even though its methodology was closer to that of industry. However, because it recognized the differences between satellite types, the Air Force is also using its model to analyze the potential effects from third generation wireless systems on specific types of satellite operations. The Air Force's analysis calculates interference values for several types of satellites through their entire orbits, and calculated probability of successful contacts for those satellites at any given point in their orbits. For example, the Air Force model's output data show that interference levels for the Global Positioning Satellite were high enough, under certain modeling assumptions, to prevent successful contact, with an acceptable margin of safety, for approximately 60 percent of an orbit. The Air Force model's output data, however, has not yet presented interference levels for the period of time that the satellite is in sight of a specific ground station. Thus, the probability of successful contact is not available for each satellite at each ground station. Such an analysis is necessary to determine if alternative satellite contact plans can be devised to enable successful contacts.

The Air Force study recognizes that specific operational impact analyses should be performed for all ground stations and DOD satellites. The study recommends that the Air Force model be evolved to include (1) improved population modeling, (2) modeling of satellite contacts from specific

[5] We recognize that industry may lack the information to perform such a detailed analysis.

ground stations (3) analysis of operations under both nominal and adverse conditions, and (4) inclusion of more types of DOD satellites.

Appendix II: Replication of DOD's and Industry's IMT-2000 Base Station Interference Models

Summary

DOD and industry each developed models to predict the level of interference to DOD satellites that could arise from the worldwide build-out of IMT-2000 base stations. The level of interference predicted by these two models differed significantly. In order to determine whether DOD's and industry's interference calculations could be reproduced and to obtain a better understanding of the factors contributing to the differences between DOD's and industry's results, we replicated DOD's and industry's interference models. We also reviewed a third IMT-2000 interference study being developed for the Air Force by the Aerospace Corporation, but did not attempt to reproduce its findings. This appendix briefly describes DOD's and industry's approaches to modeling IMT-2000 interference and our approach to reconstructing those two models, and offers several observations regarding the differing assumptions used by DOD and industry for various components of their interference models.

Our replication of DOD and industry models was based on (1) the mathematical descriptions of the models provided in the referenced studies, (2) copies of the population databases used in each study (which we obtained from DOD and industry representatives), and (3) equations adopted from a standard space mission planning textbook that describe the geometrical relationship between a point on the surface of the earth and a point in space at a satellite's orbital altitude. To clarify certain matters regarding calculations used in these models, we also met and corresponded with DOD and industry representatives on several occasions. As shown in tables 2 and 3, we were able to reproduce both DOD's and industry's estimates for peak IMT-2000 interference levels to within about 0.1 dB for most orbital altitudes.

DOD's and Industry's Approaches to IMT-2000 Interference Modeling

Each analysis led to a different conclusion because, while certain general engineering principles apply to estimating spectrum interference, no single methodology or model exists today to estimate potential spectrum interference to DOD satellite operations from third generation mobile wireless systems. DOD's IMT-2000 interference model is described in DOD's final report on accommodating IMT-2000 within the 1755 to 1850

MHz band.[1] Industry's model is described in the Report of the Working Group on Satellite Control Systems.[2]

Each model incorporated a database describing the physical location (longitude and latitude) and population of the world's largest urban centers, assumed that IMT-2000 service would be provided within the 1755 to 1850 MHz band at each of these locations, and then approximated the size (geographic extent) of each urban center using a model-specific parametric equation to relate an urban center's population to its geographic area. For each geographic area, both models then computed the aggregate power spectral density (PSD) that would radiate from all of the IMT-2000 base stations needed to provide service within that geographic area. To reduce the computational complexity of this calculation, both models assumed that, for typical orbital altitudes, the aggregate PSD received from all of the IMT-2000 base stations within a given urban area could be closely approximated by a point source at the center of the geographic area whose PSD is the sum of the PSD from each IMT-2000 base station operating within the area served. Both models then employed link budget calculations to compute the interference contribution from each urban center at any given point S on an "orbital shell" defined by the altitude of a class of satellites. In logarithmic form, the interference contribution for each visible urban center is given by:

$$I_R = 10 \times \log(I_T) + G_T - 32.44 - 20 \times \log(r_{km}) - 20 \times \log(f_{MHz}) - L_E \qquad [1]$$

where:

I_R = power spectral density received at S from the urban center in decibel watts per Hertz

[1] *Department of Defense: Investigation of the Feasibility of Accommodating the International Mobile Telecommunications (IMT) 2000 Within the 1755-1850 MHz Band*; (Feb. 9, 2001).

[2] *Evaluation of Sharing between International Mobile Telecommunications (IMT) 2000 Technology and Satellite Control Systems Operating in the Band 1755-1850 MHz* (Feb. 19, 2001) [Note: This report was filed with the Federal Communications Commission as Attachment II of the *Report of the Industry Association Group on Identification of Spectrum For 3G Services* (Feb. 22, 2001) in response to the Commission's notice of proposed rulemaking on 3G.]

I_T = power spectral density transmitted from the urban center in watts per Hertz

G_T = gain of the transmitting antenna relative to an isotropic antenna (dBi)

r_{km} = slant range from the urban center to the point S in kilometers

f_{MHz} = operating frequency in megahertz

L_E = environmental loss in dB

Note that specific assumptions about the gain of the satellite receiver's antenna are suppressed in equation [1] in order to consider the interference environment generated by IMT-2000 base stations irrespective of a particular satellite receiver's antenna specifications. However, it is assumed the satellite receiver's antenna is gain-limited.

Calculating the interference contribution for each urban center required analyzing the particular earth-space geometry between the point S and the location of each urban center. Specifically, only those urban centers visible from the point S contribute to the aggregate interference level. Thus, the elevation angle of the point S as seen from each urban center had to be calculated to determine whether that urban center was visible (above the local horizon). Moreover, for the industry model, the transmitting antenna's gain, and the environmental loss were functions of this local elevation angle. In addition, the slant range between each urban center and the point S had to be calculated to complete the interference calculation. After obtaining solutions for equation [1] for each visible urban center, both models then summed these contributions to arrive at the aggregate interference level at the point S.

Finally, both models calculated the aggregate interference at each point S´ on a lattice that spanned the orbital shell from –180 degrees to 180 degrees longitude, and from –90 degrees to 90 degrees latitude to find the approximate location and value of the highest predicted interference level worldwide. This interference level was then used to examine the "worst case" effects of IMT-2000 interference on satellite receivers. Each model performed this analysis for four orbital shells representing four typical satellite orbital altitudes: (1) 250 km, the typical orbital altitude of the space shuttle; (2) 833 km, the orbital altitude of DOD's Defense Meteorological Satellite Program (DMSP) satellites; (3) 20,200 km, the orbital altitude of DOD's Global Positioning System (GPS) satellites; and (4) 35,784 km,[3] the orbital altitude of several types of geosynchronous satellites including the Defense Support Program (DSP) and the Defense Satellite Communications System (DSCS). Each step in this calculation is described in some detail later in this appendix.

Results of DOD and Industry Interference Calculations

DOD's and industry's results for peak IMT-2000 interference differed significantly. As shown in table 1, DOD's peak PSD levels are about 5 dB higher than industry's levels for each of the orbital shells analyzed. For both models, values in the table refer to the PSD at the front end of the satellite's antenna and are, therefore, independent of the specific characteristics of this antenna.[4]

Table 1: Results of DOD and Industry Interference Calculations

Satellite altitude (km)	DOD peak PSD (dBw/Hz)	Industry peak PSD (dBW/Hz)	Difference (dB)
250	- 161.5	- 166.2	4.7
833	- 166.6	- 173.2	6.6
20,200	- 186.7	- 191.9	5.2
35,784[a]	- 191.1	- 195.8	4.7

[a]Industry used a slightly smaller value for this geosynchronous earth orbit altitude; the use of DOD's slightly larger value would likely decrease industry's peak PSD for this altitude by less than 0.01 dB

Analysis of DOD's and Industry's IMT-2000 Interference Calculations

In order to determine whether DOD's and industry's interference calculations could be reproduced and to obtain a better understanding of the factors contributing to the differences between DOD's and industry's results, we replicated DOD's and industry's interference models. In general, sufficient information was available in the published DOD and industry reports to recreate the two models once we had obtained the models' urban center population databases. Both the DOD and industry reports provided their versions of equation [1] used to calculate the

[3] Industry used a slightly smaller assumed value for its analysis of the geosynchronous orbital shell.

[4] It should be noted that industry's report on IMT-2000 interference to satellites shows interference results that are 5 dB lower in each case than those given in table 1 because industry's interference levels were calculated at the front end of the satellite receiver after accounting for the (assumed) – 5 dB gain of the satellite receiver's antenna. Because DOD's reported PSD levels are taken at the front end of the satellite antenna, industry's numbers have been adjusted here to make possible an "apples-to-apples" comparison.

interference from a single urban center to a point S on the orbital shell at a given slant range and local elevation angle. To clarify certain matters regarding calculations used in these models, we also met and corresponded with DOD and industry representatives on several occasions. We developed versions of DOD's and industry's models that incorporated all of the salient features of the original models.

DOD's and industry's databases containing the longitude, latitude and population of the world's largest urban centers were obtained from DOD and industry representatives and incorporated into our models. For each model, we first developed a "single-point" PSD calculation module that could calculate the aggregate PSD from all of the urban centers in the model's database within view of any single point S (defined by its longitude, latitude and orbital altitude). We applied slant range and satellite viewing angle formulas from a standard textbook on space mission planning.[5] Specifically, we applied suitable forms of equations from this source in our replication of DOD's and industry's models. Equations derived from the DOD and industry reports that calculated an urban center's geographic area, the aggregate PSD radiating from an urban center, the base station antenna gain, and base station PSD environmental losses were also incorporated into our models. Finally a suitable form of equation [1] was incorporated into our models to calculate the interference contribution from each visible urban center at the point S.

To calculate the PSD for a lattice of points that spanned the entire orbital shell, we incorporated our "single-point" PSD calculation modules into an iterative routine that calculated and stored the location information (longitude and latitude) and associated PSD value for each point on the orbital shell's lattice. The data generated were then analyzed to determine the value and location of the peak PSD for the orbital shell. We carried out calculations over a 2-degree by 2-degree lattice using the same four orbital shells analyzed by DOD and industry. Each key element of the modeling exercise is discussed briefly below. In addition, selected observations on DOD's and industry's assumptions with respect to those elements of the models are also included.

[5] *Space Mission Analysis and Design; 2nd. ed.* Wiley J. Larson and James R. Wertz (editors); Kluwer Academic Publishers (1992); Chapter 5; "Space Mission Geometry"; pp. 110-111.

1. IMT-2000 Base Station Service Area for Each Urban Center – DOD and industry both used databases describing the location (longitude and latitude) and population of the world's largest urban centers, and then approximated the size (geographic extent) of each urban center using a model-specific parametric equation to relate an urban center's population to its geographic area.

1.1 Population Databases – DOD's model used a database describing the physical location (longitude and latitude) and population of 2,763 of the world's most populous urban centers, with a total population of 1.33 billion. Data were obtained from a variety of sources, including United Nations statistical data and U.S. Census Bureau data. Industry used a similar (though not identical) database of 3,312 of the world's most populous urban centers obtained from United Nations data with a total population of 1.64 billion. Both of these databases were generally limited to urban centers with populations of 100,000 or more, and both were based on 1990-era census data. In contrast, the United Nations Population Division has estimated the world's urban population at about 2.85 billion in 2000 and projects that this figure will grow to about 3.82 billion by 2015.

1.2 Urban Center Area Estimation – Both DOD and industry approximated the size (geographic extent) of the urban centers in their respective database by applying a parametric equation of the form:

$$R_P = \alpha \times P^{\beta} \qquad [2]$$

to each urban center where:

R_P = radius of the urban center with population P

P = urban center's population

α = constant of proportionality

β = scaling factor

DOD used data on the population and land area of 8 large urban centers around the world (including 3 urban centers in the United States) to calculate an average inverse population density of 144.2 km^2 per million people, and applied this constant of proportionality to all 2,763 urban centers in its database. Assuming that the area of each urban center is a circle, this relationship can be expressed in the parametric form of equation [2] with:

$$\alpha_{DOD} = \sqrt{\frac{144.2}{\pi \times 1{,}000{,}000}} \approx .006775 \qquad [2A]$$

$$\beta_{DOD} = 0.5 \qquad [2B]$$

Industry used a more extensive sampling of data from the 1990 U.S. census to obtain a “best fit” to the parametric equation described in equation [2] for cities within the United States, and used United Nations data to obtain a “best fit” for cities outside the United States. For cities within the United States, industry calculated values of:

$$\alpha_{Industry} = 0.035 \qquad [2C]$$

$$\beta_{Industry} = 0.44 \qquad [2D]$$

According to industry's report, for cities outside the United States, this scaling factor remains unchanged, but a smaller constant of proportionality was calculated to account for the fact that urban centers outside the United States tend to be more densely populated than urban centers within the United States. However, the principal author of industry's study informed us that he had, in fact, used the single, more conservative constant shown in equation [2C].

Our models replicate these calculations to obtain estimates for the geographic area of each of the urban centers. It should be noted that industry's model assumed that urban centers are 4 to 7 times larger than DOD assumed. For example, while DOD assumed that an urban center of 1 million people would have a total land area of 144.2 km^2, industry assumed that this urban center would have a total land area of 733.2 km^2—about 5 times as large. We also compared these values with the average inverse population density calculated from our analysis of data from the 1990 U.S. Census Bureau report on the population and land area of the 396 urbanized areas in the United States.[6] We found that the average inverse population density for these 396 urbanized areas was about 1,000 km^2/million people.[7]

2. PSD Radiated by IMT-2000 Base Stations from an Urban Center – Once the geographic area of each urban center had been approximated, DOD and industry models each calculated the aggregate PSD for all of the IMT-2000 base stations that were assumed to be operating within the boundaries of each area. DOD's approach applied a constant PSD per unit area derived from reports and recommendations of the International Telecommunication Union. Industry's approach was based upon consideration of the technical characteristics of IMT-2000 base stations employing UWC-136 (TDMA) technology. Because DOD's approach was much simpler than industry's, the two approaches are described separately here.

2.1 DOD's Approach — DOD's approach to calculating the PSD radiated by IMT-2000 base stations from a given urban center was very simple. DOD assumed that IMT-2000 base stations serving all urban land areas would radiate a constant PSD per unit area of 41 µwatts/Hz/km^2, or - 43.9 dBW/Hz/km^2. This figure was derived from one report and one recommendation of the International Telecommunication Union (ITU).[8] DOD did not attempt to explicitly calculate the number of base stations to which this PSD value corresponded. Rather, DOD's model multiplies this value by the size of the urban center calculated using equation [2]. We incorporated a suitable form of this calculation into our model.

[6] *1990 Census of Population and Housing: Supplementary Reports – Urbanized Areas of the United Sates and Puerto Rico* (1990 CPH-S-1-2). U.S. Department of Commerce; Economics and Statistics Administration; Bureau of the Census (December 1993); table 2, "Rank of Urbanized Areas by 1990 Population; Housing Units, Area Measurements and Density: 1990." [Note: Nearly identical information on the 1990 population and land area of these 396 urbanized areas was also found on a commercial website – www.demographia.com].

[7] Calculated as {Total land area for the 396 urbanized areas} × 1,000,000/{Total population of the 396 urbanized areas}.

[8] Recommendation ITU-R M.687-2 (1990) estimated a PSD of 38µW/Hz/km^2 for IMT-2000 base and mobile stations. DOD updated this figure using information from ITU-R Report M.2023. We did not attempt to replicate DOD's calculation but accepted the 41µW/Hz/km^2 as the input PSD for our reproduction of DOD's model.

2.2 Industry's Approach — Industry's approach to calculating the PSD radiated from IMT-2000 base stations from a given urban center was more complex. Industry first estimated the number of base stations of a particular size and deployment penetration factor required to serve the urban center's area (as calculated using equation [2].) Industry assumed that each base station would serve a circular area of radius R_h. Industry then calculated that while the relative mix of different-sized base stations might change from one urban center to the next, the maximum number of any particular size of base stations of service radius R_h, needed to fully serve an urban center could be calculated using equation (6) from industry's report. Finally, industry assumed that the PSD radiated from a base station with a smaller service radius R_h relative to the PSD of a base station with the largest assumed service radius (10 km) $R_{h-\max}$ would be directly proportional to the square of ratio of these two radii, that is:

$$P(R_h) = P(R_{h-\max})\left(\frac{R_h}{R_{h-\max}}\right)^2 \qquad [3]$$

Industry argued that adding 2 to the number of maximum-sized base stations calculated using equation (6) from the industry report would result in an aggregate PSD for each urban center that was as least as large as the aggregate PSD from any other relative mix of 3 different-sized base stations. Industry's "upper bound" method is described in more detail in its published report. We applied suitable forms of equations derived from industry's "upper bond" method to our model.

Unlike DOD, industry did not assume that each urban center in its database would be fully "built out." Rather, industry developed a population density-dependent deployment penetration factor to account for the fact that less densely populated urban centers may not achieve the same level of IMT-2000 penetration as more densely populated urban centers. Industry's deployment penetration factor curve appears as figure 2 of its report. However, because the industry report did not explain, in detail, its assumed values for this curve, we did not initially have enough data to replicate this curve precisely for all population densities. Consequently, we approximated this curve by visually extracting data points from the published curve and then fitting this data to a curve that would adequately reproduced the published curve. To approximate industry's penetration curve, we used a four-parameter equation of the form:

$$\eta_P(D) = \left(1 - \exp(aD^b + cD^e)\right) \qquad [4]$$

where:

$\eta_P(D)$ = IMT-2000 deployment penetration factor

D = urban center's population density (people/km^2).

a, b, c, e are a set of "best fit" parameters

During subsequent correspondence with the principal author of the industry study, we were provided with the table of values for population density versus deployment penetration factor used in the industry model. However, a comparison between the estimated total number of base stations worldwide predicted using our "best fit" penetration curve and the total number predicted using industry's approach showed less than a 0.1 percent difference. Consequently, we did not adjust this factor in our replication of industry's model.

We noted that industry's introduction of a deployment penetration factor into its model ultimately made very little difference to the predicted aggregate PSD level because most urban centers in industry's database had relatively large (calculated) population densities, resulting in penetration factors close to one, and because industry's "upper bound" method tended to suppress the effects of the generally lower penetration factors calculated for the smaller urban centers in industry's database. For example, we calculated that the 3,312 urban centers in industry's database would be served by a total of 11,974 base stations based upon our "best fit" penetration curve, but that using a 100 percent penetration factor for all urban centers increased this total by only 203 base stations (to 12,177) or by about 1.7 percent.

3. PSD Received at Point S – Once the aggregate PSD radiated from each urban center is calculated, equation [1] is used to calculate the contribution from each visible urban center at the point S. This requires consideration of the IMT-2000 base stations vertical antenna gain pattern and elevation-dependent environmental losses.

3.1 IMT-2000 Base Station Antenna Gain Pattern – DOD's model assumed that IMT-2000 base stations would radiate power isotropically. Thus, DOD assumed that in calculating an urban center's interference contribution using equation [1], $G_T = 0$ in all cases. Our reproduction of DOD's model incorporates this assumption. Industry's model used an antenna gain pattern based upon an ITU document[9] to calculate an elevation angle-dependent antenna gain $G_T(\varepsilon)$, which is described by equations (11a) and (11b) in industry's report. We incorporated a suitable form of these equations into our reproduction of industry's model.

3.2 IMT-2000 Environmental Losses – DOD's model assumed that 90 percent of the power radiated from IMT-2000 base stations would be lost to the environment before reaching satellite orbital altitudes irrespective of the local elevation angle; thus DOD assumed that in calculating an urban center's interference contribution using equation [1], $L_E = 10$ dB in all cases. Industry's model assumed an elevation angle-dependent environmental loss factor as follows:

$$L_E(\varepsilon) = 10 \text{ dB(for } \varepsilon \leq 20^0) \qquad [5A]$$

$$L_E(\varepsilon) = 10 \times \frac{(60^0 - \varepsilon)}{(60^0 - 20^0)} \text{ dB(for } 20^0 < \varepsilon \leq 60^0) \qquad [5B]$$

$$L_E(\varepsilon) = 0 \text{ dB(for } \varepsilon > 60^0) \qquad [5C]$$

We incorporated a suitable form of equation [5] into our reproduction of industry's model. We noted that neither DOD nor industry made conservative assumptions regarding environmental losses. For example, during our limited review of the Air Force's IMT-2000 interference model, we discussed environmental losses with Aerospace Corporation representatives. The Air Force model assumed environmental losses would be much less than either DOD or industry assumed.

[9] Recommendation ITU-R F.1336 with k = 0.

Results From the Replication of DOD's and Industry's IMT-2000 Base Station Interference Models

We were generally able to reproduce the value of the peak IMT-2000 interference levels predicted by DOD's and industry's original models for each orbital shell to within about 0.1 dB. In addition, the locations of those peaks generally corresponded well with those predicted by DOD and industry. It should be noted, however, that because DOD calculated PSD values for every point on a 1-degree longitude by 1-degree latitude lattice, whereas our PSD values were calculated over a 2-degree longitude by 2-degree latitude lattice, some minor differences exist in the location of the peak PSD value on the orbital shell. Tables 2 and 3 summarize these results for DOD and industry, respectively.

Table 2: Comparison of DOD and Our Interference Results based upon Our Replication of DOD's Model

Satellite altitude (km)	DOD peak PSD (dBw/Hz)	Replication of DOD's peak PSD (dBW/Hz)	Difference (dB)
250	- 161.5 (at +39 lat./+117 long.)	- 161.5 (at +38 lat./+118 long.)	+ 0.0
833	- 166.6 (at +36 lat./+119 long.)	- 166.6 (at +36 lat./+120 long.)	+ 0.0
20,200	- 186.7 (at +72 lat./+48 long.)	- 186.7 (at +72 lat./+48 long.)	+ 0.0
35,784	- 191.1 (at +73 lat./+16 long.)	- 191.0 (at +72 lat./+18 long.)	- 0.1

Table 3: Comparison of Industry and Our Interference Results based upon Our Replication of Industry's Model

Satellite altitude (km)	Industry's peak PSD (dBw/Hz)	Replication of Industry's peak PSD (dBW/Hz)	Difference (dB)
250	- 166.2 (at +52 lat./-2 long.)	- 166.2 (at +52 lat./-2 long.)	+ 0.0
833	- 173.2 (at +52 lat./+4 long.)	- 173.2 (at +52 lat./+4 long.)	+ 0.0
20,200	- 191.9 (at +64 lat./-6 long.); (at +64 lat./-4 long.)	- 191.3 (at +64 lat./-2 long.)	- 0.6
35,784	- 195.8 (at +54 lat./+8 long.); (at +56 lat./+4 long.); (at +62 lat./-18 long.)	- 195.8 (at +56 lat./+4 long.)	+ 0.0

With respect to table 3, we did not attempt to resolve the –0.6 dB discrepancy with industry representatives. As discussed above, we used a slightly different approach to calculating the IMT-2000 base station penetration factor, which might account for part of this difference. Moreover, we did not attempt to review, in detail, industry's assumptions regarding values used for fundamental physical constants, or rounding of intermediate calculations. While additional work would likely have resolved this discrepancy, the – 0.6 dB difference is not large enough to justify that exercise.

Appendix III: Comments From the Department of Defense

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
6000 DEFENSE PENTAGON
WASHINGTON, DC 20301-6000

August 1, 2001

COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE

Mr. Allen Li
Director, Acquisition and Sourcing Management
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Li:

This is the Department of Defense (DoD) response to the GAO draft report, 'Defense Spectrum Management: More Analysis Needed to Support Spectrum Use Decisions of the 1755 to 1850 MHz Band," dated July 23, 2001, (GAO Code 120017/OSD Case 01-795).

The Department reviewed the subject report and concurs with GAO's basic premise that the decision on the 1755-1850 MHz band is too critical to make without having as much accurate information as is possible.

The Department also strongly agrees with the recommendation to direct NTIA to identify comparable alternate spectrum. We believe this effort will be more effective if a recommendation is included that the FCC should also identify spectrum, in order to include full consideration of potentially available non-government and shared bands.

The GAO report focused on DoD's study of the potential for sharing or segmenting the 1755-1850 MHz frequency band. One GAO recommendation would essentially require the DoD to invest significant additional resources in studying the options of sharing or segmenting the 1755-1850 MHz band. However, we question whether the original options identified by national regulators and addressed by the previous DoD study are the best options for future study. DoD's resources would be better spent if spectrum options and associated timelines used as the basis for further study were redefined by NTIA and FCC, in cooperation with industry and the Federal agencies. Industry proposals to date for resolving many of the potential interference issues do not provide workable solutions for compatible near-term use of this band by third generation systems.

The GAO report focuses primarily on the issue of interference from third generation wireless base stations to DoD satellites. Although the satellite issue is critical, it is just one of many that must be resolved before national decisions are made regarding the possible use of this band. DoD's non-space systems provide essential military capabilities and must be given equivalent attention in sharing, segmentation, and relocation studies, as they have in the DoD report.

The Department would like to express its appreciation to the GAO staff for their detailed analysis of the potential satellite interference issue. Please direct questions on the issues addressed in the attached review of the GAO report to Mr. Roger Porter, Spectrum Management Directorate, (703) 607-0712, roger.porter@osd.mil.

Sincerely,

Robert M. Nutwell, RADM, USN
Deputy Assistant Secretary of Defense,
(C3ISR and Space)

Atch: DoD Comments to Draft Report

GAO DRAFT REPORT, "DEFENSE SPECTRUM MANAGEMENT: More Analysis Needed to Support Spectrum Use Decisions for the 1755 to 1850 MHz Band, Dated July 23, 2001 (Code 120017/Case 01-795)"

DEPARTMENT OF DEFENSE COMMENTS

To more accurately assess the potential impacts to the Department of Defense should the 1755 to 1850 MHz band be selected for 3G in the United States, we recommend that the Secretary of Defense: (p. 23/GAO Draft Report)

RECOMMENDATION 1: Complete a system-by-system analysis to determine existing and future spectrum needs and requirements of systems in the 1755 to 1850 MHz band. (p. 23/GAO Draft Report)

DOD RESPONSE: Concur with comments. Although major systems impacts were addressed in the DoD report, time limitations prevented addressal of specific, detailed impacts for all DoD systems. Requirements for programmed future systems were included in DoD report, but assessment of potential and unprogrammed requirements, including anticipated growth in DoD future spectrum requirements, was not assessed.

RECOMMENDATION 2: Prepare a long-range spectrum plan and make programmatic decisions necessary to carry out that plan. (p.23/GAO Draft Report)

DOD RESPONSE: Concur with comments. This recommendation appears outside the scope of the GAO original tasking. Nevertheless, such an effort can be used to provide DoD input/requirements to assist in development of a National Spectrum Strategy, mentioned in congressional testimony by senior level government officials including the Secretary of Commerce and Chairman, Federal Communications Commission. DoD has been working on a DoD Strategic Plan that outlines DoD goals, objectives and associated strategies to assure the availability of, and access to, sufficient electromagnetic spectrum. This plan is based on the conceptual framework outlined in the DoD Joint Spectrum Vision 2010 (JSV2010) and will be extended to include available information for the 2020 time frame.

RECOMMENDATION 3: Complete the technical, operational, and cost assessments of satellite systems in the 1755 to 1850 MHz band, and review and complete assessments of other systems as necessary. (p. 23/GAO Draft Report)

DOD RESPONSE: Concur with comments. Complete and accurate technical, operational and costs analyses cannot be conducted until spectrum with suitable technical characteristics and equivalent regulatory status is identified. Selection of comparable spectrum in the same spectral regions reduces variations in impact to DoD but is extremely problematic and challenging, given overcrowding resident in alternate bands used by the government and private sector. DoD impacts will increase if designated alternate spectrum varies significantly from currently employed frequencies. Identification and selection of alternate transition spectrum also allows assessment of second and third tier DoD impacts such as training, deployment and re-negotiation of overseas host nation frequency agreements. In addition to comparable spectrum, prior to initiating further DoD studies, guidelines must be established by the regulatory authorities that include mutually agreed-upon assumptions, definitions, database information and third generation system technical characteristics. Disputes between government and industry on any of the facts, assumptions, data elements or study methodology should be resolved before further study begins.

To provide DoD with adequate time and guidance to complete its plans and analysis, the GAO made three recommendations to the Secretary of Commerce. The following comments are provided with respect to these recommendations.

Now on p. 23.

RECOMMENDATION 4: Incorporate a sufficient amount of time into the new NTIA plan to select spectrum for third generation mobile wireless systems to address the issues discussed in this report, specifically with respect to satellite operations:

DOD RESPONSE: Concur. DoD will work with NTIA and FCC in the development of a reasonable timeline to conduct further studies.

Now on pp. 23-24.

RECOMMENDATION 5: Direct the NTIA to identify comparable alternate spectrum for use by the DoD systems before a decision is made to reallocate the 1755 to 1850 MHz band, should such an action be contemplated:

DOD RESPONSE: Concur with comments. This effort will be more effective if a recommendation is included that the FCC should also identify spectrum in this process, in order to include full consideration of potentially available non-government and shared bands. The identification of comparable alternate spectrum for possible use by the DoD and other Federal agencies is a critical one that should be pursued by the regulatory authorities on a priority basis. The identification of alternative spectrum that is certified as 'comparable' in accordance with PL 106-65 is an essential element in determining the DoD cost and operational impacts in the 1755 to 1850 MHz band should relocation of DoD systems become necessary.

Now on p. 24.

RECOMMENDATION 6: Coordination with appropriate Executive Branch agencies to review existing national spectrum management plans and policies, and, if necessary, to establish a clearly defined national spectrum strategy reflecting DoD requirements for international agreements and spectrum requirements to operate overseas.

DOD RESPONSE: Concur with comments. Since DoD operational capability is a global requirement, any discussion to develop a national spectrum strategy and policy should necessarily include DoD international requirements. Negotiation of new international agreements for frequency use of alternate bands both on a host-nation basis and within the framework of the ITU for satellite systems will be difficult in view of the global growth of telecommunications services in general and satellite operations in particular. These international considerations must be included to determine the full impact on DoD operations that may be caused if a decision is made to allow third generation services to use the 1755-1850 MHz band. Since NTIA regulates spectrum for all Federal agencies, the decision to initiate development of a national or government spectrum strategy must be agreed to by NTIA. DoD will recommend that NTIA initiate such actions. We recommend that the GAO report include statements to encourage NTIA to develop such a strategy that would include consideration of DoD and other Federal government spectrum requirements.

ADDITIONAL DOD COMMENTS ON DRAFT GAO REPORT: General comments and recommendations regarding the Draft GAO Report are provided below. Specific and more detailed comments are provided in the Annex to this attachment.

1. The Draft GAO Report underscores the importance of the pending US Third Generation (3G) decision to National Security and Economic Development and that any decision of the 1755-1850 MHz band should not be taken lightly or rushed. More detailed assessments by NTIA, DoD and industry are needed and recommended.

2. The Draft GAO Report does little to speak to the yet to be substantiated requirements for additional spectrum for 3G, further underscoring the importance of not 'rushing to judgment' on the 3G decision.

3. The presentation of ideas in the draft report may lead the casual reader to believe the DoD study, DoD Investigation of the Feasibility of Accommodating the International Mobile Telecommunications {IMT} 2000 Within the 1755-1850 MHz Band, dated 9 Feb 2001, is flawed by criticizing the DoD study methodology and study assumptions. The DoD study methodology and assumptions were validated by the NTIA. The technical characteristics and methodology for 3G used in the DoD study were developed, coordinated, and approved by NTIA, FCC and DoD.

4. The dates mentioned in the Draft GAO Report to transition current DoD operations to an alternate band were based, inter alia, on the assumption of full cost reimbursement by FY2002. These dates will move further into the future if this funding condition is not satisfied.

5. Although the Draft GAO Report mentions the problem of comparable alternate spectrum, further emphasis should be made in the report because this issue is so significant. Additionally, the DoD report indicated that DoD's preliminary review of alternate bands could not find comparable government bands for many of the major systems in the 1755-1850 MHz band. This was also noted to be problematic in the NTIA report. The Draft GAO Report should also include these interim results to clarify and emphasize this very serious issue.

6. The Draft GAO Report focuses mostly on one of the four major DoD systems, satellite operations, and as a result the other three major systems, ACTS, PGM and TRR are somewhat left in the background and not given sufficient visibility or careful study. These non-space systems will cause and experience interference to and from all third generation systems, regardless of the resolution of the issue on satellite interference. This key fact is not addressed adequately in the report.

7. The Draft GAO Report recommends that the Secretary of Defense and the Secretary of Commerce carry out additional analyses and studies in order to more accurately assess the potential impacts of reallocation of the 1755-1850 MHz band; however, GAO does not recommend industry carry out any additional studies. It is noted that industry proposals to date for resolving many of the potential interference issues do not provide workable solutions for compatible near-term use of this band by 3G systems. Consequently, the recommended effort for further DoD analysis will be significantly hampered unless combined with further industry analysis and identification of additional workable solutions as a basis for consideration in future DoD studies. This point should be made in the draft report.

Appendix IV: Comments From the Department of Commerce

THE SECRETARY OF COMMERCE
Washington, D.C. 20230

AUG - 2 2001

Mr. Allen Li
Director, Acquisition and
Sourcing Management
United States General Accounting Office
Washington, DC 20548

Dear Mr. Li:

Thank you for providing a copy of the General Accounting Office's draft report entitled "Defense Spectrum Management: More Analysis Needed to Support Spectrum Use Decisions for the 1755 to 1850 MHz Band" (GAO-01-795) for review and comment. The spectrum allocation decision supporting the implementation of third generation (3G) mobile wireless services in the United States will have far-reaching implications for the economic well-being of our Nation.

Your report focused on the analyses performed in support of our final report on 3G allocations, and found that more analyses were needed before an informed decision on reallocation of the 1755-1850 MHz band could be made. Recently, Chairman Powell of the Federal Communications Commission (FCC) sent me a letter indicating more time is needed in the 3G allocation decision-making process, and requested that the Department of Commerce work with the FCC to develop a revised allocation plan and auction timetable. I agreed with Chairman Powell and have directed the National Telecommunications and Information Administration (NTIA) to work with the FCC, in coordination with appropriate Executive Branch agencies, to develop a new plan for the selection of 3G spectrum. This new plan will ensure that sufficient time is incorporated to permit the issues raised in your report to be addressed and, at the same time, to provide a timely 3G spectrum allocation decision.

I also want to assure you that the Department of Commerce is well aware of its obligation to identify comparable spectrum for the Department of Defense's use if spectrum is made available in the 1755-1850 MHz band for 3G services. In such an event, NTIA will work cooperatively with the Department of Defense and the FCC to study all options for such comparable spectrum.

Finally, please note that the Department of Commerce, through NTIA, works with the federal agencies and the FCC on an ongoing basis to review existing national spectrum management plans and policies, to develop the U.S. Government's position in international conferences, and to propose revisions to the international Table of Frequency Allocations with the goal of assisting the Department of Defense and other federal agencies to meet their international spectrum needs. This coordination will certainly continue.

Again, thank you for this opportunity to review the draft report and to provide these comments.

Warm regards,

Donald L. Evans

Appendix V: Comments From the Federal Communications Commission

FEDERAL COMMUNICATIONS COMMISSION
Washington, D. C. 20554

OFFICE OF
MANAGING DIRECTOR

August 3, 2001

Mr. Allen Li, Director
Acquisition and Sourcing Management
U.S. General Accounting Office
Washington, DC 20548

Dear Mr. Li:

The Chairman has asked me to respond to your July 23, 2001, letter to him requesting comment on the General Accounting Office's draft report *"Defense Spectrum Management: More Analysis Needed to Support Spectrum Use Decisions for the 1755 to 1850 MHz Band."* Thank you for this opportunity. The Federal Communications Commission has enclosed specific edits for your consideration in finalizing the report.

Overall, the report provides a thorough presentation of the challenging issues involved in consideration of the reallocation of the 1755-1850 MHz spectrum band. The FCC agrees that additional time is required to study these issues and that we need to work together with the National Telecommunications and Information Administration at the Department of Commerce to effectively manage our nation's valuable spectrum resources in the public interest. In particular, we need to work together to address how best to make available sufficient U.S. spectrum for advanced wireless communications systems.

You note in your draft report the importance of mutual cooperation and information sharing. I agree with this point and want to emphasize that it is essential that all interested parties, including the commercial wireless industry and the Department of Defense, work together to resolve these important issues. While the draft GAO report cites additional time to conduct analysis as critical to resolving the outstanding issues with the 1755-1850 MHz band, such additional analysis will only be effective if all stakeholders have complete access to relevant data that will aid decision makers.

Again, thank you for consideration of our views. If you need further assistance, please contact Jerry Cowden at 418-0447.

Sincerely,

Andrew S. Fishel
Managing Director

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