Department of Defense (DoD)

Strategic Spectrum Plan

Submitted to the Department of Commerce

In Response to

The Presidential Spectrum Policy Reform Initiative

February 2008

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1.0 Introduction

The President established the US Spectrum Policy Initiative in May 2003.[1] The initiative directed the Secretary of Commerce to prepare recommendations for improving US spectrum management. Through an NTIA led Federal Government Spectrum Task Force, recommendations were developed and provided in a two-part series of reports released by the Secretary of Commerce in June 2004 under the title "Spectrum Policy for the 21st Century – The Presidents Spectrum Policy Initiative (Reports)."[2] A subsequent Executive memorandum[3] dated November 30, 2004 directed that Executive Departments and Agencies implement the recommendations from the reports. The Executive memorandum provided additional direction for federal government offices and agencies to implement, which complements the recommendations. The additional direction included the following specific guidance:

> *"Within 1 year of the date of this memorandum, the heads of agencies selected by the Secretary of Commerce shall provide agency-specific strategic spectrum plans (agency plans) to the Secretary of Commerce that include:*
>
> *(1) spectrum requirements, including bandwidth and frequency location for future technologies or services;*
> *(2) the planned uses of new technologies or expanded services requiring spectrum over a period of time agreed to by the selected agencies; and*
> *(3) suggested spectrum efficient approaches to meeting identified spectrum requirements.*
>
> *The heads of agencies shall update their agency plans biennially. In addition, the heads of agencies will implement a formal process to evaluate their proposed needs for spectrum. Such process shall include an analysis and assessment of the options available to obtain the associated communications services that are most spectrum-efficient and the effective alternatives available to meet the agency mission requirements. Heads of agencies shall provide their analysis and assessment to the National Telecommunications*

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[1] *See* Memorandum on the Spectrum Policy for the 21st Century, 39 Weekly Comp. Pres. Doc. 726, 727 (May 29, 2003) (Spectrum Policy Memorandum), *available at* http://www.whitehouse.gov/news/releases/2003/06/20030605-4.html; *see also* Appendix 2.

[2] *Spectrum Policy for the 21st Century – The President's Spectrum Policy Initiative: Report 1*, US Department of Commerce (2004) (Report 1), *available at* http://www.ntia.doc.gov/reports/specpolini/presspecpolini_report1_06242004.htm; *Spectrum Policy for the 21st Century – The President's Spectrum Policy Initiative: Report 2*, US Department of Commerce (2004) (Report 2), *available at* http://www.ntia.doc.gov/reports/specpolini/presspecpolini_report2_06242004.htm. NTIA serves as the President's principal adviser on telecommunications and information policies and as manager of the federal government's use of the radio spectrum. 47 USC. § 902(b)(2).

[3] *See* Presidential Determination: Memorandum for the Heads of Executive Departments and Agencies, 40 Weekly Comp. Pres. Doc. 2875, 2876, sec. 3(c) (Nov. 30, 2004) (Executive Memorandum), *available at* http://www.whitehouse.gov/news/releases/2004/11/20041130-8.html; *see also* Appendix 3.

and Information Administration (NTIA) for review when seeking spectrum certification from the NTIA."

The Secretary of Commerce selected the Department of Defense (DoD) to be one of the agencies to submit an agency-specific strategic spectrum plan in a March 10, 2005 Memorandum[4]. In response, DoD prepared and submitted the *Department of Defense Strategic Spectrum Plan* in November 2005. This report, the 2008 DoD Strategic Spectrum Plan, has been prepared to address the President's direction to agency heads that respective spectrum plans be updated on a biennial basis[5].

1.1 The Mission of the Department of Defense

This section addresses the mission of the Department of Defense (DoD) and establishes the basis upon which DoD will address its needs for electromagnetic spectrum resources.

1.1.1 National Security Strategy[6]

The United States national security strategy is based on a distinctly American internationalism that reflects the union of values and national interests. The aim of this strategy is to help make the world not only safer but also better. US goals, concerning the path to progress, are clear - political and economic freedom, peaceful relations with other states, and respect for human dignity. To achieve these goals, the United States will:

- Champion aspirations for human dignity;
- Strengthen alliances to defeat global terrorism and work to prevent attacks against the US and its allies;
- Work with other countries to defuse regional conflicts;
- Prevent enemies from threatening us, our allies, and our friends, with weapons of mass destruction;
- Ignite a new era of global economic growth through free markets and free trade;
- Expand the circle of development by opening societies and building the infrastructure of democracy;
- Develop agendas for cooperative action with other main centers of global power; and
- Transform America's national security institutions to meet the challenges and opportunities of the twenty-first century.

1.1.2 National Defense Strategy[7]

The US national security strategy provides the basis and direction for the US national defense strategy. The defense strategy serves broad national objectives of peace, freedom, and prosperity. DoD has developed a strategic framework to defend the nation and secure a viable

[4] Secretary of Commerce Memorandum to the Secretary of Defense, March 10, 2005.
[5] Department of Commerce Assistant Secretary of Communications and Information Letter to Assistant Secretary of Defense for Networks and Information Integration & Chief Information Officer, 2 Aug 2007
[6] National Security Strategy, 2002.
[7] National Defense Strategy, March 2005.

peace[8]. This framework is based on four major defense policy goals which provide the foundation for the definition and prioritization of missions and capabilities. These four policy goals are:

- Assuring allies and friends;
- Dissuading potential adversaries;
- Deterring aggression and countering coercion against US interests; and
- If deterrence fails, decisively defeating any adversary.

Diplomatic and economic efforts seek to promote these objectives globally by encouraging democracy and free markets. US defense strategy seeks to defend freedom for the United States and its allies and friends, and it helps to secure an international environment of peace which makes other goals possible.

1.1.3 Military Transformation

The President has repeatedly emphasized the vital importance of military transformation to the future defense of the United States. The significance of military transformation to US defense strategy is also apparent by its inclusion as one of the seven interconnected strategic tenets. The transformation strategy is one for large-scale innovation.

The 2002 National Security Strategy[9] states that the goal of military transformation "must be to provide the President with a wider range of military options to discourage aggression or any form of coercion against the United States, our allies, and our friends. Our forces will be strong enough to dissuade potential adversaries from pursuing a military build-up in hopes of surpassing, or equaling, the power of the United States."

DoD's *Transformation Planning Guidance*[10] describes transformation as: A process that shapes the changing nature of military competition and cooperation through new combinations of concepts, capabilities, people, and organizations that exploit our nation's advantages and protects against our asymmetric vulnerabilities to sustain our strategic position, which helps underpin peace and stability in the world. Transformation is necessary to ensure that US forces continue to operate from a position of overwhelming military advantage in support of strategic objectives.

Over the long-term, our security (and the prospect for peace and stability for much of the rest of the world) depends on the success of transformation. We are at the confluence of three broad trends: the movement of our society and much of the world from the industrial age to the information age; the appearance of an expanded array of threats in a more uncertain context; and vast technological opportunities available to both friend and foe alike.

The Department's transformation will be shaped and influenced by the emerging realities of competition in the information age and the concept of network-centric warfare (NCW). The Department has always considered the electromagnetic spectrum as a vital resource and now this resource is being incorporated into the process of shaping the change in military competition and cooperation.

[8] Military Transformation: A Strategic Approach, Fall 2003, Director of Force Transformation, Office of the Secretary of Defense, 1000 Defense Pentagon, Washington, DC 20201-1000
[9] National Security Strategy, 2002.
[10] Transformation Planning Guidance, April 2003.

1.1.4 Network-Centric Warfare

In the information age, power is increasingly derived from information sharing, information access, and speed. Network-centric warfare is the military expression of the information age; it refers to the combination of emerging tactics, techniques, and technologies that a networked force employs to create a decisive warfighting advantage. It provides a new conceptual framework with which to examine military missions, operations, and organizations in the information age.

As an organizing principle, NCW accelerates our ability to know, decide, and act by linking sensors, communications systems, and weapons systems in an interconnected grid. A warfighting force with networked capabilities allows a commander to analyze the battlespace, rapidly communicate critical information to friendly combat forces, and marshal a lethal combination of air, land, and sea capabilities to exert massed effects against an adversary. A force employing network-centric operations will be able to move into a new competitive space, thereby gaining a decided advantage over a force conducting traditional platform-centric operations.

Although the transformation of the US Armed Forces is a continuing process, the recent performance of US forces in the successful conduct of Operation Enduring Freedom and Operation Iraqi Freedom has provided a glimpse of the future potential of the emerging way of war. The basic tenets of NCW, set forth in *Network Centric Warfare: Department of Defense Report to Congress* (July 27, 2001), are as follows:

- A robustly networked force improves information sharing;
- Information sharing enhances the quality of information and shared situational awareness; and
- Shared situational awareness enables collaboration and self-synchronization and enhances sustainability and speed of command.

NCW represents a powerful set of warfighting concepts and associated military capabilities which allow warfighters to take full advantage of all available information and bring all available assets to bear in a timely and flexible manner. The transformed joint force will be capable of achieving US strategic and operational objectives more quickly while employing more agile and rapidly deployable forces.

In February 2006, The Secretary of Defense issued the *Quadrennial Defense Review Report*[11] (*QDR Report*), which builds upon the transformational defense agenda directed by the President (as expressed in the 2001 *QDR Report*), the changes in the US global defense posture, and the operational experiences of the previous four years. The 2006 *QDR Report* emphasizes the importance of joint capabilities and net-centricity in achieving a truly integrated joint force that is more agile, more rapidly deployable, and more capable against the wider range of threats. To respond to these unpredictable threats, US Armed Forces who traditionally focused on

[11] Quadrennial Defense Review Report, Office of the Secretary of Defense, February 6, 2006.

deterrence, stability, and warfighting missions arising in overseas theaters must now also assist in securing the homeland.

The 2006 *QDR Report* highlights the shift in philosophy to meet the new strategic environment; one in which threat-based planning is replaced by capabilities-based planning; where horizontal integration in lieu of "stovepipes" is the norm; and where the emphasis is on moving data to the user and not vice versa. Each of the aforementioned has a future impact on spectrum planning, SM, and the design of spectrum-dependent systems.

1.2 The DoD Strategic Vision for Spectrum Management

The Department of Defense has always considered the electromagnetic spectrum a vital resource. This increased emphasis has resulted in changes to processes, new and restructured spectrum management organizations, and other specific initiatives.

In August 2006, Assistant Secretary of Defense, Networks and Information Integration (ASD(NII)) released the *Department of Defense Net-Centric Spectrum Management Strategy*[12] which presents a DoD vision for the management as well as use of the electromagnetic (EM) spectrum and establishes a strategy for achieving that vision. It is the realization of a networked environment that will be achieved through the implementation of highly integrated wireless systems and spectrum-dependent technologies in which EM spectrum support is a principal component of the Global Information Grid's (GIG's) foundation layer.

DoD Spectrum Management Vision - In a net-centric environment, the DoD vision is that EM spectrum will be accessible to all spectrum-dependent systems on an as needed basis. Spectrum situational awareness will allow multiple spectrum-dependant systems to maximize use of available spectrum to exploit battlefield opportunities while preventing interference to other authorized users. This will be enabled through the use of spectrum standards, SM protocols, and software agents that will provide both an understanding of the type and amount of spectrum in use and access to the most operationally effective spectrum available. The tenants of the net-centric spectrum management strategy is shown in Table 1-1.

Table 1-1 DoD Net-Centric Spectrum Management Strategy

Vision for Spectrum	Strategy
Understandable ⇨	Spectrum information to be *defined via standards and SM protocols* so users and spectrum-dependent devices can discern spectrum data available on the GIG. Users post spectrum *usage via spectrum data elements* that describe the essential attributes of spectrum utilization. Spectrum situational awareness is maintained through a *Spectrum User-Defined Operational Picture (S-UDOP).*
Agile ⇨	SM policies and practices to provide the flexibility to allow systems to *dynamically adjust and scale* to support change in size and scope of demand to be responsive to mission requirements.
Seamless ⇨	Enabled by agile SM policies and practices, future spectrum-dependent devices will *reconfigure spectrum use and spectrum control attributes independently*.
Integrated ⇨	*Net-Centric SM considerations are infused into DOD processes*, practices, planning, doctrine, training and operations. SM recognized throughout DOD as a necessary and complementary function that is essential to maintaining the network.

The network will be “dynamic”, interactive, and instantly aware of spectrum that is available for reuse and reprioritization by other wireless systems; as the network moves, the SM structure will adapt as necessary to ensure the systems remain optimized. To accommodate the complexity and demands associated with supporting network centric operations within the mobile tactical framework, SM must be decentralized and performed autonomously throughout the network to be successful.

It is essential that DoD engage in both the National and International planning process to support the goal of achieving global DoD net-centric capabilities; thus, DoD will continue to coordinate with the National Telecommunications and Information Administration (NTIA) and other federal agencies prior to the introduction of dymanic, transformational spectrum capabilities.

The *DoD Net-Centric Spectrum Management Strategy* is one of the principal drivers in DoD’s strategic planning for spectrum management. Among the methods envisioned is the development of a SM architectural framework, which will include a transition strategy and roadmap with detailed descriptions of the operational capabilities, environment characteristics, and architecture imperatives for each transition point.

2.0 Executive Summary

The President's Executive Memorandum[13] of November 30, 2004 directed that Executive Departments and Agencies implement the recommendations from the reports. The Executive Memorandum provided additional direction for Federal Government offices and agencies to implement and to complement the recommendations, namely that agency heads provide agency-specific strategic spectrum plans to the Secretary of Commerce which include the following:

(1) spectrum requirements, including bandwidth and frequency location for future technologies or services;

(2) the planned uses of new technologies or expanded services requiring spectrum over a period of time agreed to by the selected agencies; and

(3) suggested spectrum efficient approaches to meeting identified spectrum requirements.

The Secretary of Commerce selected the Department of Defense (DoD) to be one of the agencies to submit an agency-specific strategic spectrum plan in a March 10, 2005 Memorandum[14]. In response, DoD prepared and submitted the *Department of Defense Strategic Spectrum Plan* in November 2005. This document, the 2008 DoD Strategic Spectrum Plan, has been prepared to satisfy the President's direction to agency heads that respective spectrum plans be updated on a biennial basis[15].

2.1 Key Current Spectrum Requirements

There has been no significant change in DoD current spectrum usage from that reported in the 2005 DoD Strategic Spectrum Plan. DoD continues to operate in most government exclusive spectrum bands and in many shared bands (as shown in Figure 2-1). The preponderance of DoD frequency assignments occur below 6 GHz is conducive to reliable, moderate capacity terrestrial and mobile operations while spectrum above 6 GHz supports critical DoD functions and applications requiring higher capacity services. Figure 2-1 provides a graphical depiction of the many spectrum bands throughout the managed electromagnetic spectrum where DoD has critical operations.

DoD's current spectrum usage and needs are addressed in Section 3, in which baseline requirements are described according to individual spectrum bands. Each band's importance to DoD is described as well as the primary operations, applications, and key systems DoD uses in the band. DoD has not identified spectrum parameters such as frequency or bandwidth in this document; to do so would, as a minimum, classify this document as "For Official Use Only".

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[13] *See* Presidential Determination: Memorandum for the Heads of Executive Departments and Agencies, 40 Weekly Comp. Pres. Doc. 2875, 2876, sec. 3(c) (Nov. 30, 2004) (Executive Memorandum), *available at* http://www.whitehouse.gov/news/releases/2004/11/20041130-8.html; s*ee also* Appendix 3.

[14] Secretary of Commerce Memorandum to the Secretary of Defense, March 10, 2005.

[15] National Security Strategy, 2002.

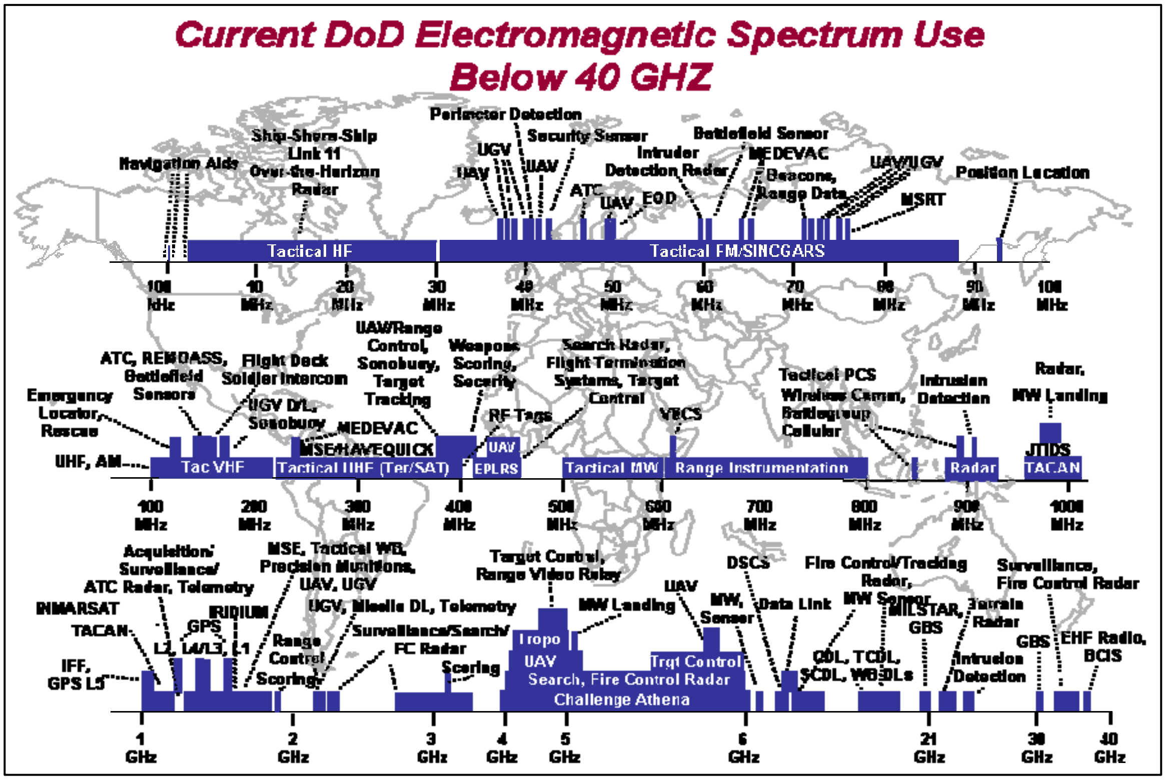

Figure 2-1 Depiction of DoD operations in spectrum bands below 40 GHz

2.2 DoD Trends in Future Spectrum Use and New Technology

In the future, warfighters will operate in a dynamic, multi-layered, multi-dimensional battlespace, as illustrated in Figure 2-2. In this environment, they will rely on robust, secure connectivity from the "first tactical mile." Such capability will only be attained through a broad array of secure net-centric links interconnecting people and systems, independent of time or location, will provide improved military situational awareness, better access to Department of Defense (DoD) information, and shortened decision cycles. The key enabler for net-centricity is the DoD Global Information Grid (GIG).

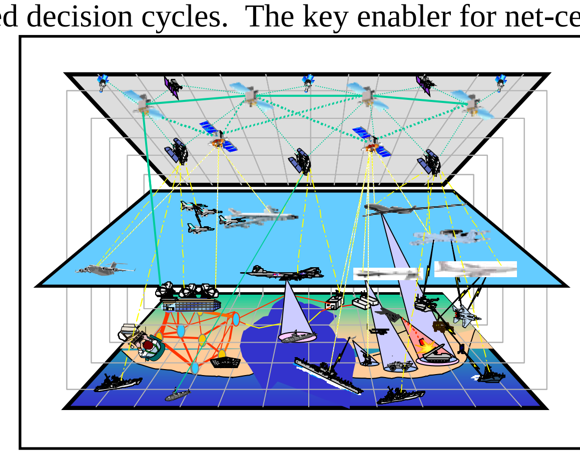

Figure 2-2. Future Battlespace in the Net-Centric Operational Environment

The GIG is supported by a seamless communications environment that includes both commercial and military networks accommodating a range of transmission media, standards, and protocols. Extension of the GIG down to the lowest warfighting echelons will be made possible through coupling integrated wireless architectures with spectrum-dependent systems such as communications, weapons, precision munitions, sensors, geo-location, and other wireless devices. As these wireless architectures are realized, the DoD requirement for throughput is increasing dramatically while worldwide competition for electromagnetic (EM) spectrum continues to put pressure on US military spectrum access. Future access to sufficient spectrum will only be achieved through both the application of technologies that increase channel efficiencies and supplements to spectrum available to DoD through the sharing of access to other government and commercial networks worldwide.

DoD's future spectrum needs, as described in Section 4, are addressed primarily according to major categories of service. The categories used for DoD's future spectrum demands assessment include terrestrial and satellite communications, radar, and test/training. The discussion of bands used for satellite communications encompasses both current (baseline) and future needs. Each category of future spectrum needs includes an assessment of how applicable bands and systems are projected to experience an increased demand for use in the future.

2.2.1 Future Spectrum Use

Critical to achieving this capability is communications connectivity and flexibility across geographically dispersed, heterogeneous systems at capacity levels far greater than previously experienced. Indications are that DoD will experience increased usage of EM spectrum for numerous systems in the future; the frequency bands most affected for terrestrial systems are depicted in Figure 2-3.

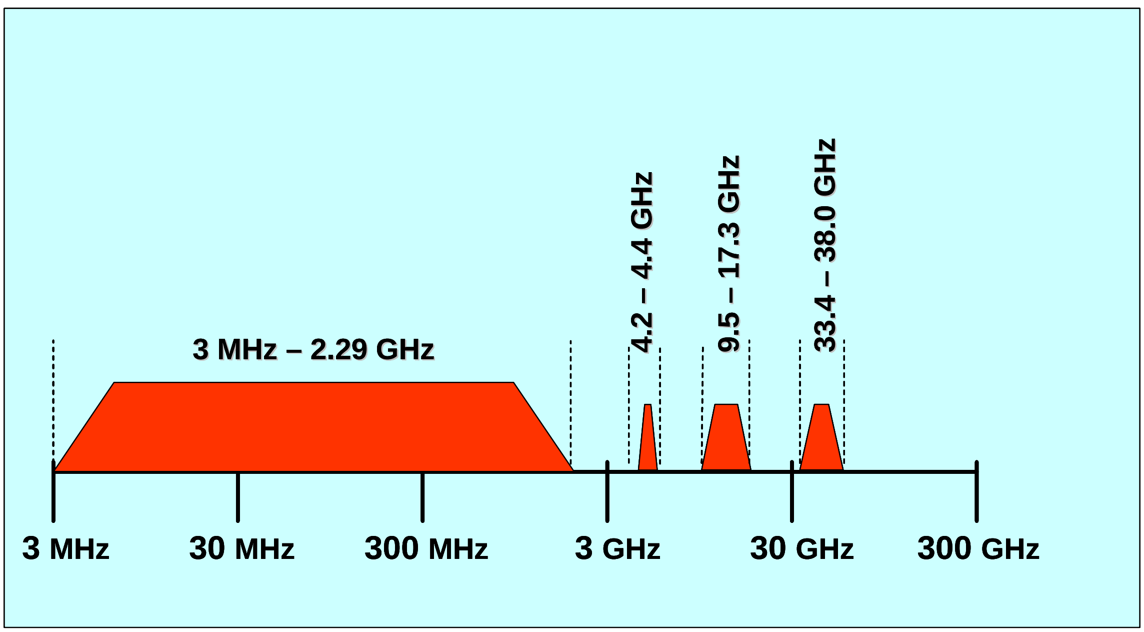

Figure 2-3 Bands in which DoD spectrum usage is expected to increase.

For terrestrial mobile operations using spectrum below 3 GHz, DoD's need for spectrum access will increase significantly over the next decade and beyond. This increase is in support of the Joint Transformational Communications concepts of the Army and Marine Corps Future Combat Systems, the Air Force Command and Control Constellation, and Navy FORCEnet. Mobile spectrum usage beyond 2014 is driven by transition to Wideband Network Waveform

(WNW) wireless networks that contribute to the realization of Network-Centric Warfare. These networks will provide increased situational awareness, dissemination of timely intelligence, and direct high-bandwidth communications to all battlefield users.

For terrestrial mobile operations using spectrum above 3 GHz, data link requirements for battlefield systems are projected to grow significantly through 2015. This growth is driven by the need to support the increased use of battlefield sensors and high data rate transfers associated with airborne high-resolution, hyper-spectral sensor data. Moreover, new requirements are surfacing for Secure Wireless LANs in the 5 GHz band and UAV Command & Control links along with Future Combat System (FCS) Data Networks in the 30 GHz to 40 GHz frequency band.

With respect to DoD's need for spectrum in bands allocated for satellite communications (SATCOM), both government and non-government spectrum bands are addressed. To satisfy the increased demand for SATCOM associated with transformational warfighting and DoD's need for information, DoD is planning to field several new satellite constellations that will require access to satellite spectrum. As these systems are expected to operate in the current bands identified for satellite utilization, the increase in the number of constellations utilizing the same frequency bands will put pressure on the frequency spectrum to satisfy this demand while providing necessary assurance of interference free operations.

Since all currently used SATCOM frequency spectrum is projected for continued or expanded use, there is growing competition for SATCOM spectrum. This competition will increase as new commercial satellite constellations and DoD transformational SATCOM constellation is fielded. Future systems will use the totality of the existing SATCOM frequency bands and the associated orbital slot assignments unless, or until, other bands or services can better meet requirements. Consequently, sufficient nationally and internationally allocated frequency spectrum and orbital slots must be retained/obtained as an essential enabler of military-unique systems and capabilities. Denying the warfighters' use of any portion of the spectrum would reduce flexibility and jeopardize mission accomplishment.

Current DoD radar spectrum requirements are extensive and will grow in the future; the trend in military radar is towards wider bandwidths both to better discriminate target objects and to provide additional signal processing for anti-jam techniques. New developments in radar systems are planned for the upper frequency bands (above 10 GHz), but these developments are generally intended to enhance capabilities rather than supplant the existing systems in the lower bands.

Training and test and evaluation (T&E) missions each have different, independent objectives. However, they most often share common radio frequency (RF) equipment and common resources and are often conducted in parallel to ensure realistic operational testing while maximizing training opportunities for military units. The demand for spectrum to support training and T&E events has increased over the last decade and will continue to increase as the design, development, testing, fielding, and employment of systems in support of force transformation is matched more closely with DoD warfighting needs.

As with many other DoD systems and services, the spectrum requirements of unmanned systems will continue in all of the same frequency bands utilized today but will grow in selected bands. In these selected bands, there will be a steady rise in the number of frequencies required to support the growing use of unmanned systems, an increase in the bandwidth for frequencies to support increased data transfer, and an increase in the time of operation due to longer on-station requirements. Meeting the increased requirement for spectrum dedicated to support unmanned systems will require increased attention to spectrum management schemes and scheduling to promote sharing of frequencies. Additionally, technologies that increase onboard processing and compression of sensor data will assist in reducing the amount of contiguous bandwidth needed to support airborne data links. Without significant spectrum reuse and fielding of spectrum efficient technologies, unmanned systems will be constrained in their use of spectrum to achieve overall mission needs and may require highly refined scheduling plans to ensure operations are executed within the limits of available spectrum.

2.2.2 DoD Technology Trends

Technological superiority is one of the cornerstones of US national military strategy and maintaining this advantage becomes even more significant in light of the objective to achieve and maintain dominance across the full range of crises and military operations even as the size of US forces decreases. The Department of Defense's focus on investing in technologies that will enable improvements in spectrum access and utilization efficiency is evidenced by the allocation of Army, Navy, and Air Force technology funding on specific research and development projects related to improving spectrum use.

Realizing DoD's vision for network-centric operations requires the achievement of high capacity, flexible, networked, communications connectivity across geographically dispersed, heterogeneous, on-the-move systems. Advances in communications and networking technology are an underlying mechanism necessary to achieve the revolutionary capabilities expected to support the N-C environment. This includes the technologies for the management of the individual media and the creation and management of networks for devices using the media.

To this end, DoD research and development activities range from antennas, transmission media, signal specifications, and standards to architectures, protocols, networking technologies, and network management, for example:

- Scaleable video compression schemes which dynamically trade off bandwidth and quality based upon the priority of the required information;
- Multi-mode, multi-function, sense-and-adapt air-mobile communications capability to dynamically alter communications methods under fast-changing environments;
- Bandwidth and network management techniques that can effectively manage and allocate wireless bandwidth across tactical and theater levels;
- Signal processing techniques to enable reliable low-power multi-media communications among highly mobile users under adverse wireless conditions; and
- Multi-input, multi-output, multi-carrier waveforms which exploit non-contiguous spectrum during mobile operations.

Through the insertion of such technologies, spectrum utilization efficiencies will be enhanced along with the goal of seamless communication between globally dispersed locations and positions in theater down to the lowest echelon will be achieved.

2.3 Strategies for Assessing and Meeting Future Spectrum Needs

The *DoD Net-Centric Spectrum Management Strategy*[16] presents the future view of SM in the net-centric environment. The strategy presents the *what* – the vision of net-centric SM. However, it does not describe the *how* – the specific approach and implementation required to achieve the vision. It identifies SM practices necessary to support the net-centric environment to assure that SM is infused into future wireless architectures, systems, and capabilities. As illustrated in Figure 2-4, the intent of the *strategy* is not to describe the technologies and programs that will implement net-centric SM; the intent is to provide a description of what is needed for SM to accomplish its vital role as an enabler for net-centric operations.

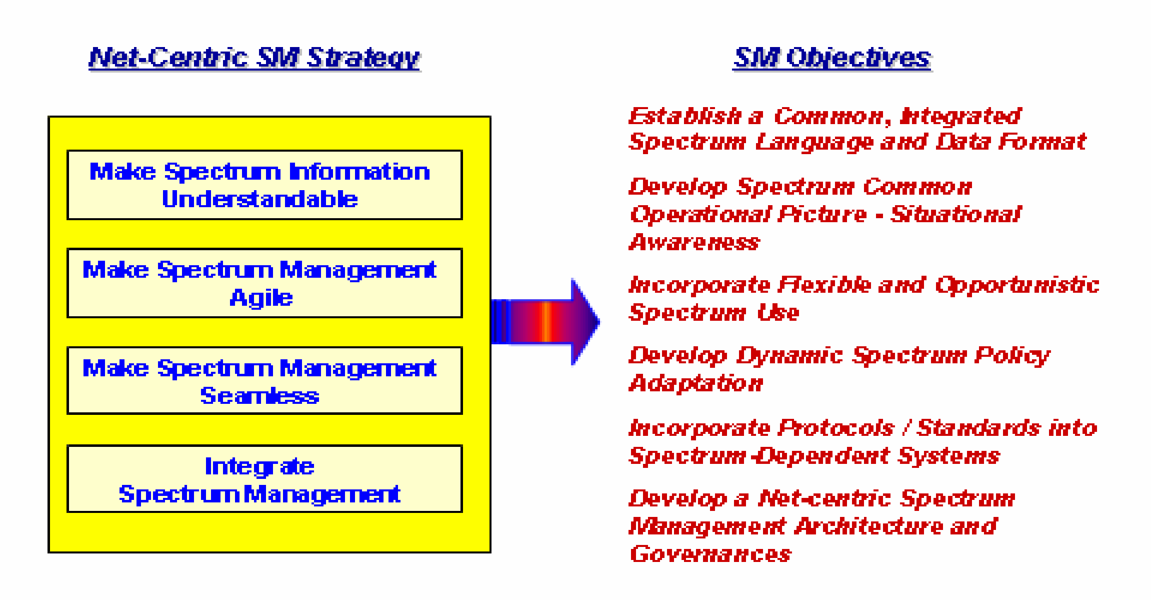

Figure 2-4 DoD Net-Centric SM Objectives

Through the experiences acquired in developing the 2005 DoD Strategic Spectrum Plan[17] the DoD has recognized the need for near- and far-term spectrum planning processes that provide a high degree of predictability. As such, the Department envisions a plan for the development of a current user needs analysis for spectrum dependent systems and a methodology for characterization and forecasting of long-range spectrum requirements."

The Department recognizes that the development of an effective biennial process will be a significant challenge. Furthermore, the department recognizes the increasingly global nature of the telecommunications marketplace and the effect of spectrum encroachment on critical DoD systems. As a result, the department must assist other executive departments and agencies of the

[16] *Op. Cit.*
[17] *The Department of Defense Strategic Spectrum Plan*, November 30, 2005.

U.S. government in developing a unified coherent National Strategic Spectrum plan that will include an approach to addressing the concern of spectrum encroachment on critical DoD systems worldwide. Additionally, DoD will work closely with NTIA and the Commerce Department to ensure that DoD's future process is optimized to meet the intent of the Presidential Memorandum.

2.3.1 The DoD Electromagnetic Spectrum Management Strategic Plan

The Department of Defense has long understood the criticality of electromagnetic spectrum access. Net-centricity depends on an environment that provides full connectivity and interoperability to produce and share a common understanding of all dimensions of the battlespace. The key enabler for net-centricity is the DoD Global Information Grid (GIG). The GIG is supported by a seamless communications environment which includes both commercial and military networks accommodating a range of transmission media, standards, and protocols. Extension of the GIG down to the lowest warfighting echelons will be made possible through coupling integrated wireless architectures with spectrum-dependent systems such as communications, weapons, precision munitions, sensors, geo-location, and various wireless devices.

The vision of assured spectrum access led to the development of the *draft 2007 DoD Electromagnetic Spectrum Management Strategic Plan* (EM SMSP). This plan establishes goals and associated objectives to "assure the availability of, and access to, sufficient electromagnetic spectrum."[18] The goals of the DoD plan are presented in Figure 2-5.

Goal 1	**Achieve a seamless SM and E3 control environment through the transformation of processes, practices, and operations as envisioned by the DOD Net-Centric Spectrum Management Strategy.**
Goal 2	**Evolve near- and far-term spectrum planning processes that provide a high degree of predictability for achieving assured spectrum access on a worldwide basis.**
Goal 3	**Advance net-centric SM principles within the warfighting and business domains of DOD through education and outreach.**
Goal 4	**Advocate and defend DOD spectrum positions in national and international arenas that will achieve the tenets of net-centric SM.**
Goal 5	**Improve EM spectrum utilization through technology insertion to achieve net-centric SM**

Figure 2-5 Goals of the draft 2007 DOD EM Spectrum Management Strategic Plan

2.3.2 The Defense Spectrum Management Architecture

With regard to the goals and objectives of the EM SMSP, it is recognized that a detailed and systematic understanding of SM processes, systems, and impacts of emerging technologies is

[18] Joint Spectrum Vision 2010, September 27, 1999.

needed to guide implementation. DoD has developed an enterprise architecture, The Defense Spectrum Management Architecture (DMSA), for spectrum management (See Figure 2-6). The purpose of the DMSA is to provide decision makers and supporting staffs with a comprehensive, standardized description of the organizational information exchange and system functions required to satisfy DoD spectrum requirements.

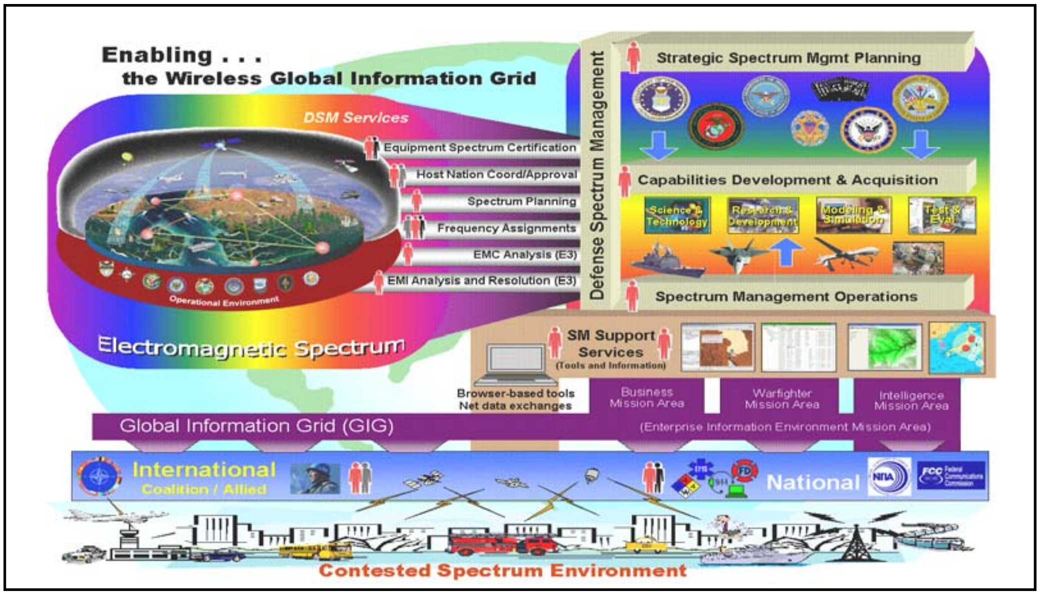

Fig 2-6 Defense Spectrum Management Architecture (OV-1)

The DSMA will be used to support capital planning and investment, joint capabilities integration and development, DoD Acquisition, and interoperability between and among information technology (IT) systems as required by OMB. To properly depict the Department's transition to its objective capability, select operational system and technical architecture views also document the future architecture for SM within DoD for three incremental timeframes (Transitional Architectures) and for the "To-Be" spectrum management environment (Target Architecture). The objective timeframe is projected for 2025+ and describes the spectrum management capability needed to assure spectrum access required to support DoD in net-centric warfare and operations.

2.4 DoD Leadership Goals and Objectives for SM

DoD began an evaluation of its SM policies and plans to better support military transformation. The Deputy Secretary of Defense (DepSecDef) issued the *Department of Defense Electromagnetic Spectrum Management Strategic Plan*[19] in December 2002 to enable SM transformation. The plan embraced a vision for SM and electromagnetic environmental effects (E3) control and established strategic goals whose attainment would enable the warfighter to access the spectrum required to prevail in the dynamic battlespace of the future. Shortly after the release of the 2002 plan, a revision to DoD Directive 4650.1, *Policy for Management and*

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[19] Department of Defense, Office of Assistant Secretary of Defense (Command, Control, Communications and Intelligence), Electromagnetic Spectrum Management Strategic Plan, October 2002, Washington, D.C.

Use of the Electromagnetic Spectrum[20] was undertaken, and subsequently completed. Other actions included commencement of both the development of the *Department of Defense Net-Centric Spectrum Management Strategy* which reflects net-centric operations and the conceptualization of a Global Electromagnetic Spectrum Information System (GEMSIS).

The draft 2007 DoD Electromagnetic Spectrum Management Strategic Plan establishes goals and associated objectives to "assure the availability of, and access to, sufficient electromagnetic spectrum."[21] The timing and scope of this plan is influenced by several factors, namely:

- The President's direction "to agency heads" for improving SM policies and procedures as embodied in the President's Spectrum Policy Initiative [22] ;
- Alignment of SM goals and objectives with the 2006 *Quadrennial Defense Review (QDR) Report*[23], including the establishment of objectives that support joint warfighting capability; and
- Alignment of SM goals and objectives with US military transformation to a more agile expeditionary force, and a corresponding move toward a more Department-wide enterprise, net-centric approach. That is, SM must transform to reflect the DoD Net-Centric SM Strategy[24] and the net-centric joint operational environment[25,26,27] .

The goals of this *Plan* extend the basic tenets of the 2002 strategic plan to achieve the N-C SM vision and to assure that SM is transformed to a new net-centric paradigm. As shown in Figure 2-7, successful SM transformation is inextricably linked to achieving the goals of this plan as framed by the net-centricity decisions of the 2006 *QDR Report*, the ASD(NII) spectrum initiatives, the Net-Centric SM Strategy, and the Defense Spectrum Management Architecture.

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[20] DOD Directive NUMBER 4650.1, Policy for Management and Use of the Electromagnetic Spectrum, June 8, 2004.
[21] Joint Spectrum Vision 2010, September 27, 1999
[22] Presidential Memo on Spectrum Policy, Subject: Spectrum Policy for the 21st Century, June 2003
[23] Quadrennial Defense Review Report, Office of the Secretary of Defense, February 6, 2006
[24] Department of Defense Net-Centric Spectrum Management Strategy, ASD/NII, August 9, 2006
[25] Capstone Requirements for Joint Operations, Version 2.0, Chairman, Joint Chiefs of Staff, August 2005
[26] Net-Centric Environment - Joint Functional Concept, Version 1.0, Joint Staff, April 7, 2005
[27] Net-Centric Environment - Joint Integrating Concept, Joint Staff, October 31, 2005

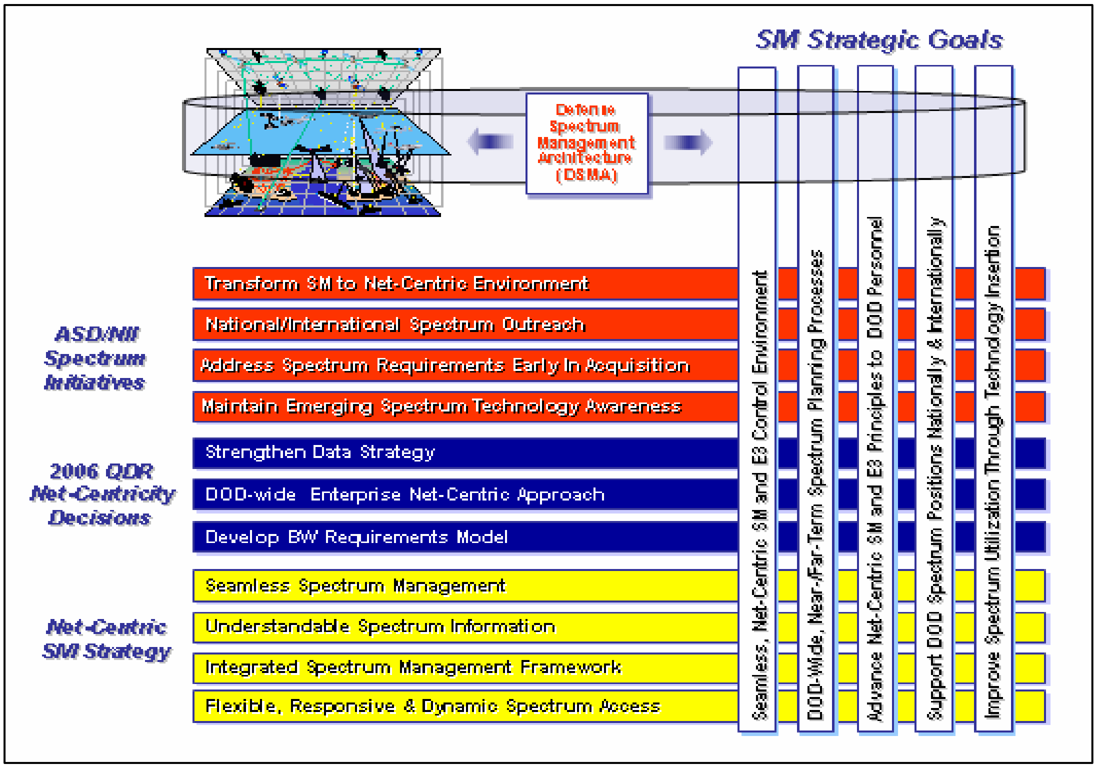

Figure 2-7 Goals of the DoD Spectrum Management Strategic Plan

Several goals of DoD's draft 2007 SM Strategic Plan have much in common with the spectrum requirements tasks directed by the Executive Memorandum; albeit focused in the near-term, it is important to note the general agreement between the Memorandum's directions and the DoD plan's objectives. For example: two objectives for Goal 2 state respectively, *"Develop a comprehensive plan for the determination of current baseline spectrum usage"* and *"Design and implement methods to analyze and forecast spectrum requirements."* Another example can be found in Goal 5 wherein one objective is to *"Recognize technologies that enhance spectrum utilization efficiency and effectiveness for all DoD systems."* Each of these objectives relate directly to the Secretary of Commerce's directions to agency heads, cited in Section 1, regarding the content required for the federal spectrum plan.

3.0 DoD's 2007 Baseline Spectrum Usage and Needs

DoD currently operates in most government exclusive spectrum bands as well as in many shared spectrum bands. The vast majority of DoD frequency assignments are below 6 GHz due to the fact that spectrum in this range is highly conducive to supporting terrestrial mobile operations with reliable, moderate capacity communications links along with many bands (See Figure 3-0). Depiction of DoD operations in spectrum bands below 40 GHz provides excellent propagation characteristics through dense foliage. DoD also employs a number of spectrum bands above 6 GHz for critical functions and applications. Figure 3-0 provides a graphical illustration of the many spectrum bands throughout the managed electromagnetic spectrum where DoD has critical operations. In order to address DoD's current spectrum usage and needs, the enclosed material is structured according to individual spectrum bands. Each band's importance to DoD is described as well as the main types of operations, applications, and key systems DoD uses in the band.

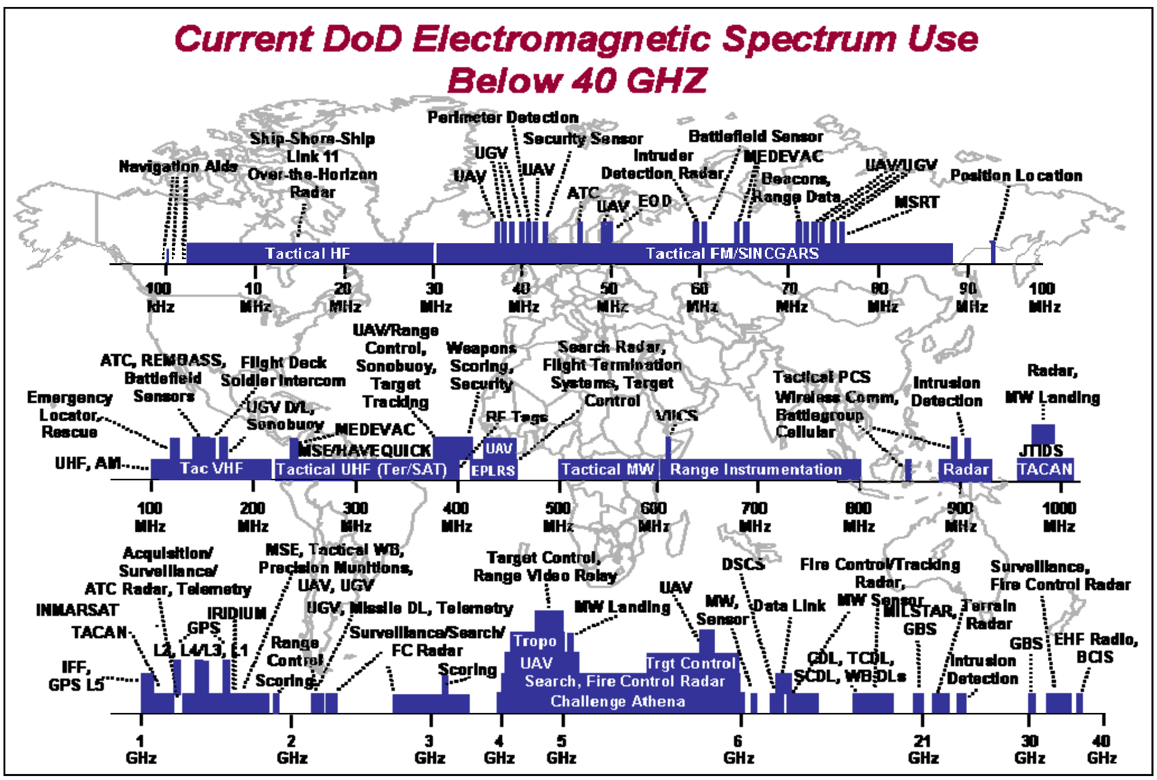

Figure 3-0 Depiction of DoD operations in spectrum bands below 40 GHz

3.1 3 – 30 MHz Band: Mission, Functions, and Usage Summary

Table 3-1 depicts the major DoD applications/operations supported in this spectrum band.

Table 3-1. DoD Operations 3-30 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Band**	**DoD Application**
3-30		X	Voice/Data Over-the Horizon Radar Training Range Operations T&E

The 3-30 MHz band is commonly referred to as the High Frequency (HF) band. This band has inherent advantages which makes it important for military and emergency communications. These advantages include rapid set-up, ease of transport, and flexible network management capability. HF also has the flexibility to simultaneously support both local and extremely long distance beyond line-of-sight communications. In mountainous areas, it may be the only terrestrial communications technology that will work for short non-line-of-sight ranges. Propagation factors decisively influence the availability of HF spectrum and the number of individual frequencies (e.g. 3 kHz channels) that can be employed. This creates challenges in addressing emergency needs in dynamic environments typical of disasters, crisies, and conflicts. Propagation factors also require that frequency channels or sub-bands of an HF pool be evenly spaced over the 3-30 MHz HF band to allow communications under various ionospheric conditions.

Criticality of 3 – 30 MHz for DoD Use: The use of fixed service and mobile service HF allocations is a common denominator in achieving interoperable communications in multi-national efforts. Such scenarios are becoming increasingly common for coalition military operations and humanitarian relief. The multi-national demand for HF band communications is understandable given that the primary alternative is high-cost satellite communications. Ad-hoc coalitions may include nations that possess only HF communications for long-range, over-the-horizon communications. HF communications may also provide point-to-multi-point (PTMP) connectivity and allows numerous telecommunications operators to monitor and coordinate activities. Virtually all military forces possess HF communications, making this type of capability a key component for readiness.

DoD HF Missions, Uses, and Applications: DoD uses HF for a variety of missions worldwide. The following are general descriptions of how HF is used in the Department of Defense from the perspective of specific mission support. The types of applications in which DoD uses the HF band include voice communications, e-mail, Web Calls, and radar.

Department of the Army Use of 3 – 30 MHz: HF equipment is used by almost every Army tactical organization, from Company through Corps level. It is primarily used for long-haul communications supporting command and control, logistics, reachback, and coalition interface. The equipment configurations are manpack, vehicular, fixed base, and aeronautical. The connectivity provided includes point-to-point, point-to-multi-point, air-to-air, and air-ground-air missions.

Department of the Air Force Use of 3 – 30 MHz: Air Forces use HF in tactical operations, strategic communications, and range control. Command and control HF communications are utilized on a daily basis to ensure readiness of weapon system crews. Coalition and Joint Force Air Component Commanders employ HF as a means of long-haul communications with subordinate units.

US Navy Use of 3 – 30 MHz: Reliable HF communications are essential to Carrier Strike Group (CSG) and Expeditionary Strike Group (ESG) operations. In addition, Fleet C4I operations are supported by long-haul HF communications capabilities. Maritime Forces utilize HF extensively for operation and training with Allied and Coalition Forces. HF is also important during periods of natural and man-made interference (i.e., sun spots, adverse ionospheric activity, and jamming) as ionospheric disturbances facilitate reliable HF communications while impairing other wireless communications.

US Marine Corps Use of 3-30MHz: The Marine Corps has a significant investment in communications equipment that transmits and receives via the HF band. Units at all levels of the Marine Corps routinely communicate with ground, air, and maritime assets using the HF band. Like the Army, the Marine Corps relies on HF for long and short-range communications. The Marines also rely on HF communications to establish voice and data links with Coalition and Joint Forces.

3.2 30 – 88 MHz Band: Mission, Functions, and Usage Summary

Table 3-2 depicts the major DoD application/operations supported in this spectrum band.

Table 3-2. DoD Operations 33-88 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Band**	**DoD Application**
30-88	X	X	Voice/Data NAVAIDS Command Control Link RDT&E Test Range Operations

The largest and most significant DoD operations supported in this portion of the spectrum include tactical and tactical exercise communications as well as non-tactical communications. The band is used in air-to-air, air-to-surface-to-air, and surface-to-surface link configurations for communications with both US and Allied forces. The band is also used to support tactical training exercises using equipment such as the Mobile Subscriber Radio Telephone (MSRT) and Radio Access Unit (RAU) components of the Mobile Subscriber Equipment (MSE) and jam-resistant Single Channel Ground & Airborne Radio System (SINCGARS) communications. Other DoD operations supported in this portion of the spectrum include Research, Development, Test and Evaluation (RDT&E), test range support, and sustaining base/installation infrastructure support. Approximately 80% of DoD's spectrum usage in the 30-88 MHz band is in the non-shared segments below 50 MHz.

The Army and Marine Corps' primary use of this band is for Combat Net Radios and tactical training communications with either single-channel or the jam-resistant SINCGARS radios. Numerous frequencies throughout the 30-88 MHz band are required to satisfy the requirements for Combat Net Radios, which include single channel and jam-resistant SINCGARS communications and the very high frequency—frequency modulation (VHF-FM) components of the MSE. As an example, a nominal Army division requires approximately 750 individual SINCGARS nets on frequencies in this band. In addition, transmit and receive frequencies from the 30-51 MHz and 59-88 MHz segments, respectively, are required for MSRT-RAU communications. Navy operations supported in this band include tactical training, Navigational Aids (NAVAIDS) (to include marker beacons and runway lighting controls), RDT&E, and special projects. The Air Force operations in this band are tactical training, security, Civil Engineer's Prime Beef, training communication, range, and RDT&E support. Additional Air Force operations supported include flight communications, law enforcement, including communications and security systems, and NAVAIDS Marker Beacons. Other requirements supported in this band include contingency operations, explosive ordnance disposal (EOD), Civil Air Patrol (CAP), and meteor burst communications. The Air Force and Marine Corps both use temporary (temps) assignments in the band primarily for close air support communications during combat and tactical training exercises. The Marine Corps' use of temps supports ground-to-air and ground-to-ground communications during combat and tactical training exercises.

3.3 108 – 150 MHz Band: Mission, Functions, and Usage Summary

Table 3-3 depicts the major DoD application/operations supported in this spectrum band.

Table 3-3. DoD Operations 108-150 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
108-150		X	DGPS Voice/Data ATC/NAVAIDS Sensor Data Link Test/Training Range Operations RDT&E

The specific operations supported by systems in this frequency band vary in visibility and criticality, but they generally fall into one of the following categories: (1) tactical communications, such as air-to-air and multi-aircraft formation communications, sonobuoy data links, close air support, and air traffic control (ATC); (2) installation support/sustaining base, such as fire department, medical, civil engineers, and maintenance communications nets; (3) security, such as police communications, alarms, and intrusion detection systems; and (4) test/training range communications and instrumentation support, such as range control, pop-up target control, and range timing systems.

The Navy conducts sonobuoy operations in this portion of the spectrum to detect the presence and location of underwater targets (e.g., submarines). The Civil Air Patrol (CAP), Coast Guard Auxiliary, and Military Affiliate Radio System (MARS) also use this band extensively in search and rescue operations.

3.4 162 – 174 MHz Band: Mission, Functions, and Usage Summary

Table 3-4 depicts the major DoD application/operations supported in this spectrum band.

Table 3-4. DoD Operations 162-174 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
162-174	X		Voice/Data LMR Sensor

DoD operations supported in this band are primarily for land mobile systems supporting law enforcement, maintenance, fire, medical, administration, and other installation/sustaining base communications requirements. The Navy conducts sonobuoy operations to detect the presence and location of underwater targets (e.g., submarines). The Army Corps of Engineers makes extensive use of this band to support navigable waterways and to manage and operate locks and dams.

The majority of equipment operated by the military in this band is commercially available land mobile fixed stations, repeaters, and mobile and hand-held units.

3.5 216 – 225 MHz Band: Mission, Functions, and Usage Summary

Table 3-5 depicts the major DoD application/operations supported in this spectrum band.

Table 3-5. DoD Operations 216-225 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
216-225		X	Voice/Data Training Range Operations T&E Space Surveillance

DoD operations currently supported in this portion of the spectrum include a Navy space surveillance (SPASUR) system, the Air Force's hazardous fire-protection suit communications systems, and Army tactical radio-relay systems. The Army operations in this portion of the spectrum include radio-relay system training, test range support (timing, beacons, and RDT&E), and contingency operations.

The Navy's Fleet Operational Readiness Accuracy Check Site (FORACS) system Radio Direction Finder Test System (RDFTS) is used to determine and improve the accuracy of radio direction finder sets aboard ships. The RDFTS operates in conjunction with other FORACS equipment and test systems. FORACS is used to measure and improve the accuracy of shipboard navigational equipment and electromagnetic, acoustic, and optical sensors under dynamic scenarios closely approximating operating conditions. FORACS testing provides the ship with an assessment of actual sensor performance versus design standards, evaluates maintenance effectiveness and degradation of performance due to aging, weather, and other factors, and it serves to certify fleet operational readiness. The Navy also operates its SPASUR system in this portion of the spectrum. The SPASUR system is a critical tracking sensor in the Space Surveillance Network (SSN). The SSN maintains continuous surveillance of space and a complete inventory of trackable Earth-orbiting objects. As the number of objects (active and inactive satellite and debris) have grown over the years (generally at a rate of about 250 objects per year), this space surveillance mission has become increasingly important in protecting the safety of manned and unmanned missions into space. The SPASUR system is used to maintain a constant surveillance of space (high-altitude, unalerted detection of Earth-orbiting satellites, and other objects) and to provide object data for maintaining the satellite catalog, a database of orbital trackable objects in Earth orbit. The Navy also uses spectrum within this band to support vulnerability and electromagnetic radiation tests on ordnance, Boom Crane Audio-Visual Load Warning System, and a weather research data link.

3.6 225 – 399.9 MHz Band: Mission, Functions, and Usage Summary

Table 3-6 depicts the major DoD application/operations supported in this spectrum band.

Table 3-6. DoD Operations 225-399.9 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
225-399.9	X		Voice/Data Search and Rescue (SAR) ATC/NAVAIDS Command Control Link Training Range/Center Operations

Since the 1940's, the 225-399.9 MHz band has been preserved by most allied nations, throughout the North Atlantic Treaty Organization (NATO), and within the individual member countries themselves for military operations. The military nature of this band has also been maintained by certain allied and friendly nations outside the NATO alliance such as Australia, Israel, Japan, Korea, New Zealand, Saudi Arabia, and most recently by the European Cooperation Partners (CP) nations and the Partners for Peace (PFP) nations.

DoD supports a variety of missions within this band as a result of its historic availability for military operations and the propagation benefits of the lower ultra high frequency (UHF) range. DoD uses the 225-399.9 MHz band to maintain vital command and control (C2) and communications on a global scale as well as within a theater of operations. Specific missions include flight operations, tactical training, installation and sustaining base, test and training range operations, and contingency command and control. Global C2 is supported by UHF satellite communications (SATCOM). Theater command, control, and communications (C3) is carried out by single and multi-channel voice and data systems supporting SATCOM, air-to-air (A/A), air-to-ground-air (A/G/A), and ground-to-ground (G/G) operations. In addition, DoD relies on the 225-399.9 MHz band to perform other critical missions such as air traffic control (ATC) and search and rescue (SAR). This band also supports many non-traditional systems such as the Joint Readiness Training Center Instrumentation System (JRTC-IS) datalink, weather buoy radio beacons, sonobuoy, and weapons location systems. A small portion of this band (328.6-335.4 MHz) is set aside for the Glide Slope Instrument Landing System (ILS).

DoD operations supported in this spectrum band also include conventional land mobile radio (LMR) nets and trunked radio systems in support of installation support/sustaining base, security/law enforcement, medical, maintenance, research and development, test/training range communications, and instrumentation support. The Navy and Marine Corps have also begun the installation of an Enterprise-LMR (E-LMR) system that uses spectrum efficient technologies. This system is intended to provide capabilities for linking Anti-Terrorist and Force Protection communications between various Navy and Marine Corps Installations.

The 225-399.9 MHz band is the only available portion of the spectrum that can support the diversity of communications required for peacetime, tactical training, and wartime operations and can support the communications interoperability needed for joint operations involving US and Allied/Coalition forces.

3.7 400.05 – 420 MHz Band: Mission, Functions, and Usage Summary

Table 3-7 depicts the major DoD application/operations supported in this spectrum band.

Table 3-7. DoD Operations 400.05-420 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
400.05-420		X	Voice/Data LMR Command Control Link Meteorological Aids Search and Rescue

DoD operations supported in this spectrum band include installation support/sustaining base, security/law enforcement, medical, maintenance, research and development, test/training, range communications, and instrumentation support. DoD uses both conventional land mobile radio (LMR) nets and trunked radio systems in support of these requirements. The

CombatSurvivor Evader Locator (CSEL) radio system operates in this band as well as the Army's Observer/Controller radio systems.

DoD uses this band to collect and disseminate weather data to support ATC operations and various DoD missions. DoD also uses a portion of this band for search and rescue operations/missions.

3.8 420 – 450 MHz Band: Mission, Functions, and Usage Summary

Table 3-8 depicts the major DoD application/operations supported in this spectrum band.

Table 3-8. DoD Operations 420-450 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
420-450	X		Voice/Data LMR EPLRS 2D Air Search Airborne Early Warning (AEW) Space Surveillance EW Training Command Control Link

DoD operations supported in this portion of the spectrum include national airspace surveillance and early warning radars, shipborne and airborne early warning radars, remotely piloted, unmanned air vehicle telecommand and flight termination systems, missile and rocket flight termination equipment, and troop position and location reporting equipment. Recently, the operations of radar equipment in this band received renewed interest when it was confirmed that radar operations below 1000 MHz are more conducive to low-observable target detection. The Position Location Reporting System (PLRS) and its successor, the enhanced PLRS (EPLRS), are employed during tactical operations and exercises for three-dimensional positioning, navigation, and friendly-force identification.

3.9 902 – 928 MHz Band: Mission, Functions, and Usage Summary

Table 3-9 depicts the major DoD application/operations supported in this spectrum band.

Table 3-9. DoD Operations 902-928 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
902-928	X		2D Air Search Target Acquisition NAVAIDS Shipboard Air Defense Command Control Link Test Range Operations

DoD uses this band principally for military operations and Industrial, Scientific and Medical (ISM) systems. There are two key DoD systems that use the entire 902-928 MHz band. One is the Navy's primary two-dimensional shipboard air defense radar used on all aircraft carriers, other ships, and some Navy shore installations. The other system tracks and controls drones and other land and air vehicles at military test ranges.

3.10 932 – 935 MHz Band: Mission, Functions, and Usage Summary

Table 3-10 depicts the major DoD application/operations supported in this spectrum band.

Table 3-10. DoD Operations 932-935 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
932-935		X	Voice/Data Air Defense Radar Radiolocation Command Control Link

The Department of Defense operations supported in this portion of the spectrum include point-to-point and multi-point fixed microwave systems, transportable tactical communications, radiolocation operations, utilities control, remote system controls, and passive (receive only) systems.

This band is used by the Navy to support the Tactical Aircrew Combat Training System's (TACTS) electronic warfare data links. Additionally, the Navy operates search radar systems in this portion of the spectrum. The Air Force also operates its utilities and energy control system in this band.

3.11 941 – 944 MHz Band: Mission, Functions, and Usage Summary

Table 3-11 depicts the major DoD application/operations supported in this spectrum band.

Table 3-11. DoD Operations 941-944 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
941-944		X	Voice/Data Air Surveillance Radar Command Control Link AFRTS Audio/Visual

DoD requirements supported in this spectrum band include, point-to-point and multi-point fixed microwave systems, transportable tactical communications, and radiolocation operations.

Navy operations supported in this band are very similar to its operations in the 932-935 MHz band. The Navy uses this band to support the Tactical Aircrew Training System (TACTS) electronic warfare data links using the Multi-point-point 19 Communications System. The Navy also supports the Armed Forces Radio and Television Service (AFRTS) operation in this portion of the spectrum. The Air Force also supports operations of its utilities and energy control system within this portion of the spectrum.

3.12 960 – 1215 MHz Band: Mission, Functions, and Usage Summary

Table 3-12 depicts the major DoD application/operations supported in this spectrum band.

Table 3-12. DoD Operations 960-1215 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
960-1215		X	Voice/Data JTIDS/MIDS Command Control Link ATC Secondary Surveillance Radar TACAN Aircraft IFF Long Range Radar

The 960-1215 MHz band is used both nationally and internationally for aircraft identification, tracking, control, navigation, and collision avoidance. In addition to these operations, DoD employs this band for integrated communications, navigation, and identification (ICNI).

The peacetime functions of radionavigation and identification equipment that operate in this band segment are essential to Air Traffic Control (ATC) in the US National Airspace System (NAS) and abroad. Wartime operations vary slightly from peacetime operations with the major difference being the addition of a cooperative aircraft identification and battlefield information distribution system.

DoD also supports operation of Tactical Air Navigation (TACAN) (airborne and ground-based), Mark X and Mark XII, Identification Friend or Foe (IFF), and Secondary Surveillance Radar (SSR) in this portion of the spectrum. TACAN ground beacons are in operation throughout the US in support of DoD flight operations. All Mark X and XII, IFF, and SSR operations only use 1030 and 1090 MHz. IFF/SSR-related capabilities, including Mode S as well as the Traffic Alert and Collision Avoidance System (TCAS) operations, also employ 1030 and 1090 MHz. DoD also operates a tactical spread spectrum datalink, the Joint Tactical Information Distribution System (JTIDS), with Air Traffic Control and Landing Systems (ATCALS) operations in this band.

The Navy and Marine Corps support an electronic warfare (EW) training simulator in this band.

3.13 1215 – 1390 MHz Band: Mission, Functions, and Usage Summary

Table 3-13 depicts the major DoD application/operations supported in this spectrum band.

Table 3-13. DoD Operations 1215-1390 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
1215-1390		X	Voice/Data Command Control Link ATC/NAVAIDS Range & Test Operations GPS ICBM Detection/Surveillance Radar Long-Medium Air Defense Radar Training Range Operations

The key DoD operations performed in this band include long and medium-range air defense, radionavigation, test range support, and tactical fixed and mobile communications. Government military equipment authorized to operate in this band include the following: long and short-range air defense radar (ADR) equipment; an inter-continental ballistic missile (lCBM) detection/surveillance radar; tactical line-of-sight (LOS) radio relay equipment; aerial unmanned target/drone control equipment; manned and unmanned aircraft time, space, and position reporting equipment; and satellite downlink equipment. Although they differ greatly in application, each operation is necessary for both peacetime and wartime operations. The long and medium-range air defense radars are used for North American border surveillance. Radionavigation functions supported in this band include satellite-based navigational systems and ground-based en route ATC systems. The Global Positioning System (GPS) provides satellite-based precision radionavigation to DoD elements worldwide. Tactical communications radio systems, used by the Army and Marine Corps also operate in this frequency band. Test range support equipment such as the Range Applications Joint Program Office (RAJPO) datalinks are employed during testing and training operations. Range applications systems provide the military with the means to monitor and control drones and other air vehicles with significant precision at many of the national test ranges. Shipborne systems provide point defense and anti-missile engagement capabilities against sea skimming missiles.

The GPS provides worldwide precision navigation not only to the US military and its allies but also to a global civilian population. GPS is a space-based radionavigation system that is operated by the US Air Force for the US Government. The GPS system is composed of space, control, and user segments.

The GPS Space Segment is composed of twenty-four satellites in six orbital planes. The satellites operate in 20,200 km orbits at an inclination angle of 55° and within a twelve-hour period. The satellites are arranged so that a minimum of five satellites are visible at any time to users worldwide. The GPS Control Segment is composed of five monitor stations and three ground antennas with uplink capabilities. The GPS User Segment consists of a myriad of configurations, many of which have the antenna and receiver processor integrated with the user platform. The User Segment computes navigation solutions to provide positioning, velocity, and precise timing to the user.

3.14 1390 – 1710 MHz Band: Mission, Functions, and Usage Summary

Table 3-14 depicts the major DoD application/operations supported in this spectrum band.

Table 3-14. DoD Operations 1390-1710 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
1390-1710		X	Voice/Data ATM Low-Altitude Aircraft Detection Precision Guided Munitions Command Control Link RDT&E

Within the 1390-1710 MHz band, the 1432-1435 MHz band has been reallocated from primary government fixed and mobile services to commercial use in accordance with Title III of the Balanced Budget Act of 1997 (Public Law 105-33)(BBA-97), effective January 1, 1999. Essential federal government operations and associated airspace will be protected indefinitely at the sites listed in Table 3-15. DoD uses this band for tactical radio relay communications, military test range aeronautical telemetry and telecommand, and various types of guided weapon systems.

The Air Force operates data links in the 1432-1435 MHz band to rebroadcast aircraft position during tests and training. The associated system is deployed at all major military aircraft and missile test centers.

The Navy uses the band for a variety of missions and functions. These include testing of shipboard electronics, control of remotely-operated aircraft (ROA), and operation of aerostat balloons to detect low-flying aircraft suspected of carrying drugs. In addition, the Navy operates data links in the 1427-1435 MHz band to rebroadcast aircraft position during tests and training. Other Navy data links are used to control the trajectory of live airborne munitions. This system is deployed at major military aircraft and missile test centers.

The Army use the 1390-1710 MHz band for tactical radio relay systems in support of proficiency training at specific Army installations. These tactical radio relay systems have broad tuning ranges, which include the 200-400, 600-1000, and 1350-2690 MHz ranges. In addition, the Army data links in 1350-1400 MHz and 1427-1435 MHz rebroadcast aircraft position during tests and training.

Table 3-15.
Sites at which federal systems in the 1432-1435 MHz band will be protected indefinitely.

Location	Site Coordinates	Protection Radius (km)
China Lake/Edwards AFB, CA	35° 29' N 117° 16' W	100
White Sands Missile Range/Holloman AFB, NM	32° 11' N 106° 20' W	160
Utah Test and Training Range/Dugway Proving Ground/Hill AFB, UT	40° 57' N 113° 05' W	160
NAS Patuxent River, MD	38° 17' N 076° 24' W	70
Nellis Range, NV	37° 32' N 115° 46' W	130
Fort Huachuca, AZ	31° 33' N 110° 18' W	80
Eglin AFB, Tyndall AFB, FL/Gulfport ANG Range, MS/Fort Rucker, AL	30° 28' N 086° 31' W	140
Yuma Proving Ground, AZ	32° 29' N 114° 20' W	160
Fort Greely, AK	63° 47' N 145° 52' W	80
Redstone Arsenal, AL	34° 35' N 086° 35' W	80
Alpene Range, MI	44° 23' N 083° 20' W	80
Camp Shelby, MS	31° 20' N 089° 18' W	80
MCAS Beaufort, SC	32° 26' N 080° 40' W	160
MCAS Cherry Point, NC	34° 54' N 076° 53' W	100
NAS Cecil Field, FL	30° 13' N 081° 53' W	160
NAS Fallon, NV	39° 30' N 118° 46' W	100
NAS Oceana, VA	36° 49' N 076° 01' W	100
NAS Whidbey Island, WA	48° 21' N 122° 39' W	70
NAS Lemoore, CA	36° 20' N 119° 57' W	120
Naval Space Operations Center, ME	44° 24' N 068° 01' W	80
Savannah River, SC	33° 15' N 081° 39' W	3

3.15 1710 – 1755 MHz Band: Mission, Functions, and Usage Summary

Table 3-16 depicts the major DoD application/operations supported in this spectrum band.

Table 3-16. DoD Operations 1710-1755MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
1710-1755		Mixed Use	Voice/Data Data/Video Links CIDDS Range Telemetry Precision Guided Munitions Air Combat Training

DoD has historically employed the 1710-1755 MHz band to support a broad range of critical mobile/transportable systems and a large number of installation infrastructure services. The major operations supported in the band include transportable tactical radio relay communications, air combat training, fixed radio relay communications, and mobile video control links. Specific systems include, but are not limited to, Mobile Subscriber Equipment (MSE) and Digital Wideband Transmission System (DWTS) which support tactical battlefield communications, and Precision Guided Munitions (PGMs) systems. A detailed description of these systems is provided in the discussion of the 1755-1850 MHz band. The 1710-1755 MHz band was previously reallocated for mixed use from Government exclusive use. The mixed use allocation was provided for DoD operations in a primary status at 16 protected sites. As a result of a national level effort to identify additional spectrum bands for commercial advanced wireless services (AWS), the 16 protected sites were reduced to 2 protected sites; Yuma, AZ and Cherry Point, NC[28]. The Federal Communications Commission (FCC) has auctioned the band. Thus, the relocation efforts of incumbent DoD systems from the other 14 protected sites are underway. Proceeds from the auction will be used to fund the relocation of affected federal systems as required by law. The Marine Corps will continue operations indefinitely at the two protected sites.

3.16 1755 – 1850 MHz Band: Mission, Functions, and Usage Summary

Table 3-17 depicts the major DoD application/operations supported in this spectrum band.

Table 3-17. DoD Operations 1755-1850 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
1755-1850		X	Voice/Data Data/Video Links CIDDS Range Telemetry Precision Guided Munitions Space Operations Air Combat Training

[28] *An Assessment of the Viability of Accommodating Advanced Mobile Wireless (3G) Systems in the 1710-1770 MHz and 2110-2170 MHz Bands*, National Telecommunications and Information Administration, July 22, 2002.

DoD employs the 1755-1850 MHz band to support a broad range of critical mobile/transportable systems and a large number of installation infrastructure services, as well as advanced wireless systems in development. The major operations supported in the band include Tracking, Telemetry, and Commanding (TT&C) of DoD space systems, transportable tactical radio relay communications, air combat training, fixed radio relay communications, and mobile video control links. Specific systems include, but are not limited to, the Space Ground Link Subsystem (SGLS) which provides spacecraft TT&C, which support tactical battlefield communications, the Air Combat Training Systems (ACTS) used to support air combat training, and Precision Guided Munitions (PGMs) systems. The major DoD systems that operate in this band are described below in detail. DoD also operates numerous other systems in this band that are critical to global operations in addition to test and training functions.

Satellite Operations (SATOPS)

DoD uses this band as the only communications link for initial contact with newly launched satellites, for early orbit checkout of those satellites and for emergency access to spinning/tumbling satellites. It is also vital for command and control, mission data retrieval, and on-orbit maneuvering of its many satellites in all orbits from low earth to geostationary. SGLS, the primary component of this network, provides continuous, worldwide, command and control of satellites used for missile warning, navigation, military communications, weather tracking and reporting, and intelligence, surveillance and reconnaissance (ISR). The information provided by these satellites to our National Command Authority, Combatant Commanders, Military Services, and national level decision-makers is crucial to successful execution of our national strategies. Additionally, other federal government agencies, such as the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), the Federal Emergency Management Agency, state and local governments and the commercial sector benefit from the capabilities of the satellites controlled by this network.

Tactical Radio Relay Systems

The Army, Navy, and Marine Corps operate tactical communications systems in this frequency band that provide high capacity, digital information to the battlefield. The Army operates the Mobile Subscriber Equipment (MSE) system in this band. The MSE system is deployed from the corps-level headquarters to the maneuver battalions. These systems provide a digital microwave backbone to link mid-level and lower-level battlefield commanders. The system operates like a high-capacity cellular telephone system with highly transportable base stations. A corps-size deployment could deploy twelve or more microwave links depending on the operational or exercise scenario. From command and control traffic to intelligence imagery, logistics, medical, and morale and welfare support, MSE provides the battlefield commanders the ability to maintain effective control over forces. MSE is a tactical system designed for rapid mobility in the field. This is because headquarters units, with signature electronic emissions, are targeted for artillery and missile attacks by the enemy. The ability to set up, establish a link to higher headquarters and subordinate units and then take the link down and move is key to the survivability of the headquarter units and supports the concept of maneuver warfare. The microwave radio equipment and antennas are transportable and robust for field conditions. To maintain the operator's capability to quickly establish a tactical microwave link, continuous field training is required.

The Navy and Marine Corps operate the Digital Wideband Transmission System (DWTS) in this band. The Navy/Marine Corps DWTS provides a backbone digital communications capability supporting amphibious operations and ground combat operations. The system supports command, control and data transfer from the Marine Expeditionary Force (MEF) level down to the regimental level. The Marine Corps element of this radio system providing digital backbone services (voice, video, and data). This link is the only transmission media available to the Marine Corps with sufficient bandwidth to carry large quantities of critical data such as maps, overlays, intelligence pictures, and other data to the battlefield commanders. The Navy has a ship-to-shore link of DWTS primarily used for amphibious operations where most of the critical information flow is from the ship to the landing forces. Like MSE, DWTS is a tactical system designed to enable microwave links to be quickly established in support of combat operations and maneuver warfare.

Air Combat Training Systems (ACTS)

The Tactical Air Combat Training System/Aircrew Combat Maneuvering and Instrumentation (TACTS/ACMI) is a complex system of hardware and software components configured and interfaced to measure, monitor, process, communicate, store, and display weapon and aircraft information in real-time to provide realistic training for tactical aircrews. The US Air Force uses ACMI while TACTS supports the US Navy and Marine Corps. TACTS/ACMI is comprised of airborne and ground-based components linked through RF communications and operates within many prescribed training ranges in the US. The TACTS/ACMI supports training aircrews in realistic warfighting scenarios. It supports simultaneous engagement of multiple air combat participants in state-of-the-art air-to-air, air-to-ground, ground-to-air, and electronic warfare (EW) environments. The system provides real-time monitoring, tracking and recording of the training activities and includes post mission reconstruction capabilities so that crews can receive accurate debriefing and critique of their mission thereby maximizing the benefit of the training activities. The system provides aircrew training such as Aircraft Handling Capability, Basic Fighter Maneuver, or Intercept and Air Combat Training sorties up to and including large composite force training. TACTS/ACMI is the primary tool at virtually all air combat training ranges and supports every level of training from initial schools where pilots first learn to fly the aircraft they will take into battle to advanced tactics training schools that hone combat skills. To ensure interoperability, training sorties are conducted with Allied Forces, both inside and outside of the US.

Tactical Control Links/Precision Guided Munitions

Tactical Control Links that support Precision Guided Munitions (PGM) provide a decisive combat edge to US forces. These weapons provide the capability to attack single targets with one aircraft or one standoff weapon. PGMs increase aircrew survivability by allowing the launch of weapons outside of any enemy anti-air system threat envelope, thereby significantly decreasing aircrew vulnerability. PGMs require regular testing and training at CONUS sites by operational units to maintain operational readiness. Developmental activities also require regular testing as the PGMs are updated for new missions, threats, and capabilities.

Other Systems

The operations of a number of additional DoD systems rely on spectrum between 1755 and 1850 MHz in addition to those of the four major DoD functional capabilities described above. Long-range point-to-point microwave system operations represent a majority of these additional systems. These systems primarily operate at fixed locations and employ directional antennas. A number of other mobile operations are also authorized in this band. Two mobile systems, the Combat Identification for the Dismounted Soldier (CIDDS) and the Land Warrior Local Area Network (LAN), are developmental systems whose operations also are dependent on spectrum in this band segment. Land Warrior is a first-generation integrated fighting system for dismounted soldiers. A number of Unmanned Aerial Systems (UAS) are authorized to operate in this band. These systems transmit video and status data from the UAS to the ground control system (GCS) using analog FM video and data on subcarriers. Fixed point-to-point microwave, CIDDS, the Land Warrior LAN, and UASs represent significant other uses of the 1755 to 1850 MHz band.

The Army Corps of Engineers (ACE) operates a nation-wide system of fixed point-to-point microwave links providing connectivity for monitoring water levels, remote alarms, and communications for remote locks, dams, and other water systems. These systems provide microwave links where no commercial communications connectivity exists. The systems are essential to the ACE operations because they allow for remote monitoring of critical waterway operations negating the need for full time, on-site personnel. The systems provide key maintenance parameters, alarm indications, and provide personnel at the facility with communications capability. These systems help ensure the safety and integrity of the nation's waterways and help prevent catastrophic events that could cost lives and economic damage as well as environmental damage.

The Land Warrior system is a close combat communications system for infantrymen, combat medics, combat engineers, forward observers, and scouts. With Land Warrior, the soldier can both send and receive voice, video images, map overlay information, operational plan diagrams, etc. The system provides situational awareness information among team members, improves survivability and increases mission effectiveness while reducing the soldier's equipment load.

The Combat Identification of the Dismounted Solder (CIDDS) program's purpose is to help prevent US forces from firing on friendly forces, otherwise known as fratricide. CIDDS employs a laser interrogator with a RF response to provide identification of friendly forces by individual and automatic weapons users. The laser interrogation signal message identifies a set of random frequency channels, spaced throughout the 1755-1850 MHz band for the transponder to use in its response. Current program documentation indicates approximately 100,000 CIDDS units will be procured to outfit dismounted soldiers in all three military services.

The Pointer UAS is a production-ready, electric, hand-launched UAS designed for remote monitoring and surveillance. The UAS transmits real-time images taken by a black and white, color, or thermal camera. A variety of alternative payloads such as air pollution sensing, chemical weapons detection, and unexploded land mine detections are currently being developed. The video link operates in the 1755-1850 MHz frequency band.

The Aberdeen Test Center (ATC) Range telemetry System provides a multi-link radio telemetry communication capability throughout the many test ranges and facilities of the ATC. It consists of several fixed receiving stations located at the high usage ranges/test areas and many transportable (vehicle housed) receiving stations that are emplaced at any of the multitude of ATC test areas or remote test sites when required to support testing projects. The test mission and workload of the ATC requires daily support by the telemetry system. It is vital to the accomplishment of the test and evaluation of military equipment, primarily combat and tactical vehicles, and many items of support equipment. Testing under dynamic conditions is a requirement, and the telemetry system provides the capability to transfer engineering measurements from the moving vehicle to a data collection center.

The Air Force Television Ordnance Scoring System (TOSS) provides a television ordinance scoring capability to range users in support of exercise and test missions. TOSS is a field proven accurate weapons scoring system with a night scoring capability using infrared cameras.

3.17 2200 – 2290 MHz Band: Mission, Functions, and Usage Summary

Table 3-18 depicts the major DoD application/operations supported in this spectrum band.

Table 3-18. DoD Operations 2200-2290 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
2200-2290		X	SGLS Telemetry TeleCommand Control Link

DoD operations supported in this band include tracking, telemetry and commanding (TT&C) of space systems and launch vehicles, and missile telemetry. The 2200-2290 MHz band supports the companion downlink to the Space Ground Link Subsystem (SGLS) uplink in the 1755-1850 MHz band. This is the most critical DoD operation supported in this band, and one of the most critical DoD uses of all spectrum. SGLS functions include tracking launch and space vehicles, telemetry (downlink) from both launch and space vehicles, and command operations. The space resources supported by SGLS are not only DoD's most expensive system of spectrum-dependent resources, but they serve as vital national sources of operational communications and surveillance data as well. The band is also used extensively for telemetry. Air- to-air and air-to-surface missiles cannot be tested without aeronautical telemetry. The 2200-2290 MHz band is the only band wherein adequate, properly allocated spectrum can be found to launch, operate, and control DoD space resources.

3.18 2290 – 2700 MHz Band: Mission, Functions, and Usage Summary

Table 3-19 depicts the major DoD application/operations supported in this spectrum band.

Table 3-19. DoD Operations 2290-2700 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
2290-2700		X	Voice/Data ATM SATCOM Tactical Communications Wireless LAN's Radar Test & Simulation Antenna Experimentation Deep Space Surveillance RDT&E

DoD operations supported in this portion of the spectrum include telemetry for aircraft and missile flight testing, deep space observation, rocket and missile launch monitoring, satellite communications, galactic and extragalactic radio astronomy, microwave communications, and the operation of simulators during combat aircrew training for surface-to-air missile operations. Additional DoD operations supported in this band include military radar tests and enemy radar simulations; scoring of air-to-air missiles against drone targets; antenna experimentation; and certification of defense navigation systems. The Air Force and Navy also use this band for target identification and certification of navigation systems at high speeds. The Army uses the 2400-2483 MHz portion of this band for tactical communications and for Wireless Local Area Networks (WLANs).

3.19 2700 – 2900 MHz Band: Mission, Functions, and Usage Summary

Table 3-20 depicts the major DoD application/operations supported in this spectrum band.

Table 3-20. DoD Operations 2700-2900 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
2700-2900		X	ATC Range ATC Weather Surveillance Radar

The primary DoD operations performed in this band include airport surveillance radar, ground control approach (GCA) radar, and weather surveillance radar. The operations of all three of these classes of equipment are essential for aviation safety.

ATC and GCA equipments are employed for terminal air guidance within sixty miles of military airports. The purpose is to detect aircraft within a specified radius of an airport terminaland to provide accurate real-time azimuth and range information to the airport air traffic controllers.

Weather radar equipments are deployed throughout the continental US (CONUS) by military and non-military organizations to monitor current weather conditions and collect data that is used to develop local and regional weather forecasts. These weather radars support weather surveillance and storm prediction throughout CONUS.

The unifying purpose of the functions supported in this band is safety-of-life. Aerial targets, drones, missiles, aerostats, and aircraft must be monitored continuously during flight to minimize potential loss of life due to controller error, weather anomaly, or equipment failure. Range air traffic controllers must manage the flight patterns of aircraft within respective airspace, or collisions between aircraft may result. Test range procedures mandate that airborne equipment under test be monitored continuously and with precision to ensure range safety.

3.20 2900 – 3100 MHz Band: Mission, Functions, and Usage Summary

Table 3-21 depicts the major DoD application/operations supported in this spectrum band.

Table 3-21. DoD Operations 2900-3100 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
2900-3100		X	**Voice/Data Distance Measuring Equipment ATC/NAVAIDS 3D Surveillance Radar Air/Surface Search & Navigation Radar**

The 2900-3100 MHz band is used nationally for three-dimensional long-range surveillance precision approach, shipborne radionavigation, and air traffic control (ATC). In accordance with safety requirements outlined by international treaty, this band is also used for maritime radionavigation on an international basis. In addition to military operations supporting long-range surveillance, precision approach, and ATC, the military uses this band to support threat simulator and experimental test operations.

Army operations in this portion of the spectrum are used to support the operations of aeronautical radionavigation, surveillance radar and RDT&E activities. Additionally, Army operates Land and Mobile Radiolocation service operations of Distance Measuring Equipment (DME) and navigational aid controls. Variants of the Conic DM-40 and DM-43 are used by the Army Corps of Engineers at dams and locks on US rivers and waterways in support of navigation.

The Navy uses this band to support coastal, dockside and sea trial operations for crew training. The Navy also supports the operation of height-finding radar and high-accuracy positioning of sea and airborne targets. The operation of sea surface surveillance radar at test facilities is also supported in this band.

The Air Force operates surveillance radars in this portion of the spectrum for air control operations, navigational aids, training, and test range support.

3.21 3100 – 3600 MHz Band: Mission, Functions, and Usage Summary

Table 3-22 depicts the major DoD application/operations supported in this spectrum band.

Table 3-22. DoD Operations 3100-3600 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
3100-3600		X	Command Control Link Counter Battery Fire Radar Search, Track & Missile Direction Navigation & Collision Avoidance Carrier-Controlled Surveillance Airborne Early Warning (AEW) Radar Altimeters Tactical Air Defense Surveillance Telemetry

The major functions of DoD systems operating in this frequency range are airborne and shipboard air surveillance, artillery location, aircraft station keeping, and missile data links. DoD uses the 3100-3600 MHz band primarily for mobile radar and missile link operations. There are several operational mobile radars in the band, and they are among the most important DoD tactical radars in use today. These radars have a primary mission of detection and tracking air targets for airborne early warning.

The Navy uses the 3100-3600 MHz band for a major Shipborne radar system. DoD also plans to develop and deploy the Navy's new volume search radar, operating in the 2-4 GHz band, on the next generation destroyers.

DoD operates a radar used for specialized surveillance and identification and control. The radar operates in the 2-4 GHz part of the spectrum.

Other DoD radar applications in this band include an Army mobile counter-battery radar that supports Field Artillery. The radar detects and tracks in-flight projectiles, providing the location of the firing unit or battery and projectile impact. There are also shipborne air traffic control radar systems used for aircraft marshaling. In addition, the Air Force uses a radar system in this band on Air Force C-130s and C-141s to perform station-keeping operations during formation flying. These units display the locations of each aircraft in formation, allow track-while-scan, and exchange maneuver messages between equipped aircraft. Another system is a ground-based zone marker used during parachute drops.

3.22 4200 – 4400 MHz Band: Mission, Functions, and Usage Summary

Table 3-23 depicts the major DoD application/operations supported in this spectrum band.

Table 3-23. DoD Operations 4200-4400 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
4200-4400		X	Radar Altimeters NAVAIDS RDT&E

The 4200-4400 MHz band is used both nationally and internationally for aircraft radar altimetry. Radar altimetry operations are essential during instrumented take-off and landing of aircraft and during instrumented flight. The altimetry data provided while en route is also essential for instrumented navigation.

The 4200-4400 MHz band is used extensively to support radar altimeter operations on both fixed and rotary-wing aircraft. DoD has approximately 17,000 aircraft in inventory of which more than 15,000 are instrumented with one or more radar altimeters. Radar altimeters are also employed on some missile variants, drone aircraft, and UASs. Because of thecapability to achieve increased precision and accuracy at altitudes less than 1,000 feet, they are often used to supply height-controlling commands in automatic approach and landing systems as well as ground proximity warning systems and weapons delivery systems. Most radar altimeters are designed to provide altitude data from ground level to a height of 5,000 feet above ground level; although, several systems currently deployed provide altitude data up to 70,000 feet above ground level.

In addition to the Army's approximately 5,900 aircraft that are instrumented with radar altimeters, the Army also supports RDT&E operations in this portion of the spectrum.

The Navy radar altimeter operations support Tomahawk cruise missile tests and Tactical Aircrew Combat Training System (TACTS) operations. Altimeter RDT&E is also performed by the Navy in this portion of the spectrum. The Navy and Marine Corps have approximately 4,800 aircraft that are instrumented with radar altimeters.

The Air Force operations in this portion of the spectrum include radar altimeter operations and some regionalized test operations involving cruise missiles and drone aircraft. Radar altimeters are primarily used as navigational aids. The Air Force has approximately 6,200 aircraft that are instrumented with radar altimeters. The Air Force Global Hawk UAS carries radar altimeters whose operations depend on the 4200-4400 MHz band for precision altitude information during takeoff and landing. Global Hawk is a high-altitude endurance UAS designed to loiter above a region and provide ground commanders with radar, visible, and infrared imagery.

3.23 4400 – 4990 MHz Band: Mission, Functions, and Usage Summary

Table 3-24 depicts the major DoD application/operations supported in this spectrum band.

Table 3-24. DoD Operations 4400-4900 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
4400-4900		X	Voice/Data Command Control Link UAS Video Links Weapon Systems Telemetry Weapon System Sensor Datalink CEC

The major functions of DoD systems operating in this frequency range are point-to-point communications, data links supporting exchange of weapons sensor data, and telemetry and command links for weapons and range systems.

DoD uses this band to satisfy many of the requirements for high capacity, multi-channel, point-to-point communications. These systems may be either digital or analog. There are thousands of frequency assignments for both fixed and transportable communications systems in this band supporting all of the Military Services as well as National Guard units. Many of the transportable units are used to affect tri-service tactical area communications. CONUS operations of these systems are almost entirely for training. US forces when deployed use these radios extensively. This band supports the operations of many fixed and transportable line-of-sight and trans-horizon radio-relay systems. It should be noted that systems with a trans-horizon mode have comparatively high-powered transmitters and use the phenomenon of tropospheric scattering to communicate at distances up to 400 km. The point-to-point, line-of-sight, and troposcatter communications systems in this band transfer voice, video, and data between individual end-users. These systems support tactical as well as training and administrative operations.

The Navy operates a system in this portion of the spectrum to transfer LAMPS MK III helicopter ASW sensor data to shipboard data terminals for aerial platforms. Helicopter radar and ESM data can also be transferred over the link. The Navy also operates its Cooperative Engagement Capability in this band. The mission of Cooperative Engagement Capability is to form a timely and highly accurate distributed AAW picture and to share fire control radar track data between individual units in the net to establish a common, composite track database that can be utilized by each unit to conduct weapons engagements.

DoD also uses this band to support datalinks and video links for several different Unmanned Aerial Systems (UAS) (Pioneer, Shadow, and Camcopter). The primary mission of UAS data links is to provide information gathered by sensors onboard various unmanned aerial vehicles to ground control stations and to control UAS operations. The UAS links in this band are line-of-sight only; other frequency bands support additional UAS links.

3.24 5000 – 5250 MHz Band: Mission, Functions, and Usage Summary

Table 3-25 depicts the major DoD application/operations supported in this spectrum band.

Table 3-25. DoD Operations 5000-5250 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
5000-5250		X	ATC

The key DoD system operating in this band is the Air Force Mobile Microwave Landing System (MMLS). This system is a tactical military precision approach and landing system that is compatible with civil Microwave Landing System (MLS), military airborne and fixed aeronautical radionavigation MLS/ILS (Instrument Landing System), tactical air navigation, and Distance Measuring Equipment (DME) systems.

Army operation in this spectrum band is limited. The only Army system identified is a Proximity Warning Device.

The Navy makes very limited use of this band and currently only operates a signal generator for special projects.

3.25 5250 – 5350 MHz Band: Mission, Functions, and Usage Summary

Table 3-26 depicts the major DoD application/operations supported in this spectrum band.

Table 3-26. DoD Operations 5250-5350 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
5250-5350	X		Telemetry Video/Data Links Mobile Air Defense Radar Surveillance & Tracking Radar Radar RDT&E UAS Datalinks

The primary DoD operations supported in this portion of the spectrum are mobile air defense radars, surveillance and tracking radars, and telemetry (video or data) links.

The Army currently has the only operational radar system in the band, the PATRIOT radar. While this is the only DoD radar system currently operating in this band, it is one of DoD's most important land-based radars. Additionally, the Navy is exploring wideband operations for a next-generation shipboard radar. These multi-function radars are specifically designed, or being designed, to simultaneously detect and track tens to hundreds of military targets and respond to threats in enough time to establish defensive measures.

The Pioneer Unmanned Aerial System (UAS) has an alternate video and telemetry link that operates in this band. Additional UAS links for the Predator and Hunter Joint Tactical UAV (JTUAV) have also been developed in this band. In the mid-term these UAS links are projected to migrate to other bands.

3.26 5350 – 5650 MHz Band: Mission, Functions, and Usage Summary

Table 3-27 depicts the major DoD application/operations supported in this spectrum band.

Table 3-27. DoD Operations 5350-5650 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
5350-5650		X	Missile & Fire-Control Sea Surface Search/Navigation Mobile Air Defense Test Range Instrumentation Range Tracking Radars UAS Datalinks

The principal DoD operations supported in this band are mobile air defense radars, weather radar, surface search/navigation radars, missile and gun fire control functions, test range instrumentation, and telemetry operations. Anti-Air Warfare (AAW) radars operate in this band as part of an advanced, ground-based air defense missile system.

The 5350-5650 MHz band supports the operation of a variety of test range radars and transponders. Most of these radars operate over a tuning range of 5400-5900 MHz. These systems are used at a number of DoD test and training ranges and missile test launch facilities located across the continental US and Hawaii.

DoD also uses this band for UAS datalink transmissions. This function is performed on a non-interference basis. The Pioneer UAS has a primary radio frequency downlink at 4 GHz. The downlink data may be video, infrared sensor, or telemetry data. The Predator UAS communications between ground elements and this UAS take place in the 5250-5850 MHz frequency range in one line-of-sight mode. Alternate downlink data transmissions take place in the lower segment of this band (5350-5450 MHz) and uplink communications take place over the entire band.

3.27 5650-5850 MHz Band: Mission, Functions, and Usage Summary

Table 3-28 depicts the major DoD application/operations supported in this spectrum band.

Table 3-28. DoD Operations 5650-5850 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
5650-5850	X		Missile & Fire-Control Air/Surface Surveillance Target Acquisition Range Tracking Radars UAS Telemetry Data/Video Links

The major DoD operations supported in this spectrum band are air surveillance, target tracking, range tracking, missile data links, UAS telemetry, and video links. While other radar bands do support simultaneous search and track radars, only the 3 GHz and 5 GHz radar bands permit the development of military radars that have small enough antenna apertures to be mobile systems. They also provide great enough range capabilities to serve as medium range radars. This critical characteristic has resulted in the development of extremely high value military radars in this band. These multi-function radars are specifically designed to concurrently detect and track hundreds of military targets and respond to threats in time to establish defensive measures.

3.28 5850 – 5925 MHz Band: Mission, Functions, and Usage Summary

Table 3-29 depicts the major DoD application/operations supported in this spectrum band.

Table 3-29. DoD Operations 5850-5925 MHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
5850-5925		X	Range Tracking Radar Beacon Transponder Voice/Video/Data

DoD operations supported in this band include instrumentation support, tracking radars, and beacon transponder operations on DoD test ranges.

Instrumentation and range tracking radars are used to support the testing of missiles, aircraft, and rockets. Additionally, beacon transponders, which operate over the 5400-5900 MHz frequency range, use a portion of this band. Beacon transponders are installed onboard missiles and other test objects to enhance radar tracking of the test objects. This tracking is accomplished through the interrogation of the beacon by the tracking radar and a response from the transponder.

Army systems in this band include range tracking radars and beacon transponders, which are used on several test ranges within the continental US. The Army also supports the Transportable Trojan Spirit II Satellite Communications Terminal in this band.

The Navy operates range tracking radars and beacon transponders in this portion of the spectrum. These systems are used for training and special operations. Additionally, the Air Force supports operation of an instrumentation radar and radar testing signal generators in this band of spectrum. Other Air Force systems operating in this band are used to track radar transponders.

3.29 7.125 – 8.450 GHz Band: Mission, Functions, and Usage Summary

Table 3-30 depicts the major DoD application/operations supported in this spectrum band.

Table 3-30. DoD Operations 7.125-8.450 GHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
7.125-8.450		X	Voice/Data Command Control Link ATC Air & Sea Surveillance Target Acquisition Low-Altitude Aircraft Detection Weapon System IFF Transponders

DoD operations in this portion of the spectrum include air traffic control (ATC), administrative point-to-point communications, RDT&E support, and satellite communications. The point-to-point circuits are used to support numerous functions such as test and training range video, specialized air defense, and Presidential support as well as test and training range safety, control, simulators, and target scoring. Other operations consist of data transfer for training systems such as the Tactical Air Combat Training System (TACTS), Air Combat Maneuvering and Instrumentation (ACMI) systems, and electronic warfare training. The band is also critical for DoD global satellite communications support.

The Army uses this spectrum for point-to-point communications using DoD satellites RDT&E support and range operations (target scoring). The Navy’s use of this band includes ATC, radar data transfer, maintenance and calibration, and remote studio links. Air Force operations include satellite communications on DoD satellites, ATC, and other training applications.

3.30 8.5 – 9.0 GHz Band: Mission, Functions, and Usage Summary

Table 3-31 depicts the major DoD application/operations supported in this spectrum band.

Table 3-31. DoD Operations 8.5-9 GHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
8.5-9.0		X	Voice/Data Command Control Link ATC Navigation & Collision Avoidance Acquisition & Tracking Missile & Fire-Control Submarine Surface Navigational/Search Aircraft Control Approach Maritime Surveillance Helicopter Search Multi-mode Fire-Control ASW Search Multi-mode Airborne Radar Navigation & Mapping Terrain Following/Avoidance SAR & Moving Target Indicator (MTI) Radar Altimeters Search, Rescue & Weather Avoidance Portable Ground Surveillance Long-Range Theatre Ballistic Missile Detection

The 8.5 - 9.0 GHz band is used primarily by DoD to support fixed, mobile, and transportable operations of target acquisition and target tracking radar systems. This band is used by DoD to support RDT&E operations on national and military test ranges. Experimental operations are included in this band but on a non-interference basis (NIB).

The Army's typical use of this band is for Distance Measuring Equipment in support of Army Corps of Engineers operations. The Army operates a rendezvous beacon transponder, which is used on helicopters. Similar equipment is also employed by the Air Force, and its operation is functionally equivalent to that of numerous other beacons fielded by the Air Force and Navy. Key equipment operated by the Navy in this band includes engagement radars whose operations support ship-borne gunnery and missile fire control for both offensive and defensive purposes, airborne surveillance radar, submarine surveillance and navigation radar and rendezvous beacon equipment. The primary Air Force capabilities include rendezvous beacon radar equipment, aircraft-based Doppler navigation radar equipment, test range bomb scoring equipment, target acquisition radar equipment, and test range support equipment. Rendezvous beacon equipment is employed on aircraft to extend the range of surface-borne tracking radars during test and training exercises. Bomb scoring equipment is employed from ground-based locations to score the performance of pilots during training exercises. Target acquisition radar equipment would typically be used to engage and target enemy aircraft during tactical operations. These operations are vital to successful flight and surveillance of military aircraft as well as testing and training exercises.

3.31 9.5 – 10.45 GHz Band: Mission, Functions, and Usage Summary

Table 3-32 depicts the major DoD application/operations supported in this spectrum band.

Table 3-32. DoD Operations 9.5-10.45 GHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
9.5-10.45		X	Navigation & Collision Avoidance Acquisition & Tracking Missile & Fire-Control Submarine Surface Nav/Search Aircraft Control Approach Maritime Surveillance Helicopter Search Multi-mode Fire-Control ASW Search Multi-mode Airborne Radar Multi-mode Weapon Control Navigation & Mapping Terrain Following/Avoidance SAR & Moving Target Indicator (MTI) Search, Rescue & Weather Avoidance Portable Ground Surveillance Long-Range Theatre Ballistic Missile Detection

DoD operations in the 9.5 to 10.45 GHz band include tactical radar operations onboard ships and aircraft, navigational aids (NAVAIDS) operations, RDT&E support, and test-range simulator operations. DoD also supports additional capabilities such as electronic warfare (EW) training, test-range simulator operations, and calibration.

Army operations include multiple ground-based radars for test and training and the operation of ground-based sensors. The Army also supports test and training with target acquisition radar, high-power illuminator radar, and a counter fire radar system. Additional capabilities/requirements supported in this band include precision acquisition radar operations at Army airfields, operation of tracking radars, rendezvous beacons, and meteorological (balloon-tracking) radars at many of the Army ranges. Key Army capabilities/requirements are artillery, rocket, and mortar locating radar including tracking radar system employed to detect and track up to 50 fast and slow-moving, fixed- or rotary-wing aircraft as well as UASs. Navy operations include Ship-borne navigation, surface and airspace search radar systems, and fire control systems. Additional one-of-a-kind equipment supported by the Navy, in this band, includes the cloud physics research radar and distance measurement equipment. The Navy also supports their Fleet Operational Readiness Accuracy Check Site (FORACS) ship-borne equipment calibration operations, simulator electronic warfare, and electronic countermeasure operations in this band on a non-interference basis. Characteristic Navy equipment are fire control and targeting radar systems. These interoperate with precision munitions like the Advanced Medium Air-to-Air Missile System (AMRAAM). The Air Force supports the contingency airborne reconnaissance system (CARS) datalink for both manned and unmanned aeronautical vehicles. It can be flown on manned aircraft as well as UASs, such as the Global Hawk. The Air Force also supports fire control radar equipment, aircraft transponder systems, synthetic aperture radar, and battlefield surveillance radar within this band. Examples of test, training, and simulation capabilities supported in this band are enemy surface-to-air missile (SAM) simulation, anti-aircraft artillery (AAA) simulation, electronic warfare, and radar bomb scoring performance evaluation systems at numerous Air Force test ranges. Airborne fire control equipment is employed on several thousand Air Force fighter and bomber aircraft. Fire control radar is employed for air-to-air combat and air-to-surface attack. The Air Force also supports the operation of airborne, all-weather ground surveillance radar that is designed to locate and track slow moving and stationary ground-based vehicles, such as tanks.

3.32 14.5 – 15.35 GHz Band: Mission, Functions, and Usage Summary

Table 3-33 depicts the major DoD application/operations supported in this spectrum band.

Table 3-33. DoD Operations 14.5-15.35 GHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
14.5 –15.35		X	Voice/Data Command Control Link ATC Air & Sea Surveillance Target Acquisition Low-Altitude Aircraft Detection Transponders

DoD operations in the 14.5 to 15.35 GHz portion of the spectrum include point-to-point and multi-point fixed communications, transportable tactical communications, electronic warfare (EW) training, and test range operations. The military Services use frequencies in this portion of the spectrum to support several key systems for point-to-point and multi-point microwave and remote sensor applications. Additionally, several types of threat emitters and simulators tune through this band and are used for Electronic Warfare (EW) exercises and training. Several transportable tactical systems tune within this band and are employed at numerous locations for exercises and training.

Point-to-point microwave communications is a major Army capability supported in the 14.5 to 15.35 GHz band. These operations support video, data, and audio requirements at test ranges throughout the US and at selected locations worldwide. The Army conducts training on MSE and “down-the-hill” radios and TERRACOM 608B training at numerous locations within the US and Possessions (US&P). Several Army installations also use an Air Defense Threat Simulator to conduct helicopter pilot training. The Navy uses this band for support of EW training using a family of threat emitters and simulators. The Navy’s Fleet Operational Readiness Accuracy Check Site (FORACS), fixed microwave systems, and an Intrusion Detection System also operate in this band. Similar to the Navy, the Air Force supports EW training using a family of threat emitters and simulators operating in this band as well as fixed microwave links supporting test range operations, remote feeds for air traffic control radar data, and video/audio links.

3.33 15.7 – 17.3 GHz Band: Mission, Functions, and Usage Summary

Table 3-34 depicts the major DoD application/operations supported in this spectrum band.

Table 3-34. DoD Operations 15.7-17.3 GHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
15.7-17.3		X	Command Control Link NAVAIDS Multi-mode Airborne Radar Fire-Control Navigation & Mapping Terrain Following/Avoidance RDT&E PGM

DoD operations/requirements supported in the 15.7-17.3 GHz band include: airborne terrain-following and forward-looking radars, RDT&E of missile guidance and target-tracking radars, experimental operations and calibration of sensors, and navigational equipment. Additional DoD operations supported in this band include airborne tactical radar training operations, navigational aids (NAVAIDS) operations, NAVAIDS RDT&E support, test-range simulator operations, and sensor calibrations. Some individual military Service applications are discussed below.

The Army uses this portion of the spectrum for ground-based radar equipment training, RDT&E operations, portable combat surveillance radar equipment, and mortar/artillery fire locating radar for training. The Army also operates a White Sands Missile Range (WSMR) tracking radar and muzzle velocity radar measurement equipment in this portion of the spectrum. The Army also supports operation of a radar cross section measurement range to evaluate refinements to the Radar Advanced Measurement and Target Scatter System (RATSCAT).

Other DoD systems operating in this band include the UAS Tactical Endurance Synthetic Aperture Radar (TESAR), Grisly Hunter demonstration radar, and the UAS Small Tactical Synthetic Aperture Radar (STACSAR). The Navy operations supported in this band include equipment associated with a Missile Defense System, operations of the LANTIRN Terrain Following Radar (TFR), and ground-based operations of a weapons delivery and drop-zone marking system. Similar to the Army, the Marine Corps operates mortar/artillery fire locating radar for training in this band. Additional Navy operations supported in this band include a six-system net of projectile velocimeter equipment for RDT&E purposes, the Navy's ship-borne fire control systems, an airborne navigation/bombing system, and an additional terrain following radar system. The Air Force operations supported in the 15.7 to 17.3 GHz band include a forward-looking, multi-mode radar on the MH-53J Pave Low III helicopter, RDT&E support operations of the Airborne Real-Time Information System (ARTIS) transponder, and another transponder employed by the Air Force Special Operations Command for special tactics team training. Other Air Force operations / capabilities supported in the 15.7 to 17.3 GHz band include the LANTIRN Terrain Following Radar (TFR), and a multi-mode radar installed on C-130 Combat Talon II aircraft. The Air Force also supports fix-tuned training and simulator operations requirements for the Roland Missile guidance command link, tracking radar, and beacon system in this band as well as fire control and additional forward-looking terrain-following radar equipment.

3.34 20.2 – 21.2 GHz Band: Mission, Functions, and Usage Summary

This band is generally addressed in section 4.4.

3.35 24.05 – 24.25 GHz Band: Mission, Functions, and Usage Summary

Table 3-35 depicts the major DoD application/operations supported in this spectrum band.

Table 3-35. DoD Operations 24.05-24.25 GHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
24.05-24.25		X	RDT&E T&E Sensor Vehicle Speed Detection

DoD primarily supports law enforcement operations in the 24.05-24.25 GHz band. Additional operations or capabilities supported in this band include operations at a radar cross-section (RCS) measurement facility, experimental operations for ship-borne calibration, intrusion detection, and antenna performance measurement equipment.

The Army, Navy, Marine Corps, and Air Force use this portion of the spectrum to support law enforcement operations. The Army also supports RDT&E and the operations of the K-Band Doppler Transceiver, which is the motion detection component of the Mobile Detection Assessment Response System-Interior (MDARS-I). In addition to law enforcement operations, the Navy also supports the operation of their FORACS system in this band. The Air Force operates a RCS measurement facility at White Sands Missile Range (WSMR) in this portion of the spectrum as well as a Signal Generator used to measure out-of-band aircraft antenna performance. The Air Force also supports operations of a Relocatable Sensor System (RSS) employed for unattended perimeter security.

3.36 25.25 – 25.5 GHz Band: Mission, Functions, and Usage Summary

Table 3-36 depicts the major DoD application/operations supported in this spectrum band.

Table 3-36. DoD Operations 25.25-25.5 GHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
25.25-25.5		X	T&E RDT&E

DoD uses this band primarily for experimental work with the Navy FORACS program and for the Air Force Radar Cross Section Measurement System. Specific uses include antenna testing, radar cross-section determination, and fleet readiness testing.

3.37 25.5 – 27.0 GHz Band: Mission, Functions, and Usage Summary

Table 3-37 depicts the major DoD application/operations supported in this spectrum band.

Table 3-37. DoD Operations 25.5-27.0 GHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
25.5-27.0		X	Voice/Video/Data Range Opns T&E WBS

DoD operations supported in this band include antenna testing, radar cross-section determination, fleet readiness testing, and test range operations.

The Army operates point-to-point microwave communication links supporting test range operations in the band. The Navy operates portions of its FORACS program in this band. As well, the Air Force supports the development and evaluation of aircraft antennas in this portion of the spectrumalong with its Radar Cross Section Measurement Systemand is developing a Wireless Broadband System (WBS) in this band. WBS is a two-way voice, video, and data distribution network for use at air bases.

3.38 27 – 27.5 GHz Band: Mission, Functions, and Usage Summary

Table 3-38 depicts the major DoD application/operations supported in this spectrum band.

Table 3-38. DoD Operations 27-27.5 GHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
27-27.5		X	RDT&E

DoD operations in this band are very limited. The operations supported include experimentation and proof of concept testing of millimeter wave links, development and evaluation of aircraft antennas, and fleet readiness testing.

DoD uses this band primarily for experimental work with the Navy FORACS program, the Air Force Radar Cross Section Measurement System, and developing and performing proof of concept demonstrations of a millimeter wave link.

3.39 30.0 – 31.0 GHz Band: Mission, Functions, and Usage Summary

This band is generally addressed in Section 4.4.

3.40 33.4 – 36.0 GHz Band: Mission, Functions, and Usage Summary

Table 3-39 depicts the major DoD application/operations supported in this spectrum band.

Table 3-39. DoD Operations 33.4-36.0 GHz Band

	US&P Allocations		
Frequency-Band (MHz)	**Government use only**	**Shared Bands**	**DoD Application**
33.4-36.0		X	MMW Radar Cloud Detection Radar Weather Surveillance Radar Space Surveillance PIRS Radar

The 33.4 to 36.0 GHz band is primarily used by DoD for supporting RDT&E operations. Specific RDT&E functions include radar cross-section (RCS) measurement, spectral imaging, re-entry vehicle splash detection, cloud surveillance, and simulation of enemy air defenses. Other DoD uses of this band include equipment calibration, weather surveillance, and vehicular speed detection.

Key Army operations supported in the 33.4 to 36.0 GHz band include the operations of a dual-band, millimeter wave (MMW) radar, and operation of cloud detection radar. The operations of these two systems support final-phase, pre-impact tracking of missiles launched for test purposes and is a constituent part of the Kwajalein Missile Range (KMR). KMR is considered to be a vital national asset because it is the only location available for testing US exoatmospheric ballistic missile defense intercepts, and it is one of only two US Anti-

Ballistic Missile Treaty-approved ballistic missile defense test locations. The Army also supports the Radar Advanced Measurement and Target Scatter System (RATSCAT) system in this portion of the spectrum and a Radar Seeker System.

The Navy operates portions of its FORACS system and the Air Force supports law enforcement, Air Force Flight Test Center RDT& E, cloud detection radar used for remote sensing and weather research, and fire control system test and evaluation in this portion of the spectrum. The Air Force also supports the operations of the Polarimetric Imaging Radar System (PIRS). The PIRS was designed to operate on aircraft strictly for test purposes (i.e., the PIRS was not designed for tactical use) and is used to collect radar imaging data. Another Air Force capability supported on a NIB is the operation of instrumentation radar used to collect radar data on various targets and terrain features from fixed platforms, buildings, and towers. The Research and Seeker Emulation Radar (ERASER) is also used to support laboratory in-house MMW seeker research. A Signal Generator used to test antennas in support of airborne equipment target classifier performance studies operates in this band. The Advanced Cross Section Measurement Radar is also supported in this band as well as the Radar Advanced Measurement and Target Scatter System (RATSCAT).

3.41 Summary of Current DoD Spectrum Usage

This section has focused on providing a general summary of the spectrum bands that the Department of Defense employs in support of the numerous spectrum-dependent capabilities that are required to uphold its global mission. The above discussion addresses the majority of bands, both federal exclusive and shared bands that DoD uses. While DoD also uses a number of other bands, those addressed above (and in a subsequent section) reflecting satellite communications spectrum use provide significant insight into the varied applications to which DoD employs spectrum to support in addition to the numerous functions for which these applications are essential. The next section will address DoD’s anticipated future demands for spectrum support and the way in which future demands will impact certain spectrum bands. The discussion of bands used for satellite communications will encompass both current and future needs.

4.0 Future Needs and Growth Assessment (2015-2020)

4.1 DoD Spectrum Requirements, Including Bandwidth and Frequency Location for Future Technologies or Services

As a result of addressing the first task from the Executive Memorandum for agency-specific strategic spectrum plans, DoD determined that it would need to address current spectrum usage and demands as well as provide information on future spectrum requirements. Current spectrum usage and demands are presented first to establish DoD's baseline spectrum usage. The approach used to address baseline spectrum requirements focuses on providing an understanding of the many spectrum bands in which DoD currently operates, and on which DoD is critically dependent. DoD's future spectrum needs are subsequently addressed and the discussion is structured primarily according to major categories of service. The categories used for DoD's future spectrum demands assessment include terrestrial, satellite communications, radar, and test/training. Future spectrum needs are addressed by providing assessments of how each of the major categories of services for applicable bands and systems are projected to experience an increased demand for spectrum use in the future.

This section of the DoD Strategic Spectrum Plan will address DoD's future systems, technologies, and services that will be both dependent on spectrum resources and have significant impact on DoD's growing spectrum needs. To help ensure that spectrum is available, DoD must first understand and articulate its spectrum needs. DoD's concern/need includes both US&P and non-US&P for day-to-day infrastructure, training, and operational scenarios. One of the major challenges here is accurately determining spectrum needs arising from the vast US&P camp/post/base/station day-to-day infrastructure activities. Not only is it difficult to determine what equipment is present, but it is also difficult to determine its specific spectrum operational use during these activities.

Over the next twenty years, US forces will experience operational environments that are increasingly complex, uncertain, and dynamic. The *Net-Centric Environment Joint Functional Concept*[29] is an information and decision superiority-based concept which describes the organization and operations of joint forces in the future. The networking of all joint force elements will enable unparalleled information sharing and collaboration. Full exploitation of both shared knowledge and technical connectivity will thereby increase the joint force mission effectiveness and efficiency in support of military transformation.

Critical to achieving this capability is communications connectivity and flexibility across geographically dispersed, heterogeneous systems at capacity levels far greater than previously experienced. Indications are that DoD will experience increased usage of EM spectrum for numerous systems in the future. The frequency bands most affected for terrrestial systems are depicted in Figure 4-1.

[29] *Net-Centric Environment Joint Functional Concept*, Version 1, Office of the Joint Chiefs of Staff, April 7, 2005

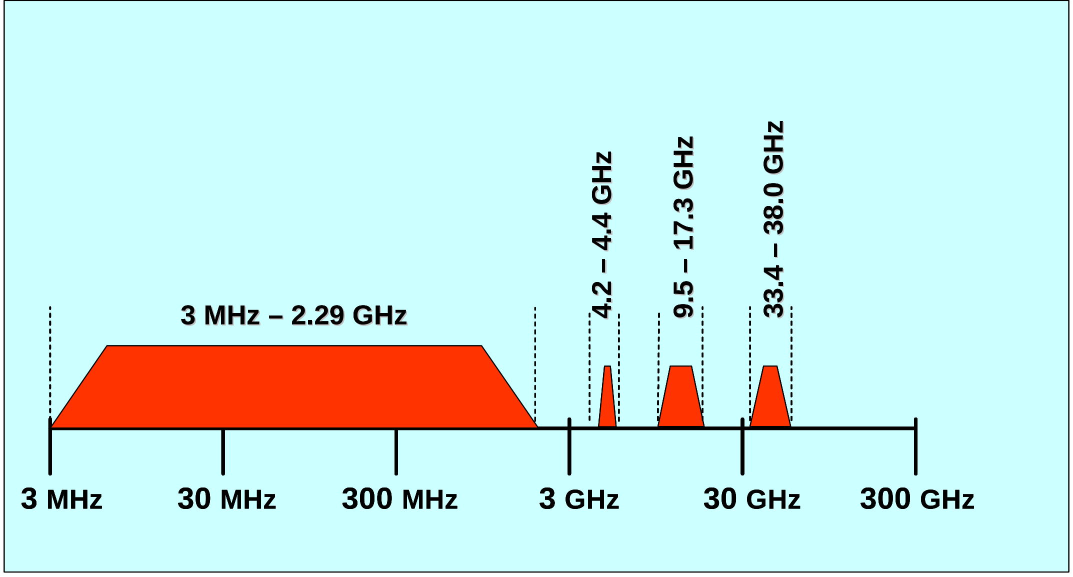

Figure 4-1 Bands in which DoD spectrum usage is expected to increase.

4.2 Transformation Development Initiatives

To this end, DoD has embarked on a comprehensive plan to reinvent the tactical communications infrastructure. The following DoD development initiatives are a manifestation of this reinvention and create the framework for addressing future spectrum needs.

Joint Tactical Radio System (JTRS) – The JTRS is a family of modular, software-defined, multi-band, multi-mode radios that will replace virtually the entire current inventory of tactical radios and, ultimately, SATCOM terminals as well. Furthermore, JTRS radios will have inherent cross banding and a networking capability that will enable mobile forces to remain connected to an Internet Protocol (IP) based network.

Warfighter Information Network – Tactical (WIN-T) – WIN-T is the US Army's high-capacity, high-speed, backbone communications network that will provide the required reach, reachback, interoperability, and network operations for the Maneuver Units of Action (UA) and seamlessly interface with JTRS. It will extend to the individual warfighter platform level and offer seamless interoperability with other networks, including legacy, joint, coalition, and even commercial networks utilizing all available links to support the warfighter anywhere on the globe.

High Capacity Line-of-Sight (HCLOS) – The HCLOS radio is part of the Army's area common user system (ACUS) program. ACUS is the first phase of the warfighter information network-terrestrial, or WIN-T program. The Army also anticipates using the HCLOS radio with MSE which is equipment configured for a brigade subscriber node for initial brigade combat teams. HCLOS technology will increase link capacities from the current 1 Mbps to more than 8 Mbps.

Wideband Networking Waveform (WNW) – High data rate waveform development is an integral part of the JTRS Program. Within the JTRS context, the Wideband Networking Waveform (WNW) is key to providing wideband networking capabilities.

Future Combat Systems (FCS) – FCS is a joint networked system of systems connected via an advanced network architecture that will enable levels of joint connectivity, situational awareness and understanding, and synchronized operations heretofore unachievable. The FCS communication network is comprised of several homogenous communication systems such as JTRS with the WNW, Soldier Radio Waveform (SRW), Network Data Link, and WIN-T. FCS leverages all available resources to provide a robust, survivable, scalable, and reliable heterogeneous communications network that seamlessly integrates ground, airborne, and spaceborne assets for constant connectivity and layered redundancy.

Common Data Link (CDL) – CDL will provide communications paths using JTRS software communications architecture. The project includes a number of separate tasks dealing with tactical CDL for UASs, a wideband integrated CDL for Network Centric Collaborative Targeting, and development of an ultra-wideband airborne laser.

In the future, these and other current and planned developments will have a dramatic impact on throughput requirements for tactical DoD systems. In addition to considering the impacts of these major developments, DoD also surveyed the research and development and the acquisition elements of the Military Departments regarding other programs. The purpose of the survey was to collect information on as many programs as possible that are expected to influence spectrum usage and requirements in the future. A significant number of survey responses were received and proved to provide very useful insights, though they represent only a portion of the actual programs that will have future impacts on spectrum requirements. The throughput requirements of the major development initiatives, as well as for those programs providing survey responses, indicate that in many instances there will be a corresponding impact on EM spectrum usage.

4.3 Future Terrestrial Spectrum Needs and Growth Trends

Each of the aforementioned has one or more terrestrial components. Taken together, these new systems will affect the amount of data being exchanged on the battlefield and, as such, will have an impact on future demand for EM spectrum. Terrestrial spectrum usage is comprised of both mobile and fixed systems as defined by the following:

Mobile Systems – Systems (used while in motion or during halts at unspecified points) that include land, maritime, and aeronautical mobile services. Generally, systems employing non-directional antennas are assigned to this category, since mobility and/or connectivity requirements would make directional antennas relatively impractical for most applications.

Fixed Systems – Within DoD, there are numerous fixed (point-to-point) systems that provide service over operating distances of up to approximately 60 km. These systems often share frequencies in the mobile bands using directional antennas. Some of these systems are permanently “fixed” in a certain location. Other systems include tactical terminals that are regarded as “fixed”, even though they are actually “fixed-transportable.” For the assessment herein, point-to-point refers to radio transmission between or among two or more stationary systems employing directional antennas.

Terrestrial spectrum requirements considered herein have been subdivided into two broad categories representing different physical operating concepts and technical implementations, namely: (1) Operations below 3 GHz and (2) Operations above 3 GHz. Each reflects unique challenges with respect to access and use of the spectrum.

4.3.1 DoD Terrestrial Spectrum Requirements Growth Below 3 GHz

DoD terrestrial mobile radio systems include the Enhanced Position Location Reporting System (EPLRS), HAVEQUICK radios, hand-held, manpack and vehicular-mounted radios (to include Abrams tanks, Bradley Fighting Vehicles, High Mobility Multi-wheeled Vehicle (HUMMV), etc.), and radios used in VHF and UHF Common Radio Nets. The point-to-point category consists primarily of terrestrial elements of weapon system command/video links, MSE radio, and the HCLOS radio (225 to 400 MHz and 1,350 to 2,690 MHz).

Projections for future mobile spectrum requirements include the JTRS family of radios and the addition of unmanned ISR and combat delivery platforms. Although the JTRS is a multi-function software supported system, its initial fielding is geared at replacing legacy radio systems and maintaining the fundamental structure of current operational communications architectures. As such, the JTRS will not have an appreciable impact on spectrum requirements until fielding of the Army's Future Force – the Unit of Action (UA) / Unit of Employment (UE) in 2014. The UA will leverage the JTRS WNW to support increased information demand and drive a corresponding increase in spectrum requirements.

DoD's need for access to EM spectrum for terrestrial mobile systems will experience significant growth over the next decade. Many of the systems operating in the bands presented in Table 4-1 reflect a projected increase in spectrum use. Most of these are due to the additional requirements to support fielding of new capabilities such as unmanned ground/air vehicles and to support additional Combat Net Radio (CNR) links associated with echelon adjustments to force structure as a result of transformation and increased use of maneuver forces.

The trend depicted in Table 4-1 is the result of a significantly increased requirement for mobile spectrum use beyond 2014. This increase is in support of the joint transformational communications concepts of the Army and Marine Corps FCS, the Air Force Command and Control Constellation, and Navy FORCEnet. Mobile spectrum usage beyond 2014 is driven by transition to WNW wireless networks that contribute to the realization of Network-Centric Warfare. These networks will provide increased situational awareness, dissemination of timely intelligence, and direct high-bandwidth communications to all battlefield users.

Table 4-1.
Future Terrestrial DoD Spectrum Usage Below 3GHz

Frequency-Band (MHz)	Service or System	Increased Usage in Band
3-30	Voice / Data	**YES**
30-88	Voice / Data	**YES**
108-150.05	Differential GPS (DGPS) Data Link Voice / Data LMR	**YES**
162-174	LMR	**YES**
216-225	Radiolocation	**YES**
225-400	SRW Command Control Link MSE HCLOS WIN-T	**YES**
400.05-420	Radar Command Control Link LMR	**YES**
420-450	LMR EPLRS	**YES**
902-928	Radar	**YES**
932-935	Radar	**YES**
941-944	Radar	**YES**
960-1215	IFF JTIDS	**YES**
1215-1390	WNW GPS MSE HCLOS	**YES**
1390-1710	WNW Command Control Link GPS Video Link WIN-T HCLOS	**YES**
1755-1850	WNW CDL HCLOS	**YES**
2200-2290	WIN-T HCLOS	**YES**
2290-2700	Flight Test Telemetry Command Control Link TCP/IP WIN-T HCLOS	**YES**
2700-2900	Meteorological Radiolocation	**UNK**
2900-3100	Radar	**YES**

4.3.2 DoD Terrestrial Spectrum Requirements Growth Above 3 GHz

High-speed, point-to-point data transfer applications are the major contributor to DoD terrestrial spectrum requirements above 3 GHz as shown in Table 4-2. Data transfer from aircraft and UASs and sensor data links are among the primary categories of battlefield data transfer requirements. Fixed infrastructure communications links are the primary non-battlefield systems category. These data transfer systems typically operate in a variety of frequency bands below 20 GHz, depending on the application characteristics. The Common Data Link (CDL), UAS C-band data links, and precision-guided munitions video and control data links are a few examples. Specific attributes for these high-data rate links include supporting throughput rates in the megabit ranges and links to ground or fixed stations with high gain, highly directional antennas. The operational battlefield geometry and operating distances along with spectrum physics determine the optimum bands for support of these high-speed data links.

Data link requirements for battlefield systems are projected to grow significantly through 2015 to support the increased use of battlefield sensors and support high data transfers associated with high-resolution and hyper-spectral sensor data projected for employment on the Global Hawk UAS. Moreover, new requirements are surfacing for Secure Wireless LANs in the 5 GHz band as well as UAS Command & Control links and FCS Data Networks in the 30 GHz to 40 GHz frequency band. Based on projections for these and other systems, an indication of where increases in band usage are expected to occur for the 2015 time frame and beyond.

Table 4-2.
Future Terrestrial DoD Spectrum Usage Above 3GHz

Frequency-Band (MHz)	**Service or System**	**Increased Usage in Band**
3100-3600	Radar	
4200-4400	Radionavigation	**YES**
4400-4990	UAS Data Link	**YES**
5250-5350	Secure Wireless LAN	**YES**
5350-5650	Secure Wireless LAN	**YES**
5650-5850	Secure Wireless LAN	**YES**
5850-5925	Secure Wireless LAN	**YES**
9500-10,450	Shipboard Wireless LAN CDL	**YES**
14,500-15,350	UAS Command & Control TCDL CDL	**YES**
15,700-17,300	Synthetic Aperture Radar CDL	**YES**
30,000-31,000	UAS Command & Control	**YES**
33,400-36,000	UAS Command & Control	**YES**
38,000	FCS Data Networks	**YES**

4.4 Satellite Communications (SATCOM) Spectrum Needs

4.4.1 Importance of SATCOM to DoD

The importance of SATCOM to DoD has increased significantly as transformational concepts requiring increased information flow to smaller combat units operating across greater distances in non-contiguous battlefields using “reach-back” have evolved. This, along with the increasing demand for more information at all echelons, has resulted in ever-increasing demands for more satellite capacity which has a direct bearing on available spectrum for satellite applications. SATCOM resources use bands between 225 MHz and 44 GHz to support military requirements. SATCOM includes both military systems (MILSATCOM) operating in the government allocated spectrum bands and commercial satellites used by DoD although provided by commercial operators using non-Government spectrum bands. DoD relies on a mixture of both MILSATCOM and commercial SATCOM services to support military operations.

DoD’s use of SATCOM has increased greatly over the past decade. SATCOM resources are inherently flexible and well suited to supporting dynamic mobile and comm-on-the-move operations required for military missions. Spanning over distance, terrain, or hostile forces, SATCOM can provide a global reach for dispersed mobile platforms such as aircraft (both manned and unmanned), submarines, and surface ships as well as vehicles and man-pack applications. SATCOM supplies mobile voice, paging, video, data, and messaging services and can deliver those services independent of the type of warfighting platform or system. Similarly, satellites keep en route forces, weapons, and support systems supplied with critical information while deploying from CONUS or overseas bases into the theater of operations. SATCOM can immediately tie sensors to shooters and provide over the horizon control of remote sensors and remoted or in-flight weapons. SATCOM systems also link together widely dispersed forces in various stages of training, mobilization, deployment, engagement, sustained operations, recovery, and redeployment. Properly designed and implemented, SATCOM services are by their very nature multi-purpose and can be dynamically reconfigured to respond to the warfighter’s changing mission needs, environments, and variety of geographical distributions.

SATCOM systems are absolutely essential in providing the assured and survivable communications demanded by the National Command Authority (NCA) and strategic and non-strategic nuclear deterrence forces. Survivable SATCOM is one of only two primary means of connectivity for these systems, and the only one with appreciable data throughput to provide secure, accurate, reliable, and unambiguous command and control to our nuclear forces. SATCOM also satisfies some of the more specialized warfighter information transfer needs. Operations in the north polar region rely on assured, robust, and capable SATCOM connectivity to support NCA operations, intelligence collection and dissemination, space surveillance, submarine and anti-submarine warfare operations, and special operations forces (SOF) as well as trans-polar flight and polar region naval activities. They are also ideal for broadcasting to multiple forces across many echelons of command and for critical information that helps provide a true, fused, real-time, common view of the joint battlespace.

4.4.2 Mix of SATCOM Requirements

DoD continually faces the challenge of ascertaining the correct mix of DoD-owned SATCOM and leased commercial SATCOM to meet its growing information transfer requirements. The stringent information needs of the warfighters and combat support require a flexible media mix. In general terms, DoD's SATCOM requirements fall into four areas: protected and survivable, wideband / high capacity, narrowband, and commercial leased SATCOM.

Protected and Survivable:

- Current: Protected and Survivable systems stress anti-jam features, covertness, and nuclear survivability. These features are currently provided to DoD by the Milstar satellite constellation.
- Mid-Term: The Advanced Extremely High Frequency (AEHF) System is the follow-on to the Milstar, and expanding the SATCOM architecture to enable Transformational Communications and Network Centric Warfare. AEHF will provide connectivity across the spectrum of mission areas, including land, air, and naval warfare; special operations; strategic nuclear operations; strategic defense; theater missile defense; and space operations and intelligence. AEHF will operate in the same spectrum bands as the Milstar constellation but with significantly higher data rates.
- Future: The Transformational Satellite System (TSAT) will address DoD's future SATCOM needs for protected services. It will have the security features currently associated with Milstar and AEHF constellations but operate at much higher data rates (see Wideband below). The TSAT constellation will be capable of establishing circuit-based crosslinks with the AEHF constellation and will also be backward compatible with AEHF circuit-based terminals. Accordingly, the TSAT constellation will operate in the current Milstar and AEHF frequency bands.

Wideband/High Capacity:

- Current: Assured capacity is the primary goal of the military's wideband satellite communications constellation. The military's wideband requirements are currently supported by the super high frequency (SHF) Defense Satellite Communications System (DSCS) and the Global Broadcast Service (GBS) as along with commercial systems (discussed below).
- Mid-Term: The Wideband Gapfiller Satellite (WGS) program will provide the next generation of wideband communications for DoD. The constellation will supplement DSCS and GBS systems while DoD transitions to more capable future systems. In addition, the WGS program will include a high-capacity two-way Ka-band capability to support mobile and tactical battlefield forces. WGS will also operate in the current DSCS and GBS spectrum bands.
- Future: As discussed under Protected and Survivable services above, the TSAT program will be DoD's primary future MILSATCOM constellation. While offering fully protected communication services it will also provide data rates historically

associated with the wideband DSCS and WGS constellations. The ability to provide high data rate protected services comes from the incorporation of new technologies such as advanced laser communications, RF-waveforms, and internet-like switching. The multi-function capability of the TSAT will require frequencies across all current satellite allocated spectrum bands.

Narrowband:

- Current: Narrowband systems emphasize support to users who need voice or low-data-rate communications and who also may be mobile or otherwise disadvantaged. Ultrahigh frequency (UHF) satellites are the workhorses for tactical ground, sea, and air forces. The current military narrowband tactical satellite communications system is the Ultra High Frequency Follow-On (UFO) system.

- Mid-Term/Future: The next-generation narrowband tactical satellite communications system is known as the Mobile User Objective System (MUOS). MUOS will provide improved and assured communications for the mobile warfighter. MUOS satellites will be fully compatible with the existing UFO system and associated legacy terminals while dramatically increasing military mobile communications availability and providing simultaneous voice, data, and video in real time to mobile warfighters around the globe. MUOS will also maximize the full feature capability of the future Joint Tactical Radio System (JTRS) terminals.

Commercial SATCOM:

The fourth segment of DoD's SATCOM media mix consists of commercial communications satellites. Commercial SATCOM is heavily used to support DoD's MILSATCOM capabilities where capacity and coverage needs are the primary consideration and jamming protection is not required. DoD leases a variety of commercial satellite resources worldwide depending on the capabilities that are needed and the available bandwidth in the region of interest able to be satisfied by commercial means.

- Current: Over the past decade or more, DoD has had to resort to employing increasing amounts of commercial SATCOM services. The on-going conflicts in the Middle East, and the increased op tempo globally, have resulted in the need for SATCOM services and capacities that have overwhelmed DoD's MILSATCOM capabilities. The growth in the use of commercial SATCOM has been with both high-capacity Fixed Satellite Services (i.e., C-Band and Ku-Band SATCOM) and with lower capacity Mobile Satellite Services (i.e., Iridium, Globalstar, INMARSAT, Thuraya, etc.).

- Future: It does not seem reasonable that DoD would continue to experience the high rate of growth in commercial SATCOM usage; however, future developments are very difficult to anticipate. DoD's planned MILSATCOM capability upgrades (MUOS, WGS, AEHF, and TSAT) continue to experience delays and program challenges. As existing commercial SATCOM capabilities are enhanced and as advanced commercial SATCOM systems (e.g., Ka-Band SATCOM) are deployed, DoD may have no other option than to leverage these emerging capabilities to meet on-going operational requirements.

Figure 4-2 depicts most military and commercial SATCOM capabilities and identifies them with associated spectrum bands.

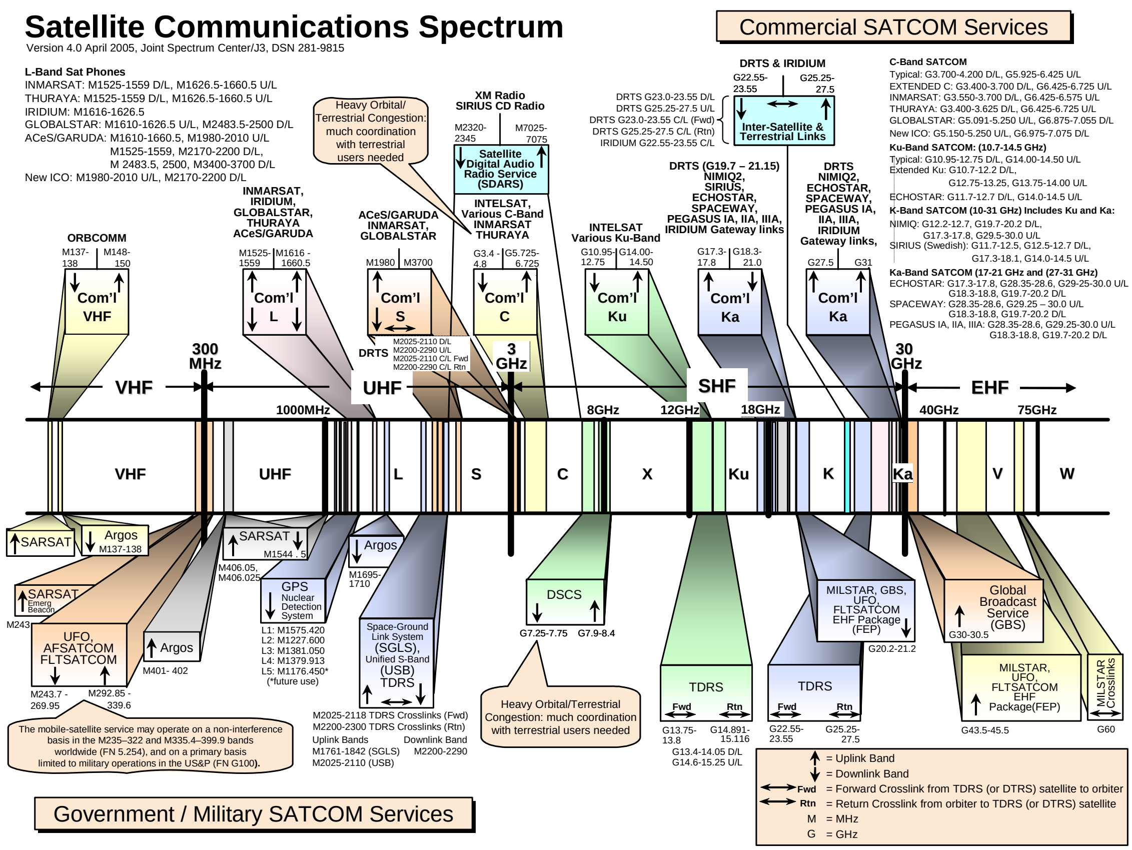

Figure 4-2. Military and Commercial SATCOM Spectrum

Determining the best mix of military and commercial SATCOM capabilities, management and control systems, and terminals to provide optimum support to all warfighter information requirements within fiscal constraints is a tremendously complex problem. The right balance must be reached between operational utility, backward compatibility, technical achievability, and affordability. Additionally, strong and unpredictable forces of change will dominate the coming decade. Factors DoD cannot accurately predict include technology, geo-politics, budgets, and the national and international legal and regulatory environments, to name but a few. The warfighters' requirements will be directly and dramatically influenced by (and will evolve in response to) these forces.

4.4.3 SATCOM Spectrum Requirements

Spectrum requirements for SATCOM depend, among other factors, on the degree that spectrum reuse can be achieved and the extent to which jamming protection is employed. Reuse is a function of the directionality of the antennas and the satellite field of view. Low earth orbit (LEO) and medium earth orbit (MEO) satellites have a smaller field of view than geosynchronous satellites and such satellite constellations can employ frequency reuse to a greater extent. Jamming protection is primarily achieved through signal processing and requires an increase in spectrum requirements in direct proportion to the processing gain supported. Factors also affecting spectrum use include details of orbital location; power and modulation; geometry including satellite and terminal locations and antenna directionality; and time or operational limitations. All of these factors must be considered when identifying satellite spectrum requirements.

Additionally, due to capability requirements, DoD must employ satellites across multiple, diverse military and commercial frequency bands. No single frequency band or single satellite communications system can satisfy the full range of needs. Each satellite communications band of the internationally regulated spectrum has its own fundamental and essential utility to the warfighter due to capabilities not easily duplicated in other bands. Especially important for certain applications is the ability to penetrate foliage or other obstacles (in general, the lower frequency bands [e.g., the (VHF) and UHF bands] penetrate foliage better than the higher bands). Higher frequency bands bring expanded capacities through higher spectral energies and available bandwidths (but with drawbacks such as increased rain attenuation effects and increased free-space loss).

Table 4-3 identifies the satellite spectrum bands currently utilized by both military and commercial satellite systems and indicates the bands where DoD spectrum growth is expected to occur in the near future. However, this does not describe the full extent of DoD's future satellite spectrum requirements. As discussed above, to satisfy the increased demand for SATCOM associated with transformational warfighting and DoD's need for information, DoD is planning to field several new satellite constellations that will require access to satellite spectrum. While these systems are expected to operate in the current bands identified for satellite utilization, the increase in the number of constellations utilizing the same frequency bands will put pressure on the spectrum availabilty to satisfy the demand while providing necessary assurance of interference free operations. Some examples of multiple systems employing the same frequency bands are noted in Table 4-3. Additionally, there is increased research into the utility of higher bands for these purposes, but the utility and ultimate use is not assured. DoD will continue to work with the NTIA and international community to identify requirements and coordinate efficient utilization of these frequency bands.

Table 4-3. SATCOM Growth Projections by Spectrum Bands

Frequency-Band (MHz)	Military	Commercial	Increased Use
108-150.05	SARSAT Uplink Argo Downlink	ORBCOMM Downlink ORBCOMM Uplink	
225-400	UFO Uplink AFSATCOM Uplink FLTSATCOM Uplink UFO Downlink AFSATCOM Downlink FLTSATCOM Downlink		YES
400.05-420	Argos Uplink SARSAT Uplink		
1215-1390	GPS L2 GPS L3 GPS L4		
1390-1710	SARSAT Downlink GPS L1 Argos Downlink	INMARSAT Downlink THURAYA Downlink ACeS/GARUDA Downlink INMARSAT Uplink IRIDIUM GLOBALSTAR Uplink THURAYA Uplink ACeS/GARUDA Uplink	
1755-1850	SGLS Uplink		
1980-2010		ACeS/GARUDA Downlink ICO Uplink	
2025-2110	USB Uplink	DRTS Downlink DRTS Fwd	YES
2170-2200		ACeS/GARUDA Downlink ICO Downlink	
2200-2290	SGLS Downlink	DRTS Uplink DRTS Rtn	
2290-2700		ACeS/GARUDA Downlink	
3400-3700		ACeS/GARUDA Downlink INMARSAT Downlink	

Table 4-3. SATCOM Growth Projections by Spectrum Bands (Continued)

Frequency-Band (MHz)	Military	Commercial	Increased Use
5000-5250		GLOBALSTAR Uplink ICO Uplink	
6425-6725		INMARSAT Uplink THURAYA Uplink	
6875-7075		GLOBALSTAR Downlink ICO Downlink	
7125-8450	DSCS Uplink DSCS Downlink		YES
11,700-12,700		ECHOSTAR Downlink NIMIQ Downlink SIRIUS Downlink	
14,000-14,500		ECHOSTAR Uplink SIRIUS Uplink	
14,500-15,350			
17,300-17,800		NIMIQ Uplink SIRIUS Uplink ECHOSTAR Uplink	YES
18,300-18,800		ECHOSTAR Downlink SPACEWAY Downlink PEGASUS IA, IIA, IIIA Downlink NIMIQ Downlink SIRIUS Downlink	YES
19,200-20,200		ECHOSTAR Downlink SPACEWAY Downlink PEGASUS IA, IIA, IIIA Downlink	YES

Table 4-3. SATCOM Growth Projections by Spectrum Bands (Continued)

Frequency-Band (MHz)	Military	Commercial	Increased Use
20,200-21,200	MILSTAR Downlink Advanced EHF Downlink GBS Downlink UFO Downlink FLTSATCOM EHF Downlink TSAT Downlink		YES
22,550-23,550		DRTS Downlink DRTS Fwd IRIDIUM	
25,250-27,500		DRTS Uplink DRTS Rtn	
28,350-28,600		ECHOSTAR Uplink SPACEWAY Uplink PEGASUS IA, IIA, IIIA Uplink	
29,000-30,000		NIMIQ Uplink ECHOSTAR Uplink SPACEWAY Uplink PEGASUS IA, IIA, IIIA Uplink	
30,000-31,000	GBS Uplink WGS Uplink		YES
43,500-45,500	MILSTAR Uplink UFO Uplink FLTSATCOM FEP Uplink TSAT Uplink		YES

4.4.4 Impact of Increased SATCOM Demand

Since all currently used SATCOM frequency spectrum is projected for continued or expanded use there is growing competition for SATCOM spectrum. This competition will increase as new commercial satellite constellations and the DoD transformational SATCOM constellation is fielded. Future systems will use the totality of the existing SATCOM frequency bands and the associated orbital slot assignments unless, or until, other bands or services can better meet requirements. Consequently, sufficient nationally and internationally allocated frequency spectrum and orbital slots must be retained/obtained as an essential enabler of military-unique systems and capabilities. Denying the warfighters' use of any portion of the spectrum would reduce flexibility and jeopardize mission accomplishment.

4.5 Radar Spectrum Needs

Current DoD radar spectrum requirements are extensive and will grow significantly in the future. Military radars perform several essential tasks including navigation, landing aides, air traffic control, surveillance, target location and tracking, weapons control, and altimeters. Successful accomplishment of these tasks is vital to DoD's ability to perform the full range of missions and conduct successful military campaigns.

For radar systems, the characteristics of the spectrum band employed have significant impact on the capability that can be achieved and therefore the information that will be provided to the user. Like most other RF based system design decisions, the frequency selection for radar systems has significant impact on the radar's application. The best frequency to use for radar is specific to the application of the system and involves many tradeoffs such as physical size, transmitted power, antenna beamwidth, and atmospheric attenuation. Typically, radars in low frequency bands provide the ability to detect targets at long distances and track space assets. On the other hand, higher frequency band systems have only limited ability for search functions but can track objects with very high precision, potentially forming an actual image of the object to assist in classification and discrimination. For example, the 8 - 12 GHz band missile defense radar requires queuing by low frequency band radar systems to focus on a specific search area. Because of these relationships between radar frequency bands and radar capabilities, the US military will continue to retain radars and develop new systems that operate throughout the full range of the electromagnetic spectrum.

New developments in radar systems are centering on the upper frequency bands (above 10 GHz), but these developments are generally intended to enhance capabilities rather than supplant the existing systems in the lower bands. Additionally, the trend in radars is towards wider bandwidths both to better discriminate target objects and to provide additional signal processing for anti-jam techniques. Another unique aspect of radar spectrum usage is that radar systems are generally unable to be retuned for flexible frequency assignment. As discussed above, military radars perform several different tasks and are further discussed below by general radar function: Search, Surveillance, and Fire Control/Imaging.

4.5.1 Search Radar

The primary functions of search radar are detection and determination of accurate ranges and bearings to targets while maintaining a complete 360° search for all targets. Search radars normally operate at relatively low frequencies below 1 GHz, permitting long range transmissions with minimum attenuation. Low frequency band systems can cover large volumes of space and are capable of foliage penetration and operation in extreme weather environments, but they have limited resolution and cannot image objects detected. Generally, search radars are used to detect targets and pass them to fire control/imaging radars for further action. In the case of search radar, existing systems are planned to operate well into the foreseeable future. Consequently, reliance on the associated bands will continue through 2020 and beyond.

4.5.2 Surveillance Radar

Similar to search radar, surveillance radar uses a 360° antenna to survey the area of interest. A key difference is that surveillance radars usually display all detections, whereas search radars attempt to filter out stationary objects. The majority of surveillance radars operate in the range from below 1 GHz up to 6 GHz; however, there are many surveillance radars that also operate in the range of 8 - 12 GHz. Although surveillance radars perform both search and tracking functions, they are typically used in self-defense or more range-limited applications than in search radar. As with search radar, existing surveillance radar systems are planned to continue to operate in the foreseeable future with the majority of systems remaining in service through 2020.

4.5.3 Fire Control/Imaging Radar

Radar that provides continuous positional data on a target is called fire control/imaging radar, or sometimes referred to as tracking radar. Fire control/imaging radar must first be directed in the general location of the desired target because of the narrow beam pattern. Fire control/imaging radars most often operate in frequency bands above 8 GHz. The radars in this category provide high-resolution performance for track identification, precision-guided munitions capabilities, and discrimination of ground targets. Current applications include high-resolution air and surface tracking radar used by air defense installations, tactical aircraft, and Navy surface ships. Fire control radar and precision munitions also rely on higher fequencies for accurate and effective targeting. DoD's use of current fire control/imaging radar systems will continue into and through the next decade and will also experience a significant increase.

4.5.4 Current DoD Radar Systems

DoD's ability to provide the full range of military capabilities needed to deter war and to protect the security of our country is heavily dependent on radar systems operating throughout the electromagnetic spectrum. This is reflected in Table 4-4 below, which depicts DoD radar frequency operating bands, the variety of radar applications resident in those bands, and the military platforms employing radar systems in the identified frequency band. As stated above, DoD plans to operate these systems in their current frequency bands in the foreseeable future with the vast majority of systems operational through the year 2020.

Table 4-4. DoD Radar Frequency Operating Bands

Frequency-Band (MHz)	Government use only	Shared Bands	DoD Application	DoD Platform		
				Ship	Aircraft	Land
3-30		X	Over-the Horizon			
216-225		X	Space Surveillance			
420-450	X		2D Air Search Airborne Early Warning (AEW)			
902-928	X		2D Air Search Target Acquisition Surveillance Radar			
1215-1390	X		Target Acquisition Aerostat-borne Surveillance 3D Long Range Air Surveillance Tactical Air Surveillance Low-Altitude Aircraft Detection Weapon System IFF			
2360-2390		X	Surveillance Search, Track & Missile Direction Tactical Air Defense Surveillance			
2900-3100		X	Surveillance Search, Track & Missile Direction Navigation & Collision Avoidance Airborne Early Warning (AEW) Tactical Air Defense Surveillance			
3100-3600	X		Search, Track & Missile Direction Navigation & Collision Avoidance Carrier-Controlled Surveillance Airborne Early Warning (AEW) Radar Altimeters Tactical Air Defense Surveillance			
4200-4400		X	Radar Altimeters			
5250-5350	X		Missile & Fire-Control			
5350-5650		X	Missile & Fire-Control Sea Surface Search			
5650-5850	X		Missile & Fire-Control Sea Surface Search			
5850-5925		X	Missile & Fire-Control			

Table 4-4. DoD Radar Frequency Operating Bands (Continued)

Frequency-Band (MHz)	Government use only	Shared Bands	DoD Application	DoD Platform		
				Ship	Aircraft	Land
8500-9000	X		Navigation & Collision Avoidance Acquisition & Tracking Missile & Fire-Control Submarine Surface Nav/Search Aircraft Control Approach Maritime Surveillance Helicopter Search Multi-mode Fire-Control ASW Search Multi-mode Airborne Radar Navigation & Mapping Terrain Following/Avoidance SAR & Moving Target Indicator (MTI) Radar Altimeters Search, Rescue & Weather Avoidance Portable Ground Surveillance Long-Range Theatre Ballistic Missile Detection			
14,500-15,350	X		SAR & Moving Target Indicator (MTI) Vehicle Speed Detection			
15,700-17,300	X		Multi-mode Airborne Radar Fire-Control Navigation & Mapping Terrain Following/Avoidance SAR/GMTI SAR for UAS Long-Range Theatre Ballistic Missile Detection Transponder Beacon			
24,050-24,250	X		Navigation & Mapping Terrain Following/Avoidance			
33,400-36,000	X		Aircraft Control Approach Navigation & Mapping Terrain Following/Avoidance Multi-mode Airborne Radar			

4.5.5 Future Radar Spectrum Requirements

DoD is projected to experience a significant increase in future spectrum use by radar systems. Although the projected growth in radar spectrum requirements will be distributed throughout the current frequency bands, the most significant growth will be in the upper bands. The growth in the lower frequency bands are due to the fielding of follow-on systems with enhanced capabilities that require increased spectrum access for functionality of the system. These new radars generally process a much wider signal bandwidth than current generation systems in order to provide additional processing capability and enhanced target recognition capabilities which fuel increased demand. Systems employed on Navy Aegis ships and the future 2-4 GHz band Volume Search Radar (VSR) to be used on the next-generation destroyer DD (X) introduce additional spectrum demand over and above current applications and reflect the trend toward increased occupied bandwidth requirements for emerging applications.

Particularly, in the case of the VSR, the increased spectrum required will improve the ability of these ships to track aircraft and missiles and to effectively counter missiles and other projectiles.

Several other new radar systems will utilize frequencies in the range from 8 to 30 GHz. The Missile Defense Agency (MDA) ground-based radar systems take advantage of the characteristics of high frequencies, as do the space-based radar, the advanced moving target indicator (MTI) radars, and Synthetic Aperture radars (SAR). Of note is the increased use of SAR and MTI radars on UASs and other airborne platforms. These radars not only provide increased resolution and imaging capability but also require greater bandwidth to achieve the detail associated with SAR and MTI images. Occupied bandwidth requirements for the new advanced SAR radars can range from 600 MHz to over 1 GHz of occupied bandwidth to support full operation. Newer applications will include features such as multi-function and dual band modes and systems designed for intrusion detection and improved space surveillance. The new MDA radar systems will afford protection against conventional and Nuclear, Biological and Chemical (NBC) theater missiles. The increased use of SAR radars systems will take advantage of the long-range propagation characteristics of radar signals and the complex information processing capability of modern digital electronics that provide the military with high-resolution imagery and targeting information.

Table 4-5 shows the radar frequency bands that DoD will utilize through 2020 and also identifies the frequency bands that will experience a significant growth in spectrum requirements.

Table 4-5. Future DoD Radar Spectrum Requirements through 2020

Frequency-Band (MHz)	Continued DoD Use	Increased Use
3-30		**YES**
30-88		
108-138		
138-144		
144-150.05		
162.0125-173.200		
173.4-174		
216-225		
225-328.6		**YES**
328.6-335.4		**YES**
335.4-399.9		**YES**
400.05-406.1		
406.1-410		
410-420		
420-450		**YES**
902-928		
932-935		
941-944		

Table 4-5. Future DoD Radar Spectrum Requirements through 2020 (Continued)

Frequency-Band (MHz)	Continued DoD Use	Increased Use
960-1215		
1215-1390		YES
1390-1400		YES
1400-1427		
1427-1432		
1432-1435		
1435-1710		
1710-1755		
1755-1850		YES
2200-2290		YES
2290-2360		YES
2360-2390		YES
2390-2700		YES
2700-2900		YES
2900-3100		YES
3100-3600		YES
4200-4400		
4400-4635		
4635-4685		
4685-4990		
5000-5250		
5250-5350		
5350-5650		
5650-5850		
5850-5925		
7125-8450		YES
8450-8500		YES
8500-9000		YES
9500-10,450		YES
10,000-10,450		YES
14,500-15,350		YES
15,700-17,300		YES
20,200-21,200		YES
24,050-24,250		YES
25,250-27,500		YES
30,000-31,000		YES
33,400-36,000		YES

4.5.6 Impact of Increased Radar Spectrum Demand

The frequency bands typically occupied by search and surveillance radar systems are heavily congested and highly coveted due to the favorable physics of these bands for communications applications. Radar and communications systems must operate in close physical proximity without causing significant interference to the other system. The limited spectrum availability for low band radar systems restricts the degree of jamming protection that can be provided, thereby, exposing such systems to greater vulnerability to enemy electronic warfare systems. Coalition forces demonstrated the effect of jamming search radar by exploiting such limitations in the enemy's search radar during Operation Iraqi Freedom. The result was the ability of coalition forces to attack with minimal detection and warning, enabling them to quickly establish air superiority and conduct a highly effective ground war with minimal impact to Allied forces. Due to the constraining environment in which these radars operate, it is unlikely that this situation can be significantly ameliorated in the foreseeable future. Any loss in spectrum would have a severe impact and would greatly increase the operational constraints, potentially to the point of precluding operation.

While the upper frequencies captured by the fire control/imaging radar category are the least constrained of the three radar categories, there is an increasing trend in the use of the upper bands for new radar systems. As discussed above, some of the very high-resolution imaging systems inherently require access to large blocks of contiguous spectrum for operation (wide band pulse as compared to frequency hopped). These large spectrum block requirements are a unique challenge in spectrum planning. Consequently, as technologies evolve to take advantage of the frequencies available in the upper bands, competition for spectrum will likewise increase. This competition can be evidenced by the increased use of the upper frequency bands by commercial applications which compete for spectrum in the 5 GHz range with military radar systems.

4.6 Training, Test and Evaluation Spectrum

Training and test and evaluation (T&E) missions each have different, independent objectives. However, they most often share common RF equipment and common resources; and, are often conducted in parallel to ensure realistic operational testing while maximizing training opportunities for military units. The demand for spectrum to support training and T&E events has increased over the last decade and will continue to increase as the design, development, testing, fielding, and employment of systems in support of force transformation is matched more closely with DoD warfighting needs. For the military to be effective and efficient, it is essential that DoD possess the requisite capabilities to accomplish the mission. In support of this objective, military equipment must be tested for operational performance at a sustained warfighting tempo and in realistic environments that best represent how and where the equipment will be required to function. Similarly, training for future military operations translates operational concepts into achievable processes for which vigorous unit training is a fundamental building block. Training fosters Service readiness and emphasizes the need for all personnel to acquire the requisite skills essential for mission accomplishment. This means that personnel must train as they intend to fight and that they must have access to required spectrum to fully evaluate and understand their operational systems as well as having spectrum for evaluation, scoring, and other post-event analysis purposes. Thus, having sufficient spectrum is essential not only to battlefield success, but it is equally important in the testing environment.

4.6.1 US Training and T&E Facilities

DoD ranges have unique and specialized spectrum requirements that are essential to military success. Training and T&E ranges support operations essential to attaining overall warfighting goals. They provide realistic environments to enable full-up systems testing, to evaluate operational effectiveness and suitability requirements, and to stress operational units before actual employment in a contingency or operation. Additionally, for all Major Defense Acquisition Programs, the legacy programs and systems that must operate with them are subject to interoperability evaluations throughout the acquisition cycle to validate their ability to support mission accomplishment. The range facilities provide the necessary real estate and specialized monitoring equipment to accomplish these tasks. Accordingly, DoD has ranges throughout the world to support required operations with the vast majority of these facilities located within the US. Although training and T&E events are ongoing daily at the majority of DoD facilities, the major range facilities conduct the bulk of T&E as well as the large-scale training events. The major US ranges are shown in Figure 4-3.

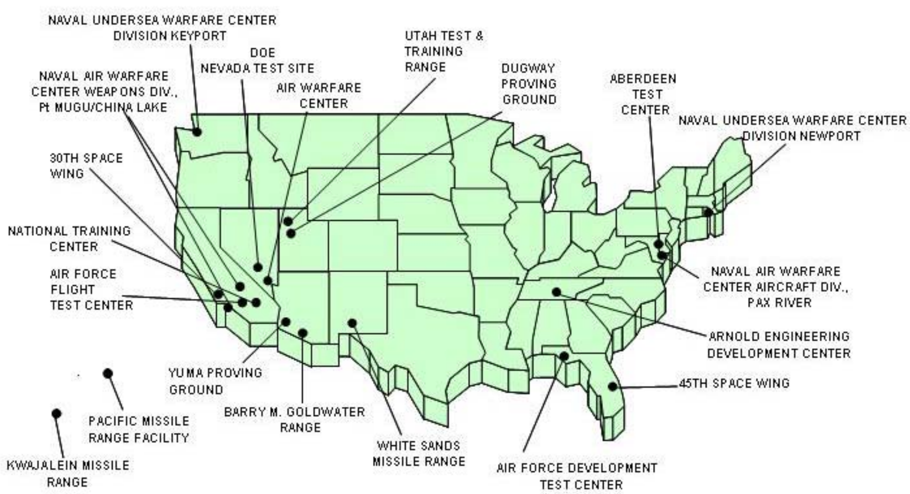

Figure 4-3. Major US Range Facilities

As seen in Figure 4-3, many of these facilities are situated near high-density population areas, which presents a challenge to have sufficient spectrum for all ongoing events in the presence of dense commercial communication activities. For example, Figure 4-4 depicts the range and test facilities with overlapping rings that represent the average radiating area of a typical S-band aeronautical telemetry transmitter. The red circles show the authorized aircraft operating radius for each of the facilities with S-band channel assignments. The dotted blue circles show the line-of-sight range of the transmitter for an aircraft flying at an altitude of 36,000 feet. The chart illustrates that electromagnetic emissions can extend substantially beyond the facility operating areas, which emphasizes the day-to-day close management and detailed scheduling that is required to avoid interference. Current management techniques include sharing of frequencies by lower priority systems and borrowing frequencies from other government facilities. While these are workable (stopgap) measures, they will not ensure spectrum support for the long term.

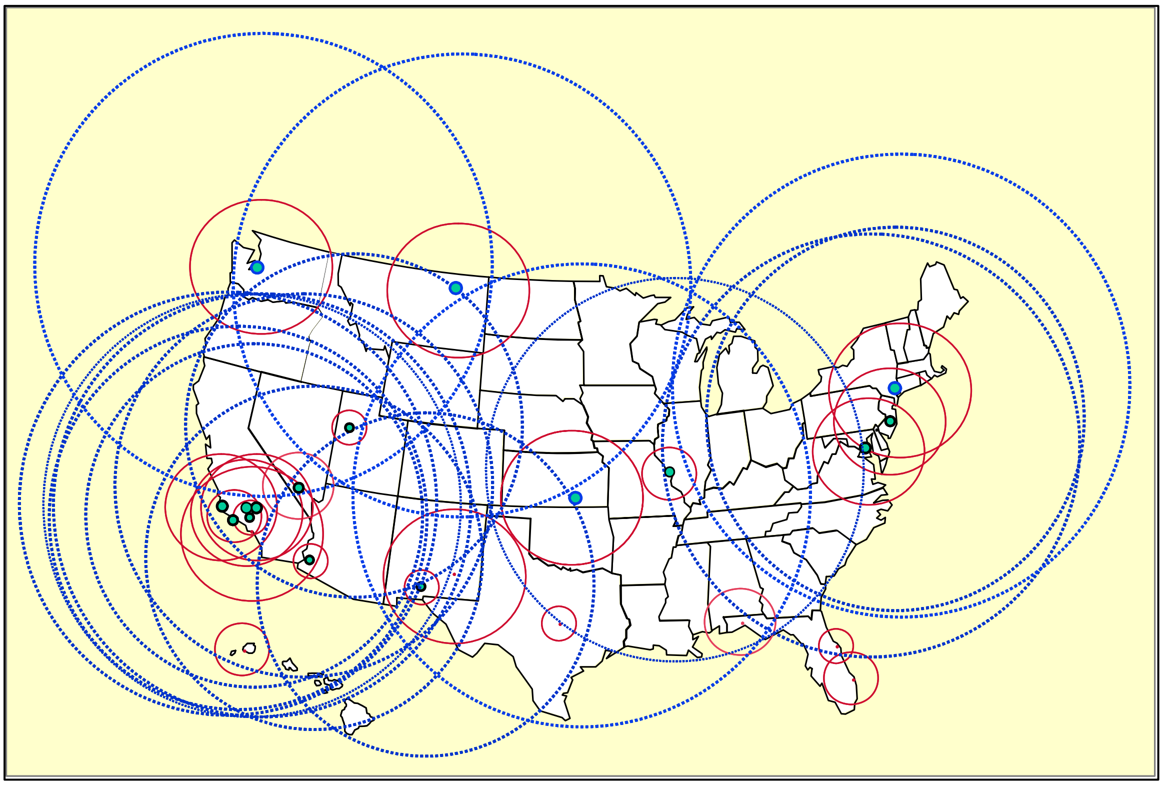

Figure 4-4. Average S-band Telemetry Radiated Distance

4.6.2 Training and T&E Spectrum Demand

Spectrum requirements for training and T&E are extensive due to the need to provide dedicated spectrum to support a variety of simultaneous functions such as:

- Spectrum for the forces conducting the training, commonly called the Blue forces;
- Spectrum for a similar size force that represents the enemy or opposing force;
- Spectrum for safety systems, scoring systems, video collection, training
- Spectrum for any new equipment undergoing tests to include unique spectrum

required for the test function, such as range control, support equipment, and test instrumentation;

- Spectrum for real-time aeronautical telemetry; and
- Spectrum required for the day-to-day operation of the training or test facility (i.e., security, fire, safety, and administrative links).

One of the challenges presented in training and T&E events is to provide sufficient spectrum for operational systems while also ensuring that range infrastructure, test instrumentation, and associated scoring equipment is spectrally supported. It is important to note that typical training requirements exceed the spectrum demand for military contingency operations. This higher spectrum demand for training is due to the discrete spectrum assigned not only for the forces conducting the training, but also for a similar size force that represents the enemy or opposing force. In addition to these requirements, there are unique demands for spectrum at individual training facilities. These requirements include safety support, scoring systems, video collection, instrumentation, and umpire (White Team) support. These three types of requirements for spectrum are each distinctive and are the major factors contributing to the high demand for spectrum in support of training. As discussed in the training and T&E facilities section above, providing sufficient spectrum for these requirements must be accomplished in many areas of the US where there also exists a large concentration of commercial RF transmissions.

This report has detailed DoD current and future spectrum requirements for operational warfighting systems. Figure 4-5 depicts the unique range functions that must also be supported, which are in addition to the operational warfighting systems and functions previously discussed.

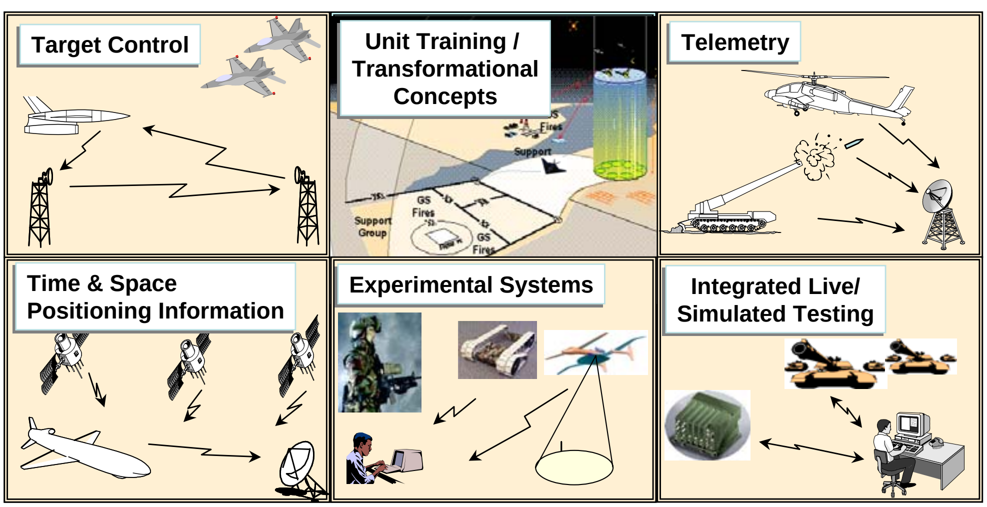

Figure 4-5. Unique DoD Range Functions

Dedicated range systems support the above functions by transmitting the data streams necessary to conduct test and training. The size and number of data streams varies with the equipment being tested and data collection requirements. When planning for spectrum, the projected number of transmitters per control station, test vehicle, number of vehicles, and size of the data streams is used to determine the bandwidth required to perform the mission and is calculated based on the projected data collection requirements. As military systems have increased in complexity, the data rates have had to increase accordingly with a corresponding increase in spectrum demand. Table 4-6 identifies the major dedicated range system applications and the associated operating bands.

Table 4-6. Training and T&E Range Applications

Bands Utilized for DoD Range Systems	
Frequency-Band (MHz)	**Range Application**
30-88	Observer Network
225-400	Weapons Scoring Systems Traget Control Assessment / Evaluation Data Transfer Range Communications
400.05-420	Weapons Scoring Systems
420-450	Range Safety Drone Control
1390-1710	Range Telemetry
1755-1850	Missile Scoring Range Telemetry Air Combat Training Target Control
2200-2290	Range Telemetry
2290-2700	Range Telemetry Weapons Scoring
3100-3600	Projectile Scoring Missile Scoring
4400-4990	Drone Control Event Video Recording
5000-5250	Event Video Recording
5350-5650	Drone Control / Range Tracking Radar
5650-5850	Drone Control / Range Tracking Radar
5850-5925	Drone Control

Of note, spectrum for instrumentation is predominantly in bands that support operational systems and is in high demand within the Continental United States (CONUS). It becomes a significant challenge to balance the needs for spectrum between the evaluation of a system under test and a unit's performance, yet provide the Training Force the spectrum it requires in order to accomplish its training objectives. As the principal function of the ranges is to evaluate and determine the adequacy and efficiency of scheduled events, instrumentation is critical. This necessitates that deference be given to instrumentation systems in making spectrum assignments at the expense of other systems in the same frequency bands. Too often, training units must shutdown or suffer a loss of operating RF frequencies.

4.6.3 Future Training Spectrum Requirements

The density of spectrum use in training areas and spectrum requirements for tactical systems will grow throughout the next decade. This growth is attributable to the increased spectrum that will be needed for tactical systems (as discussed in previous sections of this report); the need to exercise the equipment during training events; and the increase in data collection requirements.

There are many reasons for the increase in range systems spectrum needs. Each new generation of weapons system incorporates the latest increases in electronic and information technology. High performance systems are now designed to operate at the extremes of the envelope and are maintained by a complicated network of computers, sensors, and actuators whose detailed performance must be monitored. Accordingly, more data must be examined in order to evaluate performance of these advanced systems, which results in the need for very large amounts of spectrum. Spectrum demand is further compounded as overhead incurred from link security, error correction coding, network management, and other support provisions are added to the systems and therefore drive additional spectrum needs which are, in turn, added to the overall spectrum required for a test event. Consequently, the demand for training and T&E spectrum is forecasted to increase significantly in the future.

An example of this projected growth was identified in platforms with the most demanding requirements for telemetry spectrum needed only about 300 kilohertz (kHz) to support the test requirements of a single platform. In 2000, the analogous requirement was 30 MHz, a one hundred-fold increase. The same study found that by the year 2020, a test vehicle will arrive at a test range and require approximately 400 MHz of telemetry spectrum, almost twice as much as what is currently available. This projection assumes that a specific state-of-the-art spectrum efficient technology will have been implemented in the mid-term.

4.6.4 Impact of Increased Training on Spectrum Demand

Providing required training and T&E spectrum in highly populated frequency bands poses a significant challenge. Sufficient spectrum to operate all operational and threat systems is critical to successful training and a challenge in areas where government and civilian requirements co-exist.

Insufficient spectrum at range facilities to accommodate all range monitoring and performance systems will result in the loss or degradation of a critical test and evaluation function that can ultimately affect acquisition programs. If the function is a form of data collection, and the data cannot be gathered by any other means at that range, the entire test program may have to be reevaluated to determine if the data is mandatory to evaluate the effectiveness or suitability of the system undergoing testing. If it is determined that the data is essential to perform an adequate evaluation of the weapon system, the test may have to be relocated to another range that can collect the required data or a detailed risk analysis undertaken to determine the impact of the unavailable data. In many cases, a risk analysis is not sufficient to confirm operational performance and form the basis for acquisition. Depending on the lead-time, the delays to move events or to reschedule due to unacceptable risk impacts could result in significant program delays, or possibly unexpected cost overruns. Even if there are alternative means of collecting data, these methods are generally not as effective, are more time consuming, or both, which could also result in program delays or fielding less effective systems to the warfighter.

Congestion in the telemetry bands is already beginning to be experienced at some test ranges and many projects today are operating at a less than optimal test efficiency due to lack of real-time spectrum availability. Missions have been delayed and lost due to lack of sufficient spectrum to schedule activities. This has resulted in test delays, increased costs, and higher test risks. Examples of these impacts to the US test ranges were documented in a National Telecommunication and Information Administration (NTIA) special publication, which cites impacts to several military projects as a result of spectrum limitations.[30] This situation is expected to exacerbate over the foreseeable future.

4.7 Transformational Capabilities Driving Future Spectrum Needs Growth

This section presents two key capabilities (Unmanned Systems and Future Combat Systems) that are illustrative of the growth in DoD electromagnetic spectrum requirements due to the evolving DoD mission and need for increased capabilities. The discussion is intended to provide an understanding of how the military is highly dependent on electromagnetic spectrum for current and future operations and how Net-Centric warfare concepts impact the demand for spectrum access.

4.7.1 Unmanned Systems: Unmanned Air Systems (UAS) and Unmanned Ground Systems (UGS)

Current DoD demand for spectrum to support UAS and UGS is extensive and will continue to grow as a more sophisticated and capable force of unmanned systems are fielded in the next 15- 20 years. The forecasted growth is due to a variety of reasons that include the number and mix of unmanned systems deployed in support of DoD missions, the number of RF dependent devices required to remotely operate the systems and employ mission equipment, and the increased use of more sophisticated onboard sensor systems that require increased bandwidth to support enhanced processing requirements. With the need to autonomously launch, operate, and recover these systems, it is paramount to have sufficient electromagnetic spectrum to enable interference free operations.

Unmanned systems, in general, are changing the conduct of military operations. They are the preferred solution over manned counterparts especially when the requirements involve long

[30] *Spectrum Reallocation Study as Required by the Balanced Budget Act of 1997*. Special publication 98-36 National Telecommunication and Information Administration (NTIA).

dwell time for surveillance, sampling for hazardous material, and extreme exposure to hostile action. Each Service is developing a wide range of unmanned capabilities, and the Office of the Secretary of Defense (OSD) is responsible for ensuring these capabilities support the Department's larger goal of fielding transformational capabilities.

4.7.1.1 Unmanned Air Systems

DoD's use of UASs continues to expand and encompass a broad range of mission capabilities. As stated in the DoD UAS Roadmap,[31] "the use of UASs in military operations has expanded rapidly since entering the war on terror in the fall of 2001… unmanned aircraft have transformed the battlespace with innovative tactics, techniques, and procedures." UASs provide surveillance, intelligence, reconnaissance, and fire support and are becoming increasingly relied upon by Combatant Commanders.

Current and future UASs are diverse in size, weight, and mission performance. They range from Micro Air Vehicles (MAV) weighing less than one pound that can be carried and operated by an individual soldier to aircraft weighing over 40,000 pounds that require dedicated support teams to operate but provide a broader range of capabilities than the MAVs. UASs perform a vast array of DoD missions including surveillance, reconnaissance, chemical and biological detection, and weapons delivery. Figure 4-6 shows the on-going and planned UAS programs of record through 2020.

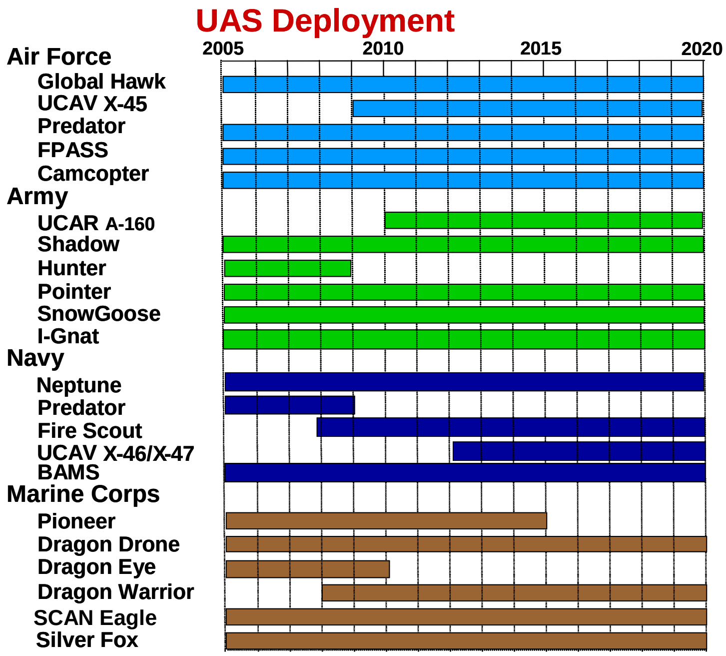

Figure 4-6. UAS Inventory through 2020

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[31] *Unmanned Aircraft Systems Roadmap 2005 -2030*. Office of the Secretary of Defense August 4, 2005

4.7.1.2 UAS Spectrum Demand

Every aspect of UAS operations depends on the assured availability of spectrum to support RF systems. Accordingly, electromagnetic spectrum use by UAS is extensive and requires systems to operate in a variety of frequency bands to provide full functionality and mission accomplishment. A typical UAS may require spectrum for its RF based systems in up to 14 different frequency bands to support such functions as: launch and recovery; platform control; payload functionality; sensor data transfer; navigation; weapons functions; situational awareness; and communications relay. The characteristics of the frequency band and regulatory allocation, as with other RF systems, have a significant bearing on the function performed by the system. The RQ-4 Global Hawk is illustrative of UAS spectrum dependency and its nominal spectrum usage is featured in Figure 4-7.

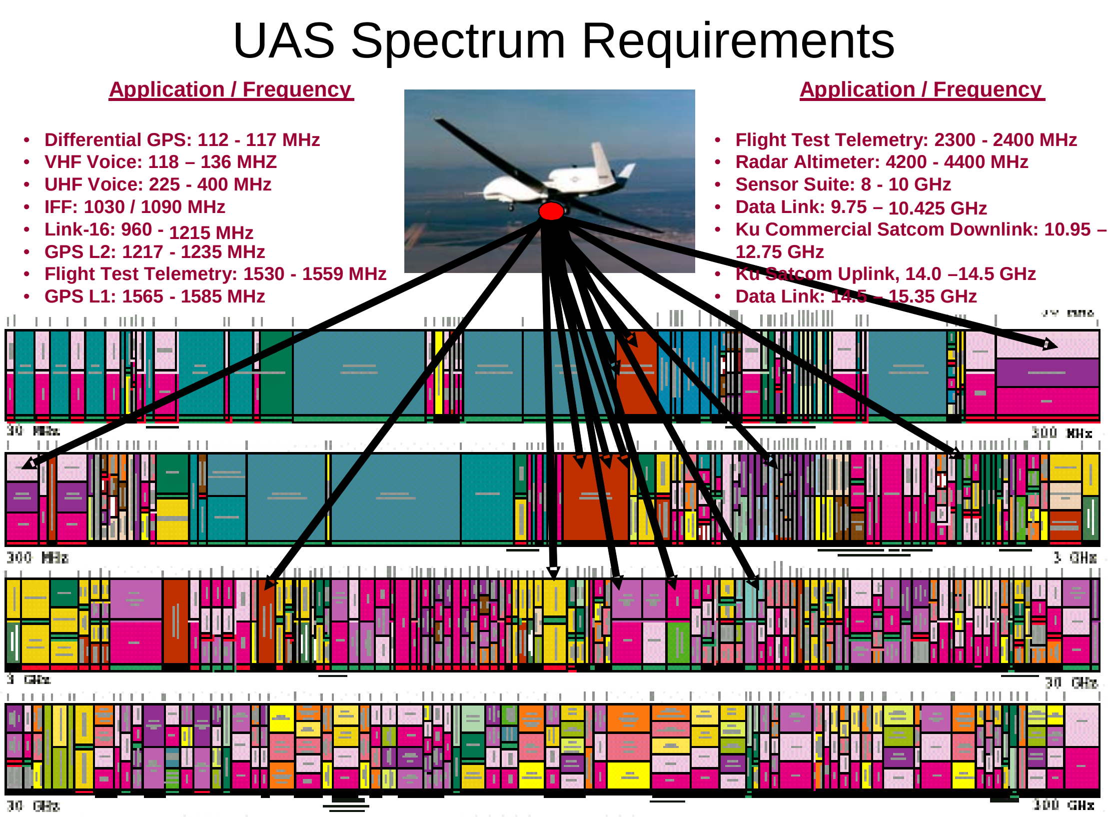

Figure 4-7. RQ-4 Global Hawk Spectrum Dependency

The Global Hawk system consists of the aircraft, Launch and Recovery Element (LRE), and Mission Control Element (MCE). The LRE controls the aircraft via the line-of-sight (LOS) Common Data Link (CDL) operating in the X and Ku-Bands, LOS VHF and UHF, and beyond line-of-sight (BLOS) UHF SATCOM radios. The MCE contains all of the aircraft control functions of the LRE. In addition, the MCE provides for sensor control as well as receipt and dissemination of payload products. The MCE maintains situational awareness via a variety of means including GPS and Link-16. MCE aircraft command and control is accomplished using narrow band LOS UHF radio and UHF SATCOM with Inmarsat as a back up command and control link. The LOS CDL as well as Ku-band SATCOM also provide command and control channels. Sensor data flows from the aircraft to the MCE via either LOS X and Ku-Band CDL or Ku-band SATCOM. Figure 4-8 depicts the current UAS RF architecture, which further illustrates UAS spectrum dependence.

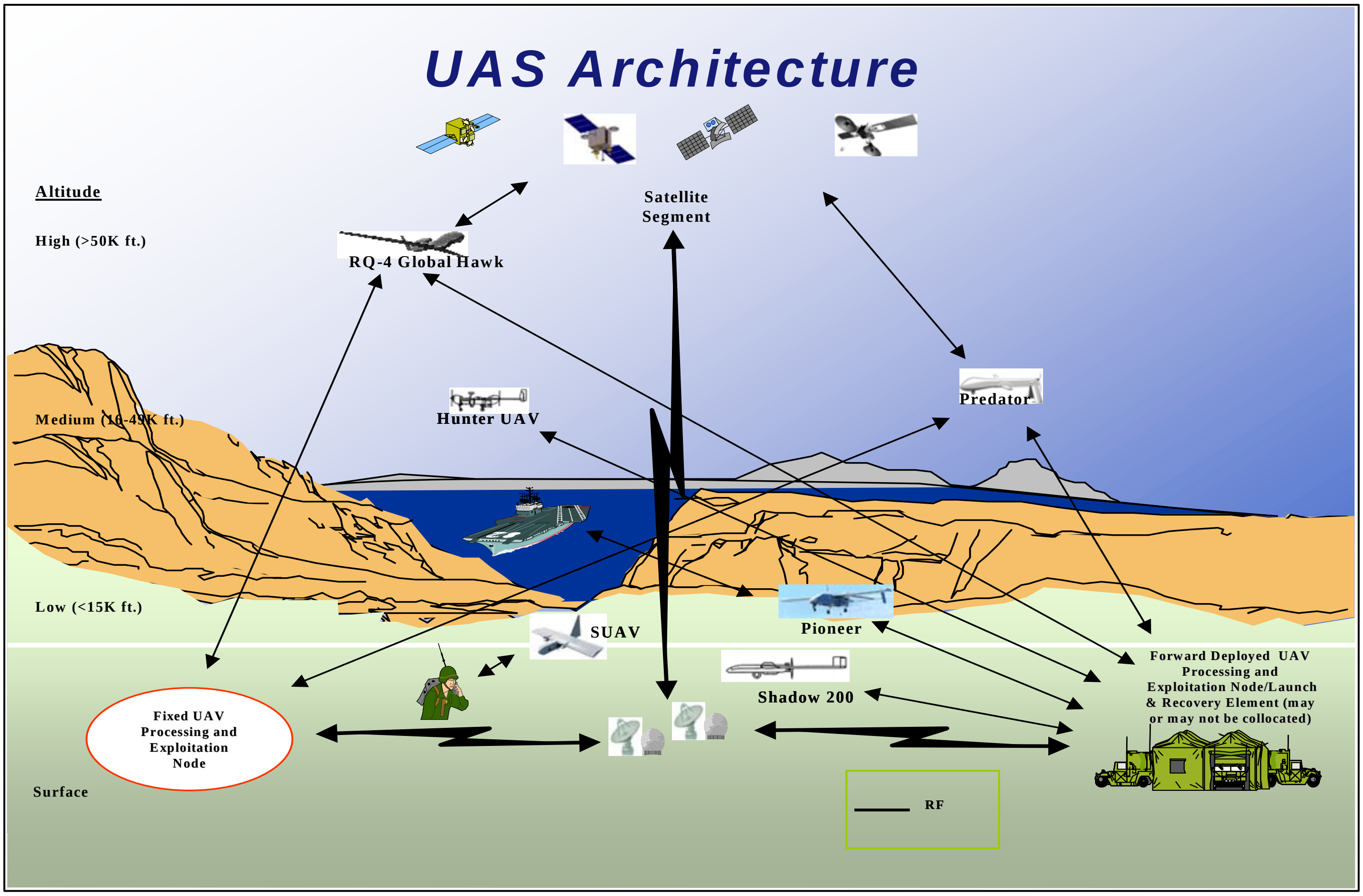

Figure 4-8. Current UAS Architecture

4.7.1.3 Unmanned Ground Systems

DoD continues to develop UGS to support a variety of missions, increase combat effectiveness, and enhance personnel safety. As with UAS, UGS are also diverse in size, weight, and mission performance. UGS missions include detection, neutralization, breaching of minefields, and other obstacles. These obstacles include: explosive ordnance disposal; physical security; fire-fighting; urban warfare; weapons employment; and operations in contaminated and other denied areas. On the battlefield, they assist in increasing situational awareness by providing observation of tactical objectives and potential danger areas beyond line-of-sight where human access is impractical or unsustainable. The Army and Marines are the largest users of UGS technology and both are expected to increase usage in the future. The Navy has also invested in UGS technology for use in the ocean environment for mine warfare, anti-submarine warfare, riverine operations, and special forces operations. Figure 4-9 shows the on-going and planned UGS programs of record through 2020.

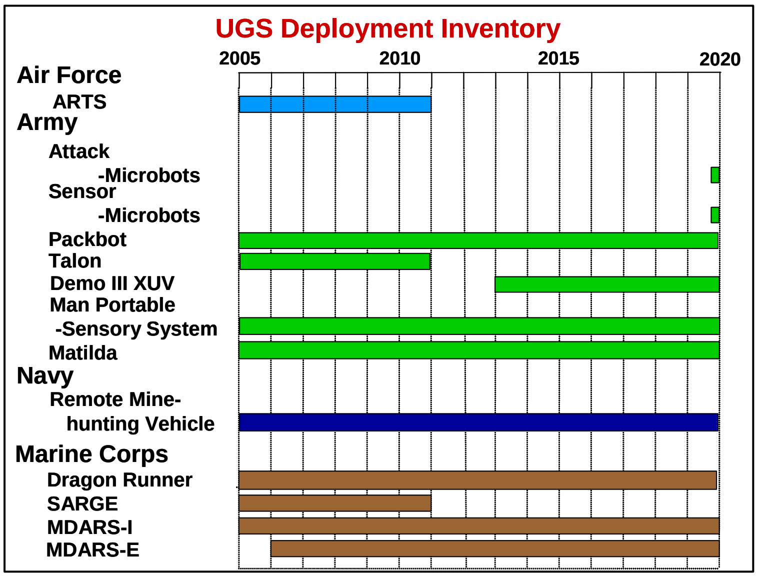

Figure 4-9. UGS Inventory Through 2020

4.7.1.4 UGS Spectrum Demand

Although UGS do not typically require as many RF systems or links to operate as UAS, they are, no less, dependent on the electromagnetic spectrum for functionality. A typical UGS mission requires spectrum in seven frequency bands. A notional system consists of the vehicle, sensor, sensor interface, remote controller, and situational awareness module. UGS control links most often operate in the VHF or UHF bands with many systems utilizing unlicensed 802.11 devices for the control function. UGS data links operate in the L and S-bands and are equipped with GPS for location information.

4.7.1.5 Future UAS and UGS Spectrum Requirements

DoD forecasts significant growth in spectrum requirements to support unmanned systems. As discussed earlier, this projected growth is due to an expected increased number of unmanned systems deployed on the battlefield and the use of more sophisticated onboard sensor systems that require additional operating bandwidth. UAS will be the greatest contributor to the increased demand for spectrum. Due to operating altitude and antenna characteristics, they must be assigned discrete frequencies to preclude interference and support safe and uninterrupted operational performance. Thus, as the number of systems and rate of use increase, the demand for dedicated operating frequencies also increases.

The single largest contributor to increased unmanned system spectrum demand will be to support airborne data links. Data link rates and processor speeds are in a race to enhance future unmanned capabilities. Today, and in the near-term, the CDL is the primary data link utilized to transfer airborne data. The CDL requires 274 MHz of spectrum in the X and Ku-band to support transfer of sensor information. As sensor resolution increases, the demand for increased data link spectrum will rise significantly. For example, the fielding of a new sensor for the Global Hawk system projected for 2015 will require over 1 GHz of bandwidth to support the associated information transfer requirements. The availability of 1 GHz of spectrum is currently difficult and will become increasingly problematic as forecasted frequency congestion occurs. This is especially true for data links in the 1-8 GHz range, which covers L, S, and C-bands. Table 4-7 presents UAS and UGS operating bands and identifies those bands that will experience increased demand as new and more capable unmanned systems are deployed.

Table 4-7. UAS and UGS Operating Bands and Future Requirements

Frequency-Band (MHz)	**Current and Future UAS and UGS**			**Increased Demand**	
	UAS	**UGS**	**DoD Application**	**UAS**	**UGS**
30-88	Pointer		Command Control Link		
108-150.05	Global Hawk UCAV X-45		GPS Voice	**Yes**	
225-399.9	Global Hawk UCAV X-45 FPASS UCAR Predator B Fire Scout (VTUAV) Dragon Eye Dragon Warrior J-UCAS Pioneer Shadow		SATCOM Command Control Link	**Yes**	
400.05-420		SARGE	Radar Command Control Link	**Yes**	
420-450	Pointer Pioneer		Video Link SAR/MTI		
902-928	Hunter	Dragon Runner	Sensor Command Control Relay		
960-1215	UCAV X-45	Remote Mine Hunting Vehicle	IFF JTIDS	**Yes**	
1215-1390	Global Hawk Predator B	Remote Mine Hunting Vehicle	GPS	**Yes**	

Table 4-7. UAS and UGS Operating Bands and Future Requirements (Continued)

Frequency-Band (MHz)	Current and Future UAS and UGS			Increased Demand	
	UAS	UGS	DoD Application	UAS	UGS
1390-1435		Remote Mine Hunting Vehicle	Command Control Link		
1435-1710	Global Hawk UCAV X-45	Remote Mine Hunting Vehicle	GPS Video Link SAR	**Yes**	
1710-1850	UCAV X-45 FPASS Pointer Dragon Eye Silver Fox SnowGoose	ARTS Packbot Talon MDARS-I MDARS-E Matilda Remote Mine Hunting Vehicle Dragon Runner	Data Link Video Link	**Yes**	**Yes**
2360-2390			Flight Test Telemetry		
2390-2700	Shadow	Packbot Talon MDARS-I MDARS-E Matilda	Command Control Link		**Yes**
4200-4400	Global Hawk UCAV X-45 BAMS I-GNAT	SARGE	Radar Altimeter	**Yes**	
4400-5250	Hunter Pioneer Shadow Predator	ARTS	Sensor	**YES**	
5250-5350	Predator Camcopter Shadow Hunter Pioneer I-GNAT				
5350-5650	Predator I-GNAT Shadow Hunter Pioneer		Video Link Telemetry		
5650-5850	Predator Shadow I-GNAT Hunter				
5850-5925			SATCOM		
7125-8500	Global Hawk		Sensor	**YES**	
8500-9000	Global Hawk		Multi-mode Radar ISAR	**YES**	
9000-9500	Global Hawk		Sensor	**YES**	
9500-10,450	Global Hawk Fire Scout		CDL	**YES**	

Table 4-7. UAS and UGS Operating Bands and Future Requirements (Continued)

Frequency-Band (MHz)	Current and Future UAS and UGS			Increased Demand	
	UAS	**UGS**	**DoD Application**	**UAS**	**UGS**
10,450-15,350	Global Hawk Predator Predator B UCAR Fire Scout (VTUAV) Dragon Warrior		SATCOM Command Control Link TCDL SAR	**YES**	
15,700-17,300	Predator		Synthetic Aperture Radar	**YES**	
20,000-21,200	Global Hawk UCAV Predator			**YES**	
30,000-31,000	Global Hawk UCAV Predator			**YES**	

4.7.1.6 Impact of UAS and UGS on Increased Demand

As with many other DoD systems and services, the spectrum requirements of unmanned systems will continue in all of the same frequency bands utilized today but will grow in selected bands as identified in Table 4-7. In these bands, there will be a steady rise in the number of frequencies required to support the growing use of unmanned systems, an increase in the bandwidth for frequencies to support increased data transfer, and an increase in the time of operation due to longer on-station requirements. Meeting the increased requirement for spectrum dedicated to support unmanned systems will require increased attention to spectrum management schemes and scheduling to promote sharing of frequencies. Additionally, technologies that increase onboard processing and compression of sensor data will assist in reducing the amount of contiguous bandwidth needed to support airborne data links. Without significant spectrum reuse and fielding of spectrum efficient technologies, unmanned systems will be constrained in the use of spectrum to achieve overall mission needs and may require highly refined scheduling plans to ensure operations are executed within the limits of available spectrum.

4.7.2 Future Combat Systems (FCS)

Future Combat System will be another key capability impacting DoD's future spectrum requirements. As detailed earlier, DoD is undergoing a transformation in capabilities and in the way we organize and support the warfighter. FCS is a core building block for this transformation and an excellent illustration of DoD's dependence on, and increased demand for, the electromagnetic spectrum. FCS is an Army led, joint networked system of systems connected via an advanced network architecture that will enable levels of joint connectivity, situational awareness and understanding, and synchronized operations heretofore unachievable on the mobile battlefield. The Army's FCS-equipped Units of Action (UA) will be its future tactical warfighting echelon. FCS will network existing systems, systems under development, and systems to be developed that meet the requirements of the UA. FCS will incorporate a variety of spectrum-dependent systems operating across various bands of the frequency spectrum, thus access to the electromagnetic spectrum will be essential to fully support FCS system functionality. After initial prototype testing and evaluation, FCS fielding will commence in 2010 with the first fully FCS equipped UA operational in 2014.

As depicted in Figure 4-10, FCS includes 18 systems consisting of unmanned ground systems; unattended munitions, the Non-Line of Sight – Launch System (NLOS-LS), and Intelligent Munitions System (IMS); four classes of UASs organic to platoon, company, battalion, and Unit of Action (UA) echelons; three classes of unmanned ground vehicles, the Armed Robotic Vehicle (ARV), Small Unmanned Ground Vehicle (SUGV), and Multi-functional Utility/Logistics and Equipment Vehicle (MULE); and eight manned ground vehicles plus the individual soldier - all integrated via the FCS wireless network.

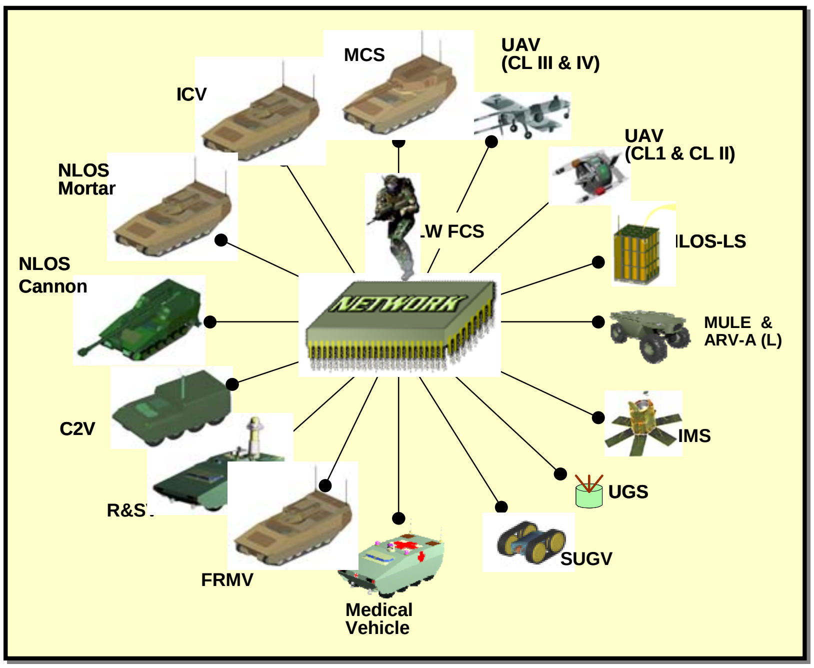

Figure 4-10. Future Combat Systems

4.7.2.1 Future Combat System Wireless Network

Individual FCS platforms will be equipped with a variety of RF emitters that will operate across frequency bands to provide offensive and defensive capabilities. However, the core of FCS will be the multi-layered FCS wireless network, which will have unprecedented range, capacity, and dependability. The FCS network will provide secure, reliable access to information sources over extended distances and complex terrain. The network will support dissemination of critical information among sensors, processors, and warfighters both within and external to the FCS-equipped organization. The network will be embedded in the FCS platforms and will move with the combat formations. This will enable superior Battle Command (BC) on-the-move to achieve offensive-oriented, high-tempo operations.

The FCS wireless network will be comprised of several homogenous communication systems such as JTRS with Wideband Network Waveform (WNW) and Soldier Radio Waveform (SRW), Network Data Link, and Warfighter Information Network–Tactical (WIN-T). FCS leverages all available resources to provide a robust, survivable, scalable, and reliable heterogeneous communications network that seamlessly integrates ground, near ground, airborne, and spaceborne assets for constant connectivity and layered redundancy. Every FCS vehicle in the Unit of Action (UA) will be equipped with a 4 or 8-channel Joint Tactical Radio System (JTRS). Soldiers and other weight and power-constrained platforms will be equipped with a 1 or 2-channel JTRS radio. In addition to the WNW and SRW communications backbone, the software programmable JTRS will support other waveforms to ensure current force Joint, Interagency, and Multi-national (JIM) interoperability. The WIN-T will provide additional communications capability within the Unit of Action (UA) as well as reach to senior echelons.

Supporting the FCS equipped UA will be a distributed and networked array of ISR sensors allowing FCS the ability to provide timely and accurate situational awareness (SA), enhance survivability by avoiding enemy fires, enable precision networked fires, and maintain contact throughout engagement. FCS will process real-time ISR data, outputs from survivability systems, situational awareness (SA) data, and target identification information to update the common operating picture (COP) containing information on friendly forces, battlespace objects (BSOs), BSO groupings and associated intent, threat potential, and vulnerabilities. The real-time distribution and dissemination of information and data are reliant on robust, reliable, and high-capacity network data links that require assured access to spectrum for functionality.

4.7.2.2 Future Combat System Spectrum Demand

Parallel with the development of FCS systems, DoD is conducting detailed engineering studies and analysis to determine spectrum requirements to support the FCS equipped UA. Although the exact requirements have not been confirmed, various studies have concluded that FCS's demand for spectrum is forecasted to grow significantly and could result in as much as a 50 – 60% increase over the spectrum required for similar sized units deployed today. The projected increase is due to the development of advanced ad-hoc networking technologies to link FCS while also supporting the information demand associated with other tactical systems such as unmanned vehicles, battlefield sensors, precision munitions, real-time video, and situational awareness. Since FCS will rely heavily on the JTRS with WNW and SRW, growth in spectrum demand will be concentrated in the frequency bands below 2 GHz commensurate with the JTRS design. Frequency bands currently under consideration for FCS use are the 225- 399.9 MHz, 1350-1390 MHz, and 1755-1850 MHz bands. Although use of these bands has not been confirmed, DoD expects that the highest demand for FCS spectrum will be in the bands between 1 and 2 GHz due to the planned implementation of WNW above 1 GHz.

To understand the demand for spectrum and heavy reliance on the frequency bands below 2 GHz, we must understand the environment, the way DoD plans to fight, and what capabilities and functionalities have to traverse RF dependent systems. As discussed earlier in this report, DoD operates RF equipment across various frequency bands due to capability requirements and the ability of various frequency bands to meet those requirements. Since spectrum bandwidth facilitates information capacity, spectrum bandwidth has become increasingly critical as the requirement for information has increased. Additionally, what makes FCS demand for spectrum inherently different from other implementations is the requirement to have a fully mobile tactical communications infrastructure that can conduct combat operations on-the-move, at the quick halt, and during sustained operations. This necessitates use of omni-directional systems, which limits spectrum reuse and sharing. A second major fundamental difference is the requirement to provide high bandwidth communications capability to large numbers of forces over a dispersed area, which requires large blocks of contiguous spectrum. Thus, the forecast requirements for spectrum to support FCS are a direct reflection of the increased capability of FCS units to conduct combat operations over extended distances in austere environments.

4.7.2.3 FCS Impact on Increased Demand

DoD recognizes that spectrum is a finite resource and the use of this resource is, and must be, prioritized. To assist in determining precise FCS spectrum requirements, the Army is collecting information exchange requirements, data from field experiments, and operational experience as well as information on legacy systems. This data is being evaluated via various models and spectrum algorithms. The main premise in identifying spectrum to support the FCS network architecture is that the required information must safely traverse the wireless network regardless of the environment and arrive within identified timelines. The result of the on-going analysis will be a spectrum requirements determination for implementation of FCS, which will be identified in future revisions to this report.

4.8 Future DoD Spectrum Needs Forecasting

DoD continues to deploy updated sensors, radars, and communications systems with greatly improved performance and capability; correspondingly, they also require more spectrum. Through the experiences acquired in developing the 2005 DoD Strategic Spectrum Plan the DoD has recognized the need for near- and far-term spectrum planning processes that provide a high degree of predictability. As such, the Department's draft 2007 Strategic Plan for Spectrum Management[32] includes two objectives that relate to spectrum requirements:

- The development of a comprehensive plan for the determination of current baseline spectrum usage.
- The design and implementation of methods to analyze and forecast spectrum requirements.

DoD also recognizes that the characterization of spectrum requirements, in terms of reflecting spectrum utilization or access, requires a consistent framework within which to classify and quantify both current and projected needs. Methodologies developed for the representation of spectrum usage must have Department-wide application which can best be achieved through the development of a structured framework for assessing spectrum needs and accessibility. This includes modeling and simulation, the application of metrics, risk assessment, and statistical methods.

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[32] Department of Defense, Office of Assistant Secretary of Defense (Networks and Information Integration), Draft 2007 Electromagnetic Spectrum Management Strategic Plan, Washington, D.C., *Op. Cit.*

5.0 Current and Future Use of Non-Federal Spectrum Offered by Commercial Service Providers

DoD typically does not buy systems that it cannot deploy worldwide. Thus, it “must” buy systems that are deployable (CONUS/OCONUS). In CONUS we can lease items but not buy for deployability purposes. In CONUS locations (base, post, camp and stations) and local operations are like mini cities. Due to local practices in the cities surrounding military installations, items such as cell phones and commercial land lines are leased or used via communication trunking stations when feasible. For instance, DoD’s mobile subscriber equipment can interface with commercial communications, however, DoD is prohibited by law from doing so; its use would interfere with the providers profit revenue.

In summary: DoD will use commercial services when possible. However, the purchase of these services is tied to the worldwide deployability of the product.

6.0 Agency Current and Future Use of "Non-Licensed" Devices

DoD's worldwide mission has presented a unique situation regarding spectrum. In the "fast track" acquisition, commercial-off-the-shelf (COTS) is often referred to as the way to field systems quickly and cheaply. That is, research and development is performed by an independent agency, and thus the Government saves money. Unfortunately, the primary market for these systems is the commercial sector. When COTS equipment is purchased by the government, it cannot always be supported in spectrum authorized for use by the military. There is, however, a sub-set of COTS known as non-licensed devices, which are low power devices approved by the FCC for use in the US&P. Some examples are: garage door openers, baby monitors, cordless phones, and remote controlled cars or planes.

Frequency conflicts from COTS devices could possibly cause problems, and technical characteristics cannot be changed once the equipment is purchased and placed into use. In order to train as we fight, we must deploy to areas outside the US&P. Spectrum is not allocated the same in every country and many of our systems are not allowed to operate in places where training is taking place. A COTS device may work well in the US&P, but its use may be restricted in another country. Thus, adopting a COTS solution is not always the best means to meet military requirements. Also, non-licensed devices must operate within the limits placed upon them by federal law. Spectrum supportability assessments, done in concert with a spectrum manager, will ensure that the best possible decision is achieved.

DoD will use COTS and non-licensed systems in US&P areas due to the following restrictions:

- Operational problems; potential loss of life;
- System can only be minimally used during peace-time exercises;
- System cannot be used during military operations; and
- Multiple systems to perform a single function because of Host Nation issues.

7.0 DoD Spectrum Dependent Technology Initiatives

In the future, military commanders will operate in a dynamic, multi-layered, multi-dimensional battlespace. This will require radio spectrum support that adapts to rapidly changing conditions for highly mobile, widely dispersed forces. The Department of Defense (DoD) demand for throughput is expected to increase dramatically. At the same time, worldwide competition for radio spectrum has placed increasing pressure on US military spectrum usage and the paradigm shift to asymmetric warfare only exacerbates this dilemma. Seemingly, future assured access to spectrum will only be achieved through both the application of technologies that increase channel efficiencies and by the supplement of spectrum allocated to DoD with access to other government and commercial networks worldwide.

7.1 Planned, Future Uses of Spectrum Dependent Technologies or Services

Over the next twenty years or so, US forces will experience operational environments that are increasingly complex, uncertain, and dynamic. The *Net-Centric Environment Joint Functional Concept*[33] is an information and decision superiority-based concept of how joint forces will organize and operate in the future. The networking of all joint force elements will enable paralleled information sharing and collaboration. DTOs supporting this concept are well targeted where the development of technologies to overcome a number of identified limitations is concerned.

Joint Tactical Radio System (JTRS) **–**JTRS is a family of modular, software-defined, multi-band, multi-mode radios that will replace virtually the entire current inventory of tactical radios as well as SATCOM terminals, eventually. Furthermore, JTRS will have inherent cross-banding and a networking capability that will enable mobile forces to remain connected to an IP network.

Warfighter Information Network – Tactical (WIN T) **–** WIN-T is the US Army's high-capacity, high-speed, backbone communications network that will provide required reach, reachback, interoperability, and network operations for the Maneuver Units of Action (UA) and will seamlessly interface with JTRS. WIN-T will extend to the individual warfighter platform level and offer continuous interoperability with other networks including legacy, joint, coalition, and even commercial networks through utilization of all available links to support the warfighters anywhere on the globe.

Common Data Link (CDL) **–** CDL will provide communications paths using JTRS/SCA architecture. The project includes a number of separate tasks dealing with tactical CDL for UAVs, a wideband integrated CDL for Network Centric Collaborative Targeting, and development of ultra-wideband airborne laser development.

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[33] *Net-Centric Environment Joint Functional Concept*, Version 0.95, Office of the Joint Chiefs of Staff, December 30, 2004

***Wideband Networking Waveform (WNW)* –** Wideband waveform development is an integral part of the JTRS program. A key waveform that will provide high speed, high bandwidth networking within the JTRS context is the WNW, which includes four signals-in-space supporting user data rates up to 13.25 Mb/s.

7.2 DoD Technology Initiatives for Achieving Spectrum Utilization Efficiencies

Future wideband networks will place new demands on efficient access to RF spectrum, even as availability of spectrum for existing systems comes under new pressures. A 2003 Defense Science Board (DSB) Task Force Report[34] recommended that efficiency of access and utilization of spectrum may be improved by:

- Bandwidth-efficient signal design (i.e., coding and modulation);
- Adaptive techniques for changing signal parameters and frequency assignments as required; and
- Using the spatial domain in conjunction with the frequency and time domains (space-time coding, adaptive, and multiple beams).

Within the Department of Defense, modulation and channel coding has been a productive area of research for enhancing efficiency of spectrum utilization. Source coding, particularly voice and video compression, reduces the bits-per-second required for a given application. DoD has benefited from commercial progress in these areas; the exception might be a case where unique requirements, such as electronic counter-countermeasures (ECCM) and low probability of intercept (LPI), need to be satisfied.

The Defense Advanced Research Project Agency's (DARPA) program for Next Generation (XG) has a goal of developing, evaluating, and integrating technology to automatically select spectrum and operating modes to both minimize disruption of existing users and to ensure the most efficient operation of systems.

Defense Research & Engineering's Project on Spectrum Efficient Technology Director is concerned with spectrum for test and training (e.g., telemetry). Areas being investigated include bandwidth-efficient modulation and coding, directional antennas, and channel modeling for multi-path.

Each of the aforementioned represents only a small sample of on-going R&D initiatives within DoD that are focused on improving spectrum utilization efficiency. Examples of other DoD technology initiatives have been extracted from the FY 2008 DoD Research & Development Descriptive Summaries (RDDS) and are presented throughout Table 7-1. The table references potential impacts of these technologies with regard to the following:

- Frequency Reuse
- Bandwidth Efficiency

[34] Report of the Defense Science Board Task Force on Wideband Radio Frequency Modulation, Office of the USD for Acquisition, Technology, and Logistics, July, 2003.

- Dynamic Management
- Interference Control
- Spectrum Sharing
- Spectrum Planning
- Increased Functionality
- Mission Enhancement

Moreover, a general description of near and long-term objectives of each R&D project is presented.

Table 7-1 Selected DoD Spectrum Dependent Technology Initiatives

ORG	Program Element		Project Title	Project Description	Spectrum Dependent Technology	Spectrum Impact							
	No.	Name				Frequency Reuse	Bandwidth Efficiency	Dynamic Management	Interference Control	Spectrum Sharing	Spectrum Planning	Increased Functionality	Mission Enhancement
ARMY	0602782A	Command, Control, Communications Technology H92 Communications Technology	Modeling and Simulation (M&S) for Network Designs	Current: Baseline network design capability to validate principles and rules that govern the behavior and performance of complex communication networks; assess and characterize the behavior and performance of the network (higher physical, data link and network layers) through analytical and M&S processes and technologies. Future: Evaluate the network design capability on a surrogate future force network; interface network design algorithms with simulation; characterize detailed end-to-end user performance metrics; assess effectiveness of new networking technologies. Extend the ad-hoc network design tool to include modeling and representation of the C4ISR nodal functionalities; develop a comprehensive representation of the internal operation and performance of network data dissemination mechanisms; improve the network traffic characterization model.	E2E Performance Ad Hoc Networks Network M&S	X		X		X		X	X
			COMPOSER	Communications Planner for Operational and Simulation Effects with Realism (COMPOSER): COMPOSER consists of the following software modules: Communication Effects Simulator (CES), Network Visualizer (NV), Spectrum Manager, and Architecture Framework. Current: Perform analysis of available radio models and waveforms and integrate the waveforms to test interoperability with COMPOSER tools; mature spectrum management capability, improve the speed and accuracy of the CES. Future: Complete enhancements to CES; will increase the integration of waveform models to CES; will complete spectrum management capability; will develop final version of COMPOSER for transition to the Coalition Joint Spectrum Management Planning Tool Joint Concept Technology Demonstrations.	Spectrum Planning Application	X		X	X	X	X	X	X
			Radio Enabling Technologies and Nextgen Applications (RETNA)	Current: Develop Handheld Manpack Small Form Fit (HMS) Joint Tactical Radio Systems (JTRS) Manpack Power Amplifier (PA) subsystem brassboard; validate the PA's component performance and associated system-level capability; identify root causes of waveform porting difficulties through failure and risk analyses to software defined radio (SDR). Future: Perform detailed investigation and experimentation into the development of HW/SW and porting of waveforms onto JTRS representative SDR platforms; will develop capability to reduce the complexity of porting software waveforms onto SDR hardware	Software Radio				X			X	
			Tactical Wireless Network Assurance (TWNA) / wireless information assurance (IA)	Current: Develop advanced IA techniques; expand wireless intrusion detection to detect attacks against mobile hosts and networks. Future: Investigate a suite of IA technologies to enable enhanced tactical battlefield information sharing across all security domains to meet emerging threats. Develop jam resistant and low signal detection communication technologies including space-time adaptive techniques, cross layer algorithms, cognitive disruptive tolerant networking, and signal processing techniques. Develop IA technologies enabling information exchange across security domains, ensuring robust survivability of tactical networks and critical information against info warfare attacks.	Space-Time Processing Disruption Tolerant Networks		X	X				X	X
			Antenna Technologies	Current: Conduct modeling and simulation to validate terrestrial directional antenna (TDA) parameters/link connectivity; develop innovative methods for integrating radio frequency (RF) electronics into X-band antenna assembly; develop methods of integrating Ku and Ka band transmit/receive into one OTM ground antenna system; develop methods of integrating power amplifiers into antenna assemblies; and investigate various low profile antenna technologies. Future complete development of TDA technologies for mobile ground platforms providing air interface for terrestrial directional networking and beam steering protocols; investigate hybrid scan and phased array antenna technologies for a low profile multi-beam OTM SATCOM antenna for use with military Ka band and commercial Ku band satellites; develop multi-beam low profile OTM SATCOM antenna in a single frequency band (Military Ka or Commercial Ku); develop tri-band low profile (Ka, Ku, Q Band) OTM SATCOM vehicle antenna.	Directive Antennas OTM SATCOM				X	X			X

Table 7-1 Selected DoD Spectrum Dependent Technology Initiatives (cont'd)

ORG	Program Element No.	Program Element Name	Project Title	Project Description	Spectrum Dependent Technology	Frequency Reuse	Bandwidth Efficiency	Dynamic Management	Interference Control	Spectrum Sharing	Spectrum Planning	Increased Functionality	Mission Enhancement
ARMY	0601104A	University and Industry Research Centers	H50 COMMS & NETWORKS COLLAB TECH ALLIANCE (CTA)	Survivable Wireless Mobile Networks: Current: Analytical and experimental studies validating dynamic and survivable resource control to enable mobile networks to predictably exploit distributed network infrastructures. Devise and validate adaptive distributed control of physical, medium-access, and network layers based on statistical inferencing to adapt communications parameters for improved performance. Future: Devise formal models, abstractions, metrics, and validation techniques for understanding the behavior of large scale military mobile ad hoc networks. Design techniques that combine social networking and network structure control functions in real time to dramatically increase the level of resource utilization in keeping with the stated intentions (outcomes) of a particular military objective. Design networking techniques for sensing the networking operating environment, identifying the best networking functional components, and dynamically composing protocols for superior performance.	Dynamic, Adaptive Spectrum Management and Network Control			X	X	X		X	
				Signal Processing for Communication-on-the-Move: Perform research in signal processing techniques to enable reliable low-power multimedia communications among highly mobile users under adverse wireless conditions. Current: Conduct analytical and experimental studies of signal processing aided medium access control algorithms that improves communications performance while on-the-move. Future: Design and validate multi-input multi-output multi-carrier waveforms that exploit non-contiguous spectrum during mobile operations. Design optimal channel-adaptive distributed multiple access techniques to provide high capacity, interference-robust, multiple access networks for communications-on-the-move.	MIMO Signal Processing		X		X	X		X	
				Secure Jam-Resistant Communication: Perform research in secure, jam-resistant, multi-user communications effective in noisy/cluttered and hostile wireless environments enabling low probability of detection/intercept. Current: Devise and study sensor array processing and interference techniques that enable adaptive antennas for improved interference rejection and spectrum reuse. Future: Low power adaptive medium access control algorithms that are energy-efficient and support duty-cycling to extend the life of sensor networks. Design signal separation techniques to mitigate packet collisions and improve signal detection for improved network performance.	Array Processing Access Control Packet Collision Mitigation		X	X	X	X			
	0603008A	Electronic Warfare Advanced Technology	Dismounted Communications in Urban Terrain	Future: Will mature communications capabilities for dismounted Soldier operating in highly complex terrain (e.g. urban environments) through the use of space-time adaptive processing, cross layer networking algorithms, and network security features such as employing random noise waveforms and other low probability of intercept, low probability of detection technologies to reduce communications systems vulnerability.	Adaptive Communications; Space-Time Processing		X	X			X		X
			Applied Communications and Information Networking (ACIN)	Future: Will mature and demonstrate commercial networking and communications technology in intelligent agents and mobile networking; will provide rapid adaptation of commercial communications equipment for military use through the development of new architectures combining commercial and military unique technologies; and will provide modeling and simulation for communications/network planning.	Protocols; Network Simulation				X	X	X		
			Proactive Integrated Link Selection for Network Robustness	Current: Mature design of planning mode components based on M&S results; mature system architecture to include design of deployed mode link selection technologies; begin M&S of deployed mode link selection algorithms. Future: Continue M&S and design of enhanced implementation of deployed mode link selection algorithms; will implement first level integration among link selection algorithms; will conduct performance characterization and scalability testing of mature link selection algorithms. Complete implementation of deployed mode link selection algorithms; will conduct final architecture, design maturation, and integration of planning and deployed mode link selection algorithms.	Access Control			X	X			X	

Table 7-1 Selected DoD Spectrum Dependent Technology Initiatives (cont'd)

ORG	Program Element No.	Program Element Name	Project Title	Project Description	Spectrum Dependent Technology	Spectrum Impact: Frequency Reuse	Bandwidth Efficiency	Dynamic Management	Interference Control	Spectrum Sharing	Spectrum Planning	Increased Functionality	Mission Enhancement
AIR FORCE	0602702F	Command, Control and Communications	4519 Communications Technology	Current: Develop communications/resource network management schemas and sensor exploitation technologies enabling the dynamic integration of communications and sensor management functions. Develop capabilities for self-organizing, self-healing, autonomous networking. Future: Initiate design and development of cognitive networking technology that senses operating environment, learns application requirements, and intelligently adapts network protocols. Complete demonstration of adaptively combined multi-dimensional (space, time, frequency, coding, polarization) transmission techniques that enable high bandwidth information transmission and exploitation capabilities. Complete demonstration of multi-mode, multi-function, sense-and-adapt air-mobile communications capability to dynamically alter communications methods under fast-changing environment. Initiate the development of scaleable video compression schemes which dynamically trade-off bandwidth and quality based upon the priority of the required information. Initiate the development of advanced, automated, network and bandwidth management technologies to move, manage, and process information in real-time.	**Adaptive Communications; Video/Data Compression; Protocols**		X	X	X	X	X	X	
AIR FORCE	0603789F	C3I Advanced Development	4216 Battlespace Information Exchange	Current: Demonstrate improved battle management command, control, and communications networked collaboration capabilities by making improvements in routing, mobile ad-hoc networks, and adaptive protocols Future: Initiate the development of advanced, automated, network and bandwidth management technologies to move, manage, and process information in real-time to provide dynamic Quality of Assurance/Quality of Service. Investigation to provide assured access (anti-jam) covert high capacity spectrum dominance for global networking.	**Dynamic Network and Bandwidth Management**	X		X		X			X
AIR FORCE	0603845F	Transformational SATCOM (TSAT)	4944 Advanced Wideband System	The Transformational Satellite Communications (TSAT) is key to global net-centric operations. As the spaceborne element of the Global Information Grid (GIG), it will extend the GIG to users without terrestrial connections providing improved connectivity and data transfer capability, vastly improving satellite communications for the warfighter. The TSAT's Internet Protocol (IP) routing will connect thousands of users through networks rather than limited point-to-point connections. TSAT will incorporate radio frequency (RF) and laser communications links to meet defense and intelligence community requirements for high data rate, protected communications. The space segment will make use of key technology advancements that have proven mature by independent testing of integrated subsystem brass boards to achieve a transformational leap in SATCOM capabilities. These technologies include but are not limited to: single and multi-access laser communications (to include wide field-of-view technology), Internet protocol based packet switching, bulk and packet encryption/decryption, battle command-on-the-move antennas, dynamic bandwidth and resource allocation techniques, and protected bandwidth efficie	**IP Switching; Packet Networks; Adaptive Antennas**	X	X		X				
AIR FORCE	0303601F	MILSATCOM Terminals	2487 MILSATCOM Terminals	Concept development work to identify commercial/military technology solutions to improve MILSATCOM terminal capabilities for the warfighters. Focus includes increasing throughput, facilitating sustainability, reducing footprint on user platform and supporting network. Future: Develop aamily of Advanced Beyond Line-of-Sight Terminals (FAB-T). Development of a High Data Rate (HDR) Radio Frequency (RF) Ground Terminal.	**Multi-beam, Multi-band, Phased Array Antennas**		X					X	X

Table 7-1 Selected DoD Spectrum Dependent Technology Initiatives (cont'd)

ORG	Program Element No.	Program Element Name	Project Title	Project Description	Spectrum Dependent Technology	Spectrum Impact: Frequency Reuse	Bandwidth Efficiency	Dynamic Management	Interference Control	Spectrum Sharing	Spectrum Planning	Increased Functionality	Mission Enhancement
NAVY	0605866N	Navy Space and Electronic Warfare (SEW) Support	0706 EMI Reduction and Radio Frequency Management	Automated capabilities will be developed that reflect research into new operational fleet battle group frequency management processes. They reflect current fleet needs for a communications planning and frequency management tool used to plan communication links and analyze, allocate, and assign communication and radar frequencies for fleet operations. Current: Developed interfaces for AESOP (Afloat Electromagnetic Spectrum Operations Program), and other automated tools to interface with evolving network protocols and to ensure currency for web based applications. Developed new algorithms for automated tools for new Navy C4ISR systems for both government and commercial communication systems being used by the Navy. Future: Develop new algorithms for automated tools for new Navy C4ISR systems for both government and commercial communication systems being used by the Navy. Implement a set of web-based capabilities utilizing latest technologies (XML) and other data standards to optimize information exchange/usability. Institutionalize frequency management process for operational fleet by developing procedures that can be utilized by all Navy Strike Groups.	Communications Planning Frequency Management Interference Control				X		X	X	X
NAVY	0205604N	Tactical Data Links	Dynamic Network Management (DNM)	Dynamic Network Management (DNM) will provide automatic reconfiguration of Link-16 networks that respond instantly to emergent warfighter requirements in the field. DNM consists of different capabilities including Network Control Technologies (NCT), new terminal protocols (Time Slot Reallocation (TSR) receipt compliance (TC) (TSR RC) and Stochastic Unified Multiple Access (SHUMA)). Current: Continued Dynamic Network Management (DNM) development allowing for data forwarding between Link-16, Internet Protocol (IP) networks and new Joint Tactical Radio System (JTRS) waveforms. Completed integration of NetworkControl Technologies (NCT) capabilities into JSS. Continue development of multi-netting capabilities and migration efforts to Wideband Networking Waveform (WNW) and JTRS waveforms. Commence development of Multi-netting Phase II capability. Continue platform integration and testing of TSR RC (AEGIS Baselines). Development of multi-netting capabilities and migration efforts to Wideband Networking Waveform (WNW) and JTRS waveforms. Future: Continue migration efforts to WNW and JTRS waveform. Achieve Stochastic Unified Multiple Access (SHUMA)/TSR RC IOC.	RF DevicesNetwork Management			X	X	X		X	
NAVY	0603235N	2919 Communications Security	Knowledge Superiority And Assurance	Ubiquitous Communications: Provides Dynamically Managed, Interoperable, High-Capacity Connectivity wireless network technology critical to the performance and robustness of naval communications by providing higher data rates, expanded coverage to disadvantaged platforms, and improved bandwidth management. Current: Complete development of Integrated Autonomous Network Management (IANM) by transitioning to ADNS Integrated Ship Network System (ISNS)/ADNS Future: Complete Ultra High Frequency (UHF)/L-Band phased array antennas for A/C carriers. Complete Ultra High Frequency (UHF)/L-Band phased array antennas for carriers. • Complete the High Altitude Airborne Relay and Router Package to deliver relay/router packages for a high and medium altitude platforms across UHF/VHF and Ku-Bands. Complete the Joint Coordinated Real-Time Engagement (JCRE) Advance Concepts Technology Demonstration (ACTD) to provide GIG-compliant core enterprise Services and COI Services which will ensure warfighting COIs access to information required from any source for rapid situation awareness assessment.	Dynamic Bandwidth Management		X	X				X	
NAVY	0602235N	Common Picture Applied Research	Ccmmunication And Networks	This initiative develops wireless communications network technologies critical to the performance and robustness of naval communications including bandwidth efficient communication techniques; advanced networking techniques for robust, highly dynamic environments; interoperable wireless networks for secure communications and protocols; and bandwidth and network management techniques that can effectively manage and allocate bandwidth across tactical and theater levels in support of ireless network centric operations Current: Complete research and development in MIMO antenna technology and OFDM signaling to improve data throughput (500 Mbps) in strong multipath environments. Finish prototyping of lab models. Development of Robust Airborne Networking Extensions (RANGE) for joint battlespace networking, networking UAVs, and hybrid mobile ad hoc networking (MANET)/satellite operation. Future: Complete development of Robust Airborne Networking Extension (RANGE) protocols and software kit for dynamic inter-UAV networking. Initiate development of frequency agile and cognitive communications. Initiate development of protocols and middleware for rapid self-configuration an	Channel Efficiency Dynamic Bandwidth Management OTM Multiple Access	X				X	X		

Table 7-1 Selected DoD Spectrum Dependent Technology Initiatives (cont'd)

ORG	Program Element No.	Program Element Name	Project Title	Project Description	Spectrum Dependent Technology	Spectrum Impact: Frequency Reuse	Bandwidth Efficiency	Dynamic Management	Interference Control	Spectrum Sharing	Spectrum Planning	Increased Functionality	Mission Enhancement
DARPA	0603760E	Command, Control and Communications Systems	Next Generation (XG)	The Next Generation (XG) program goals are to develop both the enabling technologies and system concepts to provide dramatic improvements in assured military communications in support of a full range of worldwide deployments through the dynamic redistribution of allocated spectrum along with novel waveforms. Current: Developed initial set of hardware prototypes and undertook initial field experimentation. Developed and evaluated candidate approaches for implementation complexity, on-board processor and memory capability/power, overhead, scalability and performance. Developed final set of hardware prototypes to evaluate and demonstrate system capabilities in an operational exercise. Demonstrated spectrum agility performance of prototypes in field experiments. Demonstrated spectrum effectiveness and operational characteristics. Future: Develop and demonstrate large-scale network organization and adaptation. Conduct medium and large-scale military scenario demonstrations.	Spectrum Sensing; Spectrum Adaption	X	X	X	X	X		X	X
DARPA	0603760E	Command, Control and Communications Systems	Disruption Tolerant Networking (DTN)	The Disruption Tolerant Networking (DTN) program is developing network protocols and interfaces to existing delivery mechanisms ("convergence layers") that provide high reliability information delivery using communications media that are not available at all times, such as low earth satellites, UAV over-flights, orbital mechanics, etc. Current: Demonstrated that information organized into bundles can be delivered across intermittent networks. Investigated policy cognitive operation by moving intelligence into networks to make the best choices on delivery. Commence research to show "fuzzy scheduling" can make network routing decisions in the presence of uncertainty about available or optimal paths. Future: Develop mechanisms to allow code-base-independent environmentally-aware selection of routing algorithms. Demonstrate distributed in-network cache and indexing services. Demonstrate information binding on demand from a network cache.	Network Protocols;	X				X		X	X
DARPA	0603760E	Command, Control and Communications Systems	Connectionless Networking (CN)	The Connectionless Networking (CN) program will develop technology to allow networks such as unattended ground sensors (UGS), to send and receive messages without initial link acquisition or previous sharing of routing information. This will, in turn, improve energy per bit of delivered information by as much as 100 to 1,000 times compared to conventional and near-term deployable communications systems such as contemplated by both commercial and military users. Current: Translated CN technology design and simulations into actual hardware and software. Designed and fabricated prototype CN network node devices, and performed laboratory demonstrations. Future: Develop and evaluate candidate approaches for implementation complexity, on-board processor and memory capability/power, overhead, scalability and performance. Design and fabricate prototype Connectionless Networking node devices with hardware and form factor suitable for military applications. Conduct 30 node field demonstrations using CN devices in a form factor suitable for transition.	Connectionless Networking; Adaptive Routing		X	X		X			X
Defense-Wide RDT&E	0603941D8Z	Test and Evaluation/Science and Technology (T&E/S&T)	Spectrum Efficient Technology	Current: Continued Spectrally Efficient High Data Rate Telemetry System in 3-30Ghz range effort which will combine physically compact digital technology and complex software modulation schemes capable of mitigating effects of communications channel multipath error at high Doppler rates, while achieving implementations that are both power and spectrally efficient. Continued RF MEMS effort to develop a low cost, low profile, multifunctional phased array antenna using switchable micro elements which will enable rapid antenna geometry reconfiguration. The Netcentric Systems Test (NST) focus area will address the T&E scenarios, technologies, and analysis tools required to ensure that operational networked systems delivered to the warfighter provide an assured capability to acquire, verify, protect, and assimilate information necessary for battlefield dominance within a complex netcentric environment. Future: Complete RF MEMS system integration, package development, ground testing, flight testing, test data analysis. Complete Joint Virtual Netcentric Warfare effort; demonstrate virtual mobile ad-hoc network (MANET) technology and real-time virtual communication network.	Phased Array Antennas; Modems; Adaptive Antennas; Data Compression; Modulation		X		X			X	

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8.0 DoD Biennial Strategic Spectrum Plans

DoD developed this Strategic Spectrum Plan in response to the Presidential Memorandum on Improving Spectrum Management for the 21st Century. The purpose of this report is to emphasize DoD's critical dependence on access to the electromagnetic spectrum in order to successfully employ operational military capabilities. The approach was to identify the current DoD uses of, and dependence on, spectrum as well as identify long-term spectrum needs and provide a forecast of spectrum trends. Fundamental to this report is the goal to emphasize DoD's research into spectrum technologies that will assist in mitigating spectrum requirements for future DoD systems.

This document marks the first installment on what will become a biennial process to update the DoD Strategic Spectrum Plan. The approach used for this report provides a national framework which will be enhanced and modified to support the long-term intent of the Presidential Memorandum. It is anticipated that this "living" plan will be recognized as a strategic document that will also be used to assist in guiding DoD investment in future spectrum-dependent systems and technologies.

Through the experiences acquired in developing the 2005 DoD Strategic Spectrum Plan the DoD has recognized the need for near- and far-term spectrum planning processes that provide a high degree of predictability. As such, the Department envisions a plan for the development of a current user needs analysis for spectrum dependent systems and a methodology for characterization and forecasting of long-range spectrum requirements.

The Department recognizes that the development of an effective biennial process will be a significant challenge. The size, complexity, and diversity of DoD's spectrum needs will not only require establishment of an extensive outreach structure, but it will also require the development of a standardized data repository with codified procedures for updates, additions, and enhancements. Additionally, DoD will work closely with NTIA and the Commerce Department to ensure that DoD's future process is optimized to meet the intent of the Presidential Memorandum.

One process, in particular, that is used within DoD is the JCIDS. It is a joint-concepts-centric capabilities identification process that allows joint forces to meet future military challenges. The JCIDS process assesses existing and proposed capabilities in light of contributions to future joint concepts. The JCIDS is supported by robust analytic processes and identifies capability gaps and potential solutions. This system is consistent with DoD Directive 5000.1 [35]charge for early and continuous collaboration throughout DoD. One key aspect of JCIDS is that it informs the acquisition process by identifying, assessing, and prioritizing joint military capability needs; these identified capability needs then serve as the basis for the development and production of acquisition programs. As spectrum is redefined for the future, the use of this process will be integral to its success.

[35] Department of Defense Directive 5000.1, USD (AT&L), May 12, 2003.

9.0 Additional Comments and Recommendations

9.1 Comments

The following conclusions may be drawn from the enclosed DoD Strategic Spectrum Plan regarding DoD spectrum requirements for the next 10-20 years:

- Spectrum requirements growth will be significant through 2015 and beyond, irrespective of planned and programmed modernization efforts.
- DoD's most significant spectrum requirements growth will occur in the spectrum bands below 3 GHz due to the ability of these bands to support many of the emerging -netcentric capabilities and the implementation of JTRS-based communications architectures such as FCS. This spectrum region is also where commercial demands are increasing most rapidly.
- Significant growth in DoD requirements is also projected in bands above 3 GHz. While these bands are not as densely occupied as the lower bands today, they are critical to future DoD systems.
- Forecasted spectrum requirements growth may not be fully supportable without advances in spectrum utilization technologies along with changes in spectrum management concepts and approaches.
- Any loss of spectrum access to DoD, either nationally or internationally, through reallocation or other means will exacerbate DoD's challenge to meet future spectrum requirements.

9.2 Recommendations

A credible and living strategic spectrum plan supported by focused action will be essential to ensure that all federal users of the spectrum gain sufficient spectrum access to support current and future operations and that competition for spectrum does not constrain the ability of DoD to perform all missions worldwide. DoD recommends that:

- The Department of Commerce (DoC), in collaboration with other federal agencies, develop a codified spectrum requirements process that provides a consistent federal approach for identifying current and future spectrum requirements as well as develop the following:
- A baseline Federal Spectrum Management Strategy that embraces a long-term vision;
- A comprehensive, Federal Spectrum Architecture representative of the vision;
- A Federal Spectrum Management Transformation Roadmap; and
- A Federal Spectrum Summit and Workshop, hosted by the NTIA, to discuss federal demand for current and future spectrum access and to develop an overall federal plan for utilization of the spectrum.

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