Department of Defense
Investigation of the Feasibility of Accommodating the International Mobile Telecommunications (IMT) 2000 Within the 1755-1850 MHz Band

9 February 2001

EXECUTIVE SUMMARY

In October 2000, President Clinton initiated an interagency process to consider the feasibility of accommodating International Mobile Telecommunications for the Year 2000 (IMT-2000) within the 1755-1850 and 2500-2690 MHz radio frequency bands. The following report documents the Defense Department's regulatory, technical, operational, and cost assessment with respect to the feasibility of accommodating IMT-2000 systems in the 1755-1850 MHz band.

The conclusions of this report are based on the fundamental principle that the Department of Defense (DoD) cannot accept any degradation to mission capability resulting from a spectrum reallocation action. Loss of access to spectrum, above and beyond that already relinquished as a result of the Omnibus Budget Reconciliation Act of 1993 and the Balanced Budget Act of 1997, would jeopardize the DoD's ability to execute its mission. Congress, recognizing this principle in the National Defense Authorization Act (NDAA) for Fiscal Year 2000, has directed that the Defense Department shall not surrender use of a band of frequencies in which it is a primary user, as is the case with regard to the 1755-1850 band, unless an alternative band or bands are provided of comparable technical characteristics that will ensure no loss of mission capability (as certified by the Secretary of Defense, Chairman of the Joint Chiefs of Staff, and the Secretary of Commerce). Hence, any reallocation action would have to meet the following specific conditions:

1. If a decision is made to vacate all or a part of the 1755-1850 MHz band, the DoD must retain protected access until the last DoD system has migrated. Current regulatory provisions that protect existing DoD operations in the band must continue throughout any migration or transition period.
2. DoD must be provided regulatory protection in any new band associated with a reallocation action equivalent to the protection currently provided in the 1755-1850 MHz band.
3. DoD systems moving to a new band must receive timely domestic spectrum certification and have reasonable prospect of achieving international coordination consistent with mission requirements.
4. During any transition period in which DoD is moving out of the band or a portion thereof, new users would be allowed to operate in the band only to the extent that their operations do not interfere with DoD operations.
5. Timely cost reimbursement must be provided to the DoD per NDAA 1999.

The wide variety of systems the DoD operates in the 1755-1850 MHz band are unique to this band and crucial to the defense of the United States (US) and its allies. The 1755-1850 MHz band is used for critical national defense systems such as telemetry, tracking, and commanding of satellite systems (i.e., Global Positioning System (GPS), Milstar, and Defense Support Program (DSP), among others); precision guided munitions; tactical radio relay communication systems; air combat training systems; targeting; intelligence; and the real-time delivery of voice, video, and data information to warfighters and their commanders. The US and its national defense forces would be at a substantial strategic and tactical disadvantage in combat and the outcome of battles and peacekeeping operations could be jeopardized if the DoD were to lose its use of the band without provision of comparable spectrum and satisfaction of other conditions as presented in Section 2, *Essential Conditions*.

This report examines the feasibility of accommodating IMT-2000 systems by sharing the 1755-1850 MHz band with the DoD. Full band sharing was examined. Predicted interference to both IMT-2000 and DoD systems would preclude compatible operation at a large number of metropolitan areas and over large geographic areas of the country. Unacceptable operational restrictions would be required to mitigate the interference with IMT-2000 systems. *Therefore, full band sharing is not possible.*

This report also examines whether the DoD can fully vacate the 1755-1850 MHz band to accommodate IMT-2000. The most optimistic estimates, based on funding being available in Fiscal Year 2002 (FY02) to accomplish programmatic actions, indicate the *DoD is unable to totally vacate this band until well beyond the timelines established for this study (i.e., by 2003, 2006, or 2010). Estimates indicate that, regardless of financial investment, vacating the band could not be accomplished for most non-space systems until 2010 and beyond; and legacy space systems would require continued protected access to this spectrum until 2017 and beyond.* The preliminary estimated cost to transition DoD systems out of the band in accordance with these acceptable DoD timelines, is in excess of $4.3B in Then Year dollars (TY$). Migration prior to these dates would require premature system termination, which would have extremely serious implications to the DoD's ability to effectively execute its mission. Total relocation from the band is impossible unless comparable spectrum that is operationally suitable with equivalent regulatory protection is made available and the costs of relocation are fully reimbursed. This report, however, indicates operationally suitable comparable spectrum may not be readily available.

Band segmentation options consistent with the options presented in the US Study Plan are also assessed. The segmentation options are:

- Band segmentation/Partial Band Sharing
  - 1755-1805 MHz retained for operation of government systems and 1805-1850 MHz potentially reallocated to non-government use
  - 1790-1850 MHz retained for operation of government systems, and 1755-1790 MHz potentially reallocated to non-government use as part of a phased sharing approach (1710-1755 MHz available immediately, 1755-1780 MHz available at some mid-term future date, and 1780-1790 MHz would be made available in the long term).
- Band segmentation/Partial Band sharing (as above) with the addition of access to Alternate (comparable) Bands

Due to the potential for degradation to operational capability, losing access to any portion of the 1755-1850 MHz band without access to additional comparable spectrum and adequate time to withdraw from the specified band is unacceptable to the DoD. If the conditions of provision of comparable spectrum, full cost reimbursement, on time program execution, and operationally protected use of the spectrum through the course of any necessary transition are met, some band segmentation may be feasible. The feasibility of any segmentation requires the full cooperation of, among other things, the Federal Communications Commission, the National Telecommunications and Information Administration, the IMT-2000 Industry, and other users of the radio spectrum. This cooperation entails acceptance of DoD transition timelines and DoD's continued unrestricted operation in the existing band during the course of any transition. *The timelines for accommodation of IMT-2000 in any segment of the 1755-1850 MHz band by the DoD are comparable to those of full band sharing.* Even if the above conditions are met, transition by the DoD for this option could not be completed until 2010 and beyond for most non-space systems and until 2017 and beyond for the space systems. The preliminary estimated cost to relocate DoD systems in accordance with these acceptable DoD timelines, for the band segmentation options range from at least $2.8B (TY$) to in excess of $4.3B (TY$). As in the case of vacating the total band, migration prior to these dates would require premature system termination, which would have extremely serious implications to the DoD's ability to effectively execute its mission. These dates are also predicated on funding availability in FY02.

The following bands were assessed for their ability to accommodate additional DoD systems migrated from the 1755-1850 band due to IMT-2000 accommodation: 2025-2110 MHz; 2200-2290 MHz; 4.4-5.0 GHz; and 7-8 GHz. Preliminary review indicates these bands could not accommodate the introduction of the additional non-space systems without operational degradation to and from critical systems such as the Cooperative Engagement Capability, the Defense Satellite Communication System, DoD satellite downlinks, and numerous fixed and mobile operations. The 2025-2110 MHz band may be feasible for the introduction of the DoD satellite operations functions but there are specific regulatory issues that must be addressed. Although other bands were not evaluated in this report, the availability of sufficient comparable spectrum is suspect in light of the ever-growing demand and competition for spectrum access.

In assessing the feasibility of sharing or segmentation of the designated band, or migration out of the band, this report addressed only existing and planned DoD systems. Given the growing demand for spectrum to support information-intensive operations, it is highly likely that new DoD requirements for this band and other DoD bands will arise. Thus the full impact to DoD of surrendering all or a portion of the band is likely to be greater than the assessment provided in this report.

The findings in this report are the result of a very compressed schedule, initiated by the 13 October 2000 Presidential Memorandum (PM) and the related 20 October Commerce Department Plan to Select Spectrum for third-generation (3G) Wireless Systems in the Unites States, that did not provide time for thorough analysis and review of the complex subject. Additional analysis may be required in some areas. The results of this expedited study are especially sensitive to the assumptions used in the assessment. Some of the more critical assumptions include: the relocation band selected for systems that must move; no satellites will require replacement prior to programmed replenishment; and IMT-2000 parameters. If these, or any other of the assumptions used in this assessment are altered, the results presented will significantly differ and require reassessment. Furthermore, the timelines assumed programming, budgeting, and contracting processes are successfully executed without schedule perturbations. Finally, the costs estimated herein do not take into consideration the potential secondary and tertiary costs of moving incumbent DoD users out of the band, with attendant operational changes in tactics, training, doctrine, personnel, and long-lead procurement.

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GLOSSARY

3G	Third-Generation
A/A	Air-to-Air
A/G	Air-to-Ground
AAPG	Aircraft Inter-Antenna Propagation with Graphics
AAU	Alaska Upgrade
AAW	Anti-Air Warfare
ACC	Air Combat Command
ACE	Army Corps of Engineers
ACMI	Air Combat Maneuvering Instrumentation
ACTS	Air Combat Training System
ACUS	Army Common User System
ADT	Applied Data Technology
AEHF	Advanced Extremely High Frequency
AFB	Air Force Base
AFFMA	Air Force Frequency Management Agency
AFS	Air Force Station
AFSATCOM	Air Force Satellite Communications System
AFSCN	Air Force Satellite Control Network
AFSPC	Air Force Space Command
AFWTF	Atlantic Fleet Warfare Training Facility
AGM-130	Air-to-Ground Missile 130
AIS	Airborne (or Aircraft) Instrumentation Subsystem
AISI	Airborne (or Aircraft) Instrumentation Subsystem Internal
AISI(K)	Airborne (or Aircraft) Instrumentation Subsystem Internal Encrypted
AM	Amplitude Modulated
AMRAAM	Advanced Medium Range Air-to-Air Missile
ANGB	Air National Guard Base
ARSR	Air Route Surveillance Radar
ARTS	Automated Remote Tracking Stations
ATC	Aberdeen Test Center
ATM	Aeronautical Telemetry
AW/NTC-IS	Air Warrior/National Training Center Integration System
AWACS	Airborne Warning and Control System
BAS	Broadcast Auxiliary Service
BBA-97	Balanced Budget Act of 1997
BER	Bit Error Rate
BG	Battlegroup
BPSK	Binary Phase Shift Keying
BRH	Beyond Radio Horizon

C/NOFS	Communications/Navigation Outage Forecast System
C2	Command and Control
C3	Command, Control, and Communications
CAIG	Cost Analysis Improvement Group
CATF	Commander Amphibious Task Force
CBRNE	Chemical, Biological, Radiological, Nuclear and High Yield Explosives
CDMA	Code Division Multiple Access
CEC	Cooperative Engagement Capability
CEP	Cooperative Engagement Processor
CFR	Code of Federal Regulations
CIDDS	Combat Identification for the Dismounted Soldier
CJTF	Commander Joint Task Force
CLF	Commander Landing Force
Combat ID	Combat Identification
COMSEC	Communication Security
CONUS	Continental United States
COTS	Commercial-off-the-Shelf
CSEL	Combat Survivor/Evader Locator
CTS	Colorado Tracking Station
CU	Cooperating Unit
CWCS	Countermeasures Warning and Control System

DAMA	Demand Assigned Multiple Access
dB	Decibel
dBHz	Decibel Hertz
dBi	Decibel Above Isotropic
dBm	Decibel Above a Milliwat
dBW	Decibel Above a Watt
dBW	Decibel Above a Watt per Hertz
DDS	Data Distribution System
deg	Degree
DISN	Defense Information Services Network
DLT	Data Link Terminal
DME	Distance Measuring Equipment
DMSP	Defense Meteorological Satellite Program
DoC	Department of Commerce
DoD	Department of Defense
DoE	Department of Energy
DQPSK	Differential Quadrature Phase Shift Keying
DRRTS	Dynamically Reconfigured Real Time Software
DS	Direct Sequence
DSCS	Defense Satellite Communications System
DSN	Deep Space Network
DSP	Defense Support Program
DTED	Digitized Terrain Elevation Data

DWTS	Digital Wideband Transmission System
E&MD	Engineering and Manufacturing Development
EAC	Echelons Above Corps
ECAC	Electromagnetic Compatibility Analysis Center
ECB	Echelons Corps and Below
EDGE	Enhanced Data Rates for GSM Evolution
EES	Earth Exploration Satellite
EHF	Extremely High Frequency
EIRP	Effective Isotropic Radiated Power
EMC	Electromagnetic Compatibility
EME	Electromagnetic Environment
EMI	Electromagnetic Interference
ENG	Electronic News Gathering
EVCF	Eastern Vehicle Checkout Facility
EW	Electronic Warfare
FAA	Federal Aviation Administration
FARP	Fighter Advanced Readiness Program
FCC	Federal Communications Commission
FDR	Frequency-Dependent Rejection
FDRCAL	Frequency-Dependent Rejection Calculation
FEC	Forward Error Correction
FLTSAT	Fleet Satellite Communications
FM	Frequency Modulated
FPA	Federal Power Agency
FRRS	Frequency Resource Record System
FRS	Fleet Replacement Squadron
FSK	Frequency Shift Keying
G/A	Ground-to-Air
G/G	Ground-to-Ground
G/T	Gain-to-Temperature Ratio
GA	Ground Antenna
GBS	Global Broadcast Service
GBU	Guided Bomb Unit
GCCS	Global Command and Control System
GCCS-M	Global Command and Control System – Maritime
GCS	Ground Control System
GEOSAT	Geostationary Satellite
GFO	GEOSAT Follow-On
GHz	Gigahertz
GMF	Government Master File
GMSK	Gaussian Minimum Shift Keying
GOES	Geostationary Operational Environmental Satellite

GPRS	General Packet Radio Service
GPS	Global Positioning System
GRDCS	Gulf Range Drone Control System
GSM	Global System for Mobile Communications (or Groupe Speciale Mobile)
GTS	Guam Tracking Station
HCLOS	High Capacity Line of Sight
HNA	Host Nation Agreement
HP	High Power
HPA	High Power Amplifier
HTS	Hawaii Tracking Station
Hz	Hertz
I/N	Interference-to-Noise Ratio
ID	Identification
IDN	Instrumentation Datalink Network
IEEE	Institute of Electrical and Electronics Engineers
IF	Intermediate Frequency
IITRI	Illinois Institute of Technology (IIT) Research Institute
IMT-2000	International Mobile Telecommunications for the Year 2000
INMARSAT	International Maritime Satellite
IR	Infrared
ISEM	Inverse Smooth Earth Model
ISM	Industrial, Scientific, and Medical
ISR	Intelligence, Surveillance, and Reconnaissance
ISYSCON	Integrated System Control
I_t	Interference Threshold
ITCS	Integrated Target Control System
ITFS	Instructional Television Fixed Service
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
ITU-T	ITU Telecommunication Standardization
J/F 12	DD Form 1494, Application for Equipment Frequency Allocation
JSC	Joint Spectrum Center
JTCTS	Joint Tactical Combat Training System
JTF-CS	Joint Task Force – Civil Support
JTIDS	Joint Tactical Information Distribution System
JTRS	Joint Tactical Radio System
kb/s	Kilobits per Second
kbps	Kilobits per Second
ksps	Kilosymbols per Second
kHz	Kilohertz
km	Kilometer

LAMPS	Light Airborne Multipurpose System
LAN	Local Area Network
LEO	Low-Earth-Orbit
LEO&A	Launch, Early Orbit Operations and Anomaly Resolution
LOS	Line of Sight
LP	Low Power
LPD	Low Probability of Detection
LPE	Low Probability of Exploitation
LPI	Low Probability of Intercept
LRIP	Low-Rate Initial Production
m	Meter
MB	Mainbeam
Mb/s	Megabit per second
Mbps	Megabit per second
MCAS	Marine Corps Air Station
MCC	Mission Control Complex
MCEB	Military Communications-Electronics Board
MCS	Master Control Station
MDS	Multipoint Distribution Service
MEF	Marine Expeditionary Force
MEO	Medium Earth Orbit
MHz	Megahertz
MMDS	Multichannel Multipoint Distribution Service
MOD	Modified
MS	Master Station or Monitor Station
MSE	Mobile Subscriber Equipment
MSK	Minimum Shift Keying
MSX	Midcourse Space Experiment
MTACS	Multi-Object Tracking and Control System
MTC	Major Training Center
MUOS	Mobile User Objective System
MW	Microwave
MW	Milliwatt
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NAVAIR	Naval Air Systems Command
NAVSOC	Naval Satellite Operations Center
NAWCAD	Naval Air Warfare Center Aircraft Division
NB	Narrowband
NCA	National Command Authorities
NDAA-99	National Defense Authorization Act of 1999

NDAA-00	National Defense Authorization Act of 2000
NDI	Non-Developmental Item
NDS	Nuclear Detonation Detection System
NF	Noise Figure
NHS	New Hampshire Station
NIMA	National Imagery and Mapping Agency
nmi	Nautical Miles
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-Orbiting Operating Satellite System
NPRM	Notice of Proposed Rulemaking
NRZ	Non-Return-to-Zero
NRZ-L	Non-Retrun-to-Zero-Level
NSAWC	Naval Strike and Air Warfare Center
NTIA	National Telecommunications and Information Administration
NUDET	Nuclear Detonation
OAS	Onizuka Air Station
OBRA-93	Omnibus Budget Reconciliation Act of 1993
OC	Operational Center
OCONUS	Outside the Continental United States
OOBE	Out-of-Band Emissions
OQPSK	Offset Quadrature Phase Shift Keying
OSD	Office of the Secretary of Defense
PAM	Pulse Amplitude Modulation
PCM	Pulse Code Modulation
PCS	Personal Communications Services
PGM	Precision Guided Munitions
PM	Phase Modulation
PSK	Phase Shift Keying
QPSK	Quadrature Phase Shift Keying
R&D	Research and Development
RF	Radio Frequency
RFI	Radio Frequency Interference
RHCP	Right Hand Circular Polarization
RPV	Remotely Piloted Vehicle
RS	Reed-Solomon
RTS	Remote Tracking Station
RTT	Radiotransmission Technology
Rx	Receiver
S/(I+N)	Signal-to-Interference plus Noise Ratio
S/N	Signal-to-Noise Ratio

SA	Situation Awareness
SAR	Search and Rescue
SATCOM	Satellite Communications
SATOPS	Satellite Operations
SBIRS	Space-Based Infrared System
SCADA	Supervisory Control and Data Acquisition
SCT	Single Channel Transponder
SEM	Spherical Earth Model
SFARP	Strike-Fighter Advanced Readiness Program
SGLS	Space Ground Link Subsystem
SL	Sidelobe
SLAM-ER	Standoff Land Attack Missile – Expanded Response
SMC/TE	Space and Missile Center/Test and Evaluation
SOH	State of Health
SRI	Stanford Research Institute
SS	Spread Spectrum
STDN	Space Tracking and Data Network
STGS	S-band Transportable Ground Station
STS	Space Transportation System
SV	Space Vehicle
T&E	Test and Evaluation
TACAN	Tactical Air Navigation
TACTS	Tactical Air Combat Training System
TAS	Target Acquisition System
TCM	Trellis Coded Modulation
TCTS	Tactical Combat Training System
TCU	Tracking and Communications Unit
TDMA	Time Division Multiple Access
TIREM	Terrain Integration Rough Earth Model
TIS	Tracking Instrumentation Subsystem
TOC	Tactical Operations Center
TOSS	Television Ordnance Scoring System (TCM-601)
TRI-TAC	Tri-Services Tactical Communications
TRR	Tactical Radio Relay
TST	Transportable S-band Terminal
TSTR	Transportable Space Test and Evaluation Resource
TSV	Thru Site Video
TT&C	Telemetry, Tracking, and Commanding
Tx	Transmitter
TY$	Then Year Dollars
TY$B	Then Year Dollars in Billions
TY$M	The Year Dollars in Millions
UAV	Unmanned Aerial Vehicle

UFO	UHF Follow-On
UHF	Ultra High Frequency
US	United States
US&P	United States and Possessions
USB	Unified S-band
USJFCOM	United States Joint Forces Command
USMC	United States Marine Corps
USNDS	United States Nuclear Detonation Detection System
VTS	Vandenburg Tracking Station
W	Watt
WARC-92	World Radiocommunication Conference of 1992
WB	Wideband
WCDMA	Wideband Code Division Multiple Access
WGS	Wideband Gapfiller Satellite
WLAN	Wireless Local Area Network
WMD	Weapons of Mass Destruction
WRC 2000	World Radiocommunication Conference for Year 2000
WSMR	White Sands Missile Range

1.0 INTRODUCTION

1.1 BACKGROUND

In recent years, mobile wireless telecommunications systems have experienced a growth that is matched by few other technologies. Large-scale mobile wireless common carrier services began with cellular systems, sometimes referred to as first-generation systems. Subsequently, second-generation systems, Personal Communications Services (PCS), provided many enhancements to cellular-type service. Advances in technologies have led to the development of advanced wireless technologies, sometimes referred to as third-generation (3G) services or International Mobile Telecommunications for the Year 2000 (IMT-2000). Recently, the World Radiocommunication Conference 2000 (WRC 2000) identified several frequency bands that administrations are urged to consider when developing additional advanced mobile communications services.

The frequency bands identified by WRC 2000 to support advanced mobile communications services include, but are not limited to, 698-960 MHz, 1710-1885 MHz, and 2500-2690 MHz. In the United States (US), a Presidential memorandum mandated that the IMT-2000 studies focus on the two higher frequency bands. However, 1755-1850 MHz is allocated exclusively to Government Fixed and Mobile Services. Many Executive Branch agencies make substantial use of the 1755-1850 MHz frequency range for fixed and mobile operations. Without question the predominant single user of the 1755-1850 MHz band is the Department of Defense (DoD).

The DoD employs the 1755-1850 MHz band to support a broad range of critical mobile/transportable systems, all DoD space systems, a large number of installation infrastructure services, as well as advanced wireless systems in development that are aimed at providing capabilities to support 21st century US warfighting. Major functions supported in the band include Satellite Operations (SATOPS), Tactical Radio Relay (TRR), Air Combat Training System (ACTS), Tactical Control Links/Precision Guided Munitions (PGMs), and other systems. Specific systems include, but are not limited to, the Space Ground Link Subsystem (SGLS) which provides launch, deployment, and telemetry, tracking and commanding (TT&C) of vital military satellite systems, Mobile Subscriber Equipment (MSE) and Digital Wideband Transmission System (DWTS) which support tactical communications, and the Air Combat Training Systems (ACTS) and the Joint Tactical Combat Training System (JTCTS) used to support air combat training.

In an October 2000 Memorandum, the President directed federal agencies to participate and cooperate in the activities of a government-industry effort (led by the Secretary of Commerce in cooperation with the

Federal Communications Commision (FCC)) to identify spectrum for 3G. As part of this effort, federal agencies have been asked to examine their use of the 1755-1850 MHz frequency band and to assess the prospects for sharing spectrum with IMT-2000 systems. The DoD is complying with this request by identifying all DoD systems that operate in the band of interest, assessing the technical feasibility of sharing, examining the operational impact of sharing and/or relocation, and quantifying cost issues associated with sharing and/or relocation. This report presents an assessment of the issues associated with sharing and/or relocation by examining technical, operational, and cost issues associated with selected DoD systems and several notional candidate IMT-2000 systems. While there is commercial interest in worldwide deployment of IMT-2000 services, the focus of this effort was primarily sharing issues in the US and possessions (US&P).

1.2 OBJECTIVE

The objective of this effort was to perform an assessment of technical, operational, and cost issues associated with incumbent DoD systems in the US&P and the possible introduction of IMT-2000 mobile wireless systems into the 1755-1850 MHz frequency band.

1.3 APPROACH

The approach used in this effort employed multiple steps to develop a final integrated product with technical, operational, and cost assessments. The initial step was to identify DoD radio frequency (RF) systems that operate in any or all of the 1755-1850 MHz band. The next step was to conduct technical analyses to determine the potential for undesired interactions between DoD systems and IMT-2000 systems. The results of these analyses were then assessed for several band sharing/segmentation/vacating scenario options, as described below. Based on the technical interference analysis results and considering each scenario option, DoD elements responsible for using the various systems defined the operational impacts of accommodating IMT-2000 systems into the 1755-1850 MHz band. The final step involved the determination of cost impacts to DoD systems for each of the specific accommodation scenarios.

The first step of identifying all DoD RF systems operating in the subject band was accomplished as follows. An extensive survey was conducted of DoD spectrum management databases to identify all DoD systems with the capability to operate in any portion of the band. Once systems were identified, the "owning" military department was tasked to verify with operational and acquisition/support commands the life-cycle status of the system (operational, obsolete, being replaced, etc.). The final list of valid systems (operational or funded for production) became the basis of all subsequent study efforts.

In addition to building the list of valid systems, the DoD also collected technical and operational data on each of the systems. This information included system radio frequency (RF) waveforms, transmitter parameters, system losses, antenna patterns, antenna pointing angles, siting data, receiver selectivities, and receiver performance criteria. Operational data included such information as geographical locations, link lengths, and platform operating altitudes. Planned system upgrades were also incorporated if available technical data was sufficient to support proper electromagnetic compatibility (EMC) assessments.

The next step was to conduct the engineering analyses of the interactions of DoD systems and IMT-2000 systems. Technical parameters for the RF systems were used, and likely operational scenarios were defined. Then desired and interfering signal levels were predicted at the receivers of interest, and predictions were made with respect to the likelihood of undesired interactions. If undesired interactions were predicted, then distance and/or frequency separations required to prevent interference were calculated. In addition to frequency/distance separations, other potential means to mitigate interference were also identified. The unique aspects of specific system interactions are discussed in the appendices.

In order to conduct the technical interference analyses described above, two interim steps were required. The first interim step was to determine the specific technical parameters for IMT-2000 systems that would be used in the EMC assessments. Since there is no IMT-2000 hardware in production in the US at this time, it was necessary to develop the parameters for the analysis using technical literature, selected aspects of existing wireless mobile systems, and calculations based on communications theory. The basis for the final parameters used in the assessments was a Federal Communications Commission (FCC) document presenting notional characteristics for various technologies that may be used to implement IMT-2000 services.[1] Minor modifications were made to the FCC parameters following discussions between the FCC and DoD technical staffs. The IMT-2000 technical parameters used are presented in Appendix A.

The second interim step necessary to enable the accomplishment of the technical interference analyses was the grouping or clustering of the large number of DoD systems into subsets referred to as "major systems categories." This grouping of systems was necessary for several reasons. There were over two hundred systems identified as potentially being impacted by the accommodation of IMT-2000 systems in the subject band. The study schedule did not allow sufficient time to conduct individual EMC assessments for each of these systems. In addition to the time constraint factor, a number of the systems

[1] *Spectrum Study of the 2500-2690 MHz Band: The Potential for Accommodating Third Generation Mobile Systems*, Interim Report, FCC, 15 November 2000.

were similar in both mission function and technical capabilities and that a technical interference analysis conducted for one system would be useful in drawing conclusions for multiple similar systems. Lastly, the grouping of systems into logical categories would facilitate the development of a high-level set of study conclusions that would be much more useable for the national decision process. The major categories of systems used for the study follow:

- Space/SGLS systems
- Tactical radio relay systems
- Air Combat Training Systems
- Precision Guided Munitions systems
- Miscellaneous "Other" systems

Once the technical analysis results were available for each of the major system categories, they were used to assess the "technical" feasibility of the DoD systems operating in the 1755-1850 MHz band to accommodate new IMT-2000 systems. The 3G-study plan developed in response to the Presidential Memorandum of October 13, 2000 provides that the FCC and the National Telecommunications and Information Administration (NTIA) will address band segmentation and sharing options. The following options were assessed in this DoD impact study.

- Option 1: Full band sharing (IMT-2000 systems operating anywhere in the 1755-1850 MHz band)
- Option 2: Band segmentation/Partial Band sharing
  - 1755-1805 MHz retained for operation of government systems and 1805-1850 MHz potentially reallocated to non-government use (Option 2A)
  - 1790-1850 MHz retained for operation of government systems, and 1755-1790 MHz potentially reallocated to non-government use as part of a phased sharing approach (1710-1755 MHz available immediately, 1755-1780 MHz available at some mid-term future date, and 1780-1790 MHz would be made available in the long-term). (Option 2B)
- Option 3: Band segmentation and other band combination (Options 3A/3B)
- Option 4: Vacating the Band

The next major step was to identify the operational impacts of the various sharing segmentation options. The results of the technical feasibility sharing analyses were provided to the military commands and operational communities that employ the various systems in accomplishing national security missions. These organizations were tasked to develop the operational impacts to their missions based on the technical results of each of the sharing scenarios, as well as for the potential scenario of total band loss. The operational impacts for each scenario were also required to be assessed for the three time frames of 2003, 2006, and 2010. The operational impact is defined to be the change from current or planned operational capability (to support combat operations or the ability to be fully prepared, through training and testing, to support combat operations) to the reduced level of operational capability expected once IMT-2000 systems are deployed. The reduced level of operational capability would include, but is not limited to, the applicable effects of sharing, mitigation measures, and/or migration.

Following the technical and operational assessments by major system category, the next step was to perform cost impact studies. These studies were required to address the costs of interference mitigation measures as well as band migration measures for the major systems impacted by each of the sharing scenarios. The cost impacts were developed by acquisition program offices with the participation of operational command representatives and military Service costing organization representatives. To ensure consistency in costing approaches, costing guidelines were provided for all cost efforts by the Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG).

The results of each of the three primary assessment efforts, technical, operational, and cost; were then integrated into a synthesized DoD assessment for each of the major system categories and in accordance with the tasked framework of sharing/segmentation/vacating options and the three time periods (2003, 2006, and 2010).

2.0 ESSENTIAL CONDITIONS

The 1755-1850 MHz frequency range supports several functions critical to the DoD mission and the security of the US. The compromise of any of these functions is unacceptable. Congress has recognized the importance of adequate access to radio spectrum to the DoD mission and the security of the US and has enacted legislation to provide particular protections. In particular, the National Defense Authorization Act of 2000 (NDAA-00) directs that DoD shall not surrender use of a band of frequencies of which it is a primary user unless (a) NTIA, in consultation with the FCC, has identified and made available to the DoD for its primary use, if necessary, an alternative band or bands of frequencies with comparable technical characteristics as a replacement, and (b) the Secretary of Commerce, the Secretary of Defense, and the Chairman of the Joint Chiefs of Staff have jointly certified to the Committee on Armed Services and the Committee on Commerce, Science and Transportation of the Senate; and the Committee on Armed Services and the Committee on Commerce of the House of Representatives, that the replacement band or bands of frequencies identified in (a) above provides comparable technical characteristics to restore essential military capability that will be lost when the band of frequencies is surrendered. The following general conditions cannot be compromised during the consideration of this band.

- If a decision is made to vacate all or a part of the 1755-1850 MHz band, the DoD must retain protected access until the last DoD system has migrated. Current regulatory provisions that protect existing DoD operations in the band must continue throughout any migration or transition period.
- DoD must be provided regulatory protection in any new band associated with a reallocation action equivalent to the protection currently provided in the 1755-1850 MHz band.
- DoD systems moving to a new band must receive timely domestic spectrum certification and have reasonable prospect of achieving international coordination consistent with mission requirements.
- During any transition period in which DoD is moving out of the band or a portion thereof, new users would be allowed to operate in the band only to the extent that their operations do not interfere with DoD operations.
- Timely cost reimbursement must be provided to the DoD per NDAA 1999.

- Schedules associated with Program execution cannot be altered.
- Time is a critical factor and at least a decade will be required to implement any changes.

2.1 CONDITIONS FOR SATELLITE OPERATIONS

This report is based on the following conditions with respect to transition or migration of space operations from the 1755-1850 MHz to 2025-2110 MHz band.

- Mission capability provided to end users by US national security space systems will not be degraded. The government will maintain assured access to the 1755-1850 MHz band to satisfy mission objectives until the last 1755-1850 MHz satellite is no longer functioning. This may continue until 2030.
- Domestic regulatory provisions will be implemented so that the DoD has assured access to the 2025-2110 MHz band for Launch, Early Orbit Operations and Anomaly Resolution (LEO&A) and other operations currently operating in the 1755-1850 MHz band. Specifically, the Broadcast Auxiliary Service (BAS) or Electronic News Gathering (ENG) services at transportable and mobile locations shall not claim protection from DoD operations which have been migrated to the 2025-2110 MHz band.
- Current domestic regulatory provisions that protect existing DoD operations in the 1755-1850 MHz band shall continue throughout any spectrum operations migration/transition period.
- DoD obtains appropriate regulatory protections approved national frequency spectrum certifications and assignments in the 2025-2110 MHz band consistent with mission requirements and acquisition timelines.
- The US concludes successful international coordination of DoD satellite networks in the 2025-2110 MHz band.
- DoD determines it is actually possible to successfully conduct satellite command and control operations in the 2025-2110 MHz band.

2.2 CONDITIONS FOR AIRBORNE AND TERRESTRIAL SYSTEMS

The following conditions apply to all other systems with respect to transition or migration from the 1755-1850 MHz frequency band to any other frequency band.

- Mission capabilities provided to military end users will not be degraded. The government will maintain assured access to the 1755-1850 MHz band to satisfy mission objectives until any capability supported by the 1755-1850 MHz band is successfully accommodated with equivalent regulatory protection in a new frequency band.

- Current domestic regulatory provisions that protect existing DoD operations in the 1755-1850 MHz band shall continue throughout any spectrum migration/transition period.
- DoD obtains appropriate regulatory protections approved national frequency spectrum certifications and assignments in any new frequency bands consistent with the mission requirements and acquisition timelines of affected systems.

3.0 SYSTEM DESCRIPTIONS

3.1 IMT-2000 SYSTEM DESCRIPTION

IMT-2000 and 3G services are the names commonly used to refer to advanced or next-generation mobile wireless telecommunications services. Commercial interests have generally agreed that the 3G family of services, and the systems that will provide them, are intended to reflect a high degree of commonality and are to be compatible with each other. These services will support mobile and fixed users employing a wide range of devices including small pocket terminals, handheld telephones, laptop computers, and fixed-receiver equipment. Some commercial interests envision the 3G services to be ubiquitous throughout the globe, as available in a remote part of a developing country as they are in an urban area in a highly developed country. These entities believe there are significant benefits to manufacturers and users of wireless systems to seamless roaming on a regional and global scale, hence the desire for standardization in system design and service provision for 3G services. The detailed technical parameters of IMT-2000 systems used in this assessment are contained in Appendix A.

3.2 DOD SYSTEM DESCRIPTIONS

The DoD has received spectrum certification for hundreds of communications-electronics systems in the 1755-1850 MHz frequency range and operates many thousands of these systems in the US and abroad. Each of the military services has major, critical systems in this frequency band, as well as important local systems for command and control, security, telemetry, target scoring, video links, and a variety of other functions. This frequency range is used by these critical DoD systems due to a number of factors. The propagation characteristics of the band enable reliable links with low power and low losses as well as excellent penetration of foliage. The band provides wide beamwidths for quick path alignment, inherently allows for inexpensive system components, enables simple equipment set-up methods, and supports highly mobile applications. Table 3-1 identifies some of the major systems and the functions the systems support.

Within the time and resources available for this assessment it was not possible to address all of the DoD systems certified to operate in the 1755-1850 MHz band. Several critical systems were selected for the assessments to help establish the scope of compatibility issues associated with the possible sharing of the frequency band. Overviews of these systems are provided below. Detailed descriptions and the technical parameters used in the assessments are presented in the associated appendix.

Table 3-1. Examples of DoD Systems Operating in the 1755-1850 MHz Band

System Name	Function
Space Ground Link Subsystem	Satellite telemetry, tracking, and command
Some Typical Satellite Systems GPS Milstar Defense Meteorologica Satellite Program (DMSP) Defense Support Program (DSP)	 Navigational and Precise Time Data Satellite Communications Meteorological, oceanographic Missile launch detection
AN/GRC-103	Tactical radio relay
AN/GRC-226	Tactical radio relay
AN/GRC-245	Tactical radio relay
AN/MRC-142	Tactical radio relay
AN/SRC-57	Tactical radio relay
Tactical Air Combat Training System	Air combat training
Air Force ACTS	Air combat training
Joint Tactical Combat Training Systems	Air combat training
Tactical Control Links/PGM	Control of precision strike weapons
Land Warrior	Wireless local area network for combat troops
AN/DSQ-37	Target scoring system
Combat Identification (ID) for the Dismounted Soldier	Tactical communications
Intrusion Detection System	Perimeter security
Robotics Control System	Wireless remote control

3.2.1 Satellite Operations (SATOPS)

The 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, navigational data uploads for GPS, and on-orbit maneuvering of its many satellites in all orbits from low earth to geostationary. The 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.

3.2.2 Tactical Radio Relay

The Army, Navy, and Marine Corps operate tactical communications systems in this frequency band providing high capacity, digital information to the battlefield. These systems are described below.

3.2.2.1 Mobile Subscriber Equipment (MSE)

The AN/GRC-103, AN/GRC-226, and AN/GRC-245 Radio Sets are line-of-sight (LOS) trunk radios used to link nodes (switching centers) in the Army's tactical telecommunications system or the Army Common User System (ACUS). These radios operate in the 1755-1850 MHz spectrum band. The ACUS is a seamless, tactical communications system that provides secure, highly reliable voice and data communications for both mobile and fixed elements in a tactical or battlefield environment. The ACUS operates from the front-line maneuver battalions to theater headquarters in rear areas. This communication network is formed in two parts: the MSE and the Tri-Services Tactical Communications (TRI-TAC) system. The MSE system is deployed from the corps-level headquarters to the maneuver battalions and the TRI-TAC system is deployed from corps-level headquarters to higher levels of command. These systems provide a digital microwave backbone to link mid level and lower level battlefield commanders with upper level theater decision-makers. The system operates like a high-capacity PCS with rapidly 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 their forces. MSE is a tactical system designed for rapid deployment in the field. This is because headquarters units, with their 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 headquarters 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.

3.2.2.2 Digital Wideband Transmission System (DWTS)

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 AN/MRC-142 is the Marine Corps element of this radio system providing the 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 ship-to-shore link of DWTS is the AN/SRC-57 radio. This link is essential for amphibious operations where most of the critical information flow is from the ship to the landing forces. Like ACUS/MSE, DWTS is a tactical system designed to quickly establish microwave links in support of combat operations and maneuver warfare.

3.2.3 Air Combat Training Systems (ACTS)

3.2.3.1 Tactical Air Combat Training System/Aircrew Combat Maneuvering and Instrumentation (TACTS/ACMI)

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. Typical training bases, such as Luke AFB, AZ, can average 200-plus sorties a day on their instrument range. To ensure interoperability, training sorties are also conducted with Allied Forces, both inside and outside of the US.

3.2.3.2 Joint Tactical Combat Training System (JTCTS)

JTCTS is being developed as the next generation of aircrew training system. JTCTS will fulfill the same functions as TACTS and will provide added flexibility to support “rangeless” training that the current TACTS and certain ACMI systems cannot. JTCTS will employ the GPS for position determination, thereby reducing the requirements for ground support infrastructure and allowing training to be accomplished without the need for a robust system of ground reference stations. The current JTCTS development program is being restructured due to technical issues. When finished, JTCTS will support more robust inter-service training, as the Services become more interdependent.

3.2.4 Tactical Control Links/Precision Guided Munitions

Tactical Control Links that support PGMs, like the Navy/Marine Corps Standoff Land Attack Missile-Expanded Response (SLAM-ER) and the Air Force Air-to-Ground Missile-130 (AGM-130) and Guided Bomb Unit 15 (GBU-15), provide a decisive combat edge to US forces. These weapons provide the capability to attack single targets with one aircraft or one standoff weapon with greater probability of success than by flying waves of aircraft dropping iron bombs. 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 in the continental US (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. As documented in air campaigns such as those conducted in Iraq and Kosovo, PGMs were key in the destruction of high value and highly defended targets with little or no collateral damage and aircraft losses. The combatant commanders require this capability to successfully accomplish any mission requiring the use of force.

3.2.4.1 SLAM-ER

The SLAM-ER program builds on the existing Harpoon and baseline SLAM weapon systems. SLAM is a fielded system with proven combat performance in Operation Desert Storm and Bosnia, while SLAM-ER is intended to provide dramatic weapon system performance improvements. The benefits gained from this retrofit are doubled flight range, communications range, and warhead penetration; improved lethality, countermeasures resistance, target coverage, aimpoint selectivity, and accuracy; with a much simpler mission planning and cockpit interface. SLAM-ER has provisions to store up to three pre-planned missions, including Automatic Target Acquisition missions, and one Target of Opportunity mission. Pre-planned missions are developed for fixed land targets or ships in harbor. Pre-planned missions take into account known defenses and terrain. Target of Opportunity missions are generally used for relocateable targets in both land attack missions and Anti-Surface Warfare ships-at-sea missions.

3.2.4.2 AGM-130 & GBU-15

In particular, the AGM-130 and GBU-15 precision guided weapons[2] were designed for employment against fixed, high-value targets in all weather conditions, day or night. These weapons, in the 2000-pound class of weapons, are launched from F-15E aircraft from either low or high altitude at ranges from 5 to in excess of 30 nautical miles. Equipped with TV or Infrared sensors and aided by GPS, these weapons provide operators the ability to attack targets in all weather conditions, day or night. These weapons can be controlled from either the launch aircraft or a standoff aircraft at a range of more than 100 nautical miles. Operators require access to video and command link frequencies at any time during the mission, including ground operations, post take-off pre-launch operations, and post-launch weapon flight operations. Access to the RF spectrum is critical during all training and testing operations-these operations require use of the frequencies for two hours per mission.

3.2.5 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 primary DoD functional capabilities. Long-range point-to-point microwave system operations represent a majority of the systems. These systems primarily operate at fixed locations and employ directional antennas. A number of 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 Vehicles (UAVs) such as the Pointer (FQM-151A) and the Exdrone (BQM-147A) are authorized to operate in this band. These systems transmit video and status data from the UAV to the ground control system (GCS) using analog frequency modulated (FM) video and data on subcarriers. Fixed point-to-point microwave, CIDDS, the Land Warrior LAN, and UAVs are believed to represent significant other uses of the 1755 to 1850 MHz band.

3.2.5.1 Corps of Engineers

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

[2] *Case Study: Impact Assessment on Precision Strike Weapon Data Link Systems to Accommodate IMT 2000*, Eglin AFB, FL: USAF, 5 January 2001. This case study is provided as reference material with the electronic version of this document.

locks, dams, and other water systems. This system provides microwave links where no commercial communications connectivity exists. This system is essential to the ACE operations because it allows 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. The system helps ensure the safety and integrity of the nation's waterways and helps prevent catastrophic events that could cost lives and economic damage as well as environmental damage.

3.2.5.2 Land Warrior

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 situation awareness information among all team members, improves survivability and increases mission effectiveness while reducing the soldier's equipment load. Current program documentation indicates a minimum of 41,000 units, with a potential increase to 71,000 units, are to be produced commencing in calendar year 2003.

3.2.5.3 Combat Identification of the Dismounted Soldier

The purpose of CIDDS is to help prevent friendly forces from firing on friendly forces, otherwise known as fratricide. CIDDS employs a laser interrogator with an RF response to provide identification of friendly forces by individual and automatic weapons users to a range of over 1000 meters, depending on visual conditions. Forward combat forces, in both open terrain and urban areas, use the system. 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 of all three military services. CIDDS entered into development in 1997 and the low-rate initial production of fifty units will be tested in FY01.

3.2.5.4 Pointer Unmanned Aerial Vehicle

The Pointer UAV is a production-ready, electric, hand-launched UAV designed for remote monitoring and surveillance. The UAV 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 detection are currently being developed. The video link operates in the 1755-1850 MHz frequency band.

3.2.5.5 Aberdeen Test Center

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 which are employed 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.

3.2.5.6 Television Ordnance Scoring System (TOSS)

The TOSS (TCM-601) system provides a television ordnance scoring capability to range users in support of exercise and test missions at Nellis Range. TOSS is a field proven accurate weapons scoring system with a night scoring capability using infrared cameras. Scoring can be done for live or inert conventional weapons.

4.0 ASSESSMENT APPROACH

The approach used in this effort required multiple steps in order to develop a final integrated product with technical, operational, and cost assessments. The initial step was to identify DoD RF systems that operate in any or all of the 1755-1850 MHz band. The next step was to conduct technical analyses to determine the potential for undesired interactions between DoD systems and IMT-2000 systems. The results of these analyses were then assessed for several band sharing/segmentation/vacating scenario options. Based on the technical interference analysis results and considering each scenario option, DoD elements responsible for the various systems then defined the operational and cost impacts of accommodating IMT-2000 systems into the 1755-1850 MHz band.

4.1 INTEGRATION OF TECHNICAL, OPERATIONAL, AND COST ASSESSMENTS

The compilation and integration of the various technical, operational, and cost assessments for the numerous DoD systems were based on the following approach. At the highest level, the integration framework addressed each major system category (ACTS, Tactical Radio Relay Networks, etc.) by each of the four sharing/segmentation/vacating scenarios. The key technical assessment results from each element of this framework were integrated with any applicable programmatic realities with respect to system life-cycle projections (expected phase-out, replacement or upgrade date, new system fielding dates, etc.) and potential mitigation measures. For each of the major system categories and the various sharing scenarios, the associated operational and cost assessments were then addressed. If the operational and cost assessments varied over the time frames of 2003, 2006, and 2010, they were included as distinct potential impact situations.

4.2 TECHNICAL ASSESSMENT APPROACH

The goal of this effort was to assess the potential for sharing in the 1755-1850 MHz frequency band from a technical perspective. Assessments were two-way assessments in that analysts considered both interference from DoD systems to IMT-2000 receivers and interference from IMT-2000 emitters to DoD receivers. The general technical approach was to predict undesired signal power at victim receivers by considering appropriate interfering transmitter parameters, operational configurations, coupling between systems considering antenna orientations and propagation losses, and frequency-dependent rejection when appropriate. Undesired received power levels and victim receiver interference thresholds were then used to assess the potential for interference. Interference thresholds may be either interference-to-noise ratios, desired signal-to-interference plus noise ratios, or the degradation of link margins needed to sustain acceptable bit or symbol energy-to-noise power densities. Desired signal levels were either calculated or provided by system users based on their experience with the design and use of the subject system.

It was recognized that a number of the assessment parameters may not yet be finalized or may vary depending on operational configurations. Consequently parametric assessments were performed in many cases. Many of the appendices contain either multiple figures showing variations in signal levels for different values of selected parameters or tables with multiple entries for similar reasons. Parameters that may vary include, but are not limited to, transmitter power, antenna gain, antenna pointing angles, antenna heights, data rates, receiver selectivities, and desired signal levels.

Implementation of the general technical approach had variations depending on the particular DoD systems being considered. For example, in the satellite operations (SATOPS)-to-IMT-2000 assessment, the primary SATOPS sites are fixed in locations. In this case, a terrain-dependent propagation model could be used to establish received signal level contours around the SATOPS earth station sites for various IMT-2000 base stations and mobile units. Multiple contours are provided in Attachment 1 to reflect variations in receive system parameters and different SATOPS transmit powers and antenna elevation angles.

In the case of mobile or transportable DoD systems, terrain-dependent propagation modeling was not appropriate and a smooth-earth propagation model was used. Also in these cases, this initial assessment tended to place mobile and transportable units at distance separations or altitudes that either reflected guidance from the appropriate program office or represented communications links that would be operating near minimally acceptable conditions. The latter approach is somewhat conservative and was used principally to bound the limits of sharing issues. In several cases, sharing is investigated where desired signal levels are significantly better than minimally acceptable levels. These cases are so noted in the appendices.

Source-to-victim configurations also varied in the assessments. In some cases one-to-one assessments were performed where the principal source of interference was a single emitter of one system to a single receiver of a victim system. Examples of these cases include a single AN/MRC-142 radio to a single IMT-2000 mobile receiver (Appendix C) and a single IMT-2000 base station emitter to a single ACTS ground receiver (Appendix D). In other cases, assessments addressed many-to-one interactions. Examples of these cases include multiple IMT-2000 emitters to spaceborne SGLS receivers

(Appendix B) and multiple IMT-2000 emitters to DoD aircraft participating in training exercises (Appendix E).

As reflected in the description of IMT-2000 systems, mobile wireless networks are deployed over the period of several years. When appropriate, the assessments considered the notional build-out schedule contained in Table A-7. Consideration of this schedule gives an approximate estimate of when certain systems may be affected, as IMT-2000 networks are built-out in the US. These estimates are not precise and may be subject to debate but they do identify those systems particularly sensitive to large-scale network development such as airborne and spaceborne receivers.

4.3 OPERATIONAL IMPACT ASSESSMENT APPROACH

A four-step process was performed to conduct the operational impact assessment for the introduction of IMT-2000 systems into the 1755-1850 MHz band. The first step was to define the system capabilities and associated mission for each of the major systems. Subsequently, DoD analysts assessed system and programmatic changes dictated by the possible introduction of IMT-2000 systems. The next step was to develop and distribute a series of questions to assess system impact based upon a previously identified set of operational scenarios and IMT-2000 phase-in schedules. These questions were sent to the appropriate program offices, Services, and Combatant Commands. Finally, the responses were compiled and analyzed.

The evaluation of operational impacts included an assessment of the effects resulting from changes to operating parameters, or procedures, and possible changes to concepts of operation. The evaluation also addressed the effects of radio frequency interference (RFI), RFI mitigation techniques employed, and possible changes to system hardware and/or software.

The system impact assessments were based upon the introduction of IMT-2000 systems in years 2003, 2006, and 2010 for each of the four options identified in Section 1.3, i.e., full band sharing, band segmentation, band segmentation and combination with other bands, and vacating the band.

4.4 COST ASSESSMENT APPROACH

To determine the cost of transitioning incumbent DoD systems to a new band or the cost of some other means of interference mitigation to 3G systems, it was first necessary to develop a program management plan for implementing the transition. Since DoD will not accept operational degradation caused by the introduction of 3G systems, any proposed program plan must ensure current levels of operational capability are maintained. Furthermore, any proposed plan must be realistic in the sense of execution, schedule, and risk. Additionally, since little is known regarding availability and location of possible bands that DoD could relocate its systems to, assumptions must be made in this regard to carry out the costing activity. It should be recognized that the costs are sensitive to the band selected and, to the extent that the assumptions made turn out not to be the case, the costing activity may require refinement. The methodology used to develop the estimates for cost reimbursement follow generally accepted cost estimation practices used within the DoD and is consistent with the approach to cost reimbursement proposed in the NTIA's Notice of Proposed Rulemaking (NPRM) on Mandatory Reimbursement Rules for *Frequency Band or Geographic Relocation of Federal Spectrum-Dependent Systems* (published in the Federal Register on January 17, 2001). The cost estimates developed are meant to be preliminary and representative, however, not conclusive. The costs reflect estimated funding for the candidate relocation bands and time frames assumed for relocation.

5.0 CRITICAL ASSUMPTIONS

The following assumptions were key to the assessment process and the study results.

5.1 OVERALL STUDY ASSUMPTIONS

- Equipment/system modifications or physical relocations to support sharing, segmentation, or vacating the band would not occur by the 2003 time frame due to the time required for program budgeting, and contract preparation, award, and execution.
- Scenarios were not considered feasible if they resulted in a degradation of operational capability for DoD systems.

5.2 TECHNICAL ASSUMPTIONS

- Systems grouped into major system categories (except "Other") demonstrate similar radio frequency interactions with IMT-2000 systems.
- Transportable, mobile and airborne DoD systems are assumed to operate over the full geographic area of their associated military installations (i.e., emitters could be located along the installation boundary).
- Aggressive schedules for system modifications, upgrades, or replacements were considered high risk and unlikely to be successful.

5.3 OPERATIONAL ASSUMPTIONS

- US Armed Forces are vital to the security of the US and require assured spectrum access to perform their missions.
- The ability of US Armed Forces to conduct operations and train in the US is essential to maintaining effective combat capabilities.
- US Armed Forces must be able to operate and train with systems in the US the same way these systems would be employed in the full range of missions worldwide.
- The loss of operational capability is directly linked to the potential for failure on the battlefield.
- Whatever mitigation techniques are implemented, they cannot restrict DoD systems from meeting mission requirements, i.e., DoD systems must maintain the flexibility to support current operations.
- Warfighting capabilities provided by systems addressed in this report (e.g., SATOPS, PGMs, etc.) are essential elements of the combatant commanders' ability to complete their missions.

5.4 COST ASSUMPTIONS

- Cost estimates for all systems and scenarios are preliminary and representative, not conclusive. The costs reflect estimated funding for the candidate relocation bands and time frames assumed for relocation.
- All costs are presented in Then Year dollars (TY$).
- The methodology for cost estimates follows generally accepted cost estimation practices of the DoD and is generally consistent with the cost methodology set forth in the January 17, 2001 NTIA cost reimbursement NPRM.
- Costs are sensitive to band selection and will require revisiting upon actual band determination.
- Additional manpower, where required, was included in some cost figures.
- For satellite control systems, it was assumed that no matter to what extent the 3G systems are built out, the SGLS link will remain viable. Therefore, the costs shown assume that no DoD satellites nor supporting infrastructure will require accelerated or premature replacement due to a lost TT&C link. If the SATOPS link becomes unusable at some point and, therefore, some DoD satellites will need replacing and ground infrastructure will need modifications, the costs will increase significantly relative to those presented here.

5.5 SCHEDULE ASSUMPTIONS

- Dates identified for DoD accommodation of IMT-2000 are predicated on funding for programmatic actions being available in FY02.

5.6 IMT-2000 ASSUMPTIONS

- The technical parameters describing IMT-2000 equipment used in this report are a reasonable representation of several candidate IMT-2000 systems that may be deployed in US markets.
- The spectrum requirements defined in ITU-R Report M.2023 reflect a reasonable estimate of the deployment of IMT-2000 systems at full build-out.
- IMT-2000 networks will mature over the course of several years with urban areas maturing first.
- On occasion IMT-2000 base station and mobile receivers may operate near minimally acceptable performance levels.

5.7 SATOPS ASSUMPTIONS

- SATOPS minimum antenna elevation angles may fall between 3 and 5 degrees above the horizon.
- SATOPS uplink transmitter powers may range from 100 watts to 10 kW.
- Existing emission spectra and frequency plan of current SATOPS uplinks are as defined in the SATOPS system description.
- SATOPS earth station antennas must support 360° azimuthal coverage.
- All spacecraft launched after 2010 will be Unified S-band (USB) capable.
- A space-qualified SGLS/USB capable commercial-off-the-shelf (COTS) transponder that meets DoD communication security (COMSEC) and other requirements will not be available for integration before July 2004. A transponder with program specific capabilities will not be available until 2005. This assumes the decision to proceed with the transponder program will be by July 2001.

5.8 TACTICAL RADIO RELAY ASSUMPTIONS

- Transmitter and receiver sites may occur anywhere within selected training ranges.
- National Guard and Reserve units will regularly train with radio relay systems at appropriate sites throughout the country.
- Tactical radio relay systems may occasionally operate near minimally acceptable performance levels.
- The AN/GRC-245 radio would be available in sufficient quantities to replace the AN/GRC-226 radio and the AN/GRC-103 radio before 2010.
- A new radio could be developed to support the DWTS function at frequencies above 2 GHz. However, the antenna beamwidths at higher frequencies would be much narrower than those provided by the current band. Operational needs would require the development of new antenna technology to support these mobile command and control links.

5.9 ACTS ASSUMPTIONS

- Areas around two training ranges, Cherry Point Marine Corps Air Station (MCAS) in the eastern US and Nellis Air Force Base (AFB) in the western US, may be considered typical locations for determining IMT-2000 aggregate environments to ACTS airborne receivers.
- For determining desired signal levels at airborne receivers, 35 km and 78 km separations from the ground transmitters are typical and near-maximum values, respectively, for the

TACTS/ACMI. For the JTCTS, air-to-air transmitter-to-receiver separations of 78 km and 278 km are typical and near-maximum values, respectively.

- The 9000 m altitude used for the analysis is a typical aircraft altitude used for flight training, although some altitudes as great as 20,000 m may be necessary.
- ACTS ground station antenna heights of 30 m are typical or near-maximum values.
- Specified maximum communications ranges and other capabilities of the ACTS are to remain unchanged, as system components are redesigned to operate in frequency bands different from those presently used.

5.10 TACTICAL CONTROL LINKS/PGM ASSUMPTIONS

- Operation without interference at the pod-to-terminal separation distance analyzed in the classified appendix (Appendix F) is a requirement.
- Pod and terminal altitudes can be between ground and 30,000 ft above ground level.

5.11 OTHER SYSTEM ASSUMPTIONS

- Army Corps of Engineers Fixed Point-to-Point communications antenna towers are typically no more than 80 m in height.
- Permanent frequency assignments recorded for Army Corps of Engineers Fixed Point-to-Point communications operations are indicative of actual use (i.e., that 1755 to 1850 MHz and 1710 to 1755 MHz microwave links have not been replaced with other communications media as yet).
- Locations where the Land Warrior LAN and CIDDS will operate lie within all DoD test, training, and operational areas within the US.
- Size, weight, and power will have to be minimized because of the small size of the UAV.
- The communications link budget must be maintained without added complexity.
- The Pointer and Exdrone altitudes may vary from 0 m to 3280 m above ground level.

6.0 SUMMARY OF RESULTS

6.1 RESULTS FOR CONSIDERED OPTIONS

The accommodation of IMT-2000 services into the 1755-1850 MHz band will have unacceptable impacts to the current DoD systems operating in the band, even if accommodation were deferred until 2010 or beyond. The impacts are unacceptable with regard to the ability of the US military forces that use DoD RF systems to achieve and maintain warfighting readiness. In addition, millions of civil and international users of GPS timing and navigational services will be adversely impacted. Mitigation measures would be required for both DoD systems and IMT-2000 systems for partial accommodation of IMT-2000 services under certain sharing or segmentation options. These measures would have major cost and functional impacts to the DoD and may prove unacceptable as a business case to IMT-2000 service providers. The potential for DoD to transition completely out of the band is not possible for all non-space systems until at least 2010 or later, and for space systems, it is not possible until at least 2017 or beyond. However, the government must maintain assured access to the 1755-1850 MHz band until all legacy systems operating in this band have completed their missions. These missions are expected to last until the 2020-2030 timeframe. Therefore, vacating the band is not possible for the DoD according to IMT-2000 timelines. The cost presented in Table 6-1 for total band loss (Option 4) is according to DoD timelines (2020-2030). Transition out of the band would require cost reimbursement and provision of sufficient bands of comparable spectrum below 3 GHz. Such replacement spectrum must provide primary status and equivalent regulatory protection.

With respect to cost issues, Table 6-1 summarizes preliminary reimbursement cost estimates for the options addressed in this study. Since DoD cannot modify any systems by 2003, and since operational restrictions are considered unacceptable, accommodation of IMT-2000 in this band in that timeframe is not considered feasible, thus no costs are presented. Under any 2003 scenario, the burden of mitigation would need to be borne completely by IMT-2000 systems. For the 2006 timeframe modification of DoD systems could be underway to accommodate band segmentation. However, any migration of DoD systems will not be feasible until at least 2010 or beyond, thus costs are only shown for the 2010 timeframe. Under no schedule is full band sharing considered feasible, thus no costs are shown for that option. All costs presented are extremely sensitive to the critical assumptions outlined in Section 5.

Although the costs of all affected systems are included, the differences between the band segmentation options are preliminary in the affected satellites and their associated ground stations. The portion of the band lost will determine which satellite systems will be unable to utilize SGLS in the future. The biggest single satellite system that is affected by options 2B/3B, but not by options 2A/3A, is GPS.

Because GPS uses the 1755-1850 MHz for its mission data uploads as well as TT&C, the loss of government use of the GPS uplink channel is a major cost driver.

There are many key underlying assumptions for the costs provided in Table 6-1. From a costing perspective, the most important observation is that the numbers in the table represent only one point on a graph of expected cost versus risk. All of the cost figures are very sensitive to many complex technical and budgetary unknowns. Time did not allow for the quantification of these risks and the resulting simulation that would have established the range of cost and the probability of realizing a cost within the range. Based, however, on apparent risk, it would be consistent to expect a significant range of probable cost. Changes in any of the variables, including the development of the IMT-2000 systems themselves, could cause significant changes in the results provided herein. Perhaps the most important assumption is that the DoD will maintain access to this band to satisfy mission objectives until the last 1755-1850 MHz satellite is no longer functioning. This assumption is key because if this was not the case, many DoD satellites would require replacement, increasing the overall cost many-fold. This would be operationally unacceptable because it is unclear when replacement satellites could be developed, built, and launched to maintain DoD satellite system capabilities or if industry even has the capacity to provide these replacement satellites in a timely manner. Another extremely critical assumption underlying the cost figures is that comparable alternate bands are made available for the systems that require relocation, e.g., the weapon links and the tactical radios. If comparable alternate bands are not identified, the DoD would lose the capability provided by these critical systems, which is unacceptable. Finally, secondary and tertiary impacts have not been included in the costs presented. An example of these costs includes increased comparable band coordination costs.

Table 6-1. DoD Cost and Schedule Summary (TY$B)

Full Band Sharing (Option 1)	Band Segmentation Lose 1805-1850 MHz (Option 2A/3A) Notes 1,2,3,4	Band Segmentaion Lose 1755-1790 MHz (Option 2B/3B) Notes 1,2,3,4	Total Band Loss (Option 4) Notes 1,2,3,4
Not Applicable	$2.8	$3.9	$4.3

1 Requires provision of certified comparable spectrum (NDAA 00)
2 Requires cost reimbursement (NDAA 99)
3 Requires protected spectrum access to the band through any transition
4 Complete DoD migration is not possible until beyond 2010 for non-space systems and beyond 2017 for space systems

In summary, since the band sharing option introduces significant operational risks, no costs are presented. The cost to reimburse DoD for the band segmentation options, given the assumptions and mitigation strategies discussed in detail below, is either $2.8B or $3.9B, depending on which option is chosen. If the entire band is lost, the cost would be at least $4.3B; however, total migration of DoD systems from this band is not possible within any of the dates established by the Presidential study plan and in fact could not be completed until well after 2020.

6.1.1 Full Band Sharing

Full band sharing between DoD and IMT-2000 systems is not feasible due to prohibitive separation distances. The successful simultaneous operation of DoD and IMT-2000 systems in a number of populated regions will be prevented by the interference interactions expected between DoD systems and IMT-2000 systems. It is not known whether the potential impact or possible mitigation restrictions on IMT-2000 systems are acceptable to industry, however those that may be imposed on DoD systems would have unacceptable impacts. These include major limitations on airborne operations involving aircrew training and weapons testing such that military mission requirements could not be met. Tactical communication systems would be limited in operation to only remote areas and even then would require significant coordination efforts. The ground network used for the primary control of critical DoD satellites could be required to limit operational parameters (satellite contact frequency and duration, contact time of day, transmitter power, etc.), which would put the health of all constellations at risk. On-orbit spacecraft would be susceptible to interference from aggregate IMT-2000 system emissions to the point that effective spacecraft control could be lost.

6.1.2 Band Segmentation/Partial Band Sharing

Band segmentation options consistent with those presented in the study plan were assessed. The first segmentation option (Option 2A) evaluated is the accommodation of IMT-2000 systems into the 1805-1850 MHz segment of the band while the government systems maintains its operation in the remaining 1755-1805 MHz portion of the band. This segmentation option with the addition of comparable spectrum (Option 3A) for DoD operations was also considered. Another segmentation option that allowed for a phased entry of IMT-2000 systems was addressed. In this segmentation scenario (Option 2B), government operations would be retained in 1790-1850 MHz while the 1755-1790 would potentially be reallocated to non-government use as part of a phased introduction. The phasing considered allowed IMT-2000 systems to be introduced into the 1710-1755 MHz portion of the band immediately followed by additional access to 1755-1780 MHz at a mid-term future date, and 1780-1790 MHz would be made available in the long term. The final segmentation option (Option 3B) used the same phased availability of spectrum for non-government use and also made additional comparable spectrum available for DoD use.

Options for DoD to vacate certain portions of the 1755-1850 MHz band to IMT-2000 operations will also result in significant impacts to DoD system operations. Accommodation as a result of any segmentation option would take many years and would require cost reimbursement. Absent provision of comparable spectrum (and to date no such comparable spectrum has been identified), all of the DoD major systems in the band would experience serious operating restrictions due to the loss of spectrum access under either of the segmentation options. In order to support adequate mission capabilities, DoD requires access to additional spectrum in the mid 2 GHz area and below on a primary basis with equivalent regulatory protection to 1755-1850 MHz, in order to support large military exercises, aircraft and missile testing, and fighter aircraft combat proficiency training. In addition, specific system acquisition programs would require changes and additional funding to enable DoD systems to ensure operating effectiveness under either segmentation option. These changes include program accelerations, design modifications, and fielding of upgraded systems to installations or units that currently do not plan to field the upgraded capability. While either segmentation option would have impacts to all major DoD systems, the option that would take a phased approach with initial IMT-2000 services in the 1710-1755 MHz portion of the band would reduce the impacts to most systems for a number of years. This would allow time for programs to receive funding through reimbursement to make equipment/band transitions and implement mitigation measures. Elimination of OBRA-93 conditions, i.e., the continued existence of protected federal government sites at a number of locations throughout the US at which DoD operations can continue with the same level of regulatory protection as at present, would result in an immediate impact to PGMs and other systems.

Due to the potential for degradation to operational capability, losing access to any significant portion of the 1755-1850 MHz band without access to additional comparable spectrum and adequate time to withdraw from the specified band is unacceptable to the DoD. If the conditions of full cost reimbursement, on time program execution, and operationally protected use of the spectrum through the course of any necessary transition are met, some band segmentation may be feasible. The feasibility of any segmentation requires the full cooperation of the IMT-2000 industry. This cooperation entails acceptance of DoD transition timelines and DoD’s continued unrestricted operation in the existing band during the course of any transition. The timelines for accommodation of IMT-2000 in any significant segment of the 1755-1850 MHz band by the DoD are comparable to those of full band sharing. Given that the above conditions are met, transition by the DoD for this option could not be completed until 2010 or later for the most non-space systems and until 2017 and beyond for the space systems. As in the case of vacating the total band, migration prior to these dates would require premature system termination, which would have extremely serious implications to the DoD’s ability to effectively execute its mission. These dates are also predicated on funding availability in FY02.

6.1.3 Vacating the Band

DoD vacating the 1755-1850 MHz band in the near-term would cause serious national security impacts. No amount of funding could mitigate the impacts in the near-term. Terrestrial systems would require at least 10 years (no earlier than 2010) to completely transition out of this band and into a band of comparable characteristics. To date, no bands or combination of bands surveyed by DoD or proposed by NTIA have proven suitable for a relocation of DoD systems currently resident in 1755-1850 MHz. Space systems are not expected to completely transition out of the band until after 2020-2030.

6.2 RESULTS FOR INDIVIDUAL SYSTEMS

6.2.1 Satellite Operations

The ability to support pre-launch, launch and early orbit activities, on-orbit operations, anomaly resolution, and end-of-life management is absolutely critical to satellite control and management. Impact to SATOPS functions is manifested in one of two areas: impact to the spacecraft receiver from IMT-2000 terrestrial emission, and restrictions placed upon the DoD’s terrestrial uplink operations to accommodate IMT-2000 operations. Unlike terrestrial-based systems, space-based hardware cannot undergo a frequency change once the hardware is launched. Since all of the DoD satellites rely on SGLS control afforded by the Air Force Satellite Control Network (AFSCN), Naval Satellite Operations Center (NAVSOC), GPS, and DSP networks, continued protected access to the spectrum used by these on-orbit assets is required to maintain control of the satellites and associated mission payloads.

Given that SATOPS functions are performed across the 1755-1850 MHz frequency band, band segmentation or band vacating schemes have unacceptable impacts to existing satellites utilizing the affected portions of the spectrum unless continued protected access is maintained through the course of any transition. Even with assured access, unacceptable impacts to satellite uplink closure reliability are expected starting in 2006 under typical uplink operating parameters. Under certain conditions, increased uplink power may not provide adequate link margin.

Denying SATOPS the spectrum needed to support on-orbit assets will result in a partial or complete loss of TT&C capability. This will result in varying degrees of impact to the spacecraft including orbit-positioning errors, loss of payload control leading to eventual malfunctions and mission failure, and ultimately, complete loss of the satellite. Mission capabilities such as missile warning, navigation, military communications, weather, and intelligence, surveillance and reconnaissance would be severely impacted until such time that a replacement capability could be launched. Failure to support GPS and weather services satellites not only impacts military operations but also will have adverse consequences for the civilian community.

For all three options, band segmentation, band sharing and vacating the band, the DoD must retain full SATOPS operational capability and regulatory protection to support existing satellite systems until their end-of-life. Mitigation techniques exclusive to the IMT-2000 community such as the establishment of coordination zones (areas surrounding SATOPS uplink sites) allow access to the spectrum without operational impact to the DoD. Other techniques such as IMT-2000 dynamic frequency reallocation may have some operational and cost impacts depending upon the specific implementation.

6.2.2 Tactical Radio Relay

6.2.2.1 Mobile Subscriber Equipment and TRI-TAC

For the band sharing option in the 2003 time frame, the Army must continue to operate MSE and TRI-TAC in the 1755-1850 MHz band for realistic battlefield training. Because there are no material solutions available in this time frame to facilitate sharing, it is anticipated that restrictions on military systems would result, thereby impacting operations as they are conducted today. Restricting transmitter/receiver locations and antenna pointing directions will limit realistic training of units and limits the commanders' ability to realistically deploy signal assets. Restricting training deployments to pre-planned, pre-coordinated sites exercise-after-exercise reduces the microwave operator's combat skills. The learning curve for establishing tactical links in actual deployment situations will be steeper and longer because of the lack of realistic field exercise training. The time required to establish effective command and control, especially in the information intensive battleground today, may be a deciding combat factor.

Army Guard and Reserve component units located primarily in urban/suburban areas with ACUS/MSE and TRI-TAC systems may be severely restricted in training opportunities because of their proximity to IMT-2000 base stations/mobile phone concentrations. If these units are restricted from training operations at home locations, then the units must deploy to the nearest training area thereby imposing increased costs on training that are accomplished today with relatively small investment.

If 3G systems were accommodated in this frequency band, the Army installation Frequency Managers would need to coordinate with IMT-2000 system's operators prior to conducting training exercises. The frequency managers at most of the Army's training ranges are already facing crowded frequency space and further sharing restrictions will make any large-scale exercises unworkable.

For 2006 and 2010, the operational impact to US forces if IMT-2000 systems begin operation in the 1755-1850 MHz band are the same as 2003, unless access to additional spectrum in bands up to 2690 MHz is provided on an primary basis with equivalent regulatory protection. As the High Capacity Line-of-Sight (HCLOS) radios replace the current generation of MSE and TRI-TAC equipment, the additional flexibility in frequency selection could reduce, but not eliminate, the impact resulting from loss of the 1755-1850 MHz band provided access to an equal amount of additional spectrum and operating frequencies between 1850 and 2690 MHz is granted.

By 2003 for the segmentation options, any reduction in available spectrum would further reduce the size and scope of training exercises in training areas where frequency space is already at a premium. Fielding of HCLOS radios would not be sufficient to provide any significant relief in this time frame. Impacts to Army training would be similar to those described in the band sharing option around large training areas; however, impact to Reserve and National Guard units will be minimal if access in the remaining government spectrum is maintained.

For the 2006 time frame, some impact to training is expected, however, fielding of HCLOS radios will improve the situation if access to frequencies up to the mid 2 GHz region is provided on a primary basis with equivalent regulatory protection. By the 2010 time frame, HCLOS fielding should have replaced current generation radios.

Vacating the entire 1755-1850 MHz band is not an acceptable option for the Army. This band is an essential element of Army battlefield communication networks for the foreseeable future, including the new HCLOS radio. Alternate higher frequency bands such as 4.4 – 5.0 GHz, are not suitable for tactical communication systems like MSE. The 1700 MHz band is used for mobile communications because the propagation characteristics allow for penetration of foliage, use of easy to handle coaxial cables instead of expensive and fragile wave guides, and have a wide beam width allowing for quicker path alignment. These characteristics are critical to tactical mobile communications units because of their mission to provide the Army with the ability to relocate command centers quickly. Moving the communications network to a higher frequency band would negate many of these factors, thus decreasing the operational utility of the system. The operational implications from the inability to train in the US would directly impact combat operations.

6.2.2.2 Digital Wideband Transmission System

The Navy/Marine Corps depend on the DWTS for information transfer between ships and troops ashore as well as dissemination throughout the battlefield. There are no replacement radios planned for the DWTS, so continued access to the 1755-1850 MHz band is crucial to amphibious operations training.

Full-band sharing between DWTS and 3G systems and segmentation options result in the same challenges as described previously in the section on ACUS/MSE. Restrictions on DWTS operation that would be expected under a full band-sharing scenario reduce or eliminate the utility of training in the establishment and operation of this vital link.

Limiting the size of exercises severely restricts the utility of training activities. If the Marine Corps could no longer stage MEF/division level exercises, it loses the ability to properly train its troops, and also loses the capability to rehearse for deployments. This reduces the readiness of our warfighters by increasing the time required to establish critical command and control links. Restricting training to certain specified ranges would also severely impact operations. This requires large troop movements to other training locations at an increase in both cost and lost time. This especially impacts the Reserve units, as they would no longer be able to participate in training in areas where the density of IMT-2000 is high, but would have to travel to specified training locations or ranges.

These impacts would be essentially the same in both the 2003 and 2006 time frames. As stated previously, no replacement radio is currently planned, and even if a replacement is leveraged with the HCLOS radio, redesign would be required to meet the Marine Corps requirements for mobility and platform suitability. Any replacement, incorporating the frequency flexibility of the HCLOS radio would not be available in sufficient quantities before the 2010 time frame. If such a program is executable and, if access to frequencies in bands up to the mid 2 GHz range is provided, the impact to amphibious training may be significantly reduced. However, access to frequencies in the low end of the DWTS range must be available to support the ship-to-shore communications requirements.

Vacating in either the 2003 or 2006 time frame would result in severe reductions in operational readiness of troops responsible for amphibious communications. This is not considered a viable option for the Marine Corps. Vacating the band would only be considered viable after a new specific frequency band is identified and a new system is developed, tested and fielded.

6.2.3 Air Combat Training Systems

Full band sharing of the 1755-1850 MHz spectrum with ACTS and 3G systems is not considered to be a viable option. Distance separations needed to preclude interference are substantial. Coordination and scheduling of shared spectrum between DoD training ranges and IMT-2000 is not possible due to complex range operations and the requirement for immediate support of unplanned training exercises. Sharing would limit or preclude large-scale joint training exercises and limit migration to rangeless air-to-air operational training.

No replacement or modified ACTS could be deployed by 2003; thus, it is anticipated that under full band sharing in this time frame, all current TACTS/ACMI would be forced to cease operation or face such restrictions as to render their utility nearly zero. The absence of instrumentation to support live tactical training would result in direct loss of readiness for combat forces.

Current plans call for existing ACTS to be operating well past 2010. Under the current plan, JTCTS would not begin replacing fixed range systems until after 2006, with a replacement schedule into at least the 2010 time frame. However, even with a conversion to JTCTS, there are no mitigation techniques that could be implemented in either JTCTS, legacy ACTS, or IMT-2000 to allow successful co-frequency operation in the same geographic region.

For segmentation Option 2, interference between the ACTS data link and IMT-2000 equipment will occur. The RF interference will adversely affect system operation. Interference with uplink frequencies (1830 and 1840 MHz) will render ACTS airborne instrumentation inoperative while interference with ACTS ground-to-ground RF links could vary with portions of the range becoming inoperative to total system failure. Additionally, there is no current way to limit system operation to a portion of the band; therefore, it must be assumed ACTS operation will adversely affect IMT-2000 systems. This would likely cause severe restrictions to TACTS/ACMI emissions thus significantly reducing system utility.

If the ACTS loses access to the 1805-1850 MHz band in 2006, the impacts would be similar to those described for 2003 unless modification to the existing frequency plan is pursued. A remanufacture of existing ACTS hardware (updating for obsolescence and technology advances) might make operation of the legacy systems within a reduced bandwidth feasible. It is estimated the fielding of the proposed ACTS modifications could be accomplished for all ranges by 2006 provided these modifications begin in FY02. For 2010, the assessment is the same as the assessment provided for 2006 except that risk is reduced based on additional time to deploy. The operational impact can be minimized if no spectrum conflicts arise with other incumbent systems and all the mitigation efforts are completely implemented by 2006 (schedule risk) or if turnover of the 1805-1850 MHz band is delayed at sites where mitigation measures have not been completed by 2006. The replacement of the legacy ACTS by JTCTS is not scheduled to begin until at least 2008. Any loss of current system use or functionality would impact the training and readiness of the aircrews.

Under Option 3, if IMT-2000 build-out is contained below 1755 MHz until perhaps the 2006 time frame, there would be little impact to ACTS operations during that time. If IMT-2000 equipment is deployed to use frequencies above 1755 MHz, impacts to ACTS would occur. Under the current plan, JTCTS would not begin replacing fixed range systems until after 2006, with a replacement schedule into at least the 2010 time frame. The 2006 time frame would not allow for the replacement of legacy TACTS even with a drastically accelerated JTCTS program. If started soon enough, a modification program for the legacy TACTS may allow it to keep operating in the 1780-1850 MHz band. This may allow sufficient time (i.e., until past 2010) for all legacy ACTS to be replaced by JTCTS. Once suitable spectrum is identified, the ground-to-ground microwave links may be relocated. Operational impact is none, if spectrum conflicts do not arise with other incumbent systems and all the mitigation efforts are completely implemented by 2006 (schedule risk), or if turnover of the 1755-1780 MHz band can be delayed at sites where mitigation measures have not been completed by 2006. Any loss of current system use or functionality would impact the training and readiness of the aircrews.

For vacating the band entirely, one option presented is to upgrade all ACTS ranges and equipment with a GPS tracking capability and replace existing RF hardware with new, state-of-the-art, digital equipment. The 2200-2290 MHz band is congested and unlikely to accommodate ACTS operations. This option could not be implemented by 2003. Therefore, vacating the current band in this time frame would impose unacceptable impact to combat training. One of the above options for moving to an alternate frequency band could possibly be implemented by 2006 with schedule risk or by 2010. However, unless continued operation of legacy ACMI is assured in the interim, operational training for aircrews would be severely restricted.

6.2.4 Tactical Control Links/Precision Guided Munitions

Co-frequency operation under full sharing of this frequency band with IMT-2000 systems could impose significant restrictions on DoD operations because PGMs are not able to operate with IMT-2000 systems on a non-interference basis. To accommodate IMT-2000, a modification to these data links must be made to prevent IMT-2000 systems interfering with the weapon data link in target areas where IMT-2000 systems are established. No replacement systems are currently planned for these PGM systems and until one is fielded, current PGM training must continue to use this frequency band.

Segmentation options are similarly unworkable. Due to the design of this system, any modification would be as complex and costly as vacating the entire band.

If the PGM data links have to vacate the current frequency band in 2003, there would be immediate loss of combat capability to the warfighter. The PGMs could not be used to their full potential due to training shortfalls. These are the only systems that provide precision attack capability from a fighter aircraft, and they represent the vast bulk of the total precision capability from all aircraft. By the end of 2007, all of the weapon control pods, support equipment and 20% of the weapon data terminal inventory could be modified to operate with a new set of frequencies. By the end of 2011, modification of the remaining weapon data terminals could be completed, assuming funding is available by FY02.

6.2.5 Other Systems

6.2.5.1 Corps of Engineers

Since the fixed point-to-point microwave links tend to be in remote areas, sharing should not present a problem. For those links near population centers or IMT-2000 systems, frequency sharing could be coordinated; otherwise, the link will have to be relocated in the spectrum. Band segmentation is acceptable as long as the microwave system is capable of operating in that portion of the band. This should apply to individual links, not the microwave system as a whole. Those links situated in a high-density IMT-2000 environment may need to be relocated in the spectrum. During any relocation, the current link must be kept operational until the new link is ready for cutover to prevent remote facilities from being unmonitored.

6.2.5.2 Land Warrior

Any sharing or segmentation option would require the Army, in conjunction with the IMT-2000 industry, to develop acceptable frequency use coordination procedures. Although this option appears attractive, the restrictions for sharing, such as limiting operations, locations, and link length, may inhibit the full use of this system by the Army. The Army's policy is to train as it fights; thus, limiting the size and scope of the training exercises violates this mandate. Also, Army Guard and Reserve unit training at home locations will be similarly affected. Fully vacating the band requires a system redesign and delays fielding the system.

6.2.5.3 Combat Identification for the Dismounted Soldier

Like Land Warrior, any sharing or segmentation option would require the Army, in conjunction with the IMT-2000 industry, to develop acceptable frequency use coordination procedures with the same impacts. Fully vacating the band requires a system redesign and delays fielding the system. The current operational impact is none, but delaying the fielding of the system may increase the likelihood of continued fratricide during future conflicts.

6.2.5.4 Pointer Unmanned Aerial Vehicle

Sharing may be acceptable and possibly workable but would require the Army, in conjunction with the IMT-2000 industry, to develop frequency use coordinating procedures. There may be restrictions for use that will limit the effectiveness of the system. Vacating the band would require identifying a new comparable band and equipment modification. Overall operational impact is minimal since only four models have been made so far. However, a change will delay fielding and use by Army infantry units, Air Force security forces, and NASA launch facilities monitoring.

6.2.5.5 Aberdeen Test Center

Without any mitigation, interference from IMT-2000 users operating at the same frequencies would disrupt the acquisition of data in support of the testing of military vehicles and equipment, essentially shutting down the test range. Segmentation will require modification or replacement of the range equipment. Additional frequencies must be made available and selected to eliminate interference with the current frequencies. Unless additional spectrum is allocated and current regulatory protections extended until new equipment is procured and fielded, range operations will be affected adversely.

6.2.5.6 TOSS

If mitigation from IMT-2000 is not used or the system is not replaced, TOSS would be rendered non-operational. Without the feedback from TOSS, range scoring would revert to manual methods. This inability to produce near-instantaneous feedback negatively affects the quality of crew training. Training missions involving multiple bombing runs would not have the benefit of feedback from previous ordnance drops to correct any deficiencies before the next drop. Aircrew proficiency in weapons delivery will be reduced.

6.3 ALTERNATE BANDS

Alternate bands identified in the study plan (2025-2110 MHz, 2200-2290 MHz, 4.4-5.0 GHz and 7-8 GHz) were evaluated to investigate the potential for housing DoD systems that may be displaced through accommodation of IMT-2000. Review indicates these bands could not accommodate the introduction of the additional non-space systems without operational degradation to and from critical systems such as the Cooperative Engagement Capability, the Defense Satellite Communication System, DoD satellite downlinks, and numerous fixed and mobile operations. The 2025-2110 MHz band may be feasible for the introduction of the DoD satellite operations functions but there are specific regulatory issues that must be addressed. Although other bands were not evaluated in this report, the availability of sufficient comparable spectrum is unlikely in light of the ever-growing demand and competition for spectrum access. Finally, availability of comparable spectrum must be certified in accordance with NDAA 2000 prior to any reallocation decision involving some or all of the 1755-1850 MHz band.

In assessing the feasibility of sharing or segmentation of the designated band, or migration out of the band, this report addressed only existing and planned DoD systems. Given the growing demand for spectrum to support information-intensive operations, it is highly likely that new DoD requirements for this band and other DoD bands will arise. Thus the full impact to DoD of surrendering all or a portion of the band may be greater than the assessment provided in this report.

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APPENDIX A – IMT-2000 SYSTEM DESCRIPTION

The greater portion of the International Mobile Telecommunications for the Year 2000 (IMT-2000) system description presented below has been provided by the Federal Communications Commission (FCC). The last part of the system description presents specific technical parameters for selected mobile wireless technologies. These technologies were selected primarily because more technical data was available to describe these systems. The selection of these technologies for use in this assessment does not represent an endorsement or advocacy of those systems. Some of the IMT-2000 parameters used in the assessments were calculated using communications theory and represent notional parameters rather than the characteristics of existing hardware. The parameters contained in this appendix were used in the assessment to help establish the scope of sharing issues. Calculated distances, signal levels, and margins are principally intended to assist in further analyses and to help initiate dialogue between government and industry interest groups.

IMT-2000 and third-generation (3G) services are the names commonly used to refer to the next-generation mobile wireless telecommunications services. The 3G family of services, and the systems that will provide them, are intended to reflect a high degree of commonality and are to be compatible with each other. These services will support mobile and fixed users employing a wide range of devices including small pocket terminals, handheld telephones, laptop computers, and fixed-receiver equipment. Some International Telecommunication Union (ITU) Member States and Sector Members envision 3G services to be ubiquitous throughout the globe, as available in a remote part of a developing country as they are in an urban area in a highly developed country. The radiotransmission technologies (RTTs) providing for standardized 3G air-interfaces were initially agreed upon in November 1998 by the ITU's Radiocommunication Sector (ITU-R) Task Group 8/1 and were adopted as Recommendation M.[1] Sector Members and Member States are actively working in the ITU's Telecommunication Standardization (ITU-T) Sector to develop 3G signaling and communication protocols, network requirements needed to support expected 3G services, and service definitions for IMT-2000 applications. Table A-1, derived from ITU-T Draft Recommendation Q.1701,[2] describes selected essential capabilities of IMT-2000 systems.

[1] ITU-R Recommendation M. [IMT.SPEC], ITU-R Radiocommunication Assembly, Istanbul, Turkey, May 2000.
[2] ITU-T Draft Recommendation Q.1701, Geneva.

Table A-1. IMT–2000 Services/Capabilities

Capabilities to support circuit and packet data at high bit rates: - 144 kb/s or higher in high mobility (vehicular) traffic - 384 kb/s or higher for pedestrian traffic - 2 Mb/s or higher for indoor traffic
Interoperability and roaming among IMT–2000 family of systems
Common billing/user profiles: - Sharing of usage/rate information between service providers - Standardized call detail recording - Standardized user profiles
Capability to determine geographic position of mobiles and report it to both the network and the mobile terminal
Support of multimedia services/capabilities: - Fixed and variable rate bit traffic - Bandwidth on demand - Asymmetric data rates in the forward and reverse links - Multimedia mail store and forward - Broadband access up to 2 Mb/s

A.1 IMT-2000 SYSTEM CHARACTERISTICS

During preparations for the World Radiocommunication Conference 2000 (WRC 2000), the United States (US) committed to studying the feasibility of using the 1755-1850 MHz and 2500-2690 MHz bands (or parts thereof) for IMT-2000 operations. It was understood that such a study would include determining the impact of the operation of IMT-2000 systems on the systems already authorized to operate in these bands. The 1755-1850 MHz band is used in the US to support Government services, mostly military space operations, air combat training missions, and tactical communications operations. The 1710-1755 MHz portion of the 1700/1800 MHz band identified at WRC 2000 is currently in the process of becoming available for commercial use and it could be made available for IMT–2000 services. The 1850-1885 MHz portion of the same IMT-2000 band is already used to support personal communications services (PCS) operations in the US. The 2500-2690 MHz band is used to provide instructional television fixed services (ITFS) and multipoint distribution services (MDS) throughout the US.

In order to determine the impact of operating IMT-2000 systems in bands that are encumbered, it is necessary to assess to what degree the proposed and incumbent systems can co-exist in the same band. Stated in simplistic radio engineering terms, it is necessary to determine whether or not harmful interference is generated into one of the systems (incumbent or proposed) by the operation of the other(s). Furthermore, if it is determined that harmful interference is likely to occur, it is desirable to isolate the conditions under which it occurs and whether or not means exist to mitigate its effects and the costs associated with implementing such mitigation techniques.

The interference assessment mentioned above requires identification of the technical characteristics for the systems being studied and the ability to quantify the systems' performance. These characteristics are readily available for existing systems operating in the bands of interest. This is not the case however for all the parameters that are required to characterize IMT-2000 systems. These systems, many of which are in the planning or development stage, do not have well-defined or universally accepted values associated with every system parameter. Thus it is necessary to assume values for certain of the IMT-2000 system parameters that are to be used in the conduct of the interference studies. When assumptions had to be made concerning values to be used in characterizing IMT-2000 systems, an attempt was made to adopt values that are consistent with values documented in readily available material such as the reports and recommendations of the ITU-R, and reports or findings of industry-led working groups addressing IMT-2000 issues. Absent any other readily available information, FCC rules for second-generation (PCS) mobile systems were used as guides for 3G systems. In addition to values for the technical parameters themselves, it is also necessary to assume certain characteristics of the build-out of proposed IMT-2000 services, such as when they are likely to occur, whether there will be a time-phasing of the build-out, what regions of the globe are likely to support build-out earlier than others, and within a region, whether there will be a geographical preference i.e., urban versus suburban versus rural, for the build-out. These assumptions also were based on readily available material and information where possible.

In order to perform the compatibility assessments presented in the appendices, certain specific technical parameters needed. In these cases, communications theory and reviews of second-generation systems were used to help develop the needed parameters. Tables A-2 through A-5 present the final version of the technical parameters used in the calculations documented in the appendices. It should be noted that the assessments considered only one CDMA system simply to limit the scope of the initial assessment. Further analyses and discussions of sharing should consider all of the IMT-2000 technologies equally.

Table A-2. Characteristics of IMT-2000 Mobile Stations

Parameter	CDMA-2000	CDMA-2000	UWC-136 (TDMA)	UWC-136 (TDMA) GPRS/EDGE	W-CDMA
Carrier Spacing	1.25 MHz	3.75 MHz	30 kHz	200 kHz	5 MHz
Transmitter Power	100 mW	100 mW	100 mW	100 mW	100mW
Antenna Gain	0 dBi	0 dBi	0 dBi	0 dBi	0 dBi
Antenna Height	1.5 m	1.5 m	1.5 m	1.5 m	1.5 m
Body Loss	0 dB	0 dB	0 dB	0 dB	0 dBi
Access Techniques	CDMA	CDMA	TDMA	TDMA	CDMA
Data Rates Supported	144 kb/s	384 kb/s	30 kb/s 44 kb/s	384 kb/s	384 kb/s
Modulation Type	QPSK/BPSK	QPSK/BPSK	π/4-DQPSK 8-PSK	GMSK 8-PSK	QPSK
Emission Bandwidth					
-3 dB	1.1 MHz	3.3 MHz[f]	0.026 MHz	0.18 MHz	3 GPP
-20 dB	1.4 MHz	4.2 MHz	0.034 MHz	0.22 MHz	TS25.101
-60 dB	1.5 MHz	4.5 MHz	0.036 MHz	0.24 MHz	
Receiver Noise Figure	9 dB	9 dB	9 dB	9 dB	9 dB
Receiver Thermal Noise Level	-113. dBm[a] -105 dBm[b]	-109 dBm[a] -100 dBm[b]	-121 dBm[a]	-113 dBm[a]	-109 dBm in 384 kb/s
Receiver Bandwidth					
-3 dB	1.10 MHz	3.30 MHz	0.03 MHz	0.18 MHz	N/A
-20 dB	1.6 MHz	4.7 MHz	0.04 MHz	0.25 MHz	N/A
-60 dB	3.7 MHz	11 MHz	0.09 MHz	0.58 MHz	N/A
E_b/N_o for $P_e = 10^{-3}$	6.6 dB	6.6 dB	7.8 dB	8.4 dB	3.1 dB*
Receiver Sensitivity[c]	-107 dBm	-103dBm	-113 dBm	-104 dBm	-106 dBm
Interference Threshold 1[d]	-119 dBm	-115 dBm	-127 dBm	-119 dBm	N/A
Interference Threshold 2[e]	-104 dBm	-100dBm	-111dBm	-103dBm	N/A

[a]In bandwidth equal to data rate
[b]In receiver bandwidth
[c]For a 10^{-3} raw bit error rate, theoretical E_b/N_o
[d]Desired signal at sensitivity, I/N = -6 dB for a 10 percent loss in range
[e]Desired signal 10 dB above sensitivity, S/(I+N) for a 10^{-3} bit error rate (BER)
[f]Shaded values were estimated.
* Assumes E_b/N_o for $P_e = 10^{-6}$ without diversity
N/A – Not Available
3GPP – Third-generation Partnership Project
BPSK – Binary phase shift keying
DQPSK – Differential quadrature phase shift keying
EDGE – Enhanced date rates for GSM evolution
GMSK – Gaussian minimum shift keying
GPRS – General Packet Radio Service
GSM – Global System for Mobile Communications
PSK – phase shift keying
QPSK – Quadrature phase shift keying

Table A-3. Characteristics of IMT-2000 Base Stations

Parameter	CDMA-2000	CDMA-2000	UWC-136 (TDMA)	UWC-136 (TDMA) GPRS/EDGE	W-CDMA
Operating Bandwidth	1.25 MHz	3.75 MHz	30 kHz	200 kHz	5 MHz
Transmitter Power	10 W	10 W	10 W	10 W	10 W
Antenna Gain	17 dBi per 120 deg. sector	17 dBi per 120 deg. sector	17 dBi per 120 deg. sector	17 dBi per 120 deg. sector	17 dBi per 120 deg. sector
Antenna Height	40 m	40 m	40 m	40 m	40 m
Tilt of Antenna	2.5 degs down	2.5 degs down	2.5 degs down	2.5 degs down	2.5 degs down
Access Techniques	CDMA	CDMA	TDMA	TDMA	CDMA
Data Rates Supported	144 kb/s	384 kb/s	30 kb/s 44 kb/s	384 kb/s	384 kb/s
Modulation Type	QPSK/BPSK	QPSK/BPSK	π/4-DQPSK 8-PSK	GMSK 8-PSK	QPSK
Emission Bandwidth					
-3 dB	1.1 MHz	3.3 MHz[f]	0.026 MHz	0.18 MHz	3 GPP
-20 dB	1.4 MHz	4.2 MHz	0.034 MHz	0.22 MHz	TS25.104
-60 dB	1.5 MHz	4.5 MHz	0.036 MHz	0.24 MHz	
Receiver Noise Figure	5 dB	5 dB	5 dB	5 dB	5 dB
Receiver Thermal Noise Level	-117dBm[a] -109dBm[b]	-113 dBm[a] -104 dBm[b]	-125 dBm[a]	-117 dBm[a]	-113 dBm in 384 kb/s
Receiver Bandwidth					
-3 dB	1.10 MHz	3.3 MHz	0.03 MHz	0.18 MHz	N/A
-20 dB	1.67 MHz	4.7 MHz	0.04 MHz	0.25 MHz	N/A
-60 dB	3.7 MHz	11 MHz	0.09 MHz	0.58 MHz	N/A
E_b/N_o for $P_e = 10^{-3}$	6.6 dB	6.6 dB	7.8 dB	8.4 dB	3.4 dB*
Receiver Sensitivity[c]	-111 dBm	-107 dBm	-117 dBm	-108 dBm	-110 dBm
Interference Threshold 1[d]	-123dBm	-119dBm	-131 dBm	-123 dBm	N/A
Interference Threshold 2[e]	-108 dBm	-104 dBm	-115 dBm	-107dBm	N/A

[a]In bandwidth equal to data rate
[b]In receiver bandwidth
[c]For a 10^{-3} raw bit error rate, theoretical E_b/N_o
[d]Desired signal at sensitivity, I/N = -6 dB for a 10 percent loss in range
[e]Desired signal 10 dB above sensitivity, S/(I+N) for a 10^{-3} BER
[f]Shaded values were estimated.
* Assumes E_b/N_o for $P_e = 10^{-6}$ without diversity
N/A = Not Available

Table A-4. IMT-2000 Traffic Model Characteristics[a]

Parameter	Value
Traffic Environments	Rural Vehicular Pedestrian In-building (Central business district)
Maximum Data Rates	Rural - 9.6 kb/s Vehicular - 144 kb/s Pedestrian - 384 kb/s In-building - 2 Mb/s
Cell Size	Rural - 10 km radius Vehicular - 1000 m radius Pedestrian - 315 m radius In-building - 40 m radius
Users per cell during busy hour	Rural - not significant Vehicular - 4700 Pedestrian - 42300 In-building - 1275
Percent of total uplink traffic >64 kb/s during busy hour	Rural - not significant Vehicular - 34% Pedestrian - 30% In-building - 28%
Percent of total downlink traffic >64 kb/s during busy hour	Rural - not significant Vehicular - 78% Pedestrian - 74% In-building - 73%
Average number of users per cell per MHz during busy hour assuming frequency duplex operation	Rural - not significant Vehicular < 64 kb/s - 16 > 64 kb/s - 4 Pedestrian < 64 kb/s - 150 > 64 kb/s - 64 In-building < 64 kb/s - 4 > 64 kb/s - 2

[a] Values in the table are for a mature network.

Table A-5. Rate of IMT-2000 Network Deployment[a]

	Calendar Year		
Local Environment	2003	2006	2010
Urban	10%	50%	90%
Suburban	5%	30%	60%
Rural	0%	5%	10%

[a] For some interactions the potential for interference will be influenced by the degree to which IMT-2000 networks are built out. This table identifies assumptions that will be used in the assessments with respect to the degree to which US IMT-2000 networks are developed following the granting of licenses. The levels of aggregate emissions for a fully mature IMT-2000 environment were taken from ITU-R 687.2 or other reference material as appropriate.

APPENDIX B – POTENTIAL INTERFERENCE TO AND FROM SATELLITE OPERATIONS

B.1 OPERATIONAL MISSION OVERVIEW

B.1.1 Satellite Operations Mission Overview

The United States (US) national security depends in significant measure on vital information provided by Department of Defense (DoD) and other critical, high priority US Government satellites. Satellite operations (SATOPS) allow for the control of more than 120 satellites and their payloads, transmission of mission data, and functions required to enable pre-launch, launch, and early orbit activities; on-orbit operations; anomaly resolution (emergency operations); and end-of-life management. The DoD performs Telemetry, Tracking, and Commanding (TT&C) SATOPS functions through ten Air Force Space Command (AFSPC) satellite control sites and through three Navy TT&C stations within the US and Possessions (US&P). The DoD also performs SATOPS functions outside of the US&P. This includes the Air Force Satellite Control Network (AFSCN) common user sites and dedicated Defense Support Program (DSP) and Global Positioning System (GPS) networks. TT&C is conducted via the space ground link subsystem (SGLS). Satellite control functions are absolutely critical to the operations of the spacecraft and payload. Without such control, satellites that provide for missile warning, navigation, military communications, weather, and intelligence, surveillance, and reconnaissance (ISR) would be jeopardized. The National Command Authority, Combatant Commanders, Services, and national level decision-makers would be severely impacted by a reduction or loss of the capability provided by these systems. In addition, other agencies, such as the Federal Aviation Administration (FAA), the National Aeronautics and Space Administration (NASA), and commercial interests, would be adversely impacted as well as Allied forces.

Because of the vital information provided to the highest levels of the US Government by SATOPS systems, and the associated spacecraft, the potential impacts resulting from any degradation or loss of these systems must be carefully considered. The following factors were taken into account when evaluating potential impacts:

1. TT&C functions are critical to the control and maintenance of spacecraft. S-band offers physical advantages for TT&C operations, particularly in the areas of launch, early orbit, and anomaly resolution.

2. Most DoD on-orbit satellites operate on one discrete crystal-controlled frequency that cannot be changed after launch. Only a few satellites are capable of receiving commands on more than one frequency.
3. Satellite lifetimes often significantly exceed the design lives.
4. National and international satellite frequency registrations and coordination are completed over a period of years. Frequency changes to satellites scheduled for near-term launch may be unable to secure the protection that has been achieved via these regulatory actions.
5. It will be at least three years before a space-qualified crypto-enabled dual or multi-band satellite transponder is in production**.**
6. It will be 4-8 years before registration and regulatory actions for any additional SATOPS uplink frequency band are completed. There is no guarantee that all national and international frequency coordination will be successfully completed.

B.1.2 Mission Overview of Satellites Supported by SATOPS

The following paragraphs provide a mission overview for several satellite systems supported by SATOPS. This section is not intended to be a complete list of all satellite systems supported by SATOPS.

B.1.2.1 Global Positioning System

The Global Positioning System (GPS) provides navigational data and precise time transfer capability to military and civilian users all over the world. Uses of GPS include search and rescue, satellite radionavigation for aircraft, ship and terrestrial based navigation, communications, agriculture, and recreation. US Armed Forces utilize GPS for precision guided munitions, navigation for aerial, ground, sea-based, and underwater platforms, unmanned aerial and sea platforms, and Combat Survivor Evader Locator (CSEL) for Search and Rescue (SAR) operations. In addition to its navigation and timing missions, GPS provides essential nuclear detonation (NUDET) detection data integral to the United States Nuclear Detonation Detection System (USNDS) mission. USNDS utilizes GPS data to support Integrated Threat Warning and Attack Assessment, Nuclear Force Management, and Treaty Monitoring missions. The nominal GPS operational constellation consists of 24 satellites that orbit the earth once every 12 hours. GPS relies solely upon the 1755-1850 MHz frequency band for TT&C and mission upload capabilities.

The GPS constellation operates at Medium Earth Orbit (MEO). Currently, all Block II/IIA satellites and five of the twenty Block IIR satellites have been launched with the last IIR satellite to be launched in July 2006. With about 10 years average life of GPS satellites launch rates of two to four satellites per year are planned in order to sustain the GPS constellation. A total of 12 Block IIF satellites are being built. The launch of the first and the last IIF satellite are scheduled to be in January 2006 and January 2010 respectively. The first of the Block III satellites, that are being defined, is planned to be launched in January 2009.

The GPS ground segment consists of a master control station with 4-ground antennas and 6 monitor stations. The ground antennas currently use SGLS channel 6 with uplink frequency of 1783.74 ± 2 MHz to provide space vehicle (SV) commands, navigation message uploads, state-of-health operations and anomaly resolution.

The ground segment also uses AFSCN remote tracking stations to support satellite early orbit operations, anomaly resolution and as backups to the GPS ground antennas (GAs).

There is no planned retirement of the GPS constellation, but replacement satellites are scheduled for launch well past 2010. Some of these satellites have already been built and are ready for launch. Others are on the assembly line or in the planning stage.

B.1.2.2 Defense Satellite Communications System

The Defense Satellite Communications System (DSCS) is an integral component of the global Defense Information and Services Network (DISN). The DSCS, consisting of earth, space, and control segments and numerous subsystems, provides a reliable, high-capacity, quality communications capability in support of peacetime, contingency, and wartime operations. The DSCS is a geosynchronous satellite based system engineered and configured to provide vital command, control, and communications (C3) service including antijam connectivity for a number of high priority circuits to the US and Allied forces throughout the world. Specifically, the DSCS provides high availability communications services between the National Command Authorities (NCA) and the Combatant Commands; among the Combatant Commanders and their service component commands; between component commands and their organic combat forces; and, among early warning and sensor sites and command centers. DSCS relies solely upon the 1755-1850 MHz frequency band for TT&C capabilities.

B.1.2.3 Milstar

The Milstar satellite is the space element of a communications network comprised of a series of advanced satellites linked to mobile ground terminals providing assured command and control (C2) capabilities to US forces worldwide. The system provides undeniable connectivity, antijam communications and interoperability for multi-service coordination. These features are crucial to successful operations on the modern battlefield and are not available through existing military communications networks. New third-world threats and regional conflicts require rapid command and control capability providing multi-service interaction, fast deployment, and timely intelligence updates. Milstar provides the NCA and DoD users with worldwide survivable extremely high frequency communications. The system is flexible; on-board processing can reconfigure networks to suit evolving command and control requirements. Satellite crosslinks and onboard point-to-point routing offer direct connectivity between the NCA and deployed forces in the field. Advanced EHF is the follow-on to Milstar and will provide worldwide, secure, survivable satellite communications to US strategic and tactical forces and allied nations during all levels of conflict. It will sustain the military satellite communications architecture by providing connectivity across the spectrum of mission areas to include land, air, and naval warfare, special operations, strategic nuclear operations and defense, theater missile defense, space operations, and intelligence. Milstar conducts routine TT&C operations in mission bands but relies on S-band for launch, early orbit checkout and anomaly resolution.

B.1.2.4 Defense Support Program

The geosynchronous Defense Support Program (DSP) satellites help protect the US and its allies by detecting missile launches, space launches, and nuclear detonations. The DSP satellites use an infrared sensor to detect heat from missile and booster plumes against the Earth's background. Numerous improvement projects have enabled DSP to provide accurate, reliable data in the face of evolving missile threats. On-station sensor reliability has provided uninterrupted service well past their design lifetime. Recent technological improvements in sensor design include above-the-horizon capability for full hemispheric coverage and improved resolution. Increased on-board signal-processing capability improves clutter rejection. Enhanced reliability and survivability improvements were also incorporated. DSP relies solely upon the 1755-1850 MHz frequency band for TT&C. The Space-Based Infrared System (SBIRS) is the follow-on to DSP, but DSP operations will continue through 2020.

B.1.2.5 Midcourse Space Experiment

The Midcourse Space Experiment (MSX) satellite and its associated ground support infrastructure provide deep space surveillance. The MSX space-based system improves AFSPC mission of collecting data related to deep space orbits of military and commercial satellites without the limitations inherent in ground systems. These ground system limitations include location sensitivity, dependence on weather, and time of day requirements. MSX has helped to increase our revisit rates on militarily significant objects by 50 percent and has helped to reduce the list of lost satellites by 80 percent. It has enabled the development of standardized search techniques. MSX relies solely upon the 1755-1850 MHz frequency band for TT&C capabilities. There is currently no planned replacement for the MSX program when it flies out, circa 2006.

B.1.2.6 Defense Meteorological Satellite Program

The Defense Meteorological Satellite Program (DMSP) provides timely global and infrared cloud data and other meteorological, oceanographic and solar-geophysical data vital to DoD warfighting operations. The DMSP system consists of operational satellites in a near polar orbiting, sun synchronous orbit at an altitude of approximately 830 km. The current DMSP constellation consists of five spacecraft. On-board sensors record environmental data which is stored onboard and later relayed to strategic users through the use of several worldwide ground tracking stations. Military weather forecasters use this data to monitor and predict regional and global weather patterns, including the presence of severe thunderstorms, hurricanes, and typhoons. This information is used by meteorologists and plays a significant role in the planning of US military operations worldwide. DMSP also provides worldwide, real-time weather data to small tactical terminals in the battlefield.

The DMSP satellites also measure local charged particles and electromagnetic fields to assess the impact of the ionosphere on ballistic missile early warning radar systems and long-range communications. Additionally, this data is used to monitor global auroral activity and to predict the effects of the space environment on military satellite operations.

A convergence effort of military and civilian weather satellites has formed a single, converged national environmental satellite system, National Polar-orbiting Operating Satellite System (NPOESS), scheduled for launch in the 2007-2010 time frame. The command, control and communications for the DMSP have been combined with the control for Department of Commerce (DoC) satellites. In June 1998, DoC took over the primary responsibility for flying both satellites.

B.1.2.7 GEOSAT Follow-On

The Geostationary Satellite (GEOSAT) Follow-On (GFO) system provides global ocean surface height, significant wave height and wind speed measurements to Navy ship and shore (AN/SMQ-11) terminals in real time. Data is also stored on-board and later downlinked to the Naval Oceanographic Office for input to critical oceanographic and meteorological models. These models are used to plan naval operations, including ship routing, and to develop undersea environmental profiles that are critical to submarine operations. GFO relies solely upon the 1755-1850 MHz frequency band for telemetry and commanding functions.

B.1.2.8 Fleet Satellite Communications and Ultra High Frequency Follow-On

The Fleet Satellite Communications (FLTSAT) and Ultra High Frequency Follow-On (UFO) Satellite Communications systems provide a variety of communications capabilities to the DoD and other government agencies in support of a multitude of missions. These missions include supporting communications for the NCA, Joint Chiefs of Staff, and the Unified Combatant Commands.

The FLTSAT and UFO satellites support several different types of communications systems. These systems are Ultra High Frequency (UHF), Extremely High Frequency (EHF) and Global Broadcast Service (GBS). A brief technical description of these systems follows.

UHF Communications Systems support mobile users using small, inexpensive, low-power terminals, omnidirectional antennas, and operate in most weather conditions and under foliage. They typically function in a “bent-pipe” (frequency translation) mode, but one package, the Air Force Satellite Communications System (AFSATCOM), has a processing capability. The users of this system use Demand Assigned Multiple Access (DAMA) standards to maximize the use of the available channels. UHF communications on FLTSAT and UFO provide worldwide coverage (no polar coverage).

EHF Communications Systems support users requiring protected communications. EHF system characteristics include resistance to jamming and scintillation and provide Low Probability of Intercept, Detection, and Exploitation (LPI/LPD/LPE). These are processed systems using spread spectrum technology. The EHF system on UFO is capable of cross-banding to the UHF system on the satellite to support Fleet Broadcast. The EHF systems on FLTSAT and UFO provide worldwide coverage.

The GBS system supports mobile users with high bandwidth requirements for data. GBS is a broadcast system only, providing preplanned data products to a theater in a manner similar to direct broadcast television technology. There is a provision for receiving specific data products through the system but requires an alternate communications path back to the data providers. The characteristics of this system include high power transponders, small antennas for the receiver, multimedia data, and variable data rates. This system functions as a “bent-pipe.” GBS is presently available on three UFO satellites, providing partial worldwide coverage.

FLTSAT/UFO relies upon the 1755-1850 MHz frequency band for primary TT&C. FLTSAT and UFO will eventually be supplemented then replaced by the Mobile User Objective System (MUOS). First launch of a MUOS satellite is scheduled to occur in the 2007-2008 time frame.

B.1.2.9 NATO IV/Skynet 4

The North Atlantic Treaty Organization (NATO)/Skynet Systems provide communications to the British and NATO military forces. The NATO/Skynet networks consist of earth, space, and control segments and numerous subsystems and provide a reliable, high-capacity, quality communications capability in support of peacetime, contingency, and wartime operations. The US satellite command and control support is provided under international agreements. For US provided support, NATO/Skynet relies solely upon the 1755-1850 MHz frequency band for TT&C capabilities.

B.1.2.10 SMC/TE

The Air Force Space and Missile Systems Center Test and Evaluation (SMC/TE) directorate operates a series of research and development satellites and ground capabilities to test/demonstrate new technology and operational concepts. SMC/TE relies on SGLS for launch, on orbit control, and mission data for these satellites.

Several research and development (R&D) satellites using the SGLS uplink band (i.e., ARGOS and TSX-5) are currently in orbit but should reach end-of-life before 2003. However, additional R&D satellites are currently planned for launch in the 2003-2004 time frame. These include CORIOLIS, Cloudsat, and Communications/ Navigation Outage Forecast System (C/NOFS). The CORIOLIS mission, performing risk reduction for the NPOESS program, is scheduled to launch in mid-2002 with a minimum lifetime of three years. Cloudsat is a multi-year interagency mission, led by NASA, with DoD support that will profile cloud cover from space. Also, the C/NOFS is expected to launch in late 2003 with a minimum lifetime of three years. Both CORIOLIS and C/NOFS, which use the SGLS band, are expected to have operational utility to the warfighter following completion of their R&D objectives but should reach end-of-life before 2010.

B.1.2.11 Advanced EHF

The Advanced Extremely High Frequency (Advanced EHF) is the follow-on to Milstar and will provide worldwide, secure, survivable satellite communication to US strategic and tactical forces and International Partners during all levels of conflict. It will sustain the Military Satellite Communications architecture by providing connectivity across the spectrum of mission areas to include, land, air, and naval warfare; special operation; strategic nuclear operations; strategic defense; theater missile defense; and space operations and intelligence.

B.1.2.12 Wideband Gapfiller

The DSCS satellites provide responsive Super High Frequency (SHF) Wideband and Antijam communication supporting high data rate, long haul and strategic and tactical service worldwide. The objectives of the Wideband Gapfiller Satellite Program are to provide DoD wideband data services focused on tactical users and to augment existing DSCS and GBS (Global Broadcast System consisting of payloads on 3 UFO satellites) constellations.

B.2 SYSTEM DESCRIPTION

The DoD conducts SATOPS functions in the 1755-1850 MHz (uplink) and 2200-2290 MHz (downlink) bands to launch, checkout, and operate over 120 satellites flying in both geostationary and non-geostationary orbits. The Air Force, Navy, and Army, conduct satellite operations from several control nodes within the US&P and overseas. These control nodes communicate with satellites using a combination of global antenna networks. The DoD SATOPS uplink functions, which include the transmission of commanding and ranging signals, are performed in the 1755-1850 MHz band. Downlink telemetry data is passed via the 2200-2290 MHz band. The Air Force Satellite Control Network (AFSCN) and the Naval Satellite Operations Center (NAVSOC) serve as the primary DoD common-user satellite control networks. The AFSCN performs the bulk of the satellite operations through a worldwide network of US Air Force ground stations and control centers which provide telemetry, tracking, and commanding (TT&C) services to DoD and other satellites. The AFSCN consists of two control nodes, Schriever AFB, CO, and Onizuka Air Station (OAS) at Sunnyvale, CA, plus eight Automated Remote Tracking Stations (ARTS) dispersed both within and outside the US. In addition, the US Air Force has mobile (transportable) satellite ground stations that deploy worldwide and perform satellite control functions.

The GPS dedicated ground control network consists of Ground Antennas (GA) and Monitor Stations (MS) which are used to command, receive telemetry, monitor the navigation signals and provide navigation mission data uploads to the satellite constellation. The MS passively track the GPS satellite navigation signals. Signals collected by the MS are processed at the Master Control Station (MCS). The MCS uploads the GPS satellites with corrected navigation information via the GPS-dedicated GA and one modified AFSCN remote training station (RTS) using the SGLS band. In addition to performing the navigation mission data upload function, the GPS dedicated GAs are also the principal facilities used to conduct the GPS TT&C function. GPS does use the AFSCN for LEO&A operations, the same as most other DoD satellite systems.

NAVSOC remote TT&C facilities include Laguna Peak near Point Mugu; CA, Detachment ALFA at Prospect Harbor, Maine; and Detachment CHARLIE at Finegayan, Guam. The Navy also conducts TT&C operations from Blossom Point, MD, and Quantico, VA.

Figure B-1 depicts the locations of the fixed US&P DoD Satellite control stations. Table B-1 lists the DoD US&P Fixed satellite control nodes. Table B-2 lists the DoD US&P tracking and control antennas.

Table B-1. US&P DoD Fixed Satellite Control Nodes

Agency/Program	Location
Air Force Satellite Control Network	Schriever Air Force Base (AFB), CO Onizuka Air Force Station (AFS), CA
Defense Support Program	Buckley Air National Force Base (AFB), CO
Research, Development, Test and Evaluation Spacecraft	Kirtland AFB, NM
Navy Satellite Operations Centers	Naval Research Laboratory Blossom Point Field Site, MD Naval Satellite Operations Center at Pt. Mugu Naval Air Station, CA Naval Satellite Operations Center, Detachment Delta, Schriever AFB, CO
Global Positioning System (GPS Master Control Station (MCS)	Schriever AFB, CO Vandenberg AFB, CA

Table B-2. US&P DoD Command, Control and Tracking Antennas

Agency/Program	Location
Air Force Satellite Control Network	- Guam Tracking Station (GTS) – Andersen AFB, Guam - Colorado Tracking Station (CTS) – Schriever AFB, CO - Vandenberg Tracking Station (VTS) - Vandenberg AFB, CA - Hawaii Tracking Station (HTS) – Kaena Pt., Oahu, HI - New Hampshire Tracking Station (NHS) - New Boston Air Force Station (AFS) - Transportable antennas - Vehicle Checkout Facility – Cape Canaveral, FL - Camp Parks Communications Annex – Pleasanton, CA
Global Positioning System	- Ground Antenna – Cape Canaveral, FL - Ground Antenna – Kwajalein Island
Milstar (Milsatcom)	- Contractor Facility – Sunnyvale, CA
Defense Support Program	- Buckley AFB, CO
Navy Satellite Control Network	- Laguna Peak, CA - Prospect Harbor, ME - Finegayan, Guam - Blossom Point, MD

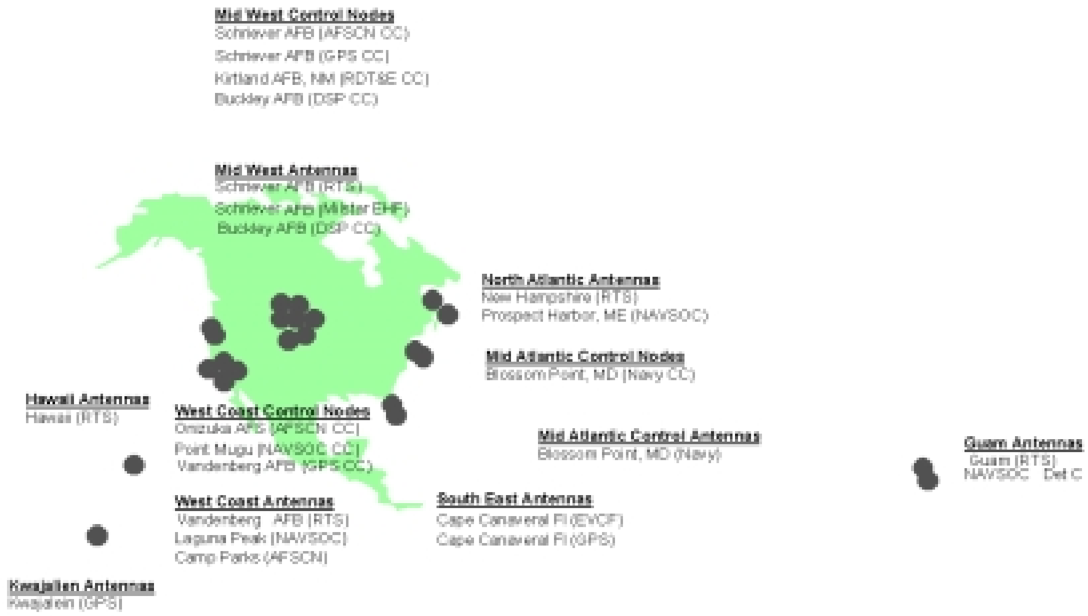

Figure B-1. Locations of the US&P DoD SATOPS Ground Stations

Table B-3 lists the 20 center frequencies for the standard AFSCN uplink frequency plan. It should be noted that most SATOPS uplinks conform to the 20-channel plan; however, select missions tune to channels in-between those reflected in the standard plan.

Table B-3. AFSCN SATOPS Uplink Frequency Plan

S-band Channel	Uplink Frequency Transmission (MHz)	S-band Channel	Uplink Frequency Transmission (MHz)
1	1763.720703	11	1803.759766
2	1767.724609	12	1807.763672
3	1771.728515	13	1811.767578
4	1775.732422	14	1815.771484
5	1779.736328	15	1819.775391
6	1783.740234	16	1823.779297
7	1787.744141	17	1827.783203
8	1791.748047	18	1831.787109
9	1795.751953	19	1835.791016
10	1799.755859	20	1839.794922

B.3 COST ISSUES

B.3.1 Satellites

DoD recently established the long-term goal of transitioning (no earlier than 2020 to 2025) the uplink frequency band for Launch, Early Orbit and Anomaly resolution (LEO&A) from 1761-1842 MHz to 2025-2110 MHz. In support of this goal, the DoD has included the requirement in two current and planned DoD satellite contracts for the satellites to carry a USB transponder. The costs to do this were not included in the cost estimates provided in this report. A final decision on the transition will be made after more detailed study and a determination if this band could provide the assured access required for DoD satellite operations.

GPS satellites use 1761-1842 MHz to both perform LEO&A and to upload their mission data. For the purposes of this report, GPS III, the next generation GPS space and controls segment will include a USB capability for LEO&A operations and a 5000-5030 MHz (5 GHz) capability to support upload of navigation mission data and “in band” commanding. All the costs both to the space vehicles and to the GPS ground stations to relocate to 5 GHz are attributable to IMT-2000 and are included here. The delta cost to change from SGLS to USB for the GPS III satellite is negligible and no costs for this are included in the report. No modifications to the Block II/IIA/IIR/IIF satellites with respect to TT&C capabilities are planned, so costs are not included for these. Those satellites will use SGLS until they fly out.

Any migration of DoD systems will not be feasible until at least 2010 or beyond. Hence, Table B-4 makes no cost distinction by introduction date. The costs of the segmentation and options differ by which SGLS channels are lost to DoD and which are maintained. Of course, total loss of the band is not possible for space systems until at least 2017 or beyond. Depending on the timing of the decision concerning the introduction of IMT-2000 into this frequency band, costs for the Wideband Gapfiller and Advanced EHF systems could vary greatly. The costs presented in Table B-4 for these programs reflect a decision date by July 2001. Should the decision go beyond that date, these two programs may incur substantial cost increases, which are not reflected in Table B-4.

Table B-4. Satellite Reimbursement Cost for Vacating the Band (TY$M)

	FY02	FY03	FY04	FY05	FY06	FY07	To Complete	Total
Milstar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wideband Gapfiller Satellite (WGS)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DSCS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DMSP	0.0	6.3	14.9	7.7	9.2	2.5	1.4	42.0
Advanced EHF	0.0	0.0	0.0	0.8	0.0	1.7	1.7	4.2
SBIRS High	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SBIRS Low	6.0	8.8	5.2	1.4	0.0	0.0	0.0	21.4
GPS	0.9	0.9	2.9	23.8	7.1	16.7	118.2	170.5
MUOS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
UFO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FLTSAT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**6.9**	**16.0**	**23.0**	**33.7**	**16.3**	**20.9**	**121.3**	**238.1**

B.3.2 Satellite Command and Control Ground Stations

The DoD currently has numerous programs which operate ground stations that broadcast over SGLS. The Air Force Satellite Control Network (AFSCN) is the primary system and supports TT&C activities for virtually all DoD systems as well as other agencies, civil users, and Allied nations. The US Navy Satellite Control Network controls various Navy satellites. GPS operates several of their own ground stations because, unlike other DoD satellite programs, GPS also uses SGLS to upload their mission data. DSP, and the follow-on program SBIRS High, have a critical early warning function and maintain their own SGLS ground system for TT&C to ensure their operations are not interrupted.

The proposed AFSCN/IMT-2000 mitigation options (band segmentation) require the local IMT-2000 service provider to implement a dynamic frequency allocation system. This system could sense if the local AFSCN site was emitting and, on what channel, and could then dynamically allocate its users to the unused portion of the band. Also, AFSCN could implement channel filters on its antennas to reduce out-of-channel emissions and finally, if necessary, could relocate the ground stations to remote sites. It is not possible to implement all of these ground station changes prior to 2003, or even 2006, but they could be completed by 2010. AFSCN costs for band sharing assume coordination zones and are for channel filters only. AFSCN costs for band segmentation/vacating the band include channel filters and ground station relocation.

The strategy of ground site relocation of some US&P sites would be a consideration with band segmentation; however, it is not clear that it will be possible to identify sites for which all of the necessary paperwork can be obtained by 2010. This is because it will be necessary to obtain BRAC permission to move, obtain regulatory and/or legislative protection of SATOPS use at the new site, and to obtain environmental permission for site development. Cost impacts for those issues have not been provided.

Tables B-5 and B-6 show the costs for both filtering and relocation of the ground stations, respectively.

Table B-5. Satellite Ground Segment Filtering Costs (TY$M)

	FY02	FY03	FY04	FY05	FY06	FY07	To Complete	Total
Ground Segment Filtering	**11.3**	**11.5**	**11.8**	**12.0**	**12.2**	**12.5**	**38.9**	**110**

Table B-6. Satellite Ground Segment Relocation Costs (TY$M)

	FY02	FY03	FY04	FY05	FY06	FY07	To Complete	Total
AFSCN	33.6	34.1	41.8	42.5	43.3	44.1	245.5	485.0
GPS	0.0	0.0	13.3	18.5	7.4	366.6	540.7	946.5
SBIRS High	49.3	68.6	38.8	11.4	2.5	2.5	50.7	223.8
GFO / NAVSOC	20.5	1.2	1.2	1.2	1.2	1.2	18.0	44.5
IMT-2000 Reimbursement	**103.4**	**103.9**	**95.1**	**73.6**	**54.4**	**414.4**	**854.9**	**1,699.8**

As discussed in the satellite section, GPS Block III plans to use USB for LEO&A and 5 GHz for navigation mission data uploads and "in band" commanding. SGLS will continue to be used for all TT&C operations and mission data uploads for the Block II/IIA/IIR/IIF satellites. Under the band sharing option there is no known cost impact. Similarly, since GPS operates on SGLS channel 6, options 2A and 3A (band segmentation) would allow DoD to retain channel 6 so there would be no cost impact to GPS. However, under band segmentation option 2B or 3B or if the entire band is lost, option 4, GPS would be required to move its mission data link to the 5 GHz band, which would entail substantial effort and cost. This move would be done in concert with the GPS III program and so would not differ significantly depending upon the introduction date of IMT-2000.

B.4 OPTION 1 – FULL BAND SHARING

B.4.1 Operational Impact

DoD must retain primary user status for SGLS SATOPS functions throughout the band for all on-orbit satellites until their end-of-life. Legacy satellite systems are expected to require SGLS support through 2030. Denying SATOPS the spectrum required to support on-orbit assets will result in a partial or complete loss of TT&C capability. This applies to any of the sharing, segmentation, or band vacating schemes. Denied spectrum access will result in varying degrees of impact to the spacecraft including orbit-positioning errors, loss of payload control leading to eventual malfunctions and mission failure, and ultimately, complete loss of the satellite. Mission capabilities for missile warning, navigation, military communications, weather, and intelligence, surveillance and reconnaissance would be severely impacted until such time as a combined satellite and ground station system in an alternate frequency band could be built and put into operational service. This would include impacts to military communications at all levels of conflict, Navy communications to the fleet, and national intelligence data, and military communications for our NATO Allies under international support agreements.

Assuming that spectrum access is assured, the operational impact to SATOPS capabilities is dependent upon two factors:

1. the impact to satellite uplink closure reliability as a result of the IMT-2000 emissions, and
2. the restrictions placed upon ground based uplink capability as a result of the mitigation techniques required to preclude EMI to IMT-2000 receivers.

Operational impact to TT&C uplinks from IMT-2000 emissions is expected in the time period 2006 and beyond when IMT-2000 system build-out has exceeded 50 % of ITU estimates for full capacity. In 2003, it is not expected that IMT-2000 build-out will be sufficient to impact SATOPS uplink operations. These results are based upon near-worst case but realistic uplink parameters. It should be noted that if uplinks were conducted from worst-case disadvantaged (size, power, restricted viewing, etc.) terminals using antennas smaller than 33 feet or lower transmitter powers, there is a potential for impact to link closure reliability in 2003. The degree of operational impact will vary as a function of the degree to which link closure is affected. It is expected that impact would occur for only a small set of systems and operating conditions, although at critical junctures such as launch or anomaly resolution, such impact would be critical.

In the 2006 and beyond timeframe, IMT-2000 emissions are expected to impact uplink closure reliability at all orbit heights with the greatest affect occurring at LEO (approximately 850 km) and medium earth orbit (MEO), approximately 20,000 km, orbit heights. Systems most impacted by this include GPS, DMSP, and certain ISR systems. Should link closure be degraded to the point where commanding cannot be performed, the impacts enumerated previous for denied spectrum access would occur. Note that there is no expected impact to MSX satellite in 2006 given that the satellite will have reached end of its predicted life.

Operational impacts on the SATOPS ground assets are generally limited to issues associated with the IMT-2000 RFI mitigation techniques. The primary mitigation technique exclusive to the IMT-2000 community is the establishment of coordination zones, areas surrounding SATOPS uplink sites within which IMT-2000 operations may be affected. The location and approximate size of these areas are illustrated in the technical assessment section of the report. Assuming SATOPS functions continue unencumbered at all current uplink locations, and that IMT-2000 systems accept the potential limitations within these coordination zones, no operational impact to DoD SATOPS ground assets is anticipated

Other IMT-2000 RFI mitigation techniques such antenna elevation angle restrictions and SATOPS uplink power restrictions offer limited benefit and in general prove operationally unacceptable due to impacts to satellite contact time and link margin.

Dynamic frequency reallocation, a technique where the IMT-2000 systems change frequencies in real time to take advantage of the SATOPS changing frequency requirements, may have varying impact on DoD ground-based SATOPS operations depending upon the specific implementation schemes. Techniques to implement this RFI mitigation scheme need to be explored in detail with the IMT-2000 community, however the impact to DoD operations may prove to be manageable.

In 2006 and beyond, the DoD will be continuing to work toward satellite control site upgrades; however, it will be necessary to continue operating on SGLS frequencies until all on-orbit satellites requiring SGLS commanding have reached their end of life.

By the 2010 time frame, two significant changes will occur:

1. most affected SGLS sites could be modified for SATOPS in an additional uplink band thus allowing the flexibility of alternate frequency use for more recent launches, (provided that no satellite or ground system program experienced delays) and
2. the IMT-2000 system build-out may have achieved levels that will quite likely result in the inability to reliably close the TT&C command uplink.

Regardless of the alternate frequency capabilities at the ground sites available in 2010, SGLS uplinks will still be required to control many on-orbit satellites. Legacy satellite systems are expected to require SGLS support through 2020-2025. By 2010 the likelihood for SATOPS uplink receiver degradation will increase as IMT-2000 nears full forecasted build out. Under these conditions, assured spectrum access alone will not preclude the impact to spacecraft/payload commanding and the associated satellite mission due to increased background power spectral density.

B.4.2 Technical Assessment

B.4.2.1 Interference from Ground Elements to IMT-2000

B.4.2.1.1 Assessment Approach

In order to assess the potential for interference to a geographically dispersed network of IMT-2000 fixed and mobile receivers, an automated model was used to generate received signal overlays as a function of transmitter and receiver parameters and terrain-dependent path loss. The results are displayed as a raster or grid of color-coded signal levels overlaid on a map. The basis for the terrain-dependent path loss calculations within the model is the Terrain-Dependent Path Loss Model (TIREM). This model considers obstructions due to terrain but does not consider additional losses due to man-made structures or foliage.

In recognition of the significant variations in SATOPS transmitter uplink and IMT-2000 receiver configurations, a parametric analysis was performed. For SATOPS uplink functions, minimum antenna elevation angles of 3, 5, and 10 degrees were selected for comparative analysis purposes only. However, 10 degrees is not acceptable from an operational perspective. Additional higher minimum elevation angles were not considered because the minimal benefit in sidelobe reduction was offset by the significant impact to operations. Based on current antenna configurations, significant sidelobe reduction is not realized until well outside of the mainbeam. These angles would be prohibitively large for typical SATOPS functions, particularly for those conducted on satellites flying in non-geostationary orbits.

For the IMT-2000 receivers, separate overlays were generated for the base stations and mobiles/portables in recognition of the differences in receiver antenna height, antenna gain, and interference threshold.

B.4.2.1.2 Analysis

The following equation was used to define the regions surrounding the SATOPS uplink sites where impact to IMT-2000 receivers may occur.

$$I = P_t + G_t + G_r - L_p - L_s - FDR$$

where

I = Assumed interfering signal level, at the IMT-2000 receiver input, in dBm
P_t = SATOPS transmitter power, in dBm
G_t = SATOPS transmitter antenna gain at the horizon, in dBi

G_r = IMT-2000 receiver antenna gain in the direction of the SATOPS transmitter, in dBi
L_p = Terrain-dependent path loss, in dB
L_s = IMT-2000 receiver system loss, in dB
FDR = Frequency-dependent rejection, in dB.

Given that the interference estimate varies as a function of the SATOPS transmitter/antenna configuration and IMT-2000 receiver susceptibility thresholds, a parametric assessment was performed for several representative SATOPS uplink sites. Table B-7 lists the SATOPS uplink sites included within this assessment. These sites were selected to represent a variety of functions, orbit types, and local terrain features over a geographically dispersed region. It is expected that the results achieved for these sites are generally representative of the potential for EMI at all SATOPS uplink sites.

Table B-7. SATOPS Uplink Sites Included in this Assessment

Terminal Name	Abbreviation	Alt Name	Location	Latitude/ Longitude	Number of Terminals	Terminal Size (feet)
Colorado Tracking Station	CTS	Pike	Colorado Springs, CO	38 48 21 N 104 31 43 W	1	33
New Hampshire Tracking Station	NHS	Boss	Manchester, NH	42 56 52 N 071 37 37 W	3	60 46 33
Onizuka Air Station	OAS	Sun	Sunnyvale, CA	37 24 25 N 122 0134 W	1	51
Eastern Vehicle Check-out Facility	EVCF	EVCF	Cape Canaveral, FL	28 27 29 N 080 34 32 W	1	23
Hawaii Tracking Station	HTS	Hula	Kaena Point, Oahu, HI	21 33 48N 158 14 54W	2	60 46
Guam Tracking Station	GTS	Guam	Anderson AFB Guam	13 36 54N 144 52 00E	2	60 46

Transmitter maximum powers in Table B-8 represent the maximum transmitter capability of the high power amplifier connected to the terminal. A minimum power of 100 Watts was selected to represent best-case EMI uplink powers under the assumption that link closure can be achieved at this level. In many instances, a transmit power of 250 Watts, 500 Watts, or even 1 kW is required for link closure to a healthy, stable, on orbit satellite. However, results from the overlays will indicate that several dB of variation in the transmit power assumptions will not change the conclusions that can be drawn from the data.

Antenna off-axis gains were determined from computer generated antenna patterns. Antenna off-axis gain at the horizon was calculated assuming 3, 5, and 10-degree minimum elevation angles. As discussed in the approach, these levels are considered to be within the range of acceptable values for analysis purposes. From an operations concept perspective, 3 degrees is acceptable, 5 degrees is acceptable for select missions, and 10 degrees is operationally unacceptable. Figures B-2 through B-5 are computer generated antenna patterns for the 60, 46, 33, and 23-foot antenna diameters. These figures were used to calculate the off-axis antenna gains at the 3, 5, and 10-degree minimum elevation angles."

Table B-8. SATOPS Model Inputs

Terminal	TX Powers (Watts)	Antenna Diameter (ft)	Antenna off-axis gain (dBi)			Effective Isotropic Radiated Power (EIRP) (dBm)		
			3º	5º	10º	3º	5º	10º
CTS	2.25K max/100 min	33	8	5	3	72/58	69/55	67/53
NHS	10K max/100 min 2.5K max/100 min 1K max/100 min	60 (A) 46 (B) 33 (DLT)	24 18 8	17 5 5	12 3 3	91/71 82/68 68/58	87/67 69/55 65/55	82/62 67/53 63/53
OAS	2K max/100 min	51 (DLT)	18	5	3	81/68	68/55	66/53
EVCF	2.25K max/100 min	23	23	16	12	87/73	80/66	76/62
HTS*	2K/500/100	46	18	No Analysis	3	81/75/68	No Analysis	66/60/53
Guam*	7Kmax/100 min	46**	18		3	90		59
(A), (B), and (DLT – Data Link Terminal) are designators used to differentiate between unique site locations. *Only a limited set of conditions were considered for the HTS and GTS sites. **The actual configuration for the Guam site is a 7K maximum power, with a 60-foot antenna. The 46-foot diameter was used for model inputs.								

Table B-9 lists the IMT-2000 data used to generate the received signal overlays. This data has been coordinated with the FCC and is consistent with IMT-2000 system specifications used to assess the other types of DoD systems in the band. Receiver interference thresholds are grouped into 10-dB bins from the most sensitive threshold provided (-121 dBm) up to greater than -71 dBm. This range of thresholds more than encompasses the region of acceptable interference values.

Table B-9. IMT-2000 Receiver Data

IMT-2000 Platform	Receiver Interference Thresholds Plotted (dBm)	Receiver Antenna Height (Meters)	Receiver Antenna Gain (dBi)
Fixed Base Stations	<-121 -111 to –121 -101 to –111 -91 to –101 -81 to –91 -71 to –81 > -71	40	17
Mobiles and Portables	<-105 -95 to –105 -85 to –95 -75 to –85 >-75	1.5	0

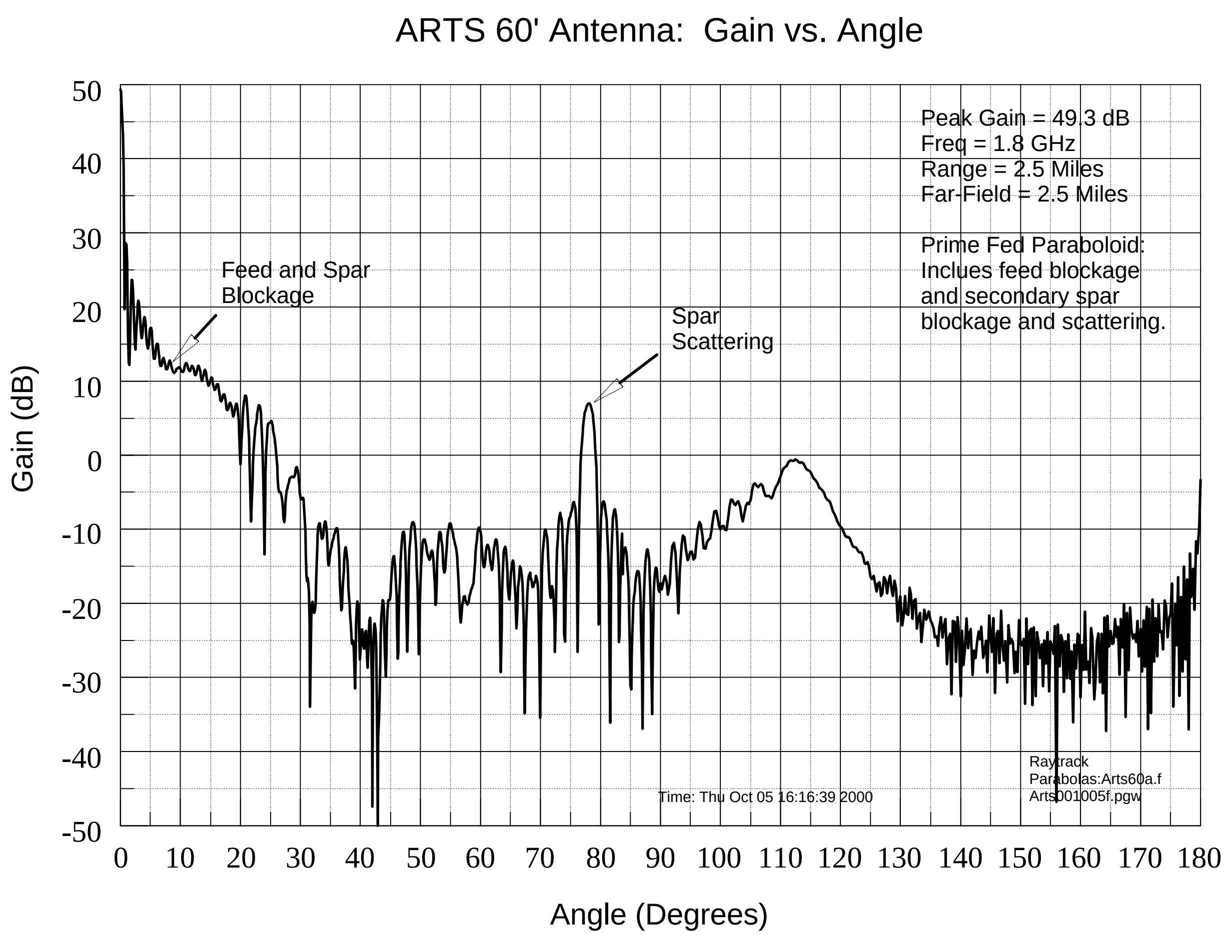

Figure B-2. Computer Generated Antenna Pattern for the Automated Remote Tracking Station (ARTS) 60-foot Antenna Diameters (Antenna Gain Values are in dBi)

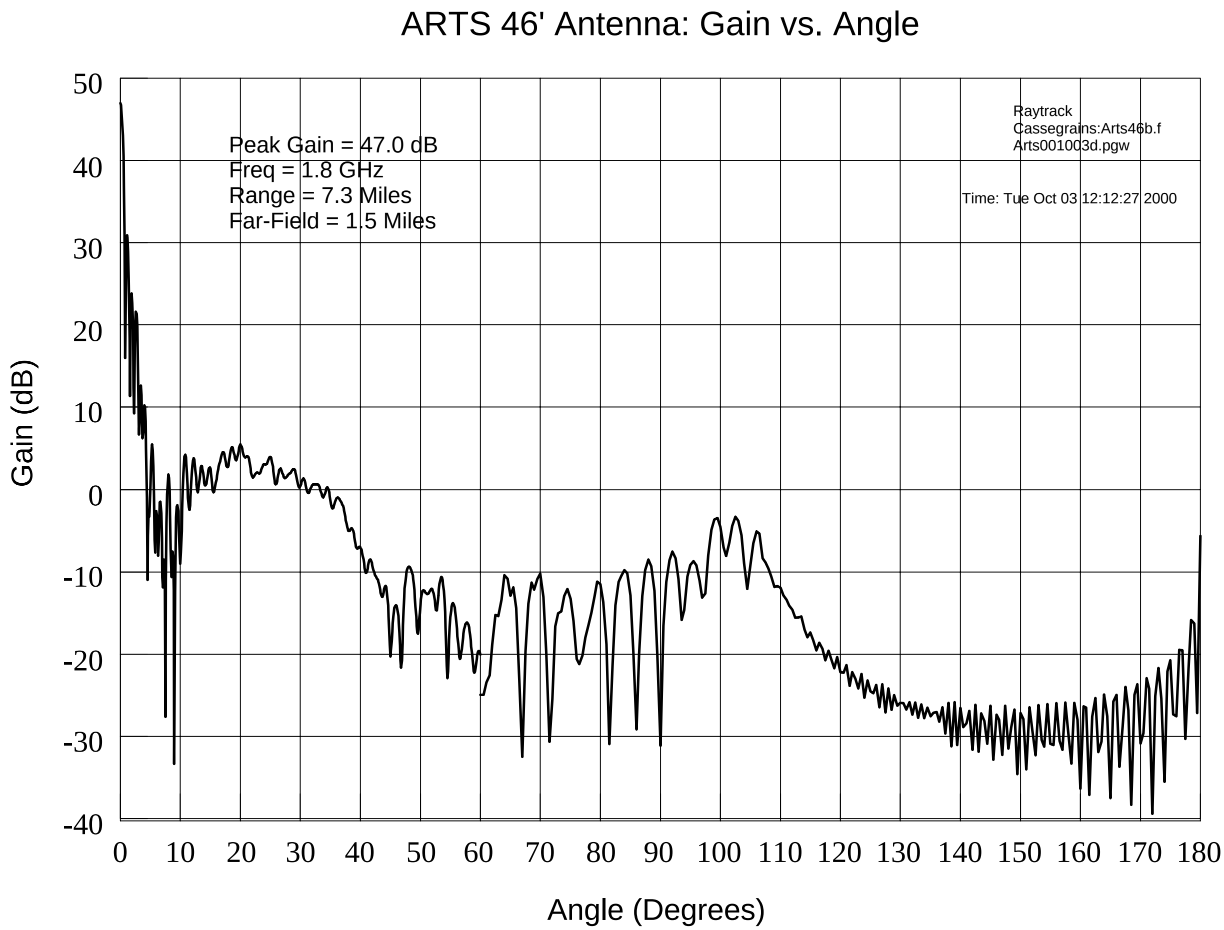

Figure B-3. Computer Generated Antenna Pattern for the 46-foot Antenna Diameters (Antenna Gain Values are in dBi)

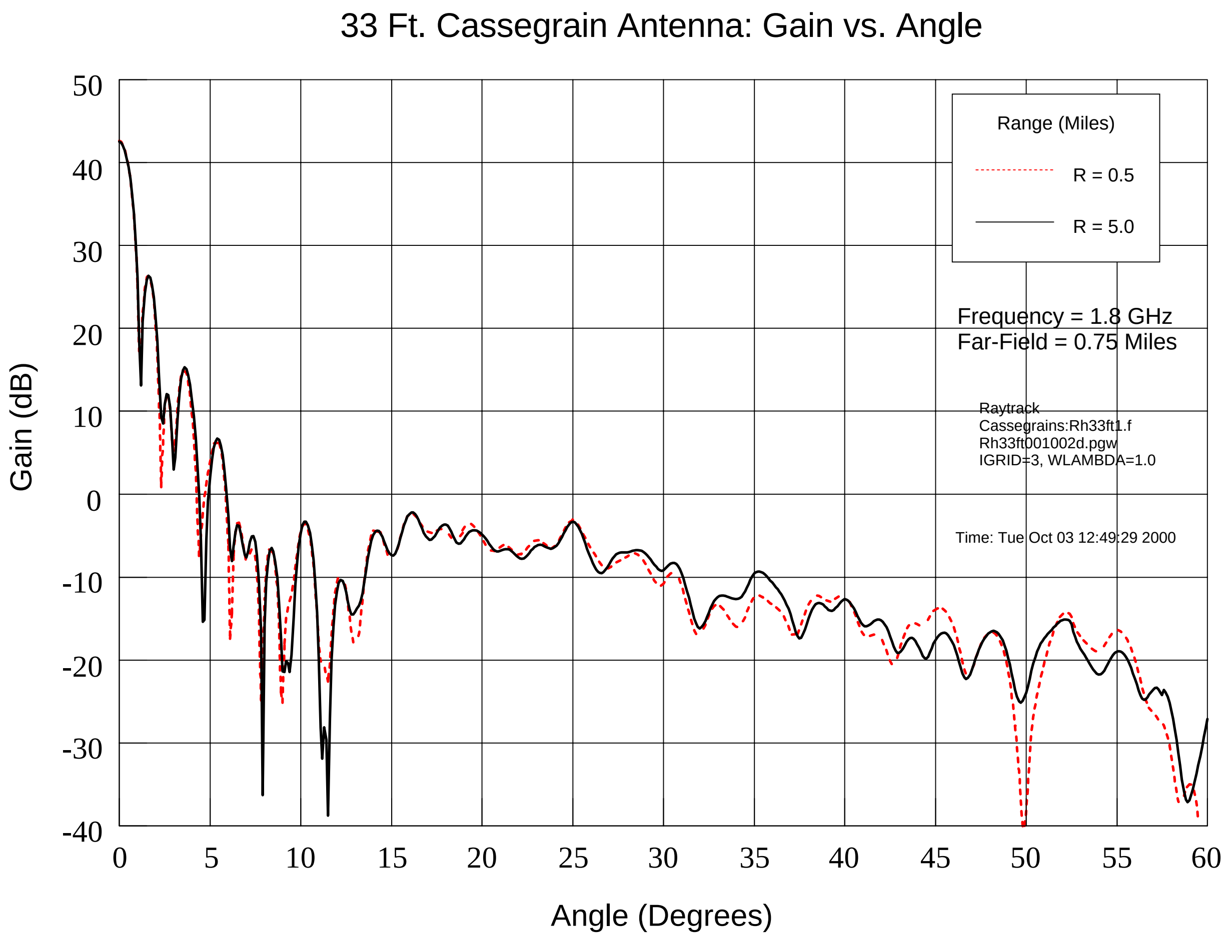

Figure B-4. Computer Generated Antenna Patterns for the 33-Foot Antenna Diameters (Antenna Gain Values are in dBi)

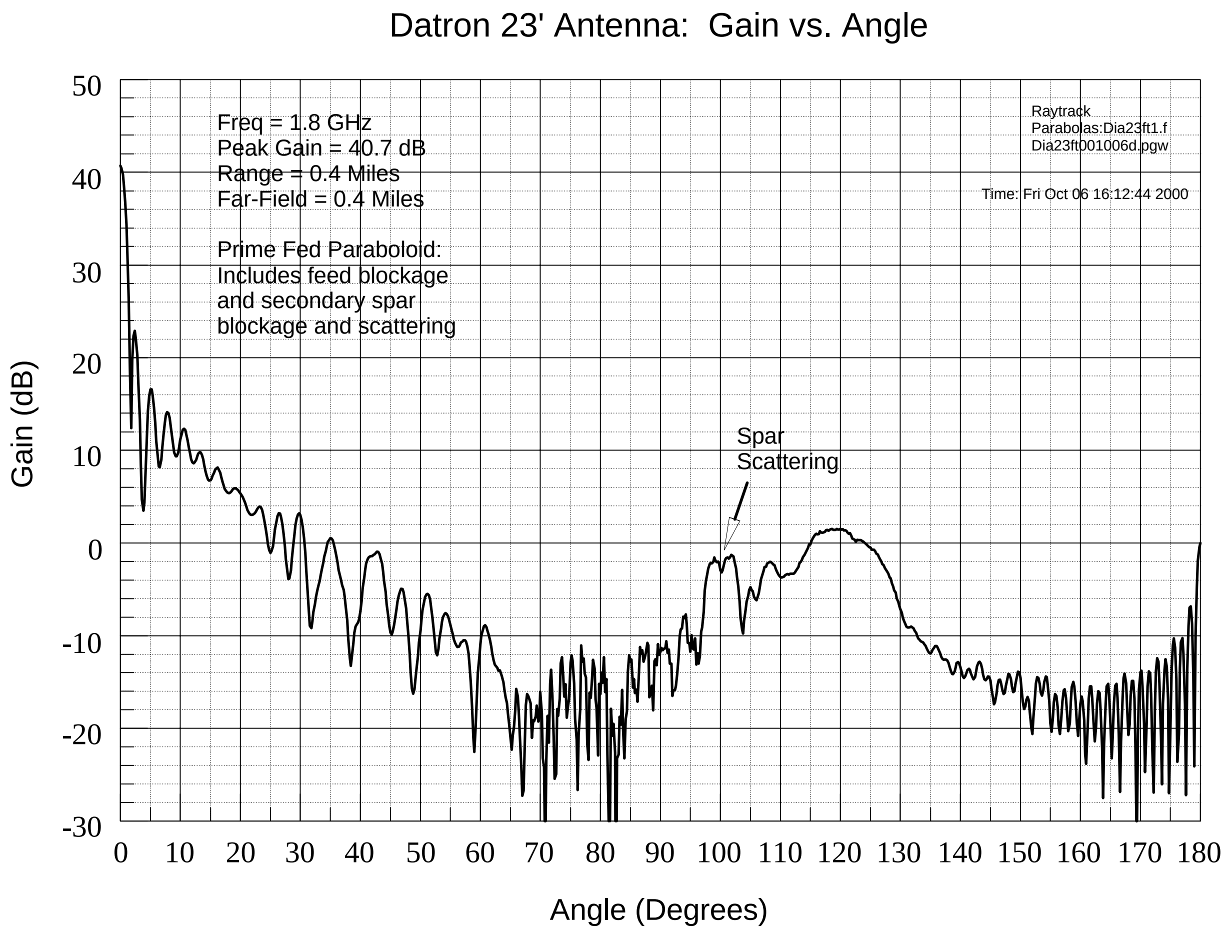

Figure B-5. Computer Generated Antenna Patterns for the 23-Foot Antenna Diameters (Antenna Gain Values are in dBi)

B.4.2.1.3 Results

Results of the signal level predictions for the six sites analyzed, CTS, NHS, OAS, EVCF, Hawaii, and Guam, are contained in Attachment 1. Three-dimensional topographic displays of the regions surrounding the sites are included to illustrate the relationship between terrain and predicted received signal level. The signal level plots do not reflect any additional attenuation due to blockage from man-made structures. In dense urban areas man-made structures may provide an additional 10-20 dB of attenuation which could reduce the interference to mobile stations with low antenna heights. Several plots are included within this section for discussion. A legend in the upper right corner of the overlays defines the IMT-2000 received threshold plotted. It should be noted that the –121 dBm threshold, which is depicted as white in the legend, is portrayed as yellow on the overlays. Below the legend are all of the input parameters used to generate the overlay.

Figure B-6 is an overlay for the worst-case conditions at NHS: maximum transmitter power (10 kW), and minimum elevation angle (3 degrees). Worst case overlay conditions apply to the IMT-2000 base stations vice the mobiles due to the increased antenna height (40 meters) and higher antenna gain (17 dBi) associated with the fixed sites. As shown in the figure, no region within the 70 X 70 km area shown meets the -121 dBm threshold. In fact, virtually all of the area depicted in the overlay experiences levels in excess of -71 dBm, well in excess of what might be considered a reasonable threshold level for the IMT-2000 receivers. Figure B-7 depicts the coverage for the same site under best-case transmitter conditions, 100 Watt transmitter power, and a 10-degree minimum elevation angle. While there is a noted reduction in the region exposed to levels in excess of -71 dBm, there is still no area that meets or even approaches the -121 dBm threshold specified. Figure B-8 depicts the best case overall (from an interference perspective) in that it depicts signal levels to a mobile receiver (reduced antenna height and antenna gain) at the lowest SATOPS transmit power and highest antenna elevation angle. Under these conditions, significant improvement is noted from the previous overlays; however, there are still significant portions that extend out 70 km and beyond from the site that exceed the -105 dBm threshold.

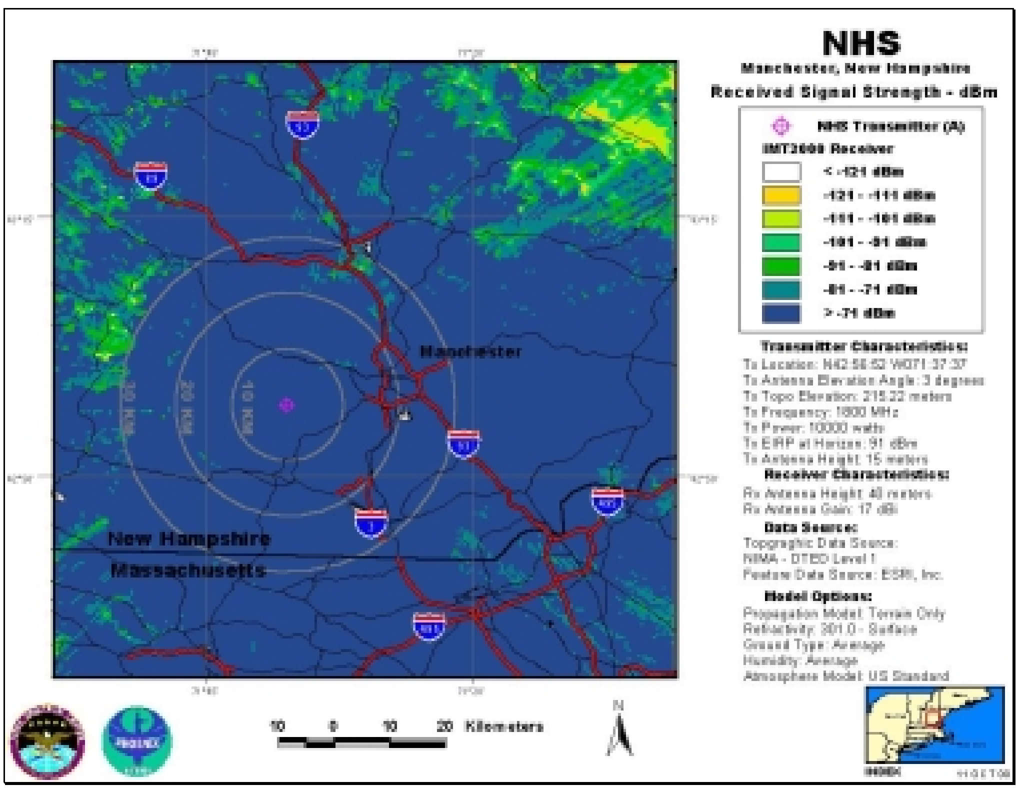

Figure B-6. NHS-A, Antenna Elevation Angle: 3°, Transmitter Power: 10,000 W, IMT-2000 Base Station

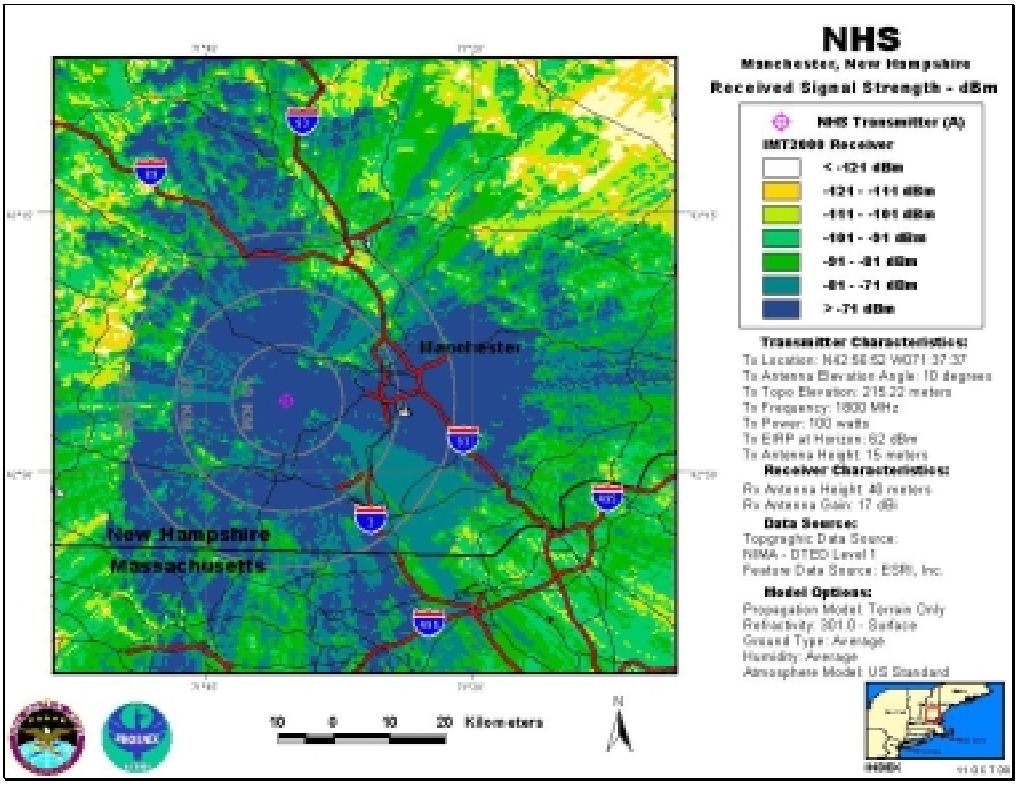

Figure B-7. NHS-A, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Base Station

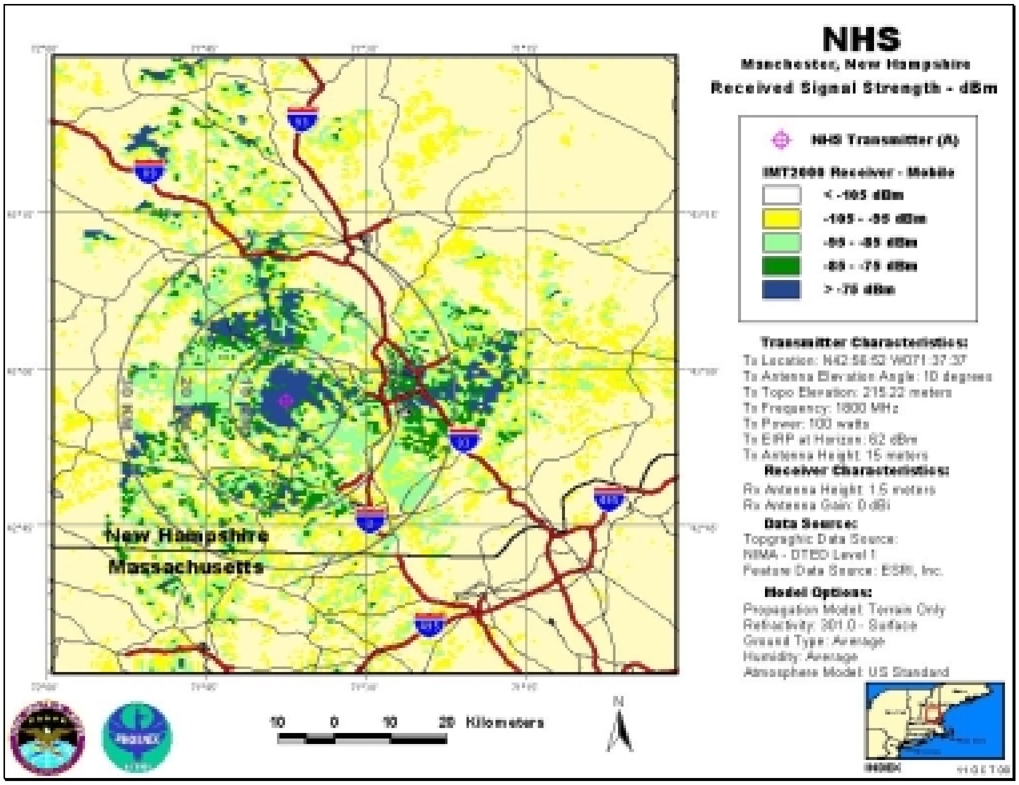

Figure B-8. NHS-A, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Mobile Station

A review of the other sites analyzed produces similar results. Figure B-9 represents worst-case SATOPS uplink conditions (maximum power, low elevation angle) for the OAS site. Like the NHS overlays, signals in excess of -71 dBm extend well beyond 70 km from the uplink terminal. Under these conditions, electromagnetic interference (EMI) from OAS extends well beyond the highly populated and highly desirable market regions of Oakland and San Francisco. Even under best case conditions (10 degrees and 100 Watts), Figure B-10 illustrates that the areas in excess of -121 dBm extend well over 75 km from the site. Figure B-11 depicts impact to IMT-2000 mobile users under best-case SATOPS uplink conditions. Like the NHS case, this represents the smallest potentially affected area. However, the region impacted still encompasses highly desirable regions from an IMT-2000 market perspective.

One exception to the overlay results applies to the IMT-2000 mobiles surrounding the Hawaii Tracking Station. At this location, terrain plays a significant role in attenuating the SATOPS undesired signal levels in the populated areas of Oahu. Hence the potentially affected area is fairly limited. Figure B-12 illustrates that the impact to IMT-2000 mobiles on Oahu with a SATOPS transmitter power of 500 Watts and a 10-degree antenna elevation angle. Most portions of the Island meet the desired interference threshold of -105 dBm.

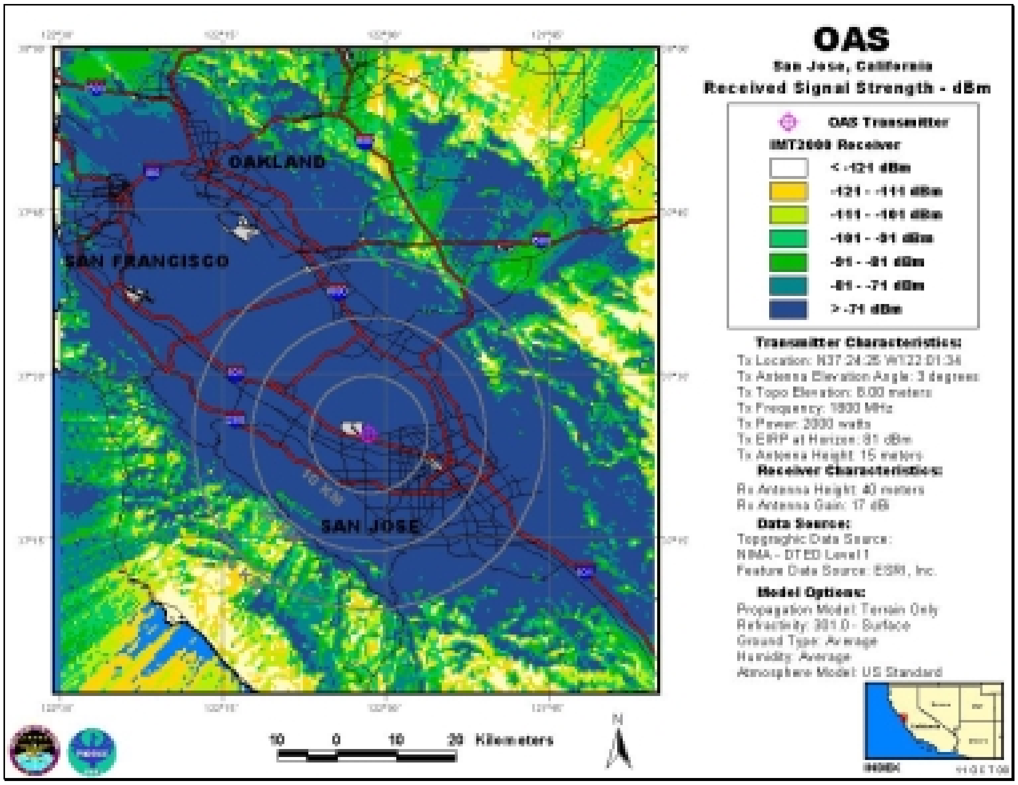

Figure B-9. OAS, Antenna Elevation Angle: 3°, Transmitter Power: 2,000 W, IMT-2000 Base Station

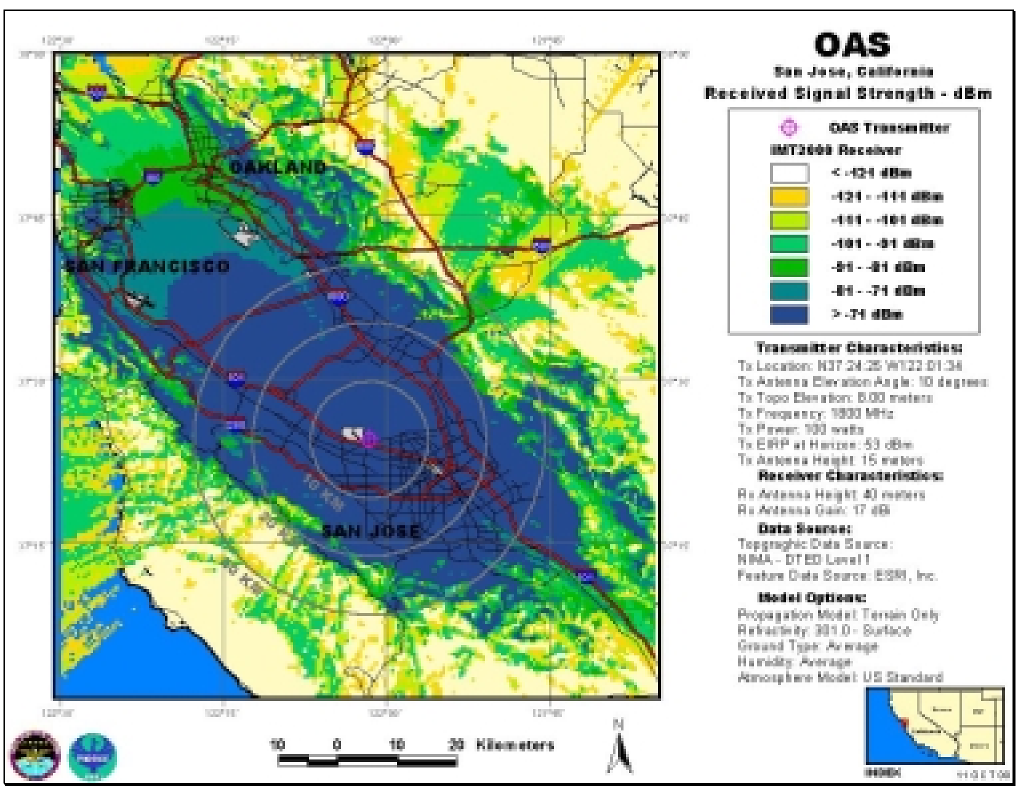

Figure B-10. OAS, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Base Station

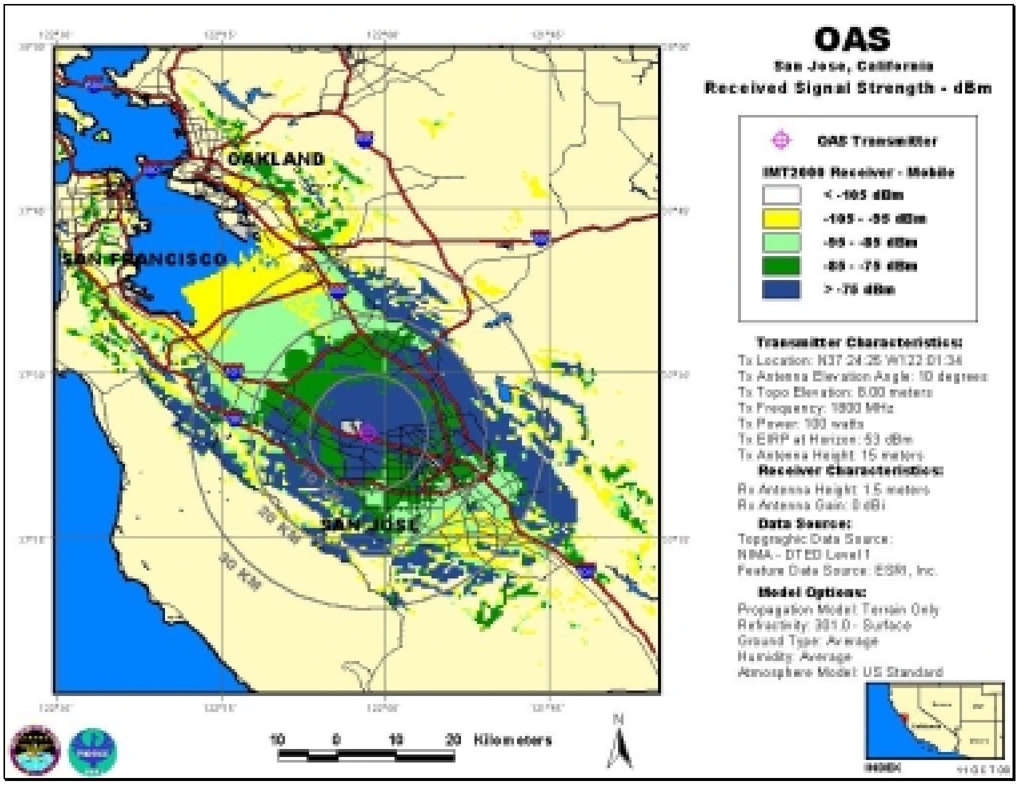

Figure B-11. OAS, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Mobile Station

It should be noted that the assessment assumes 360-degree coverage for the HTS SATOPS antenna. While for many sites this is true (including NHS), there are some sites that do concentrate activities within specific azimuth ranges, thereby lessening the effects to IMT-2000 receivers at large off-axis angles relative to the SATOPS mainbeam. It is also worthy of note that SATOPS uplink terminals only transmit on one channel at a time thereby lessening the impact to IMT-2000 users on nearby operating frequencies. This fact, coupled with the specific antenna azimuth operations, allows for the possibility of sharing on a time/frequency basis.

To illustrate the variation in impact as a function of azimuth for a fixed pointing antenna, four additional plots were generated. Figures B-13 and B-14 illustrate the base and mobile received signal levels for a 2000-Watt SATOPS uplink power and a 3-degree elevation angle. Figures B-15 and B-16 illustrate the base and mobile received signals for a 10,000-Watt SATOPS uplink power and a 3-degree elevation angle, plus an additional 50 dB of signal attenuation. In all four instances the antenna was fixed in azimuth at 33 degrees.

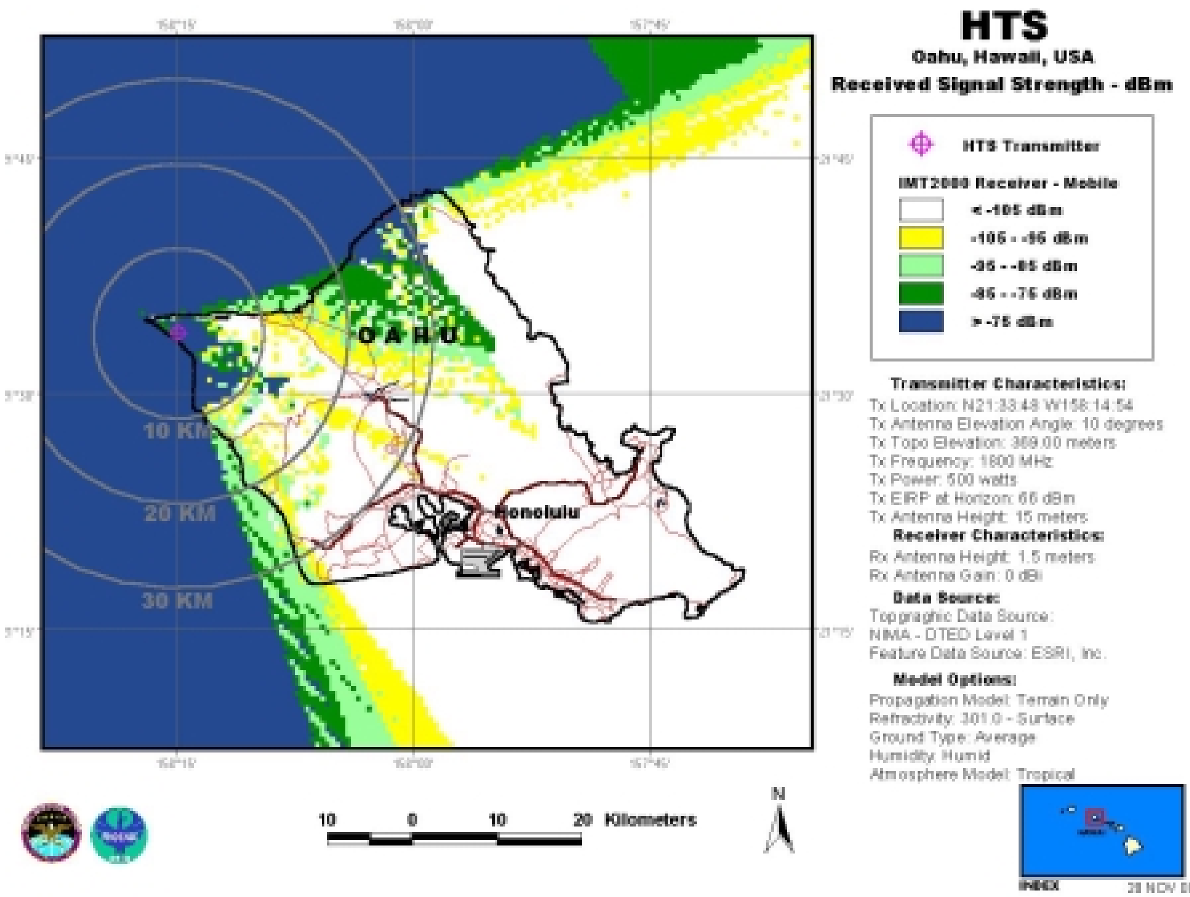

Figure B-12. HTS, Antenna Elevation Angle: 10° Transmitter Power: 500 W, IMT-2000 Mobile Station

As expected, the plots illustrate that impact to IMT-2000 receivers in the far sidelobes and backlobe of the SATOPS antenna is far less than that closer to the mainbeam. This factor should be taken into consideration when exploring mitigation techniques and frequency sharing options. It is also apparent that the benefits realized from raising the minimum elevation angle are primarily in the regions surrounding the mainbeam and first sidelobes.

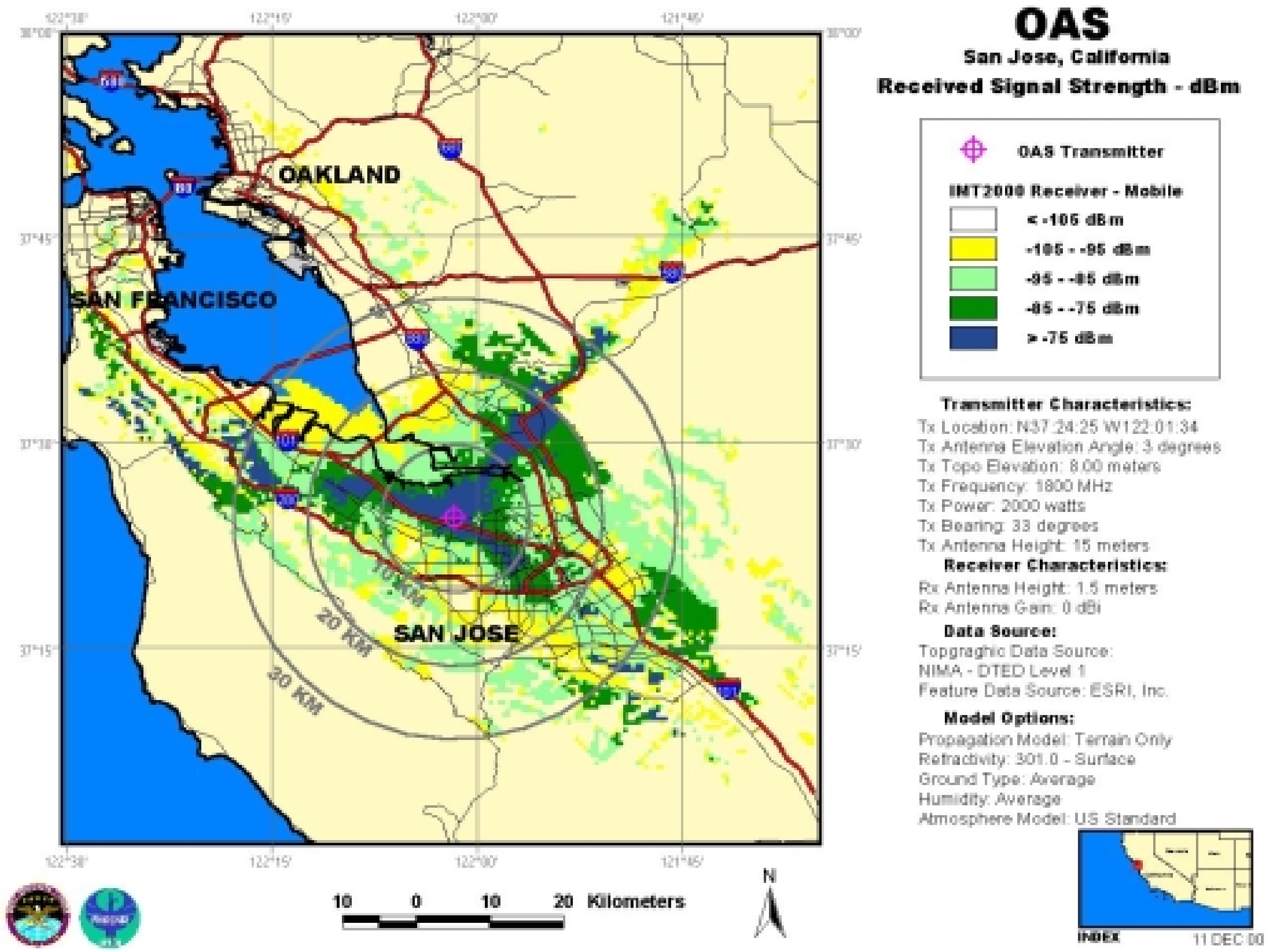

Figure B-13. OAS, Antenna Elevation Angle: 3°, Azimuth 33°, Transmitter Power: 2000 W, IMT-2000 Mobile Station

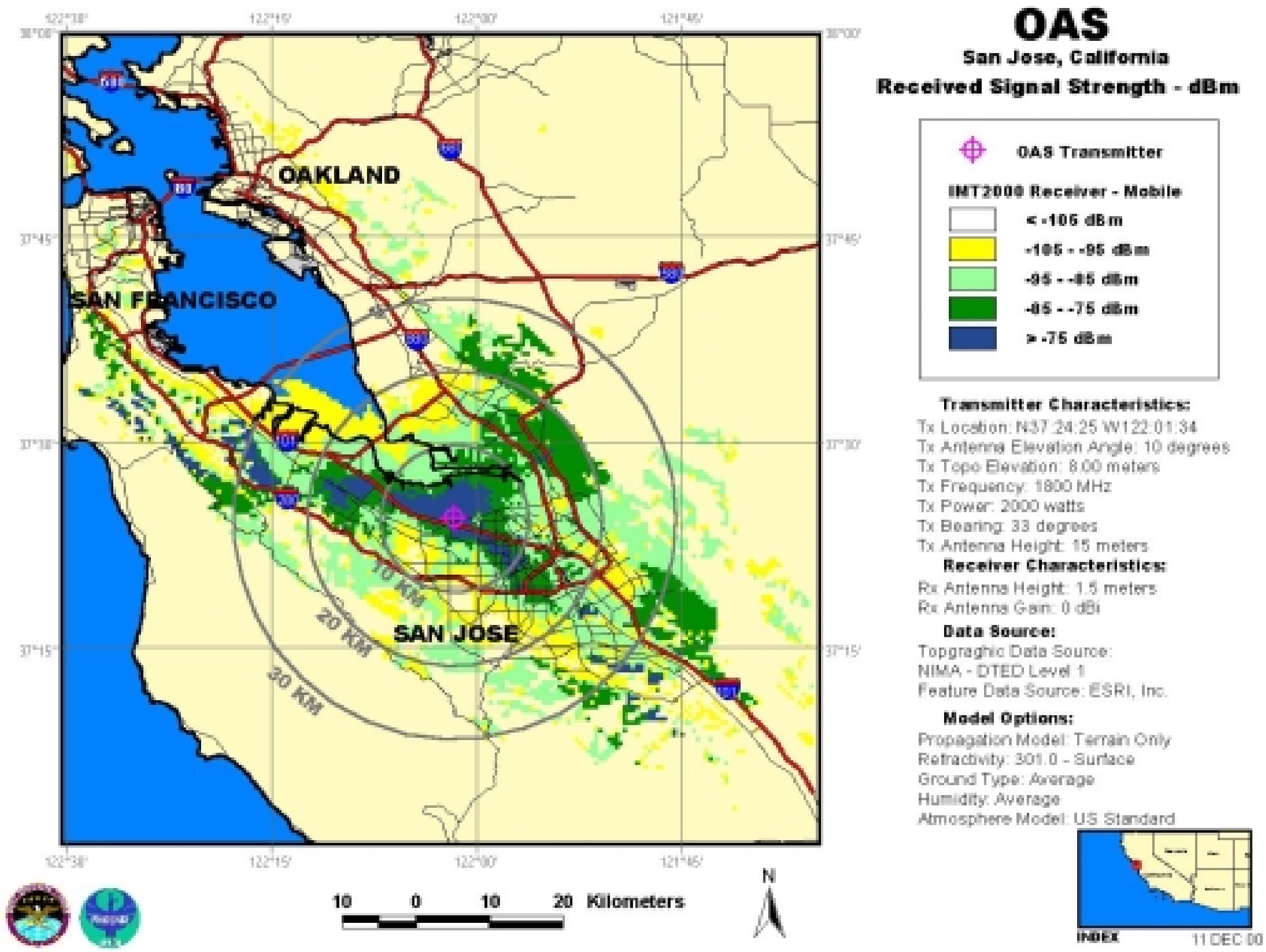

Figure B-14. OAS, Antenna Elevation Angle: 10°, Azimuth 33°, Transmitter Power: 2000 W, IMT-2000 Mobile Station

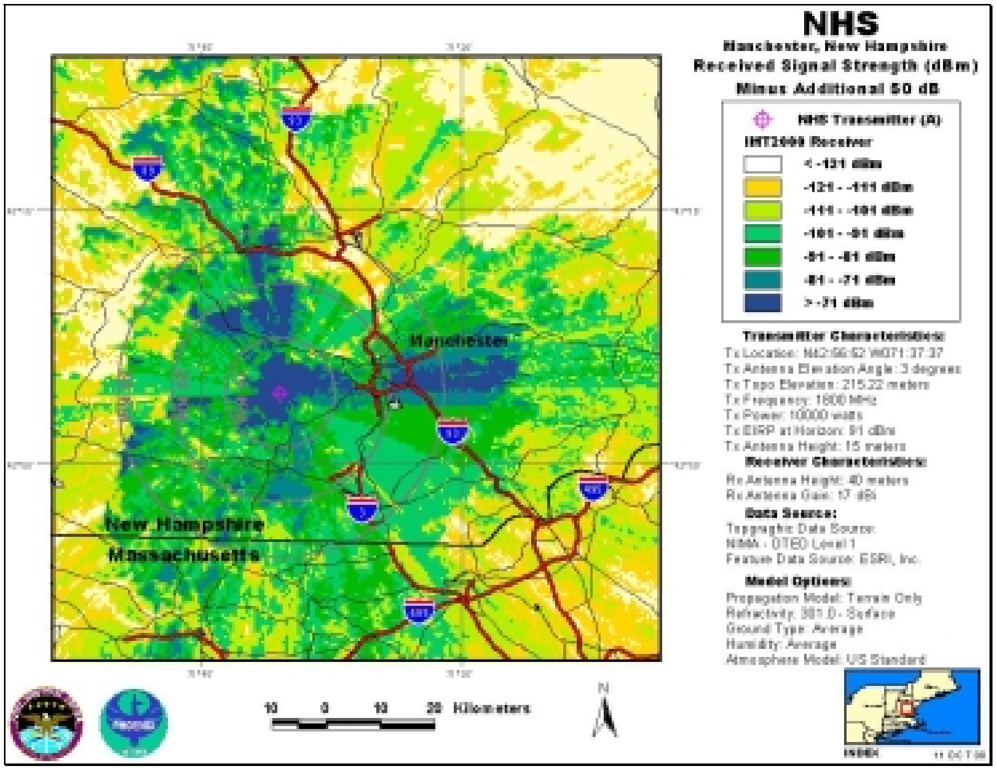

Figure B-15. NHS-A, Antenna Elevation Angle: 3°, Transmitter Power: 10,000 W, IMT-2000 Base Station, Plus an Additional 50 dB of Signal Attenuation

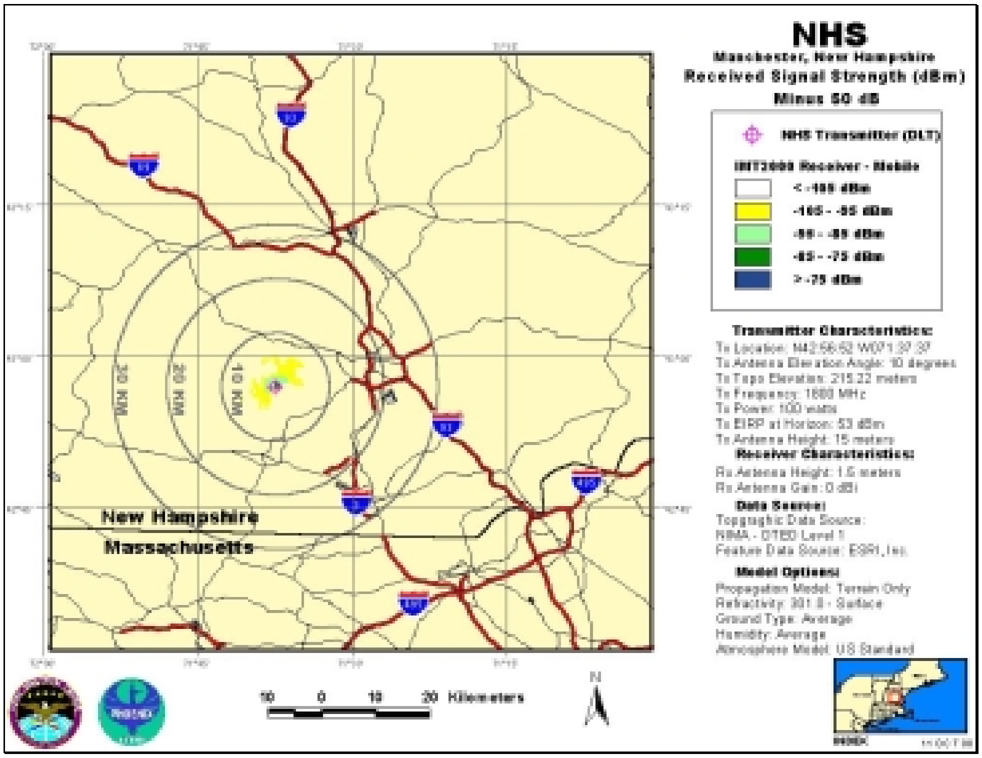

Figure B-16. NHS-DLT, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Mobile Station, Plus an Additional 50 dB of Signal Attenuation

SATOPS uplink power management, antenna elevation angle restrictions, and frequency off tuning help to reduce the affected area around the SATOPS uplink transmitter. However, if coordination regions on the order of 10 to 20 km are desired, and IMT-2000 specified interference thresholds are to be met, an orders of magnitude decrease in the undesired signal level will be required. Additional measures for reducing the uplink power at the IMT-2000 receiver coupled with power management and antenna restrictions must be implemented to significantly limit the affected area surrounding the uplink site.

B.4.2.1.4 SATOPS Uplink to IMT-2000 Receivers Interference Mitigation Measures

Based upon the results of the signal level predictions, it is apparent that additional signal attenuation is required if sharing between the services is desired. Potential mitigation techniques fall into one of three categories: measures implemented solely by the DoD SATOPS community, measures implemented solely by the IMT-2000 industry, and those techniques that require mutual implementation by both parties. The following measures are presented for discussion and consideration. It is important to note that not all costs of these mitigation techniques have been estimated. Employing any of these techniques would require a cost assessment and could dramatically alter the cost estimates presented earlier. Further analysis is warranted to address viability, cost, and implementation issues.

B.4.2.1.4.1 DoD EMI Mitigation Techniques

Relocation of the SATOPS Uplink Antennas and/or SATOPS Transmission Off-loading. Some of the current SATOPS terminals around the world are located in remote areas such as Diego Garcia and Thule, Greenland. It is expected that these regions will have a relatively low IMT-2000 user density. There are, however, several stations, such as New Hampshire or Sunnyvale, located near population centers. For sites such as these, it may be useful to consider the cost and mission impacts of moving the tracking stations, including antennas, and operations and maintenance personnel to more remote locations with lower population densities that are less desirable from an IMT-2000 market perspective. Similarly, where satisfactory visibility can be achieved, it may be possible that some of the operations currently performed by terminals in populated areas could be off-loaded to more remote terminals. It must be emphasized that relocating tracking stations and their antennas requires both time and additional funding to achieve frequency protection, negotiate international agreements, perform construction, and to acquire and install the SATOPS systems. Based on existing military construction funding rules, Congressional review would be required for each affected site.

Reduction of the Out-of-Beam Energy of the SATOPS Antennas. Assuming that the mainbeam emissions are highly focused in the SATOPS antennas, some control of the radiation in the direction of the victim receivers would be beneficial. The most common approaches to this are (1) antenna elevation angle restrictions and (2) intentional signal blockage and antenna redesign.

SATOPS Antenna Elevation Angle Restrictions. Like power management, restricting the minimum elevation angle serves to limit the power at the horizon and hence reduce the undesired signal into the IMT-2000 receiver. As illustrated in the overlays, a 10-degree minimum elevation angle reduced the size of the affected areas. However, even when coupled with power management, these measures are insufficient to reduce EMI regions to expected acceptable levels.

Signal Blockage and Antenna Redesign. Intentional signal blockage can be achieved via a cylinder surrounding the dish to reduce spillover, modification of the feed, or modification of the illumination taper to reduce sidelobes at the expense of gain.

SATOPS Power Management. SATOPS transmit power capabilities typically vary over a wide range from as low as 100 Watts to as much as 10 kW. The high-power transmissions are typically reserved for emergency operations but are also radiated periodically for system checkout and training. Link closure can typically be achieved at powers in the 100 to 500 Watt range for satellites on orbit and under nominal operating conditions. As indicated in the signal level predictions, power management does not in of itself solve the EMI problem; however, it does reduce the size of the affected regions.

It should be noted that this mitigation technique might not be possible if IMT-2000 emissions cause EMI to satellite receivers and it becomes necessary to increase the power output of the ground terminal to overcome the interference. Further, it should be noted that any increase in the transmitted power, to reduce interference to the satellites, would have adverse effects on any collocated 3G capability.

B.4.2.1.4.2 IMT-2000 EMI Mitigation Techniques

Establishment of Keep-Out Zones. Short of complete frequency separation, there is a potential for EMI to a mobile user (or fixed base station) if it is allowed to operate in proximity to an SATOPS uplink transmitter. The signal level overlays clearly show the potential size of the affected areas. The possibility of some keep-out zone, even if only a few kilometers surrounding the site, should be considered to help mitigate the most challenging close in interactions.

Base Station Antenna Nulling. It is expected that IMT-2000 antenna implementation may be similar to the current cellular/PCS designs; three-direction antenna segments each covering a 120-degree sector. This scheme introduces the possibility to add an additional highly directive antenna in the direction of the SATOPS terminal and to use that signal to null out the received signals on the broadbeam antenna in the direction of the SATOPS terminal. The hole in coverage created by this scheme could then be filled via an alternate antenna at a location such that a mainbeam interaction with the SATOPS terminal is avoided.

Polarization Discrimination. Polarization discrimination mitigation takes advantage of the fact that the mobile signals are linearly polarized, whereas the SATOPS uplinks are circularly polarized. By measuring the received polarization and cross polarizing the IMT-2000 base station to that signal, a significant reduction in interference is achievable (20 dB) with only a 3-dB reduction to the mobile signal. This proposal obviously requires an investment in technology by the IMT-2000 community and may be practical on a limited scale for base stations in specific problem areas.

B.4.2.1.4.3 Mutual EMI Mitigation Techniques

Cooperative scheduling is an attractive EMI mitigation technique that offers a potential benefit if mutual agreement and coordination with the IMT-2000 industry can be achieved. Cooperative scheduling is not unlike band segmentation in that both approaches look toward frequency separation between the systems as a technique for minimizing the potential for EMI. Note however the significant distinction between cooperative scheduling, which assumes sharing of the entire SGLS uplink band via real-time frequency deconfliction, and band segmentation, which assumes separation of systems into distinctly separate portions of the spectrum. Unlike band segmentation, cooperative scheduling addresses EMI issues associated with uplinks to currently flying systems for which only one S-band channel is available for TT&C. In these instances, there is essentially no flexibility in terms of spectrum use from the SATOPS perspective.

Cooperative scheduling takes advantage of the fact that SATOPS operations only use a limited amount of spectrum at any given instant in time. That, coupled with the specific antenna pointing required for a satellite contact, limits the affects on the environment. Therefore, at any instant, only a relatively small portion of the IMT-2000 network maybe affected. The concept behind cooperative scheduling is to allow the IMT-2000 network to dynamically assign spectrum usage to the network around the SATOPS uplink transmissions. This technique would require software enhancements and dynamic switching capabilities for the IMT-2000 systems. It also assumes that the IMT-2000 switching algorithm is fed information on the SATOPS uplink schedule either in advance via pre-coordination, in real-time via landline, or by monitoring the environment for SATOPS signal use. The requirement to pass SATOPS scheduling information to IMT-2000 service providers in turn raises operations securities issues that need to be addressed. While this mitigation technique is not without its challenges, it takes advantage of the SATOPS unique time/frequency use of the electromagnetic spectrum and, therefore, could be one of the more effective techniques to reduce EMI to the IMT-2000 users. This technique will also require channel filters to be installed at US&P sites.

B.4.2.1.5 Summary

Further study is required to quantify the benefit of the aforementioned mitigation measures. Figures B-15 and B-16 are provided to illustrate the benefit of mitigation techniques that provide an additional 50 dB of attenuation in the direction of the victim receiver. Note that under the worst-case conditions for NHS, the affected area improvement is notable but still considerably large.

B.4.2.2 Potential Interference to SATOPS uplinks from IMT-2000

B.4.2.2.1 Assessment Approach

The approach was to calculate the estimated interference environment into a spacecraft receiver based upon the power flux density per square kilometer per Hertz generated by IMT–2000 stations in an urban environment and the population density and urban area sizes visible from the spacecraft. ITU-R Recommendation M.687-2 gives the power flux density per square kilometer per Hertz generated by IMT-2000 base stations and mobile stations in a urban area. This power flux density was derived from an estimation of the spectrum needed for IMT-2000. ITU-R Report M.2023 provides an updated estimate of the spectrum required for IMT-2000. The power flux density used in this assessment was calculated from the updated spectrum requirements using the same procedure as was used in ITU-R Recommendation M.687-2. The power flux density from IMT-2000 base stations in Region 2 (North and South America) was calculated to be 41 $\Phi W/km^2/Hz$. The power flux density from IMT-2000 mobile stations in Region 2 was calculated to be 1 $\Phi W/km^2/Hz$.

In addition to the IMT-2000 base stations in urban areas, some base stations will be deployed in rural areas to serve traffic on major highways and to serve small towns. These rural base stations may actually employ higher transmitter powers than their urban counterparts since they may be required to serve a larger area. The contribution from these rural stations was not considered in this report since there was no estimate available of their numbers. The effect of interference from these stations can only increase the impact on orbiting spacecraft from the IMT-2000 systems.

The size of the world's urban areas and their populations was estimated by taking data from a variety of sources, including United Nations statistical data and US Census Bureau data. The 2763 most populous urban centers are shown in Figure B-17.

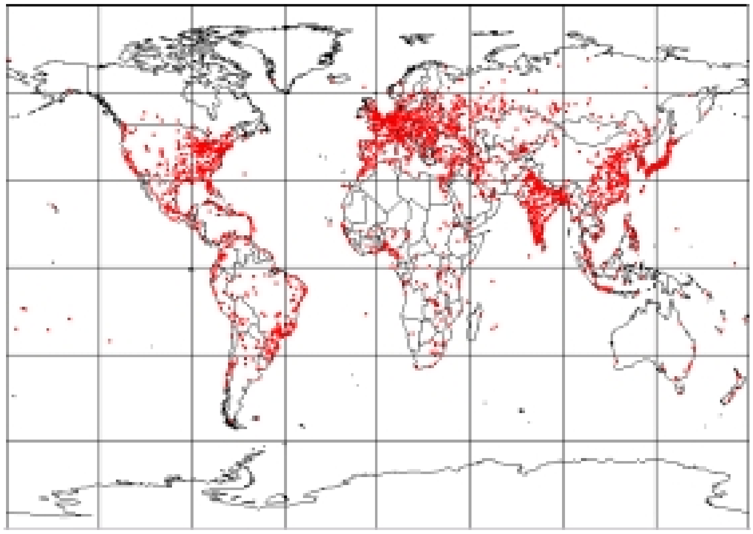

Figure B-17. Most populous urban centers

Although it was possible to identify the estimated populations of the 2763 most populous urban areas, data regarding their size was only available for less than ten percent of the areas. In order to approximate the area of each urban location, the population density of a number of cities can be used, and an average inverse population density can be derived. This is shown in Table B-10, and the resulting value is used in the computations.

Table B-10. Approximate population density (inverse) used in the analysis

City	Size (km^2)	Population (millions)	Ratio (km^2/ millions)
New York	780	7.3	106.8
London	1500	7.0	214.3
Paris	103	2.2	46.8
Berlin	891	3.5	254.6
Mexico	3000	20.9	143.5
Chicago	591	7.8	75.8
Toronto	650	5.0	130.0
Las Vegas	218	1.2	181.7
Average Ratio			144.2

A computer simulation program was developed to calculate the estimated IMT-2000 interference environment into a spacecraft receiver. The orbit shell is defined by a matrix of spacecraft latitude and longitude positions (up to ±90º in latitude, and 360º in longitude). At each position on the orbit shell, the database of cities is searched for those that are visible from the spacecraft. Using their approximated geographic size, the total interfering power density into the spacecraft receiver is calculated from Equation B-1.

$$I(dBW/Hz) = \sum_i \left\{ 10 \cdot \log\left[\left(41\mu W/km^2/Hz \right) \cdot \left(citypop_i \right) \cdot \left(144.2km^2/millions \right) \right] - \left(32.44 + 20 \cdot \log\left(range_i \cdot freq \right) \right) - L_e \right\}$$

(B-1)

where

$citypop_i$ = population of the ith visible city, in millions

$range_i$ = range to the ith visible city, in km

$freq$ = 1800 MHz in all calculations

L_e = environmental losses; 10 dB in all calculations

and, though not shown, values are converted back to linear units before summation.

A typical satellite link budget from a representative Air Force Satellite Control Network (AFSCN) transmitter to a satellite using a common telemetry, tracking, and commanding (TT&C) transponder (the L3–Com model CXS810–C) was used to compute the link margin in the absence of interference from IMT-2000 transmitters. The aggregate interference level from the IMT-2000 environment was then used to compute the net margin.

B.4.2.2.2 Link Margin calculations

Four satellite orbits were chosen for the assessment:

- A 250-kilometer orbit, typical of the Space Transportation System (STS)
- An 833-kilometer orbit, typical of meteorological satellites such as Defense Meteorological Satellite Program (DMSP)
- A 20,200-kilometer orbit, typical of the Global Positioning System (GPS)
- A 35,784-kilometer orbit, typical of geostationary satellites

For the two lowest orbits, two hypothetical AFSCN transmitter powers, 250 W and 2000 W, were used in the assessment. For the other two orbits, only the 2000 W power was used. These power levels may not be the actual powers normally used in AFSCN operations, but are representative of AFSCN capabilities.

The AFSCN uses a variety of antennas ranging in size from 23 ft to 60 ft. For this assessment, a 33-ft antenna with a gain of 41 dBi was selected for the AFSCN station. A spacecraft antenna with a -5 dBi gain was assumed as typical. Propagation losses took into account free-space path loss, cloud loss, rain loss, atmospheric loss, and polarization loss based on the slant-range to the spacecraft. Three AFSCN station elevation angles were used to determine the losses through the earth’s atmosphere.

A typical SGLS transponder, the L3 Communications CXS-810C, was used to represent the spacecraft receiver. The spacecraft effective receiver system temperature was 798° Kelvin. The threshold powers were calculated for the Command service and for the Carrier service based on the use of a 0.3 modulation index for the Command and Ranging signals.

Link margin calculations considering IMT-2000 interference were based on the IMT-2000 traffic loading characteristics of ITU Region 2 (the Americas). Since the power densities per square kilometer per Hertz from the other regions differed by less than 1 dB for the Base Stations and by approximately 3 dB for the Mobile Stations, it is reasonable to assume that the Region 2 values are indicative of the interference environment worldwide.

An example of the link budget and the net margin calculations is shown in Table B-11. The results of the link margin calculations are shown in Tables B-12 through B-19. Analysis results for the ranging function are not shown in these tables. The degradation to the command capability is always more severe than to the ranging capability. The effect of interference on ranging is to increase the time required to integrate the pseudonoise code in order to determine the range. Separate tables are shown for interference from mobile stations and base stations for each of the years 2003, 2006, and 2010 as well as for a future full buildout of the IMT-2000 system.

Table B-11. Typical Link Budget

Freq	1800	MHz		
TX Power	2000	Watts		
TX Power	63	dBm		
TX EIRP	105	dBm		
TX Ant Dia	33	Ft		
TX Ant Beamwidth	1	Deg		
TX Ant Gain	42	dBi		
Orbit Height	35784	Kilometers		
Elevation Angle	3	Deg		
Mean Earth Radius	6378	Kilometers		
Slant Range	42220	Kilometers		
Space Loss	190	dB		
Cloud Loss	0.0	dB		
Rain Loss	0.5	dB		
Atmospheric Loss	0.6	dB		
Polarization Loss	0.5	dB		
Scintillation Loss	0.0	dB		
Rx Antenna Gain	-5	dB		
Rx Antenna Temp	300	Deg K		
Rx Diplexer Loss	0.3	dB		
Rx Coupler Loss	1	dB		
Rx Cable Loss	2	dB		
Rx Cable Temp	170	Deg K		
Total Rx Line Loss	3	dB		
Receiver NF	5	dB		
Receiver Temp	627	Deg K		
Eff Rx Ant Temp	171	Deg K		
Rx System Temp	798	Deg K		
Rx System Temp	29	dBK		
Rx System Gain	-5	dB		
Rx G/T	-34	dB/K		
Rx Isotropic Carrier Pwr	-95	dBm		
	CMD	Carrier	Ranging	
Mod Index	0.3		0.3	
Mod Loss	-14	-1		
Threshold Power for a CXS810-C	-99	-125		dBm
Data Rate	2000			
Link Margin	4	30		
System Noise	-198	-198		dBW/Hz
IMT-2000 Interference + System Noise	-190	-190		dBW/Hz
Net Margin	-5	22		

Table B-12. Interference from IMT-2000 Mobile Stations in 2003

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	13.5	40.0
			5 deg	25.0	51.4	15.0	41.4
			10 deg	27.7	54.1	17.7	44.1
		2000 W	3 deg	32.6	59.0	22.6	49.0
			5 deg	34.0	60.4	24.0	50.4
			10 deg	36.7	63.1	26.7	53.1
DMSP	833 km	250 W	3 deg	17.4	43.8	13.7	40.1
			5 deg	18.3	44.8	14.6	41.1
			10 deg	20.0	46.4	16.3	42.7
		2000 W	3 deg	26.4	52.8	22.7	49.1
			5 deg	27.4	53.8	23.7	50.1
			10 deg	29.0	55.5	25.3	51.8
GPS	20,200 km	2000 W	3 deg	8.0	34.4	7.7	34.1
			5 deg	8.4	34.9	4.2	34.6
			10 deg	8.9	35.3	4.5	35.1
GEO	35,784 km	2000 W	3 deg	3.8	30.2	3.7	30.1
			5 deg	4.2	30.6	4.2	30.6
			10 deg	4.6	31.0	4.5	31.0

Table B-13. Interference from IMT-2000 Mobile Stations in 2006

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	6.5	33.0
			5 deg	25.0	51.4	8.0	34.4
			10 deg	27.7	54.1	10.7	37.1
		2000 W	3 deg	32.6	59.0	15.6	42.0
			5 deg	34.0	60.4	17.0	43.4
			10 deg	36.7	63.1	19.7	46.1
DMSP	833 km	250 W	3 deg	17.4	43.8	6.7	33.1
			5 deg	18.3	44.8	7.7	34.1
			10 deg	20.0	46.4	9.3	35.7
		2000 W	3 deg	26.4	52.8	15.7	42.1
			5 deg	27.4	53.8	16.7	43.1
			10 deg	29.0	55.5	18.3	44.8
GPS	20,200 km	2000 W	3 deg	8.0	34.4	6.8	33.2
			5 deg	8.4	34.9	7.2	33.7
			10 deg	8.9	35.3	7.7	34.1
GEO	35,784 km	2000 W	3 deg	3.8	30.2	3.5	29.9
			5 deg	4.2	30.6	3.9	30.4
			10 deg	4.6	31.0	4.3	30.8

Table B-14. Interference from IMT-2000 Mobile Stations in 2010

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	4.0	30.4
			5 deg	25.0	51.4	5.4	31.8
			10 deg	27.7	54.1	8.1	34.5
		2000 W	3 deg	32.6	59.0	13.0	39.4
			5 deg	34.0	60.4	14.5	40.9
			10 deg	36.7	63.1	17.1	43.6
DMSP	833 km	250 W	3 deg	17.4	43.8	4.1	30.6
			5 deg	18.3	44.8	5.1	31.5
			10 deg	20.0	46.4	6.8	33.2
		2000 W	3 deg	26.4	52.8	13.2	39.6
			5 deg	27.4	53.8	14.1	40.6
			10 deg	29.0	55.5	15.8	42.2
GPS	20,200 km	2000 W	3 deg	8.0	34.4	6.0	32.4
			5 deg	8.4	34.9	6.5	32.9
			10 deg	8.9	35.3	6.9	33.4
GEO	35,784 km	2000 W	3 deg	3.8	30.2	3.3	29.7
			5 deg	4.2	30.6	3.7	30.2
			10 deg	4.6	31.0	4.1	30.6

Table B-15. Interference from IMT-2000 Mobile Stations at Full Buildout

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	3.5	30.0
			5 deg	25.0	51.4	5.0	31.4
			10 deg	27.7	54.1	7.7	34.1
		2000 W	3 deg	32.6	59.0	12.6	39.0
			5 deg	34.0	60.4	14.0	40.4
			10 deg	36.7	63.1	16.7	43.1
DMSP	833 km	250 W	3 deg	17.4	43.8	3.7	30.1
			5 deg	18.3	44.8	4.6	31.1
			10 deg	20.0	46.4	6.3	32.7
		2000 W	3 deg	26.4	52.8	12.7	39.1
			5 deg	27.4	53.8	13.7	40.1
			10 deg	29.0	55.5	15.3	41.8
GPS	20,200 km	2000 W	3 deg	8.0	34.4	5.8	32.2
			5 deg	8.4	34.9	6.3	32.7
			10 deg	8.9	35.3	6.8	33.2
GEO	35,784 km	2000 W	3 deg	3.8	30.2	3.3	29.7
			5 deg	4.2	30.6	3.7	30.1
			10 deg	4.6	31.0	4.1	30.5

Table B-16. Interference from IMT-2000 Base Stations in 2003

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	-3.3	23.1
			5 deg	25.0	51.4	-1.9	24.5
			10 deg	27.7	54.1	0.8	27.2
		2000 W	3 deg	32.6	59.0	5.7	32.1
			5 deg	34.0	60.4	7.1	33.6
			10 deg	36.7	63.1	9.8	36.3
DMSP	833 km	250 W	3 deg	17.4	43.8	-3.2	23.2
			5 deg	18.3	44.8	-2.2	24.2
			10 deg	20.0	46.4	-0.5	25.9
		2000 W	3 deg	26.4	52.8	5.9	32.3
			5 deg	27.4	53.8	6.8	33.2
			10 deg	29.0	55.5	8.5	34.9
GPS	20,200 km	2000 W	3 deg	8.0	34.4	2.9	29.3
			5 deg	8.4	34.9	3.4	29.8
			10 deg	8.9	35.3	3.8	30.3
GEO	35,784 km	2000 W	3 deg	3.8	30.2	1.7	28.1
			5 deg	4.2	30.6	2.2	28.6
			10 deg	4.6	31.0	2.6	29.0

Table B-17. Interference from IMT-2000 Base Stations in 2006

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	-10.3	16.1
			5 deg	25.0	51.4	-8.9	17.5
			10 deg	27.7	54.1	-6.2	20.2
		2000 W	3 deg	32.6	59.0	-1.3	25.1
			5 deg	34.0	60.4	0.2	26.6
			10 deg	36.7	63.1	2.8	29.3
DMSP	833 km	250 W	3 deg	17.4	43.8	-10.2	16.3
			5 deg	18.3	44.8	-9.2	17.2
			10 deg	20.0	46.4	-7.5	18.9
		2000 W	3 deg	26.4	52.8	-1.1	25.3
			5 deg	27.4	53.8	-0.2	26.3
			10 deg	29.0	55.5	1.5	27.9
GPS	20,200 km	2000 W	3 deg	8.0	34.4	-4.1	22.3
			5 deg	8.4	34.9	-3.6	22.8
			10 deg	8.9	35.3	-3.1	23.3
GEO	35,784 km	2000 W	3 deg	3.8	30.2	-1.7	24.7
			5 deg	4.2	30.6	-1.2	25.2
			10 deg	4.6	31.0	-0.8	25.6

Table B-18. Interference from IMT-2000 Base Stations in 2010

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	-12.9	13.6
			5 deg	25.0	51.4	-11.4	15.0
			10 deg	27.7	54.1	-8.7	17.7
		2000 W	3 deg	32.6	59.0	-3.8	22.6
			5 deg	34.0	60.4	-2.4	24.0
			10 deg	36.7	63.1	0.3	26.7
DMSP	833 km	250 W	3 deg	17.4	43.8	-12.7	13.7
			5 deg	18.3	44.8	-11.8	14.7
			10 deg	20.0	46.4	-10.1	16.3
		2000 W	3 deg	26.4	52.8	-3.7	22.7
			5 deg	27.4	53.8	-2.7	23.7
			10 deg	29.0	55.5	-1.1	25.4
GPS	20,200 km	2000 W	3 deg	8.0	34.4	-6.6	19.8
			5 deg	8.4	34.9	-6.2	20.3
			10 deg	8.9	35.3	-5.7	20.7
GEO	35,784 km	2000 W	3 deg	3.8	30.2	-4.2	22.2
			5 deg	4.2	30.6	-3.8	22.6
			10 deg	4.6	31.0	-3.4	23.0

Table B-19. Interference from IMT-2000 Base Stations at Full Buildout

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)		Net Margin With Interference (dB)	
				Command	Carrier	Command	Carrier
STS	250 km	250 W	3 deg	23.5	50.0	-13.3	13.1
			5 deg	25.0	51.4	-11.9	14.5
			10 deg	27.7	54.1	-9.2	17.2
		2000 W	3 deg	32.6	59.0	-4.3	22.1
			5 deg	34.0	60.4	-2.9	23.6
			10 deg	36.7	63.1	-0.2	26.3
DMSP	833 km	250 W	3 deg	17.4	43.8	-13.2	13.2
			5 deg	18.3	44.8	-12.2	14.2
			10 deg	20.0	46.4	-10.5	15.9
		2000 W	3 deg	26.4	52.8	-4.1	22.3
			5 deg	27.4	53.8	-3.2	23.2
			10 deg	29.0	55.5	-1.5	24.9
GPS	20,200 km	2000 W	3 deg	8.0	34.4	-7.1	19.3
			5 deg	8.4	34.9	-6.6	19.8
			10 deg	8.9	35.3	-6.2	20.3
GEO	35,784 km	2000 W	3 deg	3.8	30.2	-4.7	21.7
			5 deg	4.2	30.6	-4.3	22.2
			10 deg	4.6	31.0	-3.9	22.6

B.4.2.2.3 Summary

Interference from IMT–2000 base stations is much more severe than from the mobile stations, but both represent potentially significant interference to SATOPS. The potential for interference is most evident at the low orbits for many of the less favorable operational scenarios. On average, the geostationary orbit interference will be quite severe. The negative net margins predicted indicate that cochannel sharing with IMT-2000 base stations may not be feasible for some systems even in the early stages of IMT-2000 implementation if the predicted levels of interference are realistic. Carrying that assumption forward for the 2006 timeframe, interference in all orbits is expected. Sharing with mobile stations will be less of a problem. Increasing transmitter power will minimize the interference on the uplink, but will increase interference to IMT-2000 receivers. Therefore, this has little practical benefit.

The satellite characteristics and performance requirements used in this assessment are representative of typical characteristics of US military space systems. For specific space programs the actual characteristics may vary. Also, SATOPS terminal values used were also considered to be representative of current systems, but future systems may use smaller antennas and may not have the power capability assumed for this analysis. Therefore, results will vary as specific ground and space systems differ, but this analysis is indicative of the magnitude of the problem.

Because this is a key element in any decision, a more comprehensive study is necessary. As stated previously, the assessment results presented in this report are based on a near worst-case scenario. Interference caused by introducing 3G users into the 1755-1850 MHz band can potentially have severe impacts to DoD satellite operations. DoD will continue to examine the impacts by conducting more comprehensive assessments to determine the impacts to DoD satellite missions.

An estimate of the magnitude of the variation in the link results may be determined by using the variations given in Table B-20.

Table B-20. Tolerances on Link Margin Calculation

Factor	Value Used	Upper Bound	Lower Bound	Explanation
EIRP	111.5 dBm	116 dBm	104	EIRP is different at different RTS due to antenna size; Modernization contract for 2004 and beyond is limited to 104 dam at most RTS, 110 dBM at 4 sites worldwide
Receive Antenna Gain	-5 dBi	0 dBi	-17 dBi	Spacecraft antenna patterns differ; most contain null between Zenith and nadir. Depends on definition of gain at edge of coverage
Receive Losses	3.3 dB	5 dB	1 dB	Depends on spacecraft design; i.e coupler or no coupler, diplexer loss, cable length.
Receiver NF	5.0 dB	6.0 dB	2.0 dB	Depends on vendor and state of the art when that spacecraft was built
Threshold Sensitivity (at 2Kbps & Mod index of .6	Cmd: -104.7dBm Carrier: -124.8 dBm	-98 dBm -120dBm	-132dBm -126dBm	Depends on vendor and state of the art when that spacecraft was built. Also directly dependent on mod index and data rate
Mod index	0.3	1.0	0.3	Depends on System design for a particular program
Mod Loss	--14 dB	-2.3dB	-14 dB	Depends on mod index
Data Rate Effect of data Rate on margin	2.0 Kbps	1.0 Kbps 3 dB	10 Kbps -7 dB	Depends on System design for a particular program

B.5 OPTION 2 – BAND SEGMENTATION/PARTIAL BAND SHARING

B.5.1 Operational Impact

In general, all of the operational impact statements regarding the full band sharing and denied spectrum access apply to those portions of the band segmented for non-government use. By retaining 1755-1805 MHz for exclusive US Government use, SGLS channels 12 through 20 would potentially become shared with non-government users. Should this be implemented, assured access would still be required for the entire 1755-1850 MHz band (including the 1805-1850 MHz portion) to support the on-orbit assets utilizing the shared spectrum. Without such access, TT&C functions would be jeopardized and resultant satellite/payload and mission failure could occur as described above.

Assuming SATOPS access to the non-government portion of the spectrum is retained, the mitigation techniques and operational impacts associated with the full band sharing option would apply. This includes those issues associated with impact to the SATOPS uplink from IMT-2000 noise levels emanating from the surface of the earth as a function of the IMT-2000 build out schedule. Impacts of course would be limited to those satellite systems operating in the spectrum occupied by non-government users. In a few rare exceptions, systems possessing two TT&C frequencies may be able to mitigate RFI by operating on a channel in the government-only portion of the band if applicable. In addition to the aforementioned mitigation options, it may be necessary to implement SATOPS transmitter filtering on those exclusive government channels adjacent to the non-government spectrum.

The satellite systems currently utilizing or scheduled to use SGLS channels 12-20 include DSCS, Milstar, FLTSAT, DMSP, ISR, TE, Advanced EHF, Wideband Gapfiller Satellite (WGS), UHF Follow-On (UFO), SBIRS, and MSX. For the satellites ready for launch or already on-orbit, their uplink frequencies are fixed. Inability to use those frequencies without interference will eventually cause mission failure. DSCS, Milstar, and UFO satellites already built or on-orbit are expected to remain operational past 2017. Mission capabilities potentially impacted include communications systems and space-based surveillance systems. Therefore, in the 2010 time frame, there will still be a large number of on-orbit satellites that require SGLS channel 12-20 for operations.

B.5.2 1755-1805 MHz Retained – Technical Assessment

This option would allow retention of SATOPS functions in the 1761-1805 MHz band (SGLS channels 1-11) and IMT-2000 operations in the 1805-1850 MHz band. This option would reduce the potential for electromagnetic interference (EMI) by maintaining a frequency separation between transmitters and receivers. Given that SATOPS functions currently support satellites operating throughout the 1761-1842 MHz band, a segmentation scheme alone would reduce but not eliminate the potential for EMI to IMT-2000 receivers. The potential for EMI would remain for those systems operating in the IMT-2000 portion of the spectrum (SGLS channels 12-20) until the requirement to support such satellites no longer exists and the band can be vacated. In some instances however, satellite programs are supported via two S-band channels. This introduces the added benefit of frequency flexibility and provides an EMI mitigation possibility if one of the two channels lies outside the IMT-2000 spectrum. Finally, for those satellites that have not yet been launched, the opportunity exists to outfit the vehicle with SATOPS transponders in the band segment allocated for TT&C.

To illustrate the impact of off-tuning the SATOPS uplink and IMT-2000 receivers on the relative size of the coordination regions, three sample overlays were generated for the New Hampshire B terminal operating at 2.5 kilowatts with a 10 degrees elevation angle. Figures B-18 through B-20 illustrate the coordination regions for IMT-2000 base station receivers assuming frequency separations of 4, 8, and 12 MHz respectively (1, 2, and 3 SATOPS uplink channels). Beyond 12 MHz, the uplink emission rolls off gradually such that additional frequency separation yields minimal benefit.

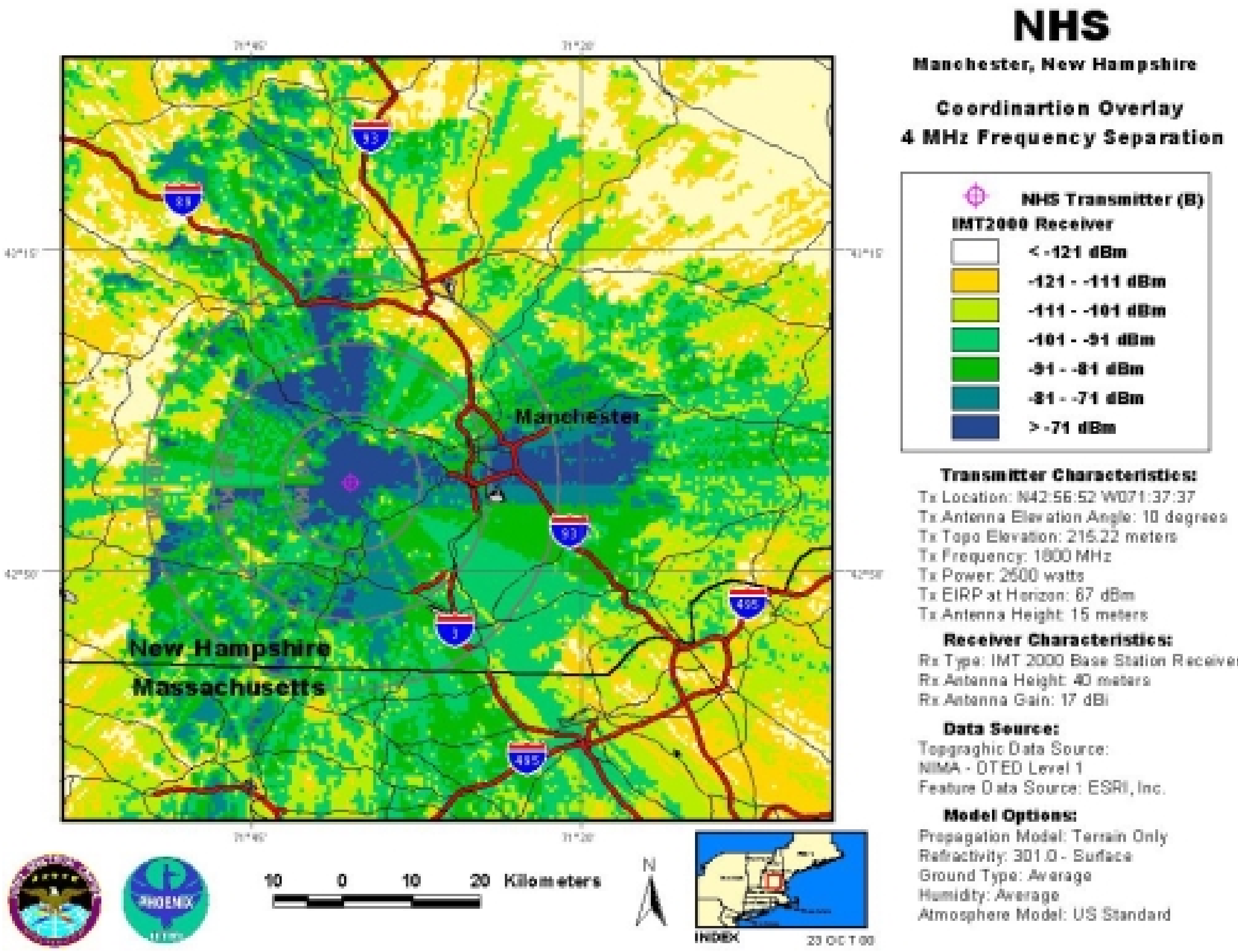

Figure B-18. Coordination Overlay for 4-MHz Frequency Separation

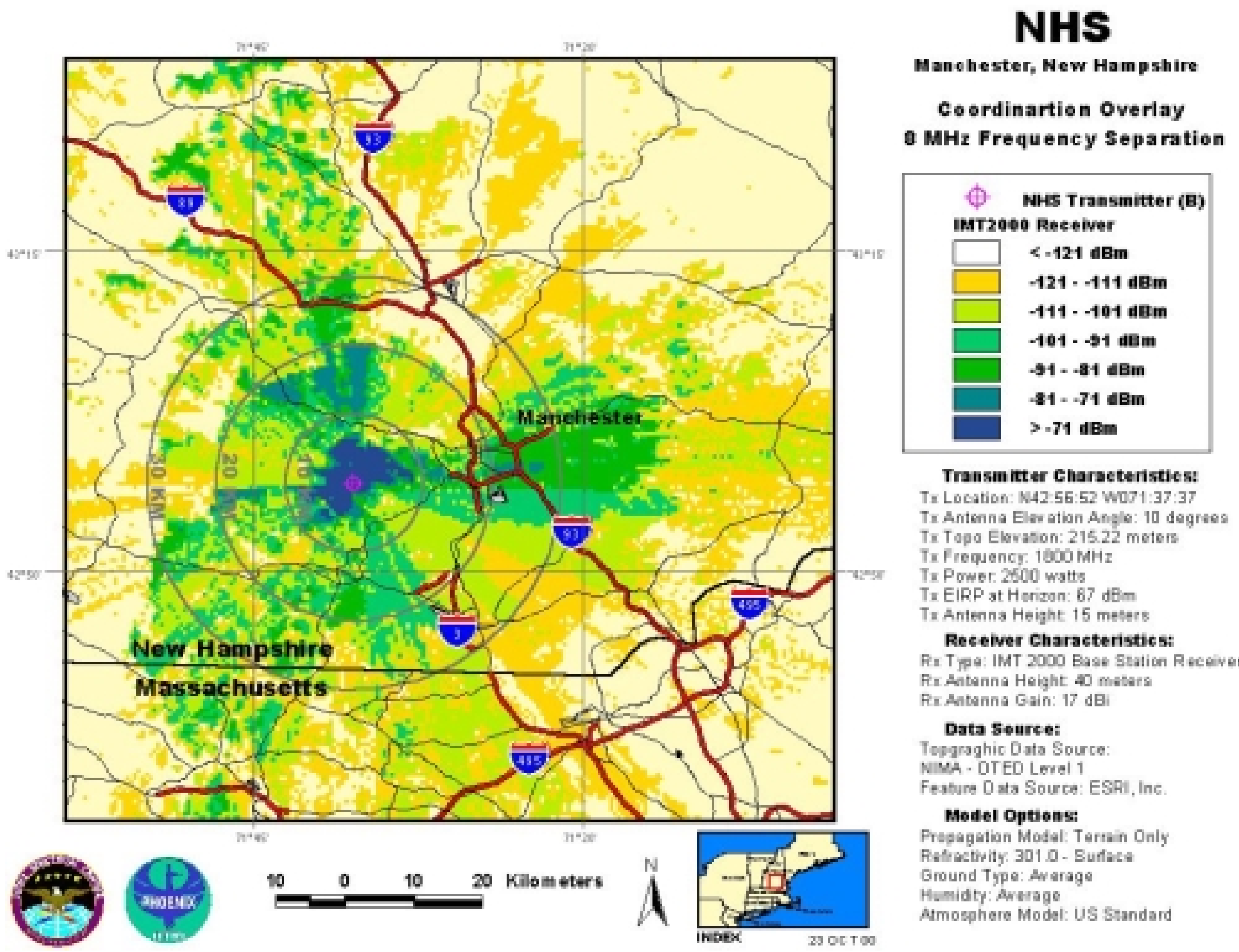

Figure B-19. Coordination Overlay for 8-MHz Frequency Separation

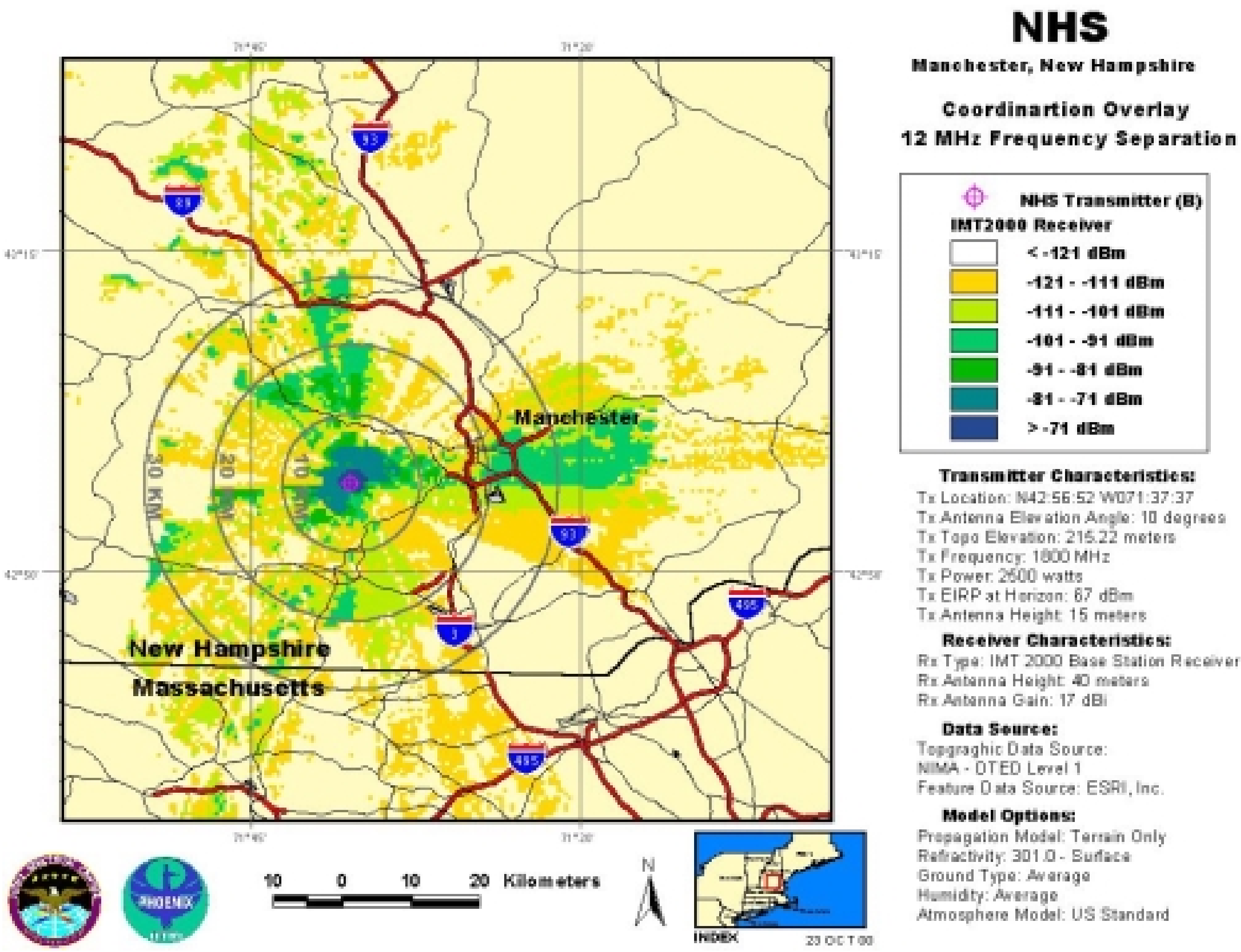

Figure B-20. Coordination Overlay for 12-MHz Frequency Separation

As can be viewed from the overlays, frequency separation clearly reduces the coordination regions, however, like other mitigation techniques discussed, it does not singly provide sufficient isolation between the systems to eliminate the potential for EMI. The limited benefit achieved through off-tuning is reflective of the typically wide/unfiltered emission spectra in the current SGLS signal structure, which is in part due to the unwanted spectral components generated via a class C amplifier. Even with a band segmentation scheme additional filtering of the AFSCN terminals will be required to mitigate interference to the IMT-2000 systems in the adjacent band. It is expected that the more spectrally efficient signal structures that are being considered for future SATOPS uplinks would yield greater benefit in a band segmentation scheme.

B.5.3 1790-1850 MHz Retained – Technical Assessment

This option would allow retention of SATOPS functions in the 1790-1842 MHz band (SGLS channels 8-20) and IMT-2000 operations in the 1755-1790 MHz band. The effects of this option are similar to that of Option 2, but a different set of SGLS channels would be affected. Systems operating on SGLS channels 1-7 would continue to require support and the potential for EMI would remain until the requirement to support such satellites no longer exists.

B.6 OPTION 3 – PARTIAL BAND SEGMENTATION/OTHER BAND COMBINATION

B.6.1 Operational Impact

This band sharing scheme involves a phased-in approach granting non-government access to the 1755-1780 MHz portion of the spectrum in 2006 and access to the 1780-1790 MHz portion of the spectrum in 2010. By retaining 1790-1850 MHz for exclusive US Government use, SGLS channels 1-7 would potentially become shared with non-government users.

Under this option, there is no impact to SATOPS functions in the 2003 timeframe. By 2006, assured access to 1755-1780 MHz portion of the spectrum for SATOPS is required to conduct TT&C for those on-orbit assets operating in the affected portions of the band. Without such access, TT&C functions in channels 1-7 would be jeopardized and resultant satellite/payload and mission failures associated with denied SATOPS spectrum access and SATOPS uplink EMI would occur. The same is true for those systems in the 1780-1790 MHz portion of the spectrum (channels 6 and 7) in 2010.

The satellite systems currently using or scheduled to use SGLS channels 1-5 in the 1755-1780 MHz portion of the band include NATO/Skynet, GFO, ISR, DMSP, and SBIRS. The potential interference from NATO/Skynet, DMSP, and SBIRS operations can be reduced by use of their alternate channel; however, Advanced EHF and GFO lack an alternate channel. Mission capabilities potentially impacted include critical US Armed Forces communications and ISR capabilities.

In 2010, SGLS channels 1-7 would be impacted. Like the other band segmentation options, a lack of assured access to this spectrum for SATOPS functions and degradation to the uplink will lead to satellite/payload and mission failure. The impacts from RFI mitigation options and IMT-2000 uplink EMI parallel those in the previous band segmentation discussions. The satellite systems currently using or scheduled to use SGLS channels 1-7 include those mentioned above, plus those using channels 6 and 7: GPS, DMSP, NPOESS, and SBIRS.

B.6.2 Technical Assessment

If a partial band segmentation option combined with migration of some satellite operations to another band is selected, the technical assessments discussed above would apply to the portion of the band retained for SATOPS. The technical assessment presented in section B.7.2 would apply to the SATOPS migrated to another band.

B.7 OPTION 4 – VACATE 1755-1850 MHZ

In addition to considering sharing possibilities between IMT-2000 and DoD systems, the identification and assessment of candidate frequency bands for the potential migration of existing and planned DoD S-band SATOPS uplink functions is required. This section discusses the issues associated with a migration from the current SGLS 1761-1842 MHz band to the band referred to as Unified S-Band (2025-2110 MHz). It should be noted that total loss of the band is not possible for space systems until at least 2017 or beyond.

The following are critical assumptions/conditions used when considering the migration of current DoD satellite operations to an alternate frequency band:

- Launch, early orbit, and anomaly (LEO&A) resolution support are critical functions that must be maintained throughout the life of a spacecraft
- Given the current implementations, S-band is uniquely suited for conducting critical, non-routine SATOPS functions
- Mission capability provided to end users by US national security space systems will not be degraded. The government will maintain assured access to the 1755-1850 MHz band to satisfy mission objectives until the last 1755-1850 MHz satellite is no longer functioning. This may continue until 2030.
- Domestic regulatory provisions will be implemented so that the DoD has assured access to the 2025-2100 MHz band for Launch, Early Orbit Operations and Anomaly Resolution (LEO&A), and other operations currently operating in the 1755-1850 MHz band. Specifically, the Broadcast Auxiliary Service (BAS) or Electronic News Gathering (ENG) services at transportable and mobile locations shall not claim protection from DoD operations which have been migrated to the 2025-2100 MHz band.

- The electromagnetic compatibility (EMC) between SATOPS uplink systems and incumbent users of the spectrum must be at least equal to that which currently exists in the SGLS frequency band
- Time must be allotted to make an orderly transition

B.7.1 Operational Impact

As indicated, SATOPS functions are absolutely critical for the control and maintenance of the spacecraft. Without alternate spectrum to command the satellite, spacecraft and payload failure would result. Without the use of SGLS in the US&P after 2003, there would be eventual mission failure for a wide range of satellites as described in Option 1. Specific mission functions impacted include missile warning, navigation, military communications, weather, and intelligence; surveillance and reconnaissance; R&D; and international systems.

Without the use of SGLS in 2006, similar results would occur, as insufficient time would be allotted for launching sufficient dual band satellite capabilities and off-loading TT&C functions to non-US sites would not achieve the desired connectivity. All of the systems identified in 2003 would be impacted in 2006, including: missile warning, navigation, military communications, weather, and intelligence; surveillance and reconnaissance; R&D; and international systems. Even with assured spectrum assess, uplink EMI will impact some spacecraft command reliabilities, particularly at the LEO and MEO orbits.

By 2010, there still will be a large number of on-orbit satellites that will require SGLS for operations. The operational impact for Advanced EHF, DSCS, Milstar, DSP, UFO, and GPS of turning off SGLS in 2010 would be the same as turning it off in 2003. These programs will require SGLS past 2017. The FLTSAT, MSX, R&D, and NATO/Skynet programs will have reached end of life, therefore there should be minimal to no impact to these programs. The satellites still on orbit requiring SGLS during this time frame cannot be adequately supported by non-US&P ground sites and therefore would suffer loss of their mission should the US Government be required to vacate 1755-1850 MHz by 2010.

B.7.1.1 GPS

Specific operational impacts associated with the potential loss of various DoD satellites is provided in the next subsections.

Civilian

- Loss of navigation and timing on land, sea, and air

Military

- Loss of navigation for military applications
- Loss of GPS aided/guided munitions
- Loss of GPS aided/guided manned/unmanned aerial platforms
- Loss of GPS aided/guided manned/unmanned land-based platforms
- Loss of GPS aided/guided manned/unmanned seaborne platforms
- Loss of GPS aided/guided manned/unmanned submarine platforms
- Loss of CSEL used in search and rescue (SAR) and all other SAR-related missions

Time Transfer Impact

- Loss of global synchronization for a wide range of military and civilian systems
- Increased risk during aerial refueling rendezvous

Civilian

- Loss of commercial and private aircraft navigational data increasing risks to safety of flight
- Loss of required navigational accuracy and signal availability to a huge number of other civil users like geo-spatial surveying, emergency vehicle dispatch, agricultural crop rotations, oil/petroleum exploration and mapping, and wildlife locations

Timing Synchronization

- A significant number of users of commercial applications require precise (GPS) timing.
- Loss of the required precise timing would severely impact Personnel Communications Services capabilities and worldwide financial institutions' computer operations (including automatic bank machines)

B.7.1.2 DSCS

- Loss of launch and early orbit capabilities for the remaining DSCS satellites
- Loss of platform control and the Single Channel Transponder (SCT) capability for DSCS
- Severe impact to DoD capability to communicate at all levels of conflict

B.7.1.3 Milstar

- Severe impact to DoD capability to communicate at all levels of conflict
- Loss of capability to perform emergency recovery

B.7.1.4 DSP

- Degradation of space based missile warning capability, critical to national security

B.7.1.5 MSX

- Loss of capability to collect data on deep space orbits of military and commercial satellites
- Loss of its unique capability to revisit (sightings) on militarily significant objects
- Impacts ability to reduce the number of lost satellites
- Increases risk to the space operations (space shuttle and other satellites) due to undetected/lost space objects

B.7.1.6 DMSP

- Loss of capability to monitor and predict regional and global weather patterns, including the presence of severe thunderstorms, hurricanes, and typhoons
- Loss of imagery of cloud cover
- Loss of moisture and temperature measurement capability
- Loss of capability to assess the impact of the ionosphere on early warning radar systems and long-range communications
- Loss of capability to monitor global auroral activity and to predict the effects of the space environment on military satellite operations
- Loss of support to civilian weather bureau

- Loss of direct support to battlefield units

B.7.1.7 NATO/Skynet

- Unable to continue to support longstanding international agreements
- Unable to perform backup satellite control of the UK's Skynet 4 constellation

B.7.1.8 FLTSAT/UFO

- Degradation of capability to perform anomaly resolution, including loss of capability to recover from a failure of normal nadir pointing, causing loss of mission capability
- Loss of critical communications for fleet operations and DoD support for GBS

B.7.1.9 GFO

- Loss of platform control for GFO satellite, causing loss of mission capability
- Loss of capability to measure ocean surface heights

B.7.1.10 RESEARCH AND DEVELOPMENT SATELLITES

- Loss of platform control and mission data for the CORIOLIS satellite would result in loss of early capability to measure wind surface speed and direction at the ocean surface. Increased risk to operational sensor on NPOESS.
- Loss of platform control and mission data for the C/NOFS satellite would result in loss of capability to predict GPS outages as well as outages in ground-space communication links due to ionospheric conditions
- Loss of platform control for Cloudsat will result in loss of capability to profile clouds with unprecedented accuracy. Increased risk to future weather predicting sensors.

B.7.2 Technical Assessment

B.7.2.1 Frequency Allocation and Regulatory Protection Issues

From a frequency allocation standpoint, telemetry, tracking and commanding (TT&C) functions fall under the category of “Space Operation Service.” Therefore spectrum appropriately allocated for space operation would most often be required to secure primary status and maximum regulatory protection. It should be noted that frequency allocation provisions currently exist which allow fully protected TT&C functions to be conducted on a primary basis in-band with mission data. In some instances, DoD satellite programs have elected to, or plan to conduct routine satellite TT&C functions in mission bands at considerably higher frequencies. However in most instances, the 1761-1842 MHz band is retained as the primary band for conducting daily operations (tracking and telemetry) in addition to LEO&A resolution and also as the primary for SGLS operations.

B.7.2.1.1 SGLS Uplink Frequency Band

Within the US&P, the 1761-1842 MHz SGLS uplink frequency band is contained within spectrum that is reserved for Federal Government use only. This band has primary status for military space operation functions (Earth-to-space) via US Footnote G42. The 1761-1842 MHz band shares primary status with US Government Fixed and Mobile Services. SGLS frequency use is registered in the US Government Master File (GMF) and DoD’s Frequency Resource Record System (FRRS). SGLS operations within the US&P are fully compliant with existing national spectrum regulations. SGLS use has been coordinated with other federal spectrum users and has full regulatory protection within the US.

Outside the US, the 1761-1842 MHz band is allocated on a primary basis for Space Operation (Earth-to-space) in ITU Region 2 (The Americas), Australia, India, Indonesia, and Japan via Footnote S5.386. Outside of these areas, space operations functions are not allocated. This band shares primary status internationally with the Fixed and Mobile Services (including Aeronautical Public Correspondence: 1800-1805 MHz).

In addition to the international regulatory allocation status, the DoD has established Host Nation Agreements (HNAs) with the countries within which SGLS operations are conducted. These HNAs have been developed to ensure maximum regulatory and RFI protection for SGLS operations overseas. Through coordination with host country government/military and civil frequency management authorities, the DoD has successfully secured a protected status for existing S-band operations. At the international level, the US SGLS uplinks have been registered with the International Telecommunication Union (ITU) and have been fully coordinated with all other potentially affected satellite systems. Given that the DoD is essentially the only user of the SGLS uplink band for TT&C, registration of satellite uplinks requires minimal coordination effort.

B.7.2.1.2 Unified S-band (USB)

Within the US&P, Unified S-band is contained within spectrum that is shared between government and civil users. Although a primary allocation to the Space Operations Service has been added to the US National Table of Allocations, US government TT&C transmissions are further governed by footnotes US222 and US346.[1] US222 allows for TT&C operations on a co-equal basis in the band 2025-2035 MHz for uplinks from Geostationary Operational Environmental Satellite Earth stations in the Space Research and Earth Exploration Satellite Service. Further these uplinks are limited to three sites within the US: Wallops Island, VA, Seattle WA, and Honolulu HI. Footnote US346 restricts uplink operations throughout the remaining areas within CONUS by requiring that government space operations not constrain the deployment of the non-government fixed and mobile use of the spectrum. It requires coordination between government and non-government stations to facilitate compatible operations. The primary non-government (civil) user of the band is the Electronic News Gathering Systems operating under the Broadcast Auxiliary Service (BAS). NASA and NOAA have coordinated government use of USB with the ENG community for TT&C uplinks at specific US sites.

US346 means that DoD SATOPS uplinks in USB would not have the same degree of regulatory protection as currently exists in the 1761-1842 MHz band. This footnote provides the civil operations with regulatory priority should successful coordination not be possible and denies assured equal access for government space operations. Although over 97% of the ENG systems are transmit only and NASA and NOAA have successfully coordinated with these non-government operations, coordination with DoD TT&C uplinks may prove more challenging given the number and location of uplink sites, coupled with the requirement for greater transmission times, increased bandwidth, and varied antenna azimuth/elevation pointing angles.

Currently, DoD SGLS uplink operations are the incumbent user in the 1761-1842 MHz frequency band and as such, new federal spectrum users must demonstrate compatibility with existing SGLS operations. In USB however, DoD SATOPS would be required to protect existing incumbent fixed users, to coordinate on a continuing basis with and protect existing transportable or mobile users, and to coordinate with and not constrain the deployment of future civil users. Therefore, from a regulatory

[1] **US346**--Except as provided by footnote US222, the use of the band 2025-2110 MHz by the Government space operation service (Earth-to-space), Earth exploration-satellite service (Earth-to-space), and space research service (Earth-to-space) shall not constrain the deployment of the Television Broadcast Auxiliary Service, the Cable Television Relay Service, or the Local Television Transmission Service. To facilitate compatible operations between non-Government terrestrial receiving stations at fixed sites and Government earth station transmitters, coordination is required. To facilitate compatible operations between non-government terrestrial transmitting stations and Government spacecraft receivers, the terrestrial transmitters shall not be high-density systems (see Recommendations ITU-R SA.1154 and ITU-R F.1247).

protection standpoint, USB does not currently afford the DoD the same status that it currently enjoys in SGLS band. If DoD is to enjoy the same protection as in the existing SGLS band, as a minimum, a change to US346 must be negotiated. After negotiations are completed, the FCC must, to comply with the Administrative Procedures Act (APA), solicit public and industry comments on any possible changes to the footnote via a Notice of Proposed Rule Making and Report and Order.

Internationally, USB shares its primary status with the Earth Exploration Satellite, Fixed, Mobile, and Space Research Services. NASA and the international science community as well as others make extensive use of this band for uplink TT&C operations. Hence SATOPS uplink functions in USB enjoy primary status and regulatory protection overseas. While USB enjoys primary status for TT&C overseas, its use for such functions is extensive. Hence the new DoD space operations registrations in this band will meet with more international registration/coordination challenges than experienced in the current SGLS uplink band, where little if any SATOPS outside the US DoD are performed. The challenges will be similar to those currently experienced in registration and coordination of the SGLS downlinks. In addition, the requirement for an orderly transition to an alternate band will require satellites to be launched with dual mode capabilities as the ground support infrastructure is developed. Such dual mode satellites may further complicate registration and coordination procedures.

B.7.2.1.3 Host Nation Agreements

All operations within a foreign nation's borders require host nation approval regardless of the ITU allocation status. Therefore, the DoD's migration to USB would require the establishment of a new set of HNAs to ensure protected operations on foreign soil. While this may not be an obstacle to success, it nevertheless requires new agreements to be established at sites where USB will be used. Consideration should be given to the likelihood of successfully completing such HNAs in the overall migration assessment.

B.7.2.1.4 National and International Registrations

A migration to USB will require filing the appropriate national and international registration paperwork. With the US, filing of DD Form 1494 Application for Equipment Frequency Allocation as well as frequency assignment paperwork will be required. Internationally, registration of the desired geostationary nodes for USB with the ITU will be critical. The extensive timeline required for the national, and more importantly international registration process requires that these efforts be initiated as soon as practical.

B.7.2.1.5 Government SATOPS Regulatory Issues Summary

- Domestic regulatory provisions must be implemented so that the DoD has assured access to the 2025-2100 MHz band for Launch, Early Orbit Operations and Anomaly Resolution (LEO&A), and other operations currently operating in the 1755-1850 MHz band. Specifically, the Broadcast Auxiliary Service (BAS) or Electronic News Gathering (ENG) services at transportable and mobile locations shall not claim protection from DoD operations which have been migrated to the 2025-2100 MHz band.
- Mission capability provided to end users by US national security space systems must not be degraded. The government must maintain assured access to the 1755-1850 MHz band to satisfy mission objectives until the last 1755-1850 MHz satellite is no longer functioning. This may continue until 2030.
- Current domestic regulatory provisions that protect existing DoD operations in the 1755-1850 MHz band must continue throughout any spectrum operations migration/transition period.
- New HNAs in USB would have to be established.
- DoD must file and successfully conclude international coordination of satellite networks in the 2025-2100 MHz band.

B.7.2.2 Electromagnetic Compatibility Issues

B.7.2.2.1 Interference to Incumbent Users – Electronic News Gathering Systems

System Description.[2] The primary user of the 2025-2110 MHz frequency band by the non-Federal government users is the Electronic News Gathering (ENG) systems operating within the Broadcast Auxiliary Service. In addition to the 2025-2110 MHz, ENG systems also operate in the 6.4-7.1 GHz and 12.77-13.2 GHz bands. This flexibility allows for the possibility of alternate frequency band use in instances where SATOPS uplinks are in proximity to ENG receiver sites.

ENG systems include both mobile point-of-view and transportable ENG systems that provide video from a variety of locations and activities. The ENG systems are used for on-location coverage of news events or live-action video during sports and entertainment events. The point-of-view systems are small light-weight microwave transmitters used for mobile and close-up video. These systems utilize essentially omnidirectional antennas with 0-3 dBi of gain with linear or circular polarization. The transportable ENG systems are used by most local television stations for on-location coverage are generally mounted in vans and operate in a stationary mode transmitting video to a fixed receive

[2] Document USTG 7-1/102, *Analysis of Antenna Gain as a Sharing Criterion between Mobile Services and the Space Research Service, Space Operations Service, and Earth Exploration Satellite Services in the 2015-2110 MHz Band*, Horne, William, D, 10 September 1993.

site. These systems utilize directional antennas with gains between 20-22 dBi mounted on top of a pneumatic mast of up to 15 m in height. ENG systems may employ linear or circular polarization to provide additional interference protection from each other. There are also a small number of mobile/transportable receivers operating in the BAS service as well (less than 3% of all ENG receivers in this band). These mobile/transportable ENG systems are used on helicopters and placed in locations with adequate line of sight to relay the broadcast to the base station receiver.

Although used throughout the day, transportable ENG systems operate primarily during weekday local news broadcasts, which usually occur around 1200-1230, 1700-1900, and 2300-2330 local time. In most markets before the afternoon news hours around 1500-1700, ENG use is also significant. The popularity of local morning shows from 0600-0900 is increasing in various markets, and these shows also use ENG systems. Transportable ENG transmitters are operated approximately twice per day. Broadcast engineers estimate that each ENG operation transmits an average of 15 minutes per operation but can vary from about 5 minutes to perhaps as long as 5 hours.

The total number of 2 GHz ENG systems in the US exceeds 4000. Although it may seem intuitive to assume that all ENG systems would transmit and receive, the vast majority of transportable ENG systems (97% according to one ENG manufacturer) posses transmit only capabilities and do not have receivers in the 2025-2110 MHz band. Potential victims of interference from SATOPS uplinks are therefore generally limited to the much smaller number of fixed receiver sites within the US.

Table B-21 lists the types of ENG systems typically employed in the US. Figure B-21 shows the ENG frequency channelization plan. In the US, the ENG frequency band is divided into seven channels each with 17 MHz, except the first channel, which is 18 MHz. ENG systems are usually operated at the center of each channel, but the lower offset and upper offset channels are also used. Consequently, 21 carrier frequencies are possible, but all carrier frequencies cannot be used simultaneously. ENG systems may operate at the center channel, the lower offset channel, the higher offset channel, or the lower and higher offset channels simultaneously, depending on the need and adjacent channel use at any time.

Table B-21. Typical 1 GHz ENG systems in use in the United States of America

Type of use	Transmitter location	Transmit power	Antenna gain (dBi)	Receiver location
ENG transportable (van)	Van mast	12 W	22	Tower
Temporary fixed link	Roof	12 W	25	Roof
Convention	Floor of convention hall	100 mW	0-5	Hall rafters
Point-of-view (e.g., skier)	On body/helmet	100 mW	0	Hillside or helicopter
Sports venues				
Playing field	Field	1 W	12	Press box
Golf course (system 1)	On golf course	3 W	16	Tethered blimp
Golf course (system 2)	On golf course	12 W	12	Crane
Racecam	In car	3 W	7	Helicopter
Helicopter	Relay helicopter	12 W	7	Ground receive
Marathon				
Motorcycle	Motorcycle	3 W	7	Helicopter
Relay vehicle	Pick-up truck	12 W	12	Helicopter
Helicopter	Relay helicopter	12 W	7	Roof

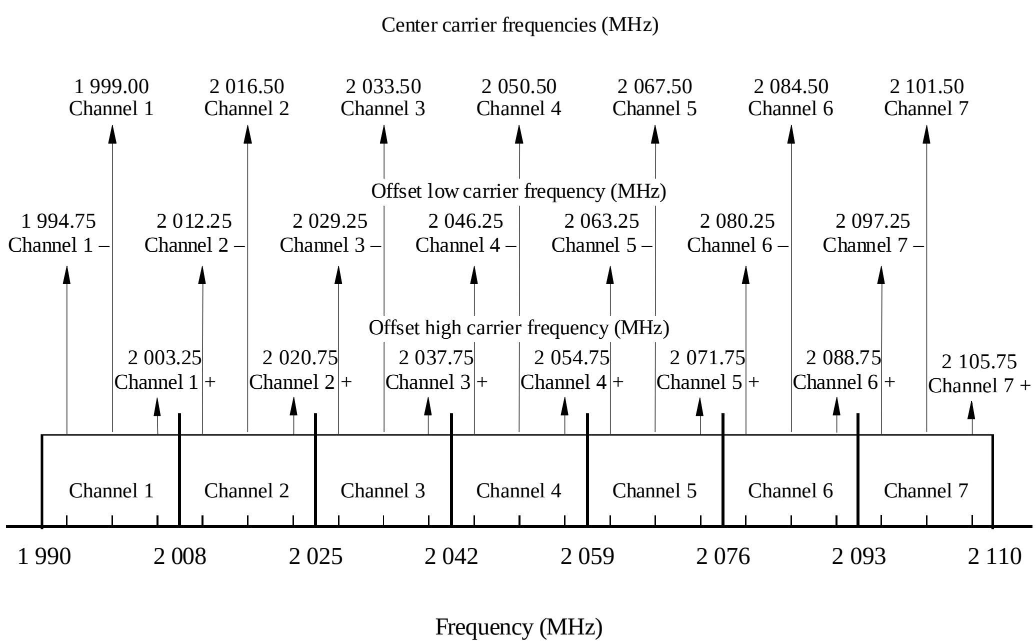

Figure B-21. US ENG Frequency Plan

EMI Assessment. To assess the potential for interference from SATOPS uplinks to ENG receivers, calculations were performed to determine the required separation distances between the SATOPS uplink sites and the ENG receivers as a function of antenna coupling. The size of the required coordination coupled with ENG FCC license data provides an indication of the number of systems potentially affected and hence the level of coordination required. The following equation was used to estimate the undesired ENG receiver signal level from the SATOPS uplinks:

$$S_r = P_t + G_t + G_r - L_p - L_s - FDR \quad \text{(B-2)}$$

where

S_r	=	Undesired signal level, at the ENG receiver input, in dBm
P_t	=	SATOPS transmitter peak power, in dBm
G_t	=	SATOPS transmitter antenna gain at the horizon, in dBi
G_r	=	ENG Receiver antenna gain in the direction of the SATOPS transmitter, in dBi
L_p	=	Path loss, in dB
L_s	=	ENG receiver system loss, in dB
FDR	=	Frequency-dependent rejection, in dB.

For the analysis, an average SATOPS transmitter uplink power of 2250 Watts was assumed. Off axis antenna gains corresponding to minimum elevation angles of 3, and10 degrees were assumed. These levels are consistent with the minimum and maximum values used to generate the signal overlays for the IMT-2000 receiver analysis. Both a mainbeam gain of 22 dBi and a sidelobe gain of 2 dBi were assumed for the ENG receivers. Given the wideband receiver of the ENG systems (17 MHz) as compared to the SATOPS uplink signal, no FDR was assumed. A typical receiver sensitivity of -108 dBm was used as the threshold for interference. The path loss was determined using a smooth-earth approximation assuming an ENG antenna height of 30 meters and accounting for the curvature of the earth. Table B-22 is a summary of the typical ENG characteristics. Table B-23 contains the SATOPS transmitter parameters used in the calculations.

Table B-22. Parameters of a Typical Electronic News Gathering Systems

Data	Value
Frequency range	1990-2110 MHz
Transmit power	12 W
Channel Bandwidth (MHz)	17.0
Antenna gain	22 dBi (mainbeam), 2 dBi (sidelobe)
Antenna height	15 m (Transportable), 30 m (Fixed Receive)
Receiver bandwidth (MHz)	17.0 (-3dB)
Receiver noise figure	3 dB
Receiver sensitivity	NA
Receiver noise power	-99 dBm
Interfering signal threshold	-108 dBm
Cable losses	2 dB

Table B-23. SATOPS Uplink Parameters

Data	Value
Transmit power	2250 W
Transmitter Frequency	2075 MHz
Antenna Size	46 foot
Antenna Gain	18 dBi (3 degrees); 3 dBi (10 Degrees)
EIRP	82 dBm (3 degrees); 67 dBm (10 degrees)
Antenna Feedpoint Height	15 m

Table B-24 lists the required separation distances as a function of antenna coupling. It should be noted that the distances provided do not account for signal attenuation from terrain or man made obstructions. These factors in some instances will make the required distance separations significantly less. Airborne ENG receivers (relay helicopters) were excluded from this assessment, however it should be noted that their usage is an increasing concern to SATOPS. A higher receiver antenna height lessons the attenuation from terrain and creates the potential for line of sight (LOS) interactions. Under these conditions, separation distances greatly exceed those specified in Table B-24 due to the additional line-of-sight distance from airborne platforms.

Table B-24. Required Distance Separations (km) to Preclude EMI to ENG Receivers

SATOPS Minimum Elevation Angle (Degrees)	Required Distance Separations (km)	
	ENG Mainbeam Antenna Coupling	ENG Sidelobe Antenna Coupling
3	201	108
10	88	59

Table B-25 lists the approximate number of fixed ENG receivers within the distance separations specified in Table B-24. It is apparent that Guam and Colorado may prove to be the least difficult to coordinate while ENG activity around the Cape is fairly extensive and therefore will require more extensive coordination. The number of receivers indicated in Table B-25 should only be used as an indication of the level of coordination required. Several factors including specific channel use, time of use, terrain dependent signal attenuation, as well as the possibility of receiver data omission in the FCC database will factor into the coordination efforts. Should DoD SATOPS functions migrate to USB, a spectrum sharing strategy should be developed in coordination with the ENG community.

Table B-25. Approximate Number of ENG Fixed Receivers Surrounding SATOPS Uplink Sites

SATOPS Uplink Site	Approximate Number of Registered ENG Receivers within the Specified Separation Requirement			
	201 km Separation Requirement	88 km Separation Requirement	108 km Separation Requirement	59 km Separation Requirement
Manchester, NH (NHS)	22	7	7	7
Colorado Springs CO (CTS)	2	1	1	1
Cape Canaveral, FL (EVCF)	34	15	21	11
Sunnyvale, CA (OAS)	10	2	4	1
HTS	6	6	6	5
Guam (GTS)	1	1	1	1

It should be noted that NASA currently employs SATOPS uplinks within the US that have been coordinated with the ENG/BAS community. The DoD should include NASA in its coordination activities with the BAS to ensure a unified government approach to band sharing.

B.7.2.3 EMI Issues Summary

- There is a potential for EMI from DoD SATOPS uplinks to the ENG services in USB
- Coordination with the ENG and other communities is essential to preclude EMI
- Coordination with NASA's current SATOPS USB uplinks is also recommended
- A spectrum sharing strategy for USB should be developed in concert with NASA and the BAS/ENG community
- Coordination regions on the order of 50-200 km may be required to address EMI issues to fixed ENG receivers. Greater coordination distances may be required when considering airborne ENG receivers

APPENDIX C – POTENTIAL FOR SHARING BETWEEN IMT-2000 AND TACTICAL RADIO RELAY IN THE 1755-1850 MHZ FREQUENCY BAND

A large number of existing Department of Defense (DoD) line-of-sight (LOS) microwave (MW) systems operate in the 1755-1850 MHz frequency band. This appendix addresses the potential for interference between the International Mobile Telecommunications for the Year 2000 (IMT-2000) systems and the DoD tactical radio relay (TRR) systems.

The LOS MW systems operating in the band are too numerous to analyze individually, and some of the fixed systems do not have unique requirements limiting the systems to frequencies below 3 GHz. One class of systems with requirements constraining operations to frequencies near the 1755-1850 MHz band are the DoD TRR systems, and these systems were analyzed in the assessment.

The military services require efficient methods of exchanging large quantities of digital data throughout the battlefield. The increased use of computers, digital video, and facsimile equipment in command and control, intelligence, and logistics will generate more data in the future. The military radios are deployable, transportable, point-to-point radio systems using low-to-moderate gain antennas. The military TRR equipment uses broad beamwidth antennas for quick link setup during deployments. The movement of the lightweight, flexible masts that support the antennas or the movement of shipboard antennas preclude the use of narrowbeam type antennas. The requirements for low/moderate power levels for the transportable radios and the broad beamwidth antenna limits applicable frequency band to below 3 GHz. The primary DoD TRR systems operating in the 1755-1850 MHz band are the United States (US) Army Mobile Subscriber Equipment (MSE), Tri-Services Tactical Communications (TRI-TAC), and the Navy/Marine Corps Digital Wideband Transmission System (DWTS).

C.1 MISSION OVERVIEW

C.1.1 Mobile Subscriber Equipment

The AN/GRC-103, AN/GRC-226, and AN/GRC-245 radio sets are LOS trunk radios used to link nodes (switching centers) in the Army's tactical telecommunications system or the Army Common User System (ACUS). These radios operate in the 1755-1850 MHz spectrum band and would be degraded by the introduction of IMT-2000 systems into the band. The ACUS is a seamless, tactical communications system that provides secure, highly reliable voice and data communications for both mobile and fixed users in a tactical environment. The ACUS operates from the front-line maneuver battalions to the theater headquarters in the rear areas. This communication network is formed in two parts; the MSE and the TRI-TAC system. The MSE system is deployed at corps-level units to maneuver battalions and the TRI-TAC system is deployed at Echelon Above Corps (corps-level units to higher headquarters). The system operates like a high capacity personal communications system with rapidly transportable base stations. A three Division corps-size deployment could deploy up to eighteen 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 and TRI-TAC provide the force commanders the ability to maintain effective control over their forces. MSE and TRI-TAC are tactical systems for rapid deployment in the field. This is because headquarters units, with their signature electronic emissions, are targeted for artillery and missile attacks by the enemy. The ability to set up a link to higher headquarters and subordinate units and then take down the link and move is key to the survivability of the headquarters 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.

ACUS/MSE is planned for use by the US Joint Forces Command (USJFCOM) to support Joint Task Force Civil Support (JTF-CS) in the event of a Weapons of Mass Destruction (WMD) incident. JTF-CS is tasked to provide support to a Designated Lead Federal Agency in the conduct of consequence management operations in response to a Chemical, Biological, Radiological, Nuclear and High Yield Explosives (CBRNE) incident or accident in the Continental United States (CONUS), Alaska, Hawaii, US territories and possessions.

Additionally, ACUS/MSE is used for other contingency operations within the US to include disaster relief, national emergencies, and other DoD support requirements to civil authorities, as directed from the National Command Authority.

C.1.2 Digital Wideband Transmission System

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 AN/MRC-142 is the Marine Corps element of this radio system, providing the 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. From command and control traffic to intelligence imagery, logistics, medical, and morale and welfare support, DWTS provides the force commanders the ability to maintain effective control over their forces. DWTS is a tactical systems designed to set up in the field quickly, similar to the Army's ACUS. Headquarters units, with their signature electronic emissions, are targeted for artillery and missile attacks by the enemy. The ability to set up a link to higher headquarters and subordinate units and then take the link down and move is key to the survivability of the headquarters 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 ship-to-shore link of DWTS is the AN/SRC-57 radio. This is essential for amphibious operations where most of the critical information flow is from the ship to the landing forces. The anticipated service life of the AN/MRC-142 extends beyond the 2010 time frame.

DWTS is a MSE equivalent system planned for use by the USJFCOM to support JTF-CS in the event of a WMD incident. JTF-CS is tasked to provide support to a designated Lead Federal Agency in the conduct of consequence management operations in response to a CBRNE incident or accident in the CONUS, Alaska, Hawaii, US and possessions (US&P).

Additionally, DWTS is used for other contingency operations within the US to include disaster relief, national emergencies, and other DoD support requirements to civil authorities, as directed from the National Command Authority.

C.2 TACTICAL RADIO RELAY SYSTEM DESCRIPTIONS

MSE. The MSE is a multi-band, tactical LOS radio system, more accurately described as a "system-of-systems," because it is composed of several components, each of which are fully operational systems. The individual components that make up the MSE are dependent upon several portions of the radio frequency spectrum (e.g., 30-88 MHz, 225-400 MHz, 1350-1850 MHz, and 14.5-15.35 GHz). The inability of any of these components to operate successfully would result in the failure of the overall system. One critical component of the MSE, the AN/GRC-226(V)2 radio, operates in the 1755-1850 MHz frequency band. It is used to connect radio access units to the node center switch of the network. Operational use plans call for 465 units per Army Corps, giving a total of 2,325 units for five Corps. The AN/GRC-226(V)2 is a digital radio that can tune to any of 4000 available channels, spaced at 125 kHz, between 1350-1850 MHz; however, due to the allocation of most of this band to other services, users rarely have access to spectrum outside of 1350-1390 MHz and 1710-1850 MHz. The AN/GRC-226(V)2 requires a 50.125-MHz minimum frequency separation between the site transmitter and receiver for a duplex link. The technical parameters of the AN/GRC-226(V)2 used in the analysis are presented in Table C-1.

Table C-1. AN/GRC-226 (V)2 Parameters (J/F 12/6102/2)

Frequency range	1350 – 1850 MHz
Transmit power	0.5 - 5 W
Emission Bandwidth (MHz)*	1.25 (-3dB), 3.5 (-20dB), 10.55 (-60dB)
Antenna gain	20 dBi (MB), 11 dBi (20-90 deg), 2 dBi (90-180 deg)
Antenna height	30 m
Receiver bandwidth (MHz)*	0.85 (-3dB), 1.6 (-20dB), 4.4 (-60dB)
Receiver noise figure	8 dB
Receiver sensitivity	-93 dBm @ BER = 10E–5 (S/N = 14 dB)
Receiver noise power	-107 dBm
Interfering signal threshold	-113 dBm
Cable losses	2.4 dB (estimated)
Waveform	2M40F9W*, 256 – 2048 kb/s MSK

*2048 kb/s is the maximum bit rate.
MB – mainbeam
MSK – minimum shift keying

TRI-TAC. The TRI-TAC system uses the AN/GRC-103(v)3 TRR unit to provide connectivity to Army Echelons Above Corps. There are over 600 of these radios in use by the Army and reserve units throughout the US. With respect to the technical assessment addressed in this appendix, the technical parameters of the AN/GRC-103(v)3 are similar to those of the AN/GRC-226. The results of the interference assessment of the AN/GRC-226 is considered to be generally applicable to the AN/GRC-103(v)3.

HCLOS. The High Capacity LOS (HCLOS) radio system is expected to eventually replace the AN/GRC-226(V)2 radios in the MSE for the ACUS. The HCLOS radio, the AN/GRC-245(V), operates in the 225-400 MHz and 1350-2690 MHz bands with increased spectral efficiency and higher data rates compared to the current radio. The AN/GRC-245(V) requires a 50.125-MHz minimum frequency separation between the site transmitter and receiver for a duplex link. The technical parameters of the AN/GRC-245(V) used in the assessment are presented in Table C-2.

Table C-2. AN/GRC-245 (V) Parameters (J/F 12/7601)

Frequency range	1350 – 2690 MHz
Transmit power	31 mW - 1.6 W
Emission Bandwidth (MHz)*	2.0 (-3dB), 2.9 (-20dB), 7.2 (-60dB)
Antenna gain	23 dBi (mainbeam)
Antenna height	30 m
Receiver bandwidth (MHz)*	6.7 (-3dB), 8.1 (-20dB), 10.0 (-60dB)
Receiver noise figure	7 dB
Receiver sensitivity*	-86 dBm @ 8192 Kb/s and BER = 10E-5
Receiver noise power*	-99 dBm
Interfering signal threshold*	-105 dBm
Cable losses	4 dB @ 1850 MHz
Waveform	2M50W1D*,320-8256 kb/s, 32 TCM, rate 4/5 code

*8256 kb/s is the maximum bit rate.
TCM – trellis coded modulation

DWTS. The DWTS is a LOS tactical radio system providing point-to-point (shore based AN/MRC-142), ship-to-ship (ship based AN/SRC-57) and ship-to-shore (AN/SRC-57 and AN/MRC-142 or the Army AN/GRC-226) communications. The DWTS provides communications vital to the Commander Joint Task Force (CJTF), Commander Amphibious Task Force (CATF), Commander Landing Force (CLF), Amphibious Forces afloat, and US Forces ashore. The system provides afloat and ashore commanders with entry into the Global Command and Control System – Maritime (GCCS-M) to ensure common access to intelligence, mapping, order of battle, and logistics information. The DWTS provides data transmissions for Battlegroup (BG) planning, video tele-conferences, BG e-mail connectivity, Internet connectivity and intra-BG telephone connectivity. DWTS provides tactical digital wideband transmissions for voice, video, and data to support landing force command elements to include Marine regiment or Expeditionary Unit and higher and Army brigade and higher. The DWTS consists of two components, the shore based USMC AN/MRC-142 and the ship based US Navy AN/SRC-57.

AN/MRC-142. The shore based component of the DWTS, the AN/MRC-142, typically uses the frequency bands 1350-1390 MHz, 1432-1435 MHz, and 1710-1850 MHz. In addition, the AN/MRC-142 ship-to-shore links have further frequency restrictions caused by ship-based interference to the AN/SRC-57 located on ships. The AN/MRC-142 requires a 63-MHz minimum frequency separation between the site transmitter and receiver for a duplex link. The technical parameters of the AN/MRC-142 used in the evaluation are presented in Table C-3.

Table C-3. AN/MRC-142 Parameters (J/F 12/6461)

Frequency range	1350 – 1850 MHz
Transmit power	3.0 W
Emission Bandwidth (MHz)	0.4 (-3dB), 1.05 (-20dB), 3.15 (-60dB)
Antenna gain	20 dBi (mainbeam), 6.3 dBi (26 deg)
Antenna height	30 m
Receiver bandwidth (MHz)	0.8 (-3dB), 1.0 (-40 dB), 4.4 (-60 dB)
Receiver noise figure	8 dB
Receiver sensitivity	-93 dBm BER = 10E-4
Receiver noise power	-107 dBm
Interfering signal threshold	-113 dBm
Waveform	610K0F7W, 576kb/s FSK
FSK – frequency shift keying	

AN/SRC-57. The ship-based AN/SRC-57 uses an omnidirectional antenna to communicate with other ships and shore-based radios. The AN/SRC-57 can tune over the 1350-1850 MHz frequency band for operations in international waters. However, the AN/SRC-57 was granted stage four spectrum certification to operate in the bands of 1350-1390 MHz and 1755-1850 MHz within the US&P. The AN/SRC-57 can experience shipboard interference interactions that could eliminate additional frequency bands. The AN/SRC-57 can receive interference from shipboard systems such as the Target Acquisition System (TAS) MK 23 radar, AN/SPS-49 radar, and International Maritime

Satellite (INMARSAT) and can cause interference to Global Positioning System (GPS), INMARSAT, and AN/SMQ-11 Weather Satellite receivers.

The AN/SRC-57 requires a 50-MHz minimum frequency separation between the site transmitter and receiver for ship-to-ship duplex links; however, ship-to-shore links must conform to the 63 MHz separation requirements of the AN/MRC-142. The technical parameters of the AN/SRC-57 used in the assessment are presented in Table C-4.

Table C-4. AN/SRC-57 Parameters (J/F 12/7652)

Frequency range	1350 – 1850 MHz
Transmit power	5 – 250 W
Emission Bandwidth (MHz)	1.0 (-3dB), 3.0 (-20 dB), 8.0 (-60 dB)
Antenna gain	1.5 dBi Omni
Antenna height	30 m
Receiver bandwidth (MHz)	1.6 (-3 dB), 4.0 (-20 dB), 9.2 (-60 dB)
Receiver noise figure	7 dB
Receiver sensitivity	-84 dBm BER = 10E-5
Receiver noise power	-105 dBm
Interfering signal threshold	-111 dBm
Waveform	2M85F7D, 144-2304 kb/s binary FSK

C.3 COST ISSUES

There are two major equipment types in this category, the Army's MSE and TRI-TAC, and the Navy/Marine Corps DWTS. Both of these systems rely on the 1755-1850 MHz band to provide the high-end frequency component of their full-duplex channel pairs. Although both equipment sets tune over an extended frequency range, loss of this particular band would significantly reduce the number of radios which could be netted together during training exercises due to non availability of alternate bands to provide the high-end frequency component of the duplex channel. The Army has already encountered this problem with their MSE and TRI-TAC systems in Europe. To alleviate the problem, they have begun the acquisition and fielding of a new generation of radio called High Capacity Line of Sight (HCLOS) or AN/GRC-245. HCLOS tunes over an even wider range than baseline MSE and TRI-TAC, and offers the potential to mitigate the IMT-2000 third-generartion (3G) problem as well. Similar to the combat aircraft training systems, the HCLOS mitigation strategy assumes that the wider tuning range will cover some new bands that can be used by the Army to setup MSE and TRI-TAC radio links. If no such bands are provided this proposed solution is not viable. DoD's mitigation strategy for the Army's MSE and TRI-TAC equipment calls for accelerating the procurement of HCLOS considerably over the baseline program DoD currently has in place. As per the cost reimbursement rules defined in NTIA's Notice of Proposed Rulemaking (NPRM), the difference in the accelerated budget requirements over and above the baseline requirements are reimbursable and so are included in the cost estimate for IMT-2000. The same MSE and TRI-TAC program plan would be implemented under either band segmentation option, band sharing, or if access to the band was lost completely. The same plan would also be implemented regardless of the 3G introduction date.

The DoD plan for mitigating the effect of the Navy/Marine Corps DWTS system on IMT-2000 is slightly more complex than the strategy for the Army's MSE. The Navy/Marine Corps rely heavily upon these links for point to point land communications and the ship to shore links. Therefore, each option (band sharing, segmentation, band loss) must be viewed independently and with reference to operational considerations and cost. The band sharing option would require the Marine Corps to operate using fixed locations and antenna orientations or power constraints, all of which are inconsistent with the Marine Corps operational doctrine for maneuver warfare. In the event of segmentation or band loss, the Marine Corps envisions replacing the existing MRC-142 with either a modified non-developmental item (NDI) (possibly a HCLOS-like) system or a new development system based on the newly assigned spectrum. Note: Since HCLOS was never designed to work with DWTS, it would require non-recurring integration effort. Tables C-5 and C-6 present reimbursement cost data.

Table C-5. Mobile Subscriber Equipment (HCLOS) Reimbursement Cost (TY$M)

	FY02	FY03	FY04	FY05	FY06	FY07	To Complete	Total
HCLOS Acceleration	**40.1**	**49.0**	**48.7**	**11.6**	**0.0**	**0.0**	**0.0**	**149.5**

Table C-6. Digital Wideband Transmission System Reimbursement Cost (TY$M)

DWTS Band Segmentation Options Reimbursement Cost (TY$M)								
	FY02	**FY03**	**FY04**	**FY05**	**FY06**	**FY07**	**To Complete**	**Total**
Marine Corps	9.9	5.1	50.6	53.6	65.6	65.6	270.0	520.4
Navy	4.0	5.0	1.5	0.5	0.5	0.5	7.0	19.0
Total	**13.9**	**10.1**	**52.1**	**54.1**	**66.1**	**66.1**	**277.0**	**539.4**
DWTS Band Vacation Option Reimbursement Cost (TY$M)								
	FY02	**FY03**	**FY04**	**FY05**	**FY06**	**FY07**	**To Complete**	**Total**
Marine Corps	10.0	15.0	15.0	55.6	53.6	65.6	320.6	535.4
Navy	5.4	6.7	11.5	10.7	10.7	10.7	9.8	65.5
Total	**15.4**	**21.7**	**26.5**	**66.3**	**64.3**	**76.3**	**330.4**	**600.9**
DWTS Band Sharing Option Reimbursement Cost (TY$M)								
	FY02	**FY03**	**FY04**	**FY05**	**FY06**	**FY07**	**To Complete**	**Total**
Marine Corps	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navy	5.4	6.7	11.5	10.7	10.7	10.7	7.0	62.7
Total	**5.4**	**6.7**	**11.5**	**10.7**	**10.7**	**10.7**	**7.0**	**62.7**

C.4 OPTION 1 – FULL BAND SHARING

C.4.1 Technical Assessment

The DoD TRR systems potential for sharing the 1755-1850 MHz frequency band with the IMT-2000 systems was investigated on a one-to-one basis. A distance separation required to protect each of four radio relay systems from each of the four candidate IMT-2000 systems and each of the four candidate IMT-2000 systems from the four radio relay systems was determined. The IMT-2000 mobiles and base stations (including main-beam and side-lobe antenna gains) were analyzed versus the radio relay main-beam and side-lobe antenna gains. The ship-based DWTS uses an omnidirectional antenna, and the DWTS was analyzed at the highest and lowest transmitter power setting.

The technical parameters for the tactical radios (see the *System Description* section) were obtained from the Spectrum Certification Applications and from data provided by the program manager for each radio. The technical parameters for the IMT-2000 radios used in the sharing assessment are presented in a previous section of this report. The interference threshold values of the IMT-2000 code division multiple access (CDMA) system receivers are referenced to the data rate of the CDMA modulation. The interference threshold referenced to the receiver bandwidth would be increased by the ratio of the receiver bandwidth to the data rate. The revised interference thresholds (I_t) are presented in Table C-7.

Table C-7. CDMA-2000 Receiver Interference Thresholds

	CDMA-2000 Narrowband (NB) (1.25 MHz)		CDMA-2000 Wideband (WB) (3.75 MHz)	
	Base	Mobile	Base	Mobile
Interference Threshold 1	-114.6 dBm	-110.6 dBm	-109.9 dBm	-105.9 dBm
Interference Threshold 2	-99.1 dBm	-95.1 dBm	-94.4 dBm	-90.4 dBm

The interference thresholds for the DoD tactical radio receivers were based on the Recommendation ITU-R F.1334, which limits the degradation due to interference in the fixed service receiver to 1 dB. This value corresponds to an allowed interference-to-noise power ratio (I/N) of –6 dB. Also, for one example, an additional, higher threshold was used, assuming a desired signal level of –75 dBm, and an signal-to-interference plus noise ratio (S/(I+N)) of 14 dB.

The analysis was performed to identify the required distance separation to protect the TRR receivers from the IMT-2000 transmitters and the IMT-2000 receivers from the TRR transmitters. The required propagation loss was calculated using transmitter powers, transmitter and receiver antenna gains, frequency-dependent rejection, and the receiver interference threshold as follows:

$$L_P = P_T + G_T + G_R + L_S - FDR - I_T \tag{C-1}$$

where:

L_P = required propagation path loss to preclude interference (dB)
P_T = output power of the source transmitter (dBm)
G_T = source transmit antenna gain in the direction of the victim receiver (dBi)
G_R = victim receive antenna gain in the direction of the source transmitter (dBi)
L_S = transmitter and receiver line losses (dB)
FDR = frequency-dependent rejection (dB)
I_T = receiver interference threshold (dBm).

The Spherical Earth Model (SEM) was used to determine the required distance separation to preclude interference. The SEM is applicable to paths over a smooth, spherical, homogenous, and imperfectly conducting earth. The dominant mode of propagation can be either LOS, diffraction, or tropospheric forward-scatter. The SEM calculates the required distance separation based on the required propagation loss, link frequency, and transmitter/receiver antenna heights.

The above assessment was used to evaluate the frequency separation versus distance separation requirements for one sample case of the AN/GRC-226 and the CDMA WB (3.75 MHz). The receiver selectivity and the transmitter emission spectrum were off-tuned, and the FDR was determined for several values of frequency separation.

C.4.2 Results

The IMT-2000 to TRR distance separation requirements are presented in Table C-8, the TRR to IMT-2000 (minimum interference threshold) distance requirements are presented in Table C-9, and the TRR to IMT-2000 (more typical interference threshold) distance separation requirements are presented in Table C-10.

For the minimum interference threshold case, the distance separation requirements between the TRR and the IMT-2000 base stations would be approximately 92 km if random antenna orientations were allowed for both systems. With the same interference threshold, the distance separation requirements between the TRR and the IMT-2000 base stations would be approximately 55 km if side-lobe antenna orientations were constrained for each system toward the other system (assumes low-power operation for the AN/SRC-57).

With the minimum interference threshold, the distance separation requirements between the TRR and the IMT-2000 mobiles would be approximately 38 km, if random antenna orientations were allowed for the TRR. If TRR main-beam antenna orientations (assumes low-power operation for the AN/SRC-57) were constrained away from areas of IMT-2000 operations and IMT-2000 mobiles were restricted from some areas of operations, the distance separation requirements would be approximately 23 km. The above distance separation requirements cannot be accommodated in many areas of TRR operations in the US.

Table C-8. IMT-2000 to Tactical Radio Relay Distance Separation Requirements Co-Channel Operation

Interference Path		CDMA NB	CDMA WB	IS-136	GSM
Source	**Victim**	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**
IMT-2000 Base	**GRC-226 MB**	87.1	78.1	91.9	91.1
IMT-2000 Base	**GRC-226 SL**	63.9	60.7	65.5	65.2
IMT-2000 Base SL	**GRC-226 SL**	52.3	49.0	53.9	53.7
IMT-2000 Mobile	**GRC-226 MB**	22.5	19.8	23.8	23.6
IMT-2000 Mobile	**GRC-226 SL**	11	9.2	11.9	11.8
IMT-2000 Base	**GRC-245 MB**	75.2	74.7	75.5	75.5
IMT-2000 Base	**GRC-245 SL**	56.8	56.5	57.0	57.0
IMT-2000 Base SL	**GRC-245 SL**	45.0	44.6	45.1	45.1
IMT-2000 Mobile	**GRC-245 MB**	18.8	18.5	19.0	19
IMT-2000 Mobile	**GRC-245 SL**	7.4	7.2	7.5	7.5
IMT-2000 Base	**MRC-142 MB**	85.5	75.7	91.9	91.1
IMT-2000 Base	**MRC-142 SL**	63.4	59.8	65.5	65.2
IMT-2000 Base SL	**MRC-142 SL**	51.8	48.0	53.9	53.7
IMT-2000 Mobile	**MRC-142 MB**	22.0	19.0	23.8	23.6
IMT-2000 Mobile	**MRC-142 SL**	10.7	8.7	11.9	11.8
IMT-2000 Base	**SRC-57**	62.0	59.0	63.3	63.1
IMT-2000 Base SL	**SRC-57**	50.3	47.2	51.7	51.5
IMT-2000 Mobile	**SRC-57**	10	8.4	10.6	10.5

Table C-9. Tactical Radio Relay to IMT-2000 Distance Separation Requirements Co-Channel Operation

Minimum Interference Threshold

Interference Path		CDMA NB	CDMA WB	IS-136	GSM
Source	**Victim***	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**
GRC-226 MB	**IMT-2000 Base**	82	75.4	85.0	84.2
GRC-226 SL	**IMT-2000 Base**	62.2	59.6	63.2	62.9
GRC-226 SL	**IMT-2000 Base SL**	50.5	47.9	51.6	51.3
GRC-226 MB	**IMT-2000 Mobile**	34	31.5	35.0	34.7
GRC-226 SL	**IMT-2000 Mobile**	19.5	17.5	20.4	20.2
GRC-245 MB	**IMT-2000 Base**	73.7	71.9	75.2	74.1
GRC-245 SL	**IMT-2000 Base**	55.4	53.5	56.1	55.9
GRC-245 SL	**IMT-2000 Base SL**	43.5	41.6	44.3	44.1
GRC-245 MB	**IMT-2000 Mobile**	30.0	28.3	30.7	30.5
GRC-245 SL	**IMT-2000 Mobile**	14.5	13.3	15.0	14.9
MRC-142 MB	**IMT-2000 Base**	81.3	73.6	91.4	90.5
MRC-142 SL	**IMT-2000 Base**	61.9	58	65.6	65
MRC-142 SL	**IMT-2000 Base SL**	50.2	46.2	54.1	53.5
MRC-142 MB	**IMT-2000 Mobile**	33.7	29.9	37.4	36.8
MRC-142 SL	**IMT-2000 Mobile**	19.4	16.3	22.5	21.9
SRC-57 HP	**IMT-2000 Base**	79.8	74.0	83.5	82.7
SRC-57 LP	**IMT-2000 Base**	62.2	59.3	63.6	63.3
SRC-57 HP	**IMT-2000 Base SL**	65.7	62.9	67.0	66.8
SRC-57 LP	**IMT-2000 Base SL**	50.6	47.6	52.0	51.7
SRC-57 HP	**IMT-2000 Mobile**	33.2	30.3	34.5	34.2
SRC-57 LP	**IMT-2000 Mobile**	19.6	17.3	20.7	20.5

*Desired signal at sensitivity, I/N = - 6 dB

Table C-10. Tactical Radio Relay to IMT-2000 Distance Separation Requirements Co-Channel Operation

Typical Interference Threshold

Interference Path		CDMA NB	CDMA WB	IS-136	GSM
Source	**Victim***	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**
GRC-226 MB	**IMT-2000 Base**	64.3	61.8	65.4	65.1
GRC-226 SL	**IMT-2000 Base**	48.2	45.6	49.3	49.0
GRC-226 SL	**IMT-2000 Base SL**	36.2	33.6	37.4	37.1
GRC-226 MB	**IMT-2000 Mobile**	21.3	19.2	22.2	22.0
GRC-226 SL	**IMT-2000 Mobile**	10.2	8.9	10.8	10.7
GRC-245 MB	**IMT-2000 Base**	60.3	58.4	61.0	60.8
GRC-245 SL	**IMT-2000 Base**	41.2	39.3	42.0	41.8
GRC-245 SL	**IMT-2000 Base SL**	29.3	27.4	30.0	29.8
GRC-245 MB	**IMT-2000 Mobile**	18.1	16.7	18.6	18.5
GRC-245 SL	**IMT-2000 Mobile**	7.0	6.2	7.3	7.2
MRC-142 MB	**IMT-2000 Base**	64.1	60.2	67.8	67.2
MRC-142 SL	**IMT-2000 Base**	47.9	43.9	51.8	51.2
MRC-142 SL	**IMT-2000 Base SL**	36.0	31.9	39.9	39.3
MRC-142 MB	**IMT-2000 Mobile**	21.1	18.0	24.4	23.8
MRC-142 SL	**IMT-2000 Mobile**	10.1	8.1	12.3	11.9
SRC-57 HP	**IMT-2000 Base**	63.6	60.7	64.9	64.6
SRC-57 LP	**IMT-2000 Base**	48.3	45.3	49.7	49.4
SRC-57 HP	**IMT-2000 Base SL**	52.0	48.9	53.3	53.0
SRC-57 LP	**IMT-2000 Base SL**	36.3	33.3	37.7	37.5
SRC-57 HP	**IMT-2000 Mobile**	20.7	18.3	21.8	21.6
SRC-57 LP	**IMT-2000 Mobile**	10.3	8.7	11.0	10.9

*Desired Signal 10 dB above sensitivity and BER = 10E-3

For one example interaction, the distance separation requirements were also determined for the case of a TRR link with a typical received signal level. The example uses CDMA WB (3.75 MHz) interference to an AN/GRC-226 receiver. The AN/GRC-226 link with an elevated site location and favorable weather parameters could receive a faded desired signal level of -75 dBm with a corresponding interference threshold of -89 dBm, for an S/(I+N) = 14 dB. The required distance separation values for this example are presented in Table C-11.

If an interference threshold for a typical received signal level (approximately 10 dB above receiver sensitivity for the IMT-2000 or -75 dBm for the AN/GRC-226) is used, the separation requirements are 68 km and 40 km for random antenna orientations (mainbeam) and sidelobe antenna orientations, respectively. These less conservative separation distances would still be difficult to implement at most TRR operations areas.

Table C-11. CDMA-2000 NB (1.25 MHz) to AN/GRC-226 Co-Channel Operation

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	Power	Antenna	TX Cable	Int Thresh	Antenna	RX Cable			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
CDMA NB Base	GRC-226 MB	40	15	1	-89	20	2.4	1.8	158.8	58.6
CDMA NB Base	GRC-226 SL	40	15	1	-89	2	2.4	1.8	140.8	42.2
CDMA NB Base SL	GRC-226 SL	40	2	1	-89	2	2.4	1.8	127.8	30.3
CDMA NB Mobile	GRC-226 MB	20	0	0	-89	20	2.4	1.8	124.8	8.2
CDMA NB Mobile	GRC-226 SL	20	0	0	-89	2	2.4	1.8	106.8	3.0

The frequency separation verses distance separation requirements for one sample case of the AN/GRC-226 and the CDMA WB (3.75 MHz) are presented in Table C-12. The frequency separation was limited to 5 MHz because data was not available on the IMT-2000 systems that are under development. These preliminary calculations indicate that separation distances of 34.5 km are required for one channel separation (5MHz) between the AN/GRC-226 and the CDMA WB (3.75 MHz) base station.

Table C-12. Frequency Vs. Distance Separation Requirements for the AN/GRC-226 and the CDMA-2000 WB (3.75 MHz)

Interference Path		Off-tuning	Separation Distance
Source	Victim	MHz	Km
AN/GRC-226 MB	CDMA WB Base	0	75.3
		1.0	75.3
		2.0	70.6
		3.0	58.3
		4.0	45.6
		5.0	34.5
CDMA WB Base	AN/GRC-226 MB	0	78.1
		1.0	75.3
		2.0	69.9
		3.0	55.7
		4.0	20.5
		5.0	16.4

C.4.3 Operational Impact

C.4.3.1 Mobile Subscriber Equipment

For the 2003 time frame, the Army must continue to operate MSE and TRI-TAC in the 1755-1850 MHz band for battlefield training. Accommodating 3G systems in the 1755-1850 MHz band will compound the difficulties the Army experiences today. Restricting transmitter/receiver locations and antenna-pointing directions will limit realistic training of units and will limit the commanders' ability to realistically deploy signal assets. Not setting up links in exercise scenario dependent locations, but instead setting them up in pre-planned, pre-coordinated sites exercise after exercise, reduces the microwave operator's combat skills. The learning curve for setting up the links in actual deployment situations will be steeper and longer because of the lack of realistic field exercise training. The time required to get effective command and control established, especially in the information intensive battleground today, can be a deciding combat factor. Because of this, realistic training operations for microwave systems must continue.

US Army Guard and Reserve units are deploying at a greater pace, and keeping their training current is vital. Guard and Reserve component units with ACUS/MSE and TRI-TAC systems may be severely restricted in training opportunities because of their proximity to IMT-2000 base stations/mobile phone concentrations. There are 10 Army National Guard Division Signal Battalions with MSE AND TRI-TAC located throughout the US and a number of Army Reserve Signal units (companies, battalions, brigades, commands) with ACUS/TRI-TAC systems using the AN/GRC-103 (V)4 radio. Army Reserve Air Defense units in the also use the AN/GRC-103 (V)4 radio. If these units are restricted from training operations at home locations, then the units must deploy to the nearest training area, thereby imposing significant cost on training that can be accomplished today with relatively small investment.

If 3G is accommodated in this frequency band, and mitigation techniques are imposed on the Army ACUS, the installation Frequency Managers would need to coordinate with the IMT-2000 system operators prior to conducting training exercises to determine acceptable frequencies for use. At bases near population centers, this will be difficult because of the large separation distances required to preclude interference under co-frequency operation and because of how ACUS is deployed. The frequency managers at Ft Hood, TX, Ft Bragg, NC, and the National Training Center at Ft Irwin, CA, are already facing crowded frequency space and further sharing restrictions will make any large-scale exercises unworkable. Restricting the size of exercises could reduce the radiation problem but could preclude full scale training exercises. If IMT-2000 systems are deployed in significant numbers around the base, the only choice is to reduce the size and scope of training exercises—directly affecting military readiness.

For 2006 and 2010, the operational impact to US forces, if IMT-2000 systems begin operation in the 1755-1850 MHz band, are the same as 2003, unless access to additional spectrum in bands up to 2690 MHz is provided on a primary basis with equivalent regulatory protection. As HCLOS radios replace the current generation of MSE and TRI-TAC equipment, additional flexibility in frequency selection could reduce, but not eliminate, the impact resulting from loss of the 1755-1850 MHz band.

C.4.3.2 Digital Wideband Transmission System

The option for full band sharing is extremely difficult, as described previously in the section on ACUS/MSE. The Navy/Marine Corps depend on the DWTS for information transfer between ships and troops ashore as well as dissemination throughout the battlefield. There are no replacement radios planned for the DWTS, so continued access to the 1755-1850 MHz band is crucial to amphibious operations training. Marine Corps training/warfare doctrine is based on maneuver warfare. The ability of the Fleet Marine Force and its commanders to effectively train troops would be severely degraded if restrictions on flexibility were imposed to allow 3G systems to operate in the same band as DWTS.

By restricting the location of transmitters and receivers, restricting the direction in which antennas can be pointed, limiting link lengths, or limiting transmitter power levels, the Marine Corps capability for training maneuver warfare and command and control is greatly reduced. The whole premise behind maneuver warfare is rapid movement and quick-strike engagement of the enemy. The communications network must remain as mobile as the rest of the command and control elements. The Marine Corps would immediately lose the capability to train Marines as they would fight.

DWTS also serves as the link between Navy amphibious support ships and the Marine Corps troop ashore. Restrictions on transmitter power, antenna pointing angles, link lengths, and other factors would reduce or eliminate the utility of this vital link. Ship movement requires broad beamwidth antennas for the shore system so that communications can be maintained while the ship retains freedom of movement for self-protection.

Limiting the size of exercises severely restricts the utility of training activities. If the Marine Corps could no longer stage MEF/division level exercises, it would lose the ability to properly train its troops and also lose the capability to rehearse for deployments. This would reduce the readiness of our warfighters by increasing the time required to establish critical command and control links. Restricting training to certain specified ranges would also severely impact operations. This will require large troop movements to other training locations at a significant price in both cost and lost time.

This especially impacts the Reserve units, as they would no longer be able to participate in local training but would have to travel to specified training locations or ranges. Given the proximity of Camp Pendleton to San Diego and other populous areas in Southern California, the entire base may become off limits to large-scale training operations. Training at Yuma, AZ, may be curtailed as well because of its location. Training at Quantico would also be in jeopardy because of its proximity to

Northern Virginia and Washington, DC. Before long, training at Camp Lejeune would likely meet a similar fate.

As stated previously, band sharing is not an option for the Marine Corps. There is no planned replacement for the AN/MRC-142 prior to a Joint Tactical Radio System (JTRS) compliant replacement, therefore any implementation of band sharing prior to 2010 results in the inability of DWTS to support the way the Navy/Marine Corps trains and fights.

C.5 OPTION 2 – BAND SEGMENTATION/PARTIAL BAND SHARING

C.5.1 1755-1805 MHz Retained

The first band segmentation option would divide the 1755-1850 MHz band into two segments with 3G in 1710-1755 MHz and 1805-1855 MHz, and TRR in the 1755-1805 MHz band. This segmentation plan would eliminate the 1805-1850 MHz band at all DoD TRR sites and possibly eliminate 1710-1755 MHz at the 16 sites at which Federal systems are to be protected indefinitely as specified in the Omnibus Budget Reconciliation Act of 1993 (OBRA-93). The TRR are currently allocated the 1350-1390 and 1755-1850 MHz bands in CONUS and will receive protection indefinitely in the 1432-1435 and 1710-1755 MHz bands at specific sites. The TRR is currently allocated between 135 and 183 MHz of spectrum depending on the location. The Army can require access to all the spectrum in the two 1350-1390 and 1755-1850 MHz sub-bands in order to satisfy data requirements at the Corps and Division level. The US Marine Corps (USMC) has similar spectrum requirements to support Marine Expeditionary Unit exercises and a requirement for shipboard-compatible frequencies for ship-to-shore links. The spectrum lost in this option would constitute 33% to 49% of the frequencies in the 1350-1850 MHz band used for the higher data rate TRR communications networks. In addition, TRR duplex link frequency assignments would not be possible at sites without access to 1350-1435 MHz frequencies because of the requirement for a minimum of 50.125-63 MHz frequency separation between transmit and receive frequencies. Sufficient band separation between transmit and receive frequencies is required by TRR systems for acceptable operation.

2003 Time Frame. Any significant loss of access to spectrum in the band 1755-1850 MHz will have unacceptable operational impact on radio relay operations.

2006 Time Frame. The IMT-2000 system is estimated at a 50% development level in urban areas and 30% level in suburban areas. The development along interstate highways is expected to be in the same range. The two sub-bands 1710-1755 and 1805-1850 MHz could be unavailable for TRR use at this time frame. As a result, spectrum would not be available to support the number of TRR communications links required in large exercises. Any significant loss of access to spectrum in the band 1755-1850 MHz will have unacceptable operational impact on radio relay operations.

The loss of access to the 1710-1755 and 1805-1850 MHz bands in 2006 would reduce the spectrum to support TRR communications network by 33% to 49%. This loss of spectrum would have a corresponding impact on the number of communications links available to support large exercises.

The impact between the TRR and the IMT-2000 systems at the band edges is addressed by a frequency-distance separation analysis. The estimates for the IMT-2000 network in 2006 are for a 50% development in urban areas and along major interstate highways. At some TRR sites, the 1755-1805 MHz band available for the TRR would have increasing power densities at the band edges from the 3G transmitters in the surrounding bands. The frequency-distance separation requirement to preclude interference was determined for both the TRR and the IMT-2000. The frequency-distance separation requirements for CDMA-WB (spread spectrum) interference to the TRR is provided in Figure C-1, and requirements for GSM (time division multiple access (TDMA)) interference to the TRR is provided in Figure C-2. TRR interference to CDMA-WB is identified in Figure C-3, and TRR interference to GSM is identified in Figure C-4.

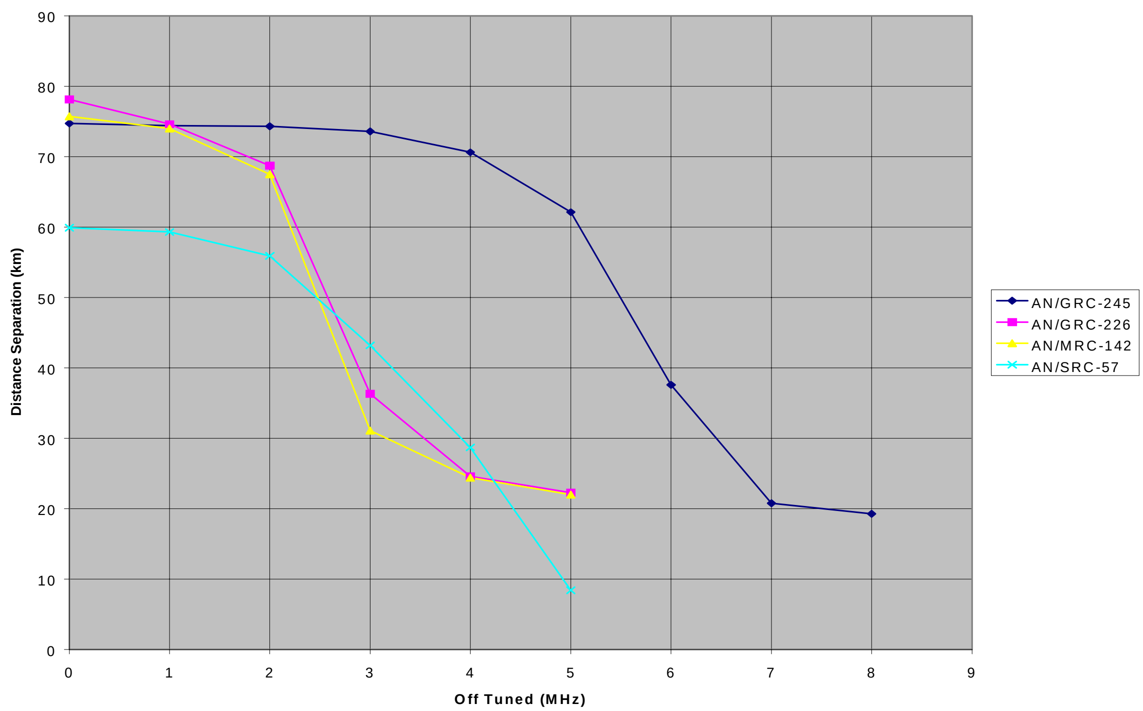

Figure C-1. Frequency-Distance Separation for CDMA-WB to TRR

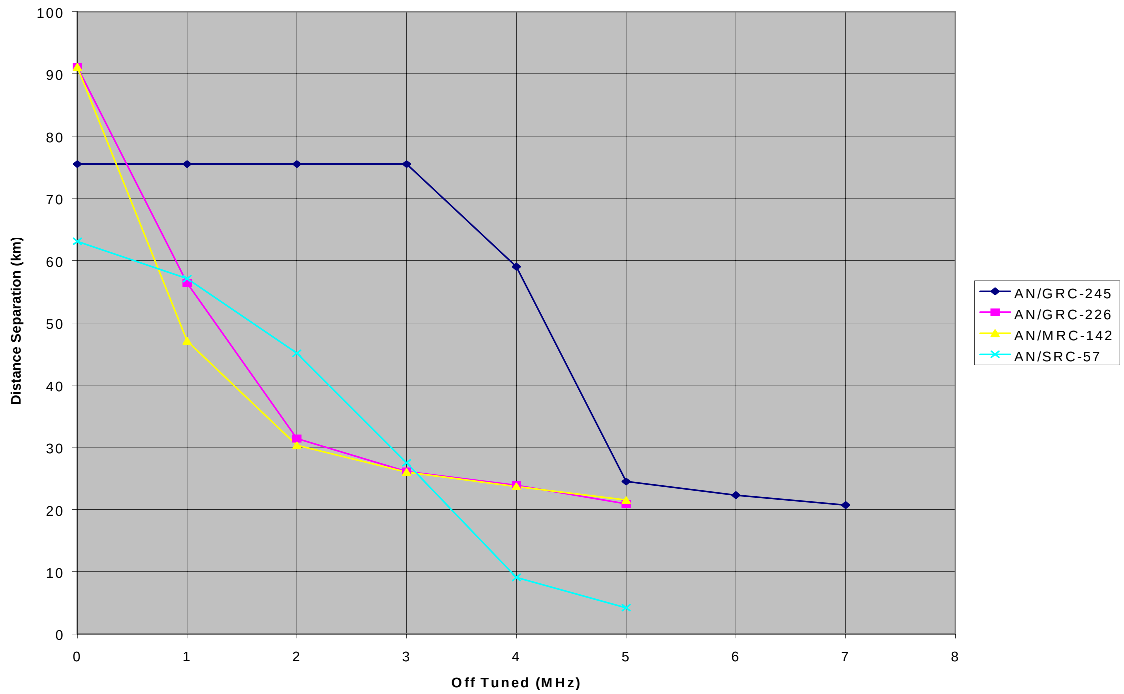

Figure C-2. Frequency-Distance Separation for IMT-2000 GSM to TRR

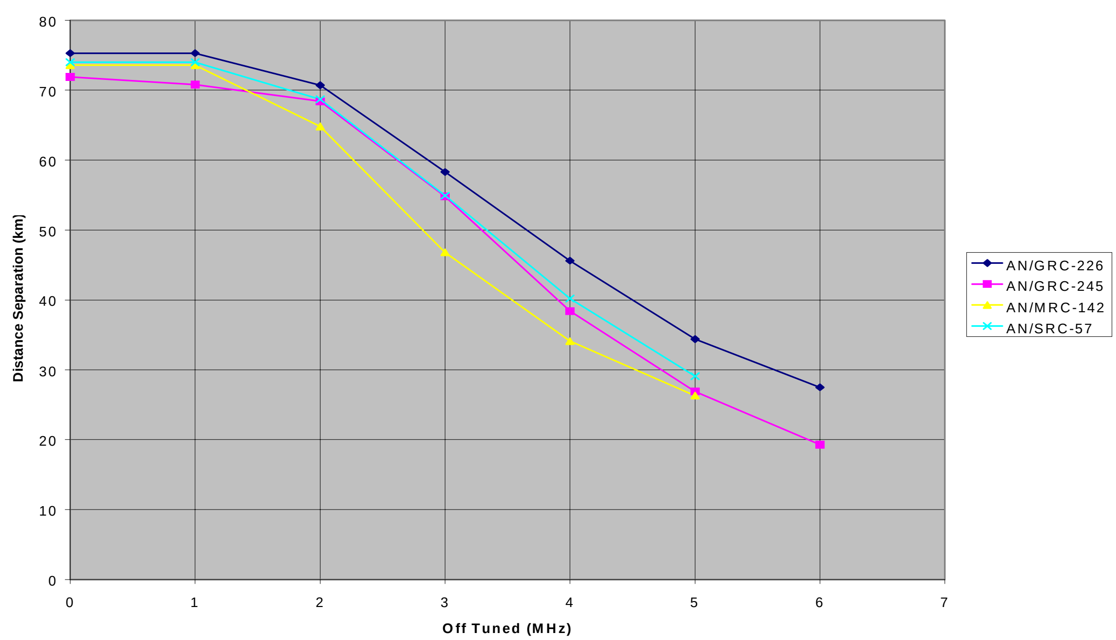

Figure C-3. Frequency-Distance Separation for TRR to CDMA-WB

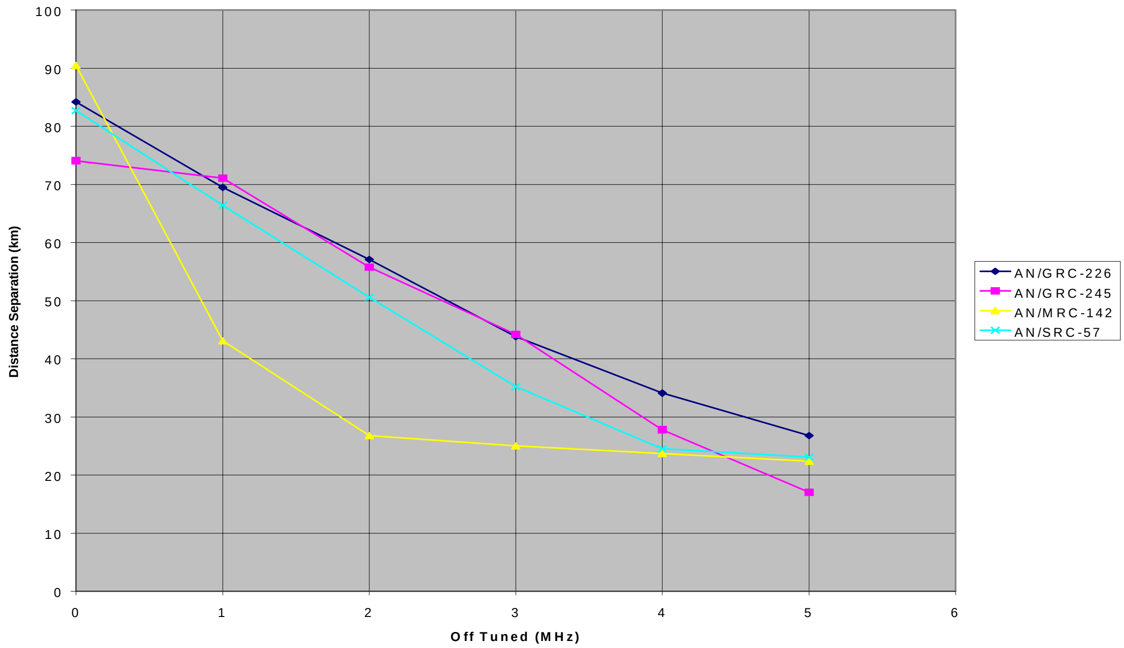

Figure C-4. Frequency-Distance Separation for TRR to GSM

The frequency-distance separation requirements in Figure C-1 to C-4 are for mainbeam antenna interactions for both the TRR and the IMT-2000 radios. The data indicates that the TRR and the IMT-2000 channel assignments at the edges of the 1755-1805 MHz would have to be controlled to avoid interference impact to the TRR and an additional loss of spectrum. For example in Figure C-1, the AN/GRC-226, AN/MRC-142 and AN/SRC-57 radios require approximately 30 km of separation with CDMA-WB base stations for frequency assignments separated by 3.75 MHz (approximately the band edge channel frequency separation) to provide compatible operations. However, the AN/GRC-245 would require 70 km of separation for band edge channels to obtain compatible operations and would have to increase the frequency separation to 6.25 MHz off tuned (approximately two channels of separation) to obtain the 30 km distance separation. The interference from the TRR transmitters to the IMT-2000 receivers in Figures C-3 and C-4 does not indicate a large difference in the separation requirement between the four TRR transmitters. In urban areas, channels on the band edges could be eliminated for TRR use if the AN/GRC-245 is assigned to the channels at the band edges.

2010 Time Frame. In the 2010 time frame, the IMT-2000 development level would be 100%, and only 1755-1805 MHz frequencies would be available for the TRR. The spectrum lost in this option would constitute 33% to 49% of the frequencies used for the higher data rate TRR communications networks. The AN/GRC-245 could experience the loss of one additional 2.5 MHz channel at each edge of the 1755-1805 MHz band at sites with high IMT-2000 traffic. In addition, TRR duplex link frequency assignments would not be possible at sites without access to 1350-1435 MHz frequencies because of the requirement for a minimum of 50.125-63 MHz frequency separation between transmit and receive frequencies.

C.5.2 Phased Segmentation to 1790-1850 MHz Retained

This band segmentation proposal would locate IMT-2000 in 1710-1790 MHz and TRR in 1790-1850 MHz. The spectrum lost in this option would constitute 26% to 44% of the frequencies in the 1350-1850 MHz band used for higher data rate tactical radio relay. The technical assessment is the same as in subsection C.5.1.

2003 Time Frame. Any significant loss of access to spectrum in the band 1755-1850 MHz will have unacceptable operational impact on radio relay operations.

2006 and 2010 Time Frame. This band segmentation proposal would locate IMT-2000 in 1710-1790 MHz and TRR in 1790-1850 MHz. The IMT-2000 frequencies are not expected to be available for TRR use in this time frame. The spectrum lost in this option would constitute 26% to 44% of the frequencies used for higher data rate tactical radio relay. The AN/GRC-245 could experience the loss of one additional 2.5 MHz channel at each edge of the 1790-1850 MHz band at sites with high IMT-2000 traffic. A limited number of duplex links would be available for the AN/GRC-226, AN/GRC-245 and AN/SRC-57 radios using only the 1790-1850 MHz band. The AN/MRC-142 radios could not obtain frequency assignments using only the 1790-1850 MHz band because of the minimum 63 MHz frequency separation between the receiver and the transmitter on duplex links.

C.5.3 Operational Impact

C.5.3.1 Mobile Subscriber Equipment

By 2003, any reduction in available spectrum would further reduce the size and scope of training exercises in training areas where frequency space is already at a premium. Fielding of HCLOS radios would not be sufficient to provide any significant relief in this time frame. Inputs to Army training would be similar to those described in Option 1, around large training areas; however, the impacts to Reserve and National Guard activities may be minimal if access in the remaining government spectrum is maintained.

For the 2006 time frame, some impact to training is still expected; however, fielding of HCLOS radios could improve the situation if access to frequencies up to 2690 MHz is provided on a primary basis with equivalent regulatory protection. By the 2010 time frame, HCLOS fielding should have replaced current generation radios and if access to frequencies up to 2690 MHz is provided, operational impacts to the Army ACUS will be minimal.

C.5.3.2 Digital Wideband Tactical System

This phased-segmentation scenario would not support the amphibious and general battlefield training requirements because of the inherent limitations as specified in Option 1. The 50 MHz of continuous frequency allocation listed in both scenarios does not allow for the requisite frequency separations needed for collocated transmit and receive operation, and access to other portions of the DWTS tuning range is already severely restricted. This would be true until a replacement radio could be developed and fielded in significant numbers, which could not be accomplished until at least the 2010 time frame.

C.6 OPTION 3 – PARTIAL BAND SEGMENTATION/COMBINATION WITH 2025-2110, 2200-2290, AND 2500-2690 MHZ BANDS

C.6.1 Technical Assessment

The first band segmentation option would divide the 1755-1850 MHz band into two segments with IMT-2000 in 1710-1755 MHz and 1805-1855 MHz, and TRR in the 1755-1805 MHz band. This segmentation plan would eliminate the 1805-1850 MHz band at all TRR sites and eliminate 1710-1755 MHz at the 16 sites at which Federal systems are to be protected indefinitely as specified in OBRA-93. The TRR are currently allocated the 1350-1390 and 1755-1850 MHz bands in CONUS and will receive protection indefinitely in the 1432-1435 and 1710-1755 MHz bands at specific sites. The TRR is currently allocated between 135 and 183 MHz of spectrum depending on the location. The spectrum lost in this option would constitute 33% to 49% of the frequencies in the 1350-1850 MHz band used for the higher data rate TRR communications networks. In addition, TRR duplex link frequency assignments would not be possible at sites without access to 1350-1435 MHz frequencies because of the requirement for a minimum of 50.125-63 MHz frequency separation between transmit and receive frequencies.

The second band segmentation proposed would locate IMT-2000 in 1710-1790 MHz and TRR in 1790-1850 MHz. The spectrum lost in this option would constitute 26% to 45% of the frequencies used for higher data rate tactical radio relay.

The spectrum lost to the TRR through one of the partial band segmentation options (between 45 and 90 MHz) could possibly be replaced by spectrum above 2000 MHz if the existing TRR are replaced by radios operating at frequencies up to 2690 MHz. The 2025-2110, 2200-2290, 2500-2690 MHz bands are evaluated for compatibility between the existing users of the band and the TRR.

2003 Time Frame. Any significant loss of access to spectrum in the band 1755-1850 MHz will have unacceptable operational impact on radio relay operations.

2006 Time Frame. The IMT-2000 system is estimated at a 50% development level by in urban areas and 30% level in suburban areas. The development along interstate highways is expected to be in the same range. The IMT-2000 frequencies are not expected to be available for TRR use in this time frame. The new TRR operating at frequencies above 2000 MHz are not expected to be available in significant numbers by 2006, which would allow for the use of frequencies above 2000 MHz. As a result, spectrum would not be available to support the number of TRR communications links required in large exercises.

The loss of access to the 1710-1755 and 1805-1850 MHz bands in 2006 would reduce the spectrum to support TRR communications network by 33% to 49%. The 1710-1790 MHz spectrum lost in the second option would eliminate 26% to 45% of the frequencies used for higher data rate tactical radio relay. This loss of spectrum would have a corresponding impact on the number of communications links available to support large exercises.

The development and fielding of new TRR operating at frequencies above 2000 MHz would not be possible before 2006. The Army has developed and received the initial procurement of the AN/GRC-245 radios that can operate from 1350-2690 MHz. The AN/GRC-245 is not expected to be procured in sufficient quantities to replace the AN/GRC-226 until near 2008. The USMC and the Navy have recently fielded the AN/MRC-142 and AN/SRC-57 DWTS radios. A replacement DWTS radio with an extended frequency range to 2690 MHz is not in development and the procurement of new radios (if technically feasible) would extend beyond the 2006 time frame.

2010 Time Frame. In the 2010 time frame the IMT-2000 development would be complete and only the 1350-1390 and 1755-1805 MHz frequency bands or the 1350-1390 and 1790-1850 MHz frequency bands would be available for TRR use. The new TRR operating at frequencies above 2 GHz could be available by 2010. If sufficient spectrum is available for operations in the higher bands, the communications requirements for large exercises could be supported. The AN/GRC-245 could experience the loss of one additional 2.5 MHz channel at each edge of the 1755-1805 MHz band at sites with high IMT-2000 traffic.

The frequency bands above 2000 MHz available for DoD operations were investigated for suitability for TRR operations. This investigation is discussed below.

C.6.1.1 2025-2110 MHz Band

The 2025-2110 MHz band is used by the non-government fixed and mobile service, specifically Electronic News Gathering (ENG) systems, by space research, by space operations (earth to space) and Earth exploration-satellite services. The band would have to be allocated with equivalent regulatory protection for government fixed and mobile services. The above incumbent systems in the band were analyzed for compatibility with the TRR.

C.6.1.1.1 Electronic News Gathering

The ENG systems are used for on-location coverage of news events or live-action video during sports and entertainment events. The transportable ENG, used by most local television stations for on-location coverage, are generally mounted in vans and operate in a stationary mode transmitting video to a fixed receive site. The total number of 2 GHz ENG systems in the US exceeds 4000. The parameters of a typical ENG system are provided in Table C-13.[1, 2]

Table C-13. Parameters of a Typical Electronic News Gathering System

Frequency range	1990-2110 MHz
Transmit power	12 W
Channel Bandwidth (MHz)	17.0
Antenna gain	22 dBi (mainbeam), 2 dBi (sidelobe)
Antenna height	15 m (Transportable), 30 m (Fixed Receive)
Receiver bandwidth (MHz)	17.0 (-3dB)
Receiver noise figure	3 dB
Receiver sensitivity	NA
Receiver noise power	-99 dBm
Interfering signal threshold	-108 dBm
Cable losses	2 dB

The interference power from the TRR to the ENG receiver was calculated using the standard received power equation. The distance separation required to reduce the TRR power to a level below the ENG interference threshold was calculated and provided in Table C-14. The reverse (ENG to TRR) interference interactions were calculated and are provided in Table C-15.

[1] W. Horne, Characteristics and Model of Electronic News Gathering Systems Operating in the 1990-2110 MHz Band, USTG 7-1/101, Greenbelt, MD: GSFC, 10 September 1993.

[2] Lloyd Apirian, et al., *EMC and Personnel Exposure Analysis of Proposed Backup GOES Earth Station*, JSC-CR-97-035, Annapolis, MD: DoD JSC, October 1997.

Table C-14. Interference Calculations TRR Transmitter to Electronic News Gathering (ENG) Receiver

2025-2110 MHz Band

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	**Victim**	**TX Power**	**TX Antenna**	**TX Cable****	**Inter Threshold*****	**RX Antenna***	**RX Cable**			**SEM**
		dBm	**dBi**	**dB**	**dBm**	**dBi**	**dB**	**dB**	**dB**	**Km**
GRC-245 MB	**ENG Mainbeam**	32	25	4	-108	22	2	0	181.0	75.2
GRC-245 MB	**ENG Sidelobe**	32	25	4	-108	2	2	0	161.0	56.0
GRC-245 SL	**ENG Sidelobe**	32	2	4	-108	2	2	0	138.0	37.3

*ENG receive station sidelobe gain is 2 dBi, receive station antenna height is 30 meters

** Cable loss from J/F 12 for GRC-245

***Desired signal at sensitivity, I/N = - 9 dB

Table C-15. Interference Calculations For Transportable Electronic News Gathering (ENG) to TRR Receiver

2025-2110 MHz Band

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	**Victim**	**TX Power**	**TX Antenna***	**TX Cable**	**Inter Threshold*****	**RX Antenna**	**RX Cable****			**SEM**
		dBm	**dBi**	**dB**	**dBm**	**dBi**	**dB**	**dB**	**dB**	**Km**
ENG Mainbeam	**GRC-245 MB**	40.8	22	2	-105	25	4	3.4	183.4	71.1
ENG Sidelobe	**GRC-245 MB**	40.8	2	2	-105	25	4	3.4	163.4	50.2
ENG Sidelobe	**GRC-245 SL**	40.8	2	2	-105	2	4	3.4	140.4	31.9

*ENG transmit station sidelobe gain is 2 dBi, transmit station antenna height is 15 meters

** Cable loss from J/F 12 for GRC-245

***Desired signal at sensitivity, I/N = - 6 dB

The distance separation requirement of 75.2 km between the TRR and the ENG fixed receive site would be difficult to accomplish. The ENG receive sites are typically in urban areas, but many TRR sites are within 75.2 km of urban areas. The distance separation requirements of 71.1 km between the transportable ENG transmitter and the TRR would be more difficult to meet because the transportable ENG range can extend into rural areas. Because of the distance separation requirements to avoid interference and the large number of ENG systems, band sharing would not be possible between the TRR and the ENG.

C.6.1.1.2 Space Ground Link Subsystem (SGLS) Uplink

The SGLS uplink operating in the 2025-2110 MHz band is assumed to have parameters that are the same as the 1755-1850 MHz uplink. The parameters of the SGLS uplink have been provided in the previous section. The analysis calculated the interference power from the SGLS transmitter to the TRR using the standard received power equation. Green shading identifies the regions on the figures where the SGLS interference exceeds the interference threshold of the TRR receiver.

The plots for the New Hampshire Station (NHS), the Colorado Tracking Station (CTS), the Eastern Vehicle Checkout Facility (EVCF) and the Onizuka Air Station (OAS) SGLS sites are provided in Figures C-5 to C-8, respectively.

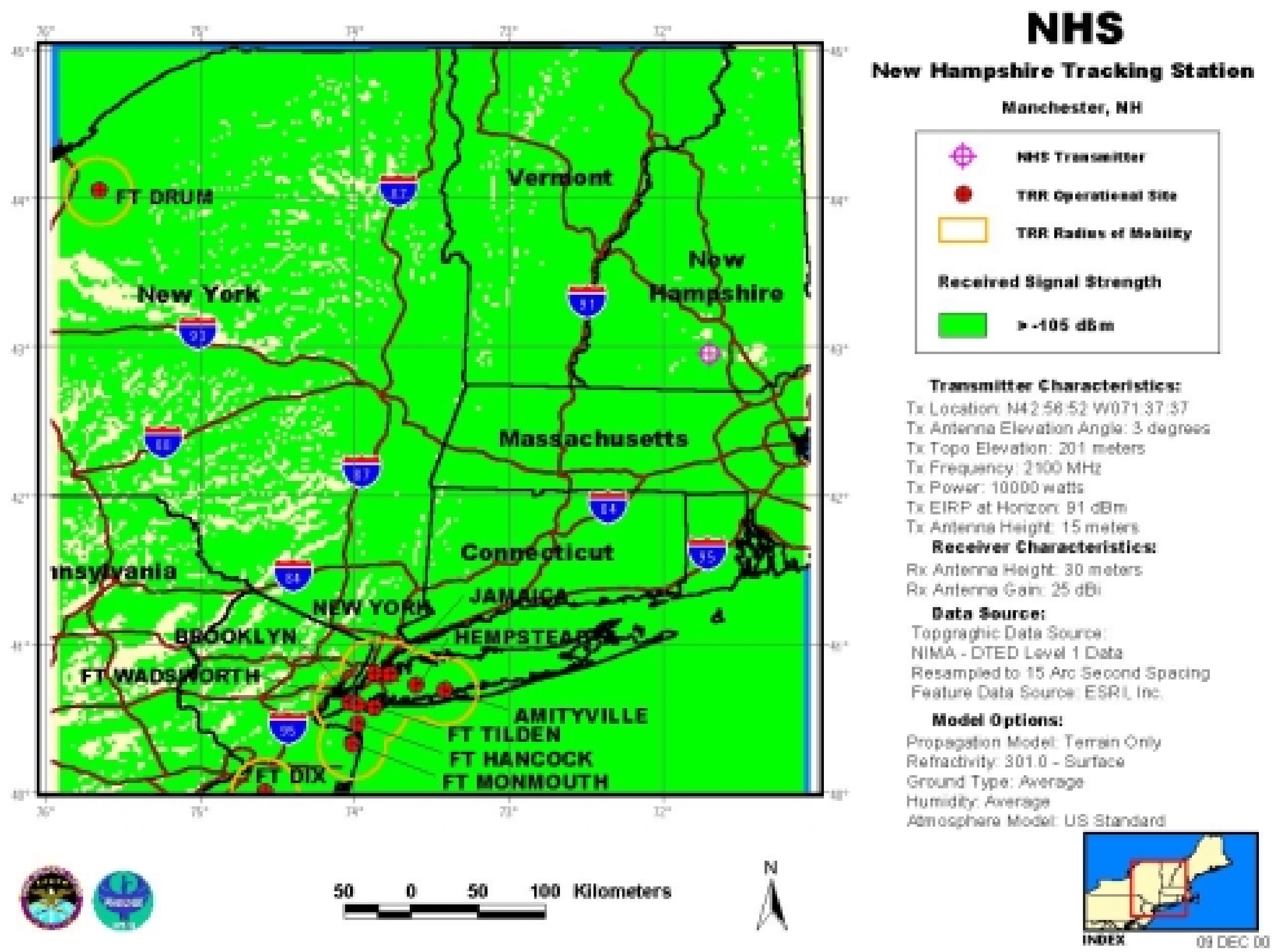

Figure C-5. Plot of NHS SGLS Interference to TRR Receivers

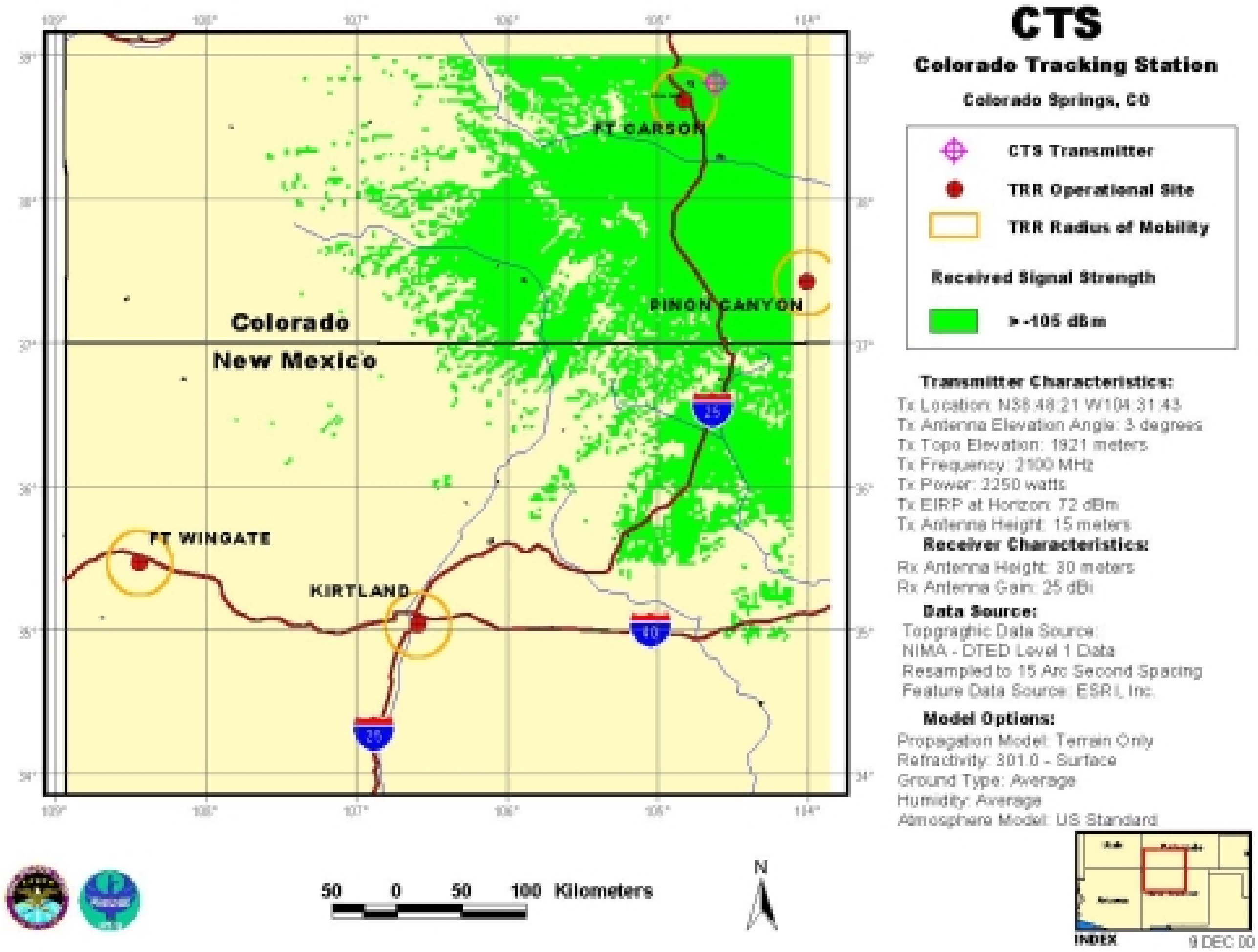

Figure C-6. Plot of CTS SGLS Interference to TRR Receivers

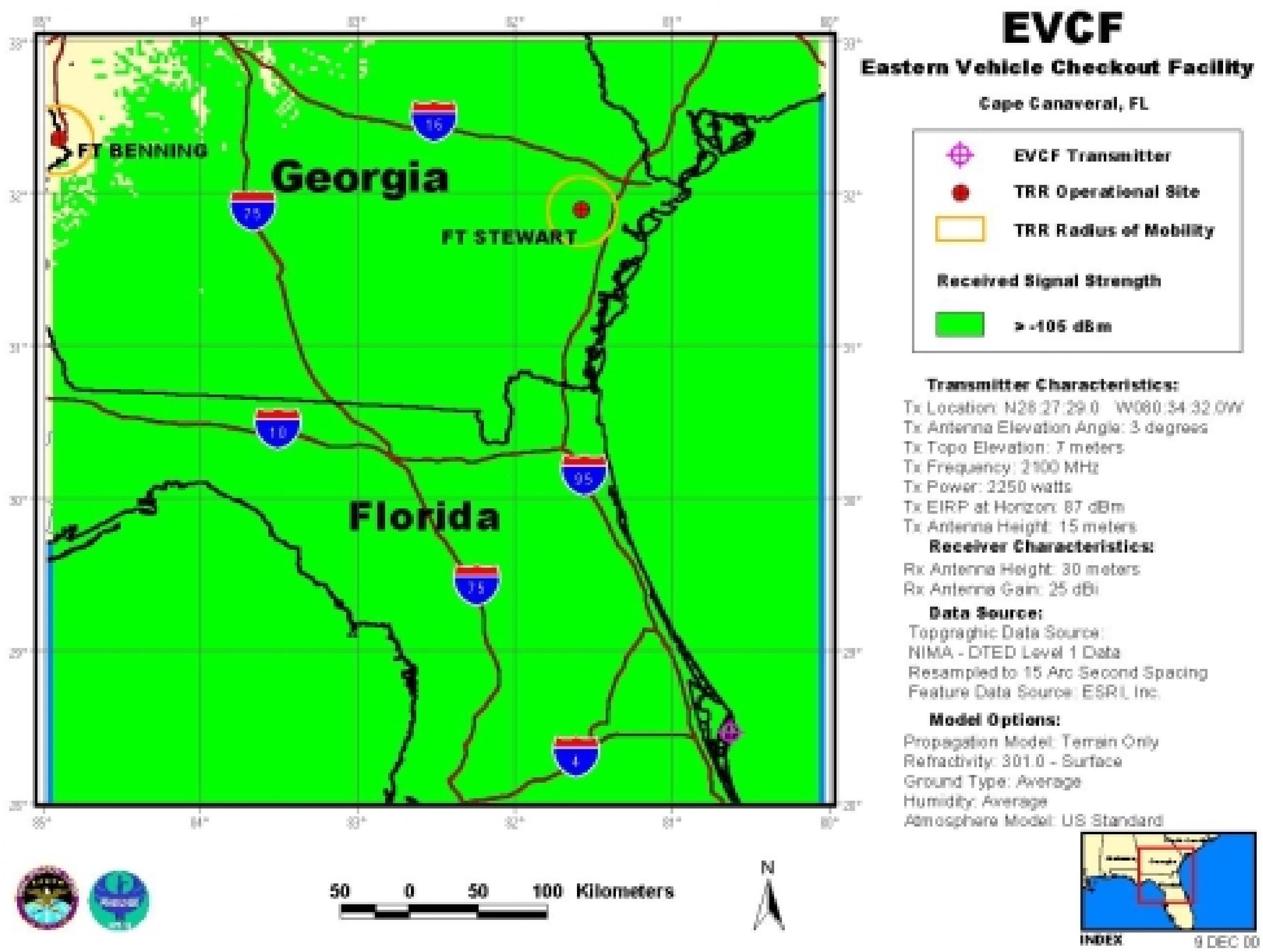

Figure C-7. Plot of EVCF SGLS Interference to TRR Receivers

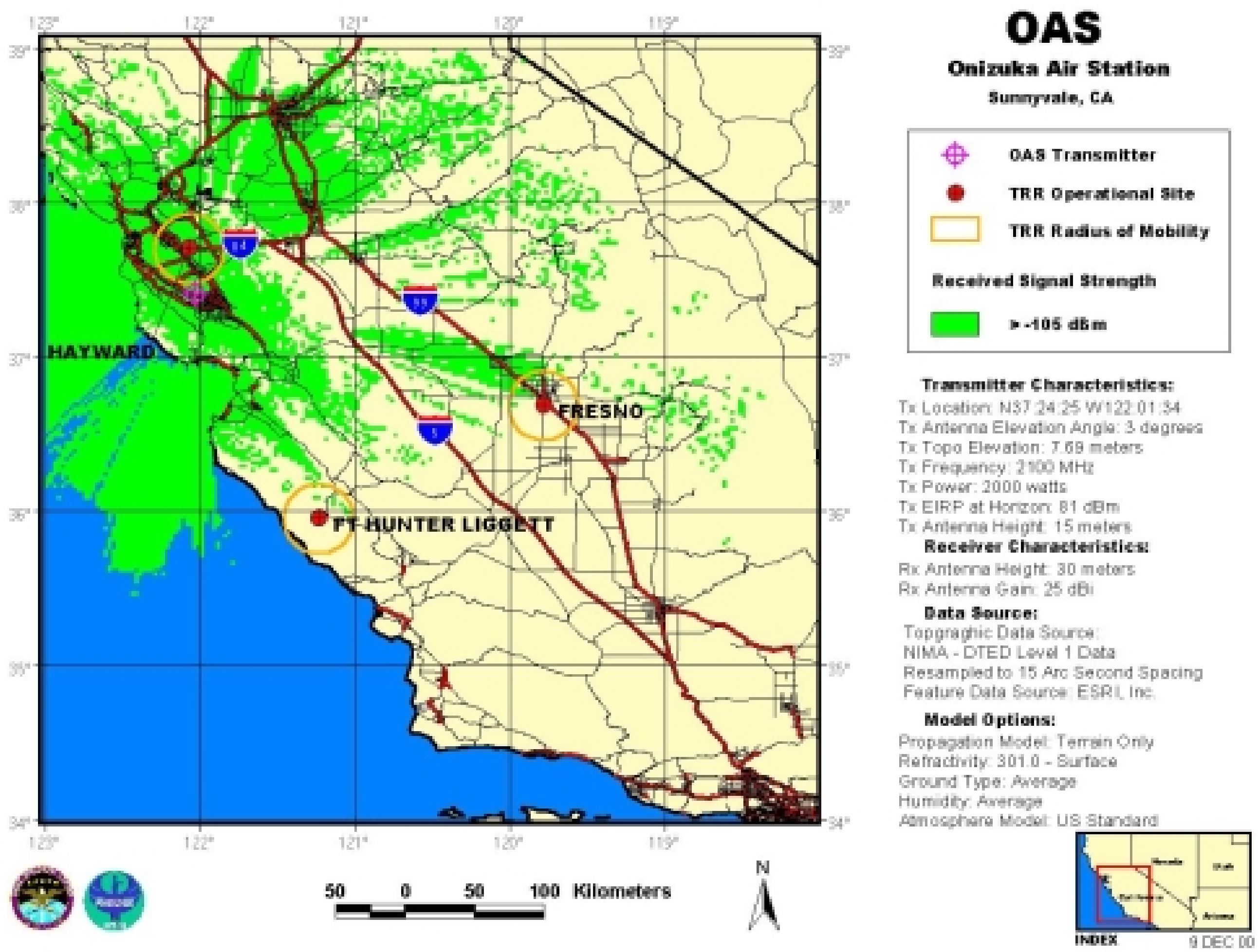

Figure C-8. Plot of OAS SGLS Interference to TRR Receivers

The analysis of the SGLS uplink interference to the TRR was based on the maximum transmit power and a 3-degree elevation angle for the antenna at each SGLS site. This situation represented the worst case interference from the SGLS transmitter to the TRR receiver. The TRR sites within the green interference areas have a potential to receive interference during some SGLS operations for co-channel frequency assignments. The SGLS also uses transportable terminals, which can operate, at any location in the US to provide additional coverage during launches, early orbit operations, anomaly resolution, and critical orbit insertion maneuvers. The parameters of the transportable SGLS terminals are similar to the parameters of the fixed SGLS systems and comparable interference contours would be generated about the temporary SGLS location. The distance separation requirements between the transportable SGLS (with the parameters of the EVCF earth terminal) and the TRR would vary between 216 km and 59 km depending on the orientation of the SGLS and TRR antennas as provided in Table C-16.

Table C-16. Interference Calculations for SGLS Transmitter to Tactical Radio Relay Receiver

2025-2110 MHz

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power	TX Antenna	TX Cable	Inter Threshold	RX Antenna	RX Cable****			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
SGLS*	GRC-245 MB	63.5	12	0	-105	23	4	0	199.5	134
SGLS*	GRC-245 SL	63.5	12	0	-105	2	4	0	178.5	59
SGLS**	GRC-245 SL	63.5	16	0	-105	2	4	0	182.5	63
SGLS***	GRC-245 MB	63.5	23	0	-105	23	4	0	210.5	216

*SGLS antenna diameter is 7 m, antenna height is 10 m, antenna gain is 12 dBi for a 10 degree antenna elevation angle

**SGLS antenna gain is 16 dBi for a 5 degree antenna elevation angle

***SGLS antenna gain is 23 dBi for a 3 degree antenna elevation angle

**** Cable loss from J/F 12 for GRC-245

Coordination between SGLS and TRR frequency managers could allow some frequencies to become available for the TRR within the contour regions. However, TRR frequency usage in this band would be subjected to positive control requiring possible shut down during SGLS emergencies. This level of control would be difficult to accomplish during large-scale exercises.

C.6.1.1.3 Space Research

The 2025-2110 MHz band is also used for earth-to-space transmissions by other government space research earth stations at Corpus Christi, TX; Fairbanks, AK; Goldstone, CA; Greenbelt, MD; Kauai, HI; Merritt Is., FL; Roseman, NC and Wallops Is., MD. The Geostationary Operational Environmental Satellite (GOES) earth stations uses the 2025-2035 MHz band at Wallops Is. for tracking, telemetry and telecommand. The distance separation requirements between the GOES earth terminal (parameters obtained from reference 2) and the TRR is provided in Table C-17.

Table C-17. Interference Calculations for GOES Transmitter to Tactical Radio Relay Receiver

2025-2035 MHz

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power	TX Antenna	TX Cable	Inter Threshold	RX Antenna	RX Cable***			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
GOES*	GRC-245 MB	51	14	0	-105	23	4	0	189	83
GOES*	GRC-245 SL	51	14	0	-105	2	4	0	168	51
GOES**	GRC-245 MB	51	7	0	-105	23	4	0	182	62
GOES**	GRC-245 SL	51	7	0	-105	2	4	0	161	45
GOES BL	GRC-245 SL	51	-10	0	-105	2	4	0	144	32

*GOES antenna diameter is 16 m, antenna height is 10 m, antenna gain is 14 dBi for a 5 degree antenna elevation angle

**GOES antenna gain is 7 dBi for a 10 degree antenna elevation angle

*** Cable loss from J/F 12 for GRC-245

C.6.1.2 2025-2110 MHz Band Assessment

The TRR systems do not have spectrum available to operate in the 2025-2110 MHz band. The 2025-2110 MHz band must be allocated for Government fixed and mobile operations to allow the TRR access to the band. In addition, the TRR can not share the band with the ENG because of the large number of ENG systems and the large distance separation required for compatible operations. If the ENG were moved to a different frequency band, the TRR would have access to most of the band at sites that were 216 km from SGLS sites and 83 km from space research earth-terminal sites.

C.6.1.3 2200-2290 MHz Band

The 2200-2290 MHz band is a government band and the DoD is the principal user. The band is allocated to government fixed and mobile services on a primary basis, constrained to LOS systems only, and to space research, space operations, and earth exploration satellite (EES), also on a primary basis, specified for satellite-to-earth and satellite-to-satellite paths. The SGLS functions in the band include tracking launch and space vehicles, telemetry from both launch and space vehicles, and command operations. The SGLS downlink in the band provides tracking return signal and telemetry functions. This band is used for the downlink of the NASA Tracking and Data Relay Satellite with more than 15 frequencies used at White Sands Missile Range (WSMR), Greenbelt, MD, and Merritt Is., FL. Critical guided missile (weapons) telemetry is also included in the band.

C.6.1.3.1 SGLS Downlink

The downlink associated with the 2025-2110 MHz and 1760-1840 MHz SGLS uplinks operates in the 2200-2290 MHz band. The SGLS downlink supports transponded range code, range rate determination, space vehicle State of Health (SOH) and mission data. The SGLS locations analyzed are the same as for the uplink analysis, the New Hampshire Station (NHS), the Colorado Tracking Station (CTS), the Eastern Vehicle Checkout Facility (EVCF) and the Onizuka Air Station (OAS). The data on the SGLS receiver is provided in Table C-18.[3]

[3] Space and Missile Systems Center, Standardized Interface Specification between AF Satellite Control Network Common User Element and Comm/range Segment and Space Vehicle, AFSCN SIS-000502A, El Segundo, CA: AFSCN, 22 October 1997.

Table C-18. SGLS Receiver Parameters

Desired Signal	Telemetry 1024 kb/s
Receiver Bandwidth (MHz)	1.0 (-3 dB)
Receiver Noise Power Density	-178 dBm/Hz
Receiver Noise	-118 dBm
Sensitivity	-108 dBm
Interference Threshold (I/N = -10 dB)	-128 dBm
Mainbeam Antenna Gain (7 m parabola)	41.5 dBi
Antenna Gain Off Boresight	23 dBi (3 deg), 16 dBi (5 deg), 12 dBi (10 deg)

The interference power from the TRR transmitter to the SGLS downlink receiver is calculated using the standard received power equation and the results are provided in Table C-19. The distance separation requirements between the TRR and the SGLS are more restrictive for the SGLS uplink to TRR interference interactions. The distance separation between TRR and SGLS to avoid interference range from 216 to 59 km in the 2025-2110 MHz band and from 132 to 49 km in the 2200-2290 MHz band. The TRR may have difficulty gaining access to spectrum in either frequency band at TRR sites such as Fort Carson which are near SGLS sites.

Table C-19. Interference Calculations For Tactical Radio Relay to SGLS Receiver

2200-2290 MHz Band

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power	TX Antenna	TX Cable*	Inter Threshold**	RX Antenna*	RX Cable			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
GRC-245 MB	SGLS ***	32	25	5	-128	23	0	3	200.0	132
GRC-245 MB	SGLS****	32	25	5	-128	16	0	3	193.0	97
GRC-245 MB	SGLS*****	32	25	5	-128	12	0	3	189.0	80
GRC-245 SL	SGLS ***	32	2	5	-128	23	0	3	177.0	58
GRC-245 SL	SGLS****	32	2	5	-128	16	0	3	170.0	52
GRC-245 SL	SGLS*****	32	2	5	-128	12	0	3	166.0	49

* Cable loss from J/F 12 for GRC-245

** Desired signal at sensitivity, I/N = - 10 dB

***SGLS antenna diameter is 7 m, antenna height is 10 m, antenna gain is 23 dBi for a 3 degree antenna elevation angle

****SGLS antenna gain is 16 dBi for a 5 degree antenna elevation angle

*****SGLS antenna gain is 12 dBi for a 10 degree antenna elevation angle

C.6.1.3.2 Telemetry

Telemetry is heavily used in this band for such purposes as airborne weapons testing, aircraft flight testing, and a wide variety of experimental and research projects. The parameters of a typical telemetry link are provided in Table C-20. The airborne telemetry transmitter and the ground-based telemetry receiver were analyzed to determine the required distance separation with the TRR radios.

The results of the analyses are provided in Table C-21 for airborne telemetry interference to TRR receivers and in Table C-22 for TRR interference to ground-based telemetry receivers.

Table C-20. Parameters of a Typical Telemetry Link

Frequency range	2200-2290 MHz
Transmitter	Aydin Vector T400 Series Telemetry (J/F 12/6260)
Transmit power	20 W
Emission Bandwidth (MHz)	5.8 (-3dB), 5.9 (-20 dB), 13.0 (-60 dB)
Antenna gain (Transmit)	0 dBi
Antenna height	9144 m (Airborne)
Receiver	Microdyne 1200 MR (J/F 12/5608
Receiver bandwidth (MHz)	6.0 (-3dB), 9.0 (-20 dB), 21.0 (-60 dB)
Receiver noise figure	5 dB (Assumed)
Receiver sensitivity	-98 dBm (Receiver bandwidth not listed)
Receiver noise power	-101dBm
Interfering signal threshold	-107 dBm
Antenna gain (Receive)	28 dBi (Mainbeam), 20 dBi (Major Sidelobe)
Antenna height	5 m

Table C-21. Interference Calculations for Airborne Telemetry Transmitter to Tactical Radio Relay Receiver

2200-2290 MHz Band

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source***	Victim	TX Power	TX Antenna	TX Cable	Inter Threshold*	RX Antenna	RX Cable**			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
Airborne Telemetry	GRC-245 MB	43	0	0	-105	25	4.0	0	169.0	416
Airborne Telemetry	GRC-245 SL	43	0	0	-105	2	4.0	0	146.0	372

*I/N = -6 dB

** Cable loss from J/F 12 for GRC-245

***Aircraft Telemetry, J/F 12/6260, aircraft height is 9144 meters, emission 6M00F1D

Table C-22. Interference Calculations For Tactical Radio Relay to Telemetry Ground Receiver (J/F 12/5608)

2250 MHz

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power	TX Antenna	TX Cable**	Inter Threshold***	RX Antenna*	RX Cable			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
GRC-245 MB	Telemetry RX (10 MHz)	32	25	4	-107	20	0	0	180.0	55.1
GRC-245 SL	Telemetry RX (10 MHz)	32	2	4	-107	20	0	0	157.0	36.7

*Telemetry receive antenna gain is 20 dBi (major sidelobe), antenna height is 5 meters

** Cable loss from J/F 12 for GRC-245

*** 6 MHz BW, desired signal at sensitivity, I/N = - 6 dB

The airborne telemetry transmitter has the potential to interfere with TRR receivers at a range of 416 km. The telemetry equipment is used at China Lake, CA; WSMR; Yuma, AZ; Eglin AFB, FL; Utah Test Range, UT; Tonapoh, NV; Edwards AFB, CA; Barksdale AFB, AR; Nellis AFB, NV; Point Mugu, CA, and Tyndal, FL. The TRR radios are expected to have little access to the 2200-2290 MHz band within 416 km of test ranges because of the heavy use of telemetry frequencies at ranges.

C.6.1.4 2200-2290 MHz Band Assessment

The 2200-2290 MHz is a critical band for SGLS and other satellite link operations because interference can disrupt satellite control. The separation distance of 132 km is required between TRR transmitters and the satellite downlink receivers to avoid interference. The large number of satellite control frequencies and the large separation distance is expected to eliminate most frequencies from TRR use around earth terminal sites in the 2200-2290 MHz band. In addition, TRR radios are expected to have little access to the 2200-2290 MHz band within 416 km of test ranges because of potential interference from telemetry operations. The allocation of the Air Combat Training System (ACTS) to the 2200-2290 MHz band would restrict TRR operations in the band at many TRR sites. Many of the current ACTS 1755-1850 MHz sites are the same sites (or are near sites) that are protected with indefinite 1710-1755 MHz band protection under OBRA-93 to accommodate the TRR. The incompatibility between the TRR and the ACTS is expected to continue for operations in the 2200-2290 MHz band.

C.6.1.5 2500-2690 MHz Band

In the United States, the 2500-2690 MHz band is currently used by the Instructional Television Fixed Service (ITFS), Multipoint Distribution Service (MDS), and Multichannel Multipoint Distribution Service (MMDS). The terms MDS and MMDS are often used interchangeably. The ITFS provides formal classroom instruction, distance learning, and videoconference capability to educational users throughout the nation. The MDS provides a commercial video programming service in this frequency band, often using leased ITFS spectrum There are four basic service offerings by ITFS/MDS: analog video, digital video, unidirectional digital data, and bi-directional digital data.

Traditional one-way ITFS/MDS systems provide one-way multichannel video programming to users or subscribers. The main station transmitter broadcasts to multiple receive sites located within the 56.3 kilometers service area. A 125 kHz response station transmitter may be located at the receive site.

In a two-way MDS/ITFS system, a main station transmitter is used to send data using digital modulation to numerous users. Each user has at least one response station transceiver with its receive antenna oriented towards the main station and its transmit antenna oriented towards its associated hub station.

There are 2,175 ITFS licenses throughout the United States with over 70,000 locations serving as registered receive sites and MDS currently has 2,570 station licensees and conditional licensees.

The technical parameters of the ITFS/MDS one-way main station transmitter/receiver and one-way response station transmitter/receiver are provided in Table C-23 and C-24, respectively.[4]

Table C-23. ITFS/MDS One-way Main Station Transmitter and Receiver

Transmitter Spectrum	2500-2686 MHz
Emission Bandwidth	6 MHz
Power (EIRP)	2000 Watts
Modulation	Video/Audio
Receiver Spectrum	2686-2690 MHz
Receiver Bandwidth	125 kHz
Modulation	AM or FM
Antenna Gain	20 dBi (assumed)
Noise Figure	2.5 dB
Receiver Noise	- 120.5 dBm (typical –107 dBm to –127 dBm)
Interference Threshold	-126.5 dBm

Table C-24. ITFS/MDS One-way Response Station Transmitter and Receiver

Transmitter Spectrum	2686-2690 MHz
Emission Bandwidth	125 kHz
Power (EIRP)	40 Watts
Modulation	AM or FM
Receiver Spectrum	2500-2686 MHz
Receiver Bandwidth	6 MHz
Modulation	Video/Audio
Antenna Gain	20 dBi (Assumed)
Noise Figure	2.5 dB
Receiver Noise	-103.5 dBm
Interference Threshold*	-98 dBm
*Based on a 45 dB desired/undesired ratio with response station 35 miles from main station	

[4] Federal Communications Commission, *Interim Report, Spectrum Study of the 2500-2690 MHz Band*, 15 November 2000.

The interference analysis of interactions between the TRR and the ITFS/MDS one-way main station and response station is provided in Tables C-25 to C-28. The two-way ITFS/MDS system was not analyzed because the systems are still in development and interference thresholds have not been finalized for the ITFS/MDS digital modulations.

Table C-25. Interference Calculations ITFS/MDS Main Station Transmitter to AN/GRC-245

ITFS/MDS main station transmitter authorized 2500-2686 MHz with a 6 MHz signal bandwidth

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX EIRP	TX Antenna*	TX Cable	Inter Threshold***	RX Antenna	RX Cable**			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
ITFS/MDS	GRC-245 MB	63	0	1	-105	25	5	0	187.0	97.0
ITFS/MDS	GRC-245 SL	63	0	1	-105	2	5	0	164.0	73.0

*ITFS/MDS MainStation antenna height is 90 meters

** Cable loss from J/F 12 for GRC-245

***Desired signal at sensitivity, I/N = - 6 dB

Table C-26. Interference Calculations for AN/GRC-245 to ITFS/MDS Main Station Receiver

ITFS/MDS main station receiver authorized 2686-2690 MHz with a 125 kHz signal bandwidth

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power	TX Antenna	TX Cable**	Inter Threshold***	RX Antenna*	RX Cable			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
GRC-245 MB	ITFS/MDS	32	25	5	-126.5	20	1	12	185.5	94.0
GRC-245 SL	ITFS/MDS	32	2	5	-126.5	20	1	12	162.5	72.0

*ITFS/MDS MainStation antenna height is 90 meters, antenna gain assumed 20 dBi

** Cable loss from J/F 12 for GRC-245

***Based on I/N= -6dB, receiver bandwidth = 125 kHz and noise figure = 2.5 dB

Table C-27. Interference Calculations for AN/GRC-245 Transmitter to ITFS/MDS Response Station Receiver

ITFS/MDS response station receiver authorized 2500-2686 MHz with a 6 MHz signal bandwidth

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power	TX Antenna	TX Cable**	Inter Threshold***	RX Antenna*	RX Cable			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
GRC-245 MB	ITFS/MDS MB	32	25	5	-98	20	1	0	169.0	50
GRC-245 SL	ITFS/MDS MB	32	2	5	-98	20	1	0	146.0	32
GRC-245 MB	ITFS/MDS SL	32	25	5	-98	2	1	0	151.0	36
GRC-245 SL	ITFS/MDS SL	32	2	5	-98	2	1	0	128.0	19

*ITFS/MDS Response Station antenna height is 10 meters, antenna gain assumed 20 dBi

** Cable loss from J/F 12 for GRC-245

***Based on S/I = 45dB, receiver bandwidth = 6 MHz

Table C-28. Interference Calculations for ITFS/MDS Response Station Transmitter to AN/GRC-245 Receiver

ITFS/MDS response station transmitter authorized 2686-2690 MHz with a 125 kHz signal bandwidth

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX EIRP	TX Antenna*	TX Cable	Inter Threshold***	RX Antenna	RX Cable**			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
ITFS/MDS MB	GRC-245 MB	46	0	1	-105	25	5	0	170.0	51.0
ITFS/MDS MB	GRC-245 SL	46	0	1	-105	2	5	0	147.0	33.0
ITFS/MDS SL	GRC-245 MB	28	0	1	-105	25	5	0	152.0	37.0
ITFS/MDS SL	GRC-245 SL	28	0	1	-105	2	5	0	129.0	20.0

*ITFS/MDS Response Station antenna height is 10 meters
** Cable loss from J/F 12 for GRC-245
***Desired signal at sensitivity, I/N = - 6 dB

C.6.1.6 2500-2690 MHz Band Assessment

The distance separation required to avoid interference between the TRR and the ITFS/MDS main stations is 97 km. The distance separation required to avoid interference between the TRR and the ITFS/MDS response stations is 51 km. However, the response stations are distributed around the main station at a distance of up to 56.3 km. As a result, the distance separation requirement between the TRR and the ITFS/MDS main station, based on the response station interference threshold, is 107.3 km. The 2175 ITFS and 2570 MDS main stations would require a separation distance of 107.3 km for TRR in-band operations. If the band can be segmented to provide some frequencies for exclusive TRR operations, the TRR could successfully utilize that portion of the band. The band made available for military use would have to be allocated to government use on a primary basis with equivalent regulatory protection.

C.6.2 Operational Impact

The MSE AND TRI-TAC impacts under this option are virtually the same as those described under Option 2.

The impacts to amphibious and general Marine Corps battlefield training would be virtually the same as those desribed under Option 2.

C.7 Option 4 – Vacate 1755-1850 MHz

C.7.1 Technical Assessment

The elimination of the 1755-1850 MHz band at all DoD TRR sites would stop operations of TRR duplex links at all sites where the 1710-1755 MHz band is not protected indefinitely by OBRA-93.

TRR duplex frequency assignments would not be possible without access to 1710-1850 MHz frequencies because of the requirement for a minimum of 50.125 to 63.0 MHz frequency separation between transmit and receive frequencies. The only band available for TRR operations, 1350-1390 MHz, can not provide the needed frequency separation. The sites without spectrum for TRR operations would include Fort Hood and Fort Carson. Some sites have access to the 1432-1435 MHz band and one high data-rate duplex link could operate at these sites.

The 2025-2110 and 2500-2690 MHz bands have been assessed for TRR use and no spectrum was identified for the TRR. The 2200-2290 MHz band is allocated for government fixed and mobile operations, but the current users of the band must be protected. The separation distance of 132 km is required between TRR transmitters and the satellite downlink receivers to avoid interference. The large number of satellite control frequencies and the large separation distance is expected to eliminate most frequencies from TRR use around earth terminal sites in the 2200-2290 MHz band. In addition, TRR radios are expected to have little access to the 2200-2290 MHz band within 416 km of test ranges because of potential interference from telemetry operations. The 2200-2290 MHz band is being investigated for ACTS use as an alternate to the current 1755-1850 MHz band. The frequency-distance separation requirements between the ACTS and the TRR are comparable to the requirements for airborne telemetry. As a result, the 4400-4940 MHz band was assessed as an alternate frequency band for TRR operation.

2003 and 2006 Time Frame. The loss of the 1755-1850 MHz band would disrupt TRR operations at sites without access to the 1710-1755 MHz band until AN/GRC-245 type radios with an ability to operate above 2000 MHz become widely available after 2006.

2010 Time Frame. The replacement of current TRR equipment with AN/GRC-245 type radios operating above 2000 MHz could be accomplished after the 2006 time frame. The government spectrum available above 2000 MHz and the non-government 2500-2690 MHz frequency band were investigated in the previous section to see if training requirements could be met in these bands and little spectrum was identified. The 4400-4940 MHz band was investigated as a candidate for TRR.

C.7.1.1 4400-4940 MHz Band

The 4400-4940 MHz band was investigated for TRR operations; however, this study did not investigate the 4400–4940 MHz band for worldwide spectrum availability for the TRR. Migration of TRR systems that operate in the 1755-1850 MHz band to the 4400-4940 MHz band is not feasible due to the operational impacts resulting from the significant difference in technical characteristics of the bands and due to the limitations required to protect incumbent users in the 4400-4940 MHz band.

The 4400–4940 MHz band supports the operations of many fixed and transportable line-of-sight and tropospheric scatter radio relay systems, for the exchange of weapons sensor data, telemetry, and command links for weapons and range systems. The systems are generally wideband, multichannel systems and are used by all the services.

The relocation of TRR operations to the 4400 – 4940 MHz band would involve a design of a new series of radios, significant changes in operational doctrine, and manpower increases to restore essential military capabilities currently supported by operations in the 1755-1850 MHz band. Parameters of notional TRR systems are provided in Table C-29.

Table C-29. Parameters of Notional Tactical Radio Relay Systems in the 4400-5000 MHz Band

Frequency range	4400 – 5000 MHz
Transmit power	1.6 W
Emission Bandwidth (MHz)*	2.0 (-3 dB)
Antenna gain	32 dBi at 4.4 GHz
Antenna height	30 m
Receiver bandwidth (MHz)*	6.7 (-3 dB)
Interfering signal threshold*	-105 dBm
Cable losses	6 dB @ 4700 MHz

A high antenna gain is needed to compensate for the increased link losses at 4400-4940 MHz. However, the 4400–4940 MHz antenna would have a beamwidth of approximately 3.5 degrees. The narrow-beam antenna will significantly reduce the mobility and survivability of military personnel and units. In some situations, link distances would be significantly reduced thereby resulting in increased numbers of TRR systems with associated increases in manpower.

A notional TRR system (Table C-29) was evaluated for electromagnetic compatibility (EMC) with the incumbent equipment in the 4400–4940 MHz band. The incumbent equipment analyzed included the AN/TRC-170, AN/GRC-222, and the Cooperative Engagement Capability (CEC).

AN/TRC-170. The AN/TRC-170 is a transportable radio terminal providing full-duplex digital voice and data at ranges up to 330 km by means of line-of-sight or tropospheric scatter modes of propagation in the 4400–4999 MHz band. The parameters of the AN/TRC-170 used in the analysis are presented in Table C-30.

Table C-30. Parameters of the AN/TRC-170 From J/F 12/4480/4

Frequency range	4400 – 4999.9 MHz
Transmit power	2 KW
Emission Bandwidth (MHz)	5.0 (-3dB), 7.0 (-20dB), 13.0 (-60dB)
Antenna gain	40.5 dBi (mainbeam)
Antenna height	5 m
Receiver bandwidth (MHz)	4.0 (-3dB), 6.0 (-20dB), 10.0 (-60dB)
Receiver noise figure	5 dB (estimate)
Receiver sensitivity	NA
Receiver noise power	-103 dBm
Interfering signal threshold	-109 dBm
Cable losses	NA
Waveform	7M00M7D

The AN/TRC-170 has the greatest number of frequency assignments in the band and there are three versions currently in use. The AN/TRC-170(V2) version has typical parameters based on a review of the frequency assignment data files and this version was used in the analysis. The AN/TRC-170 provides high capacity backbone communications in tactical, strategic and administrative environments and operates in close proximity to the MSE, TRI-TAC, and DWTS systems. The distance separation required to eliminate interference between the AN/TRC-170 and a notional TRR system was calculated using the standard interference equation and the results are provided in Figures C-9 and C-10.

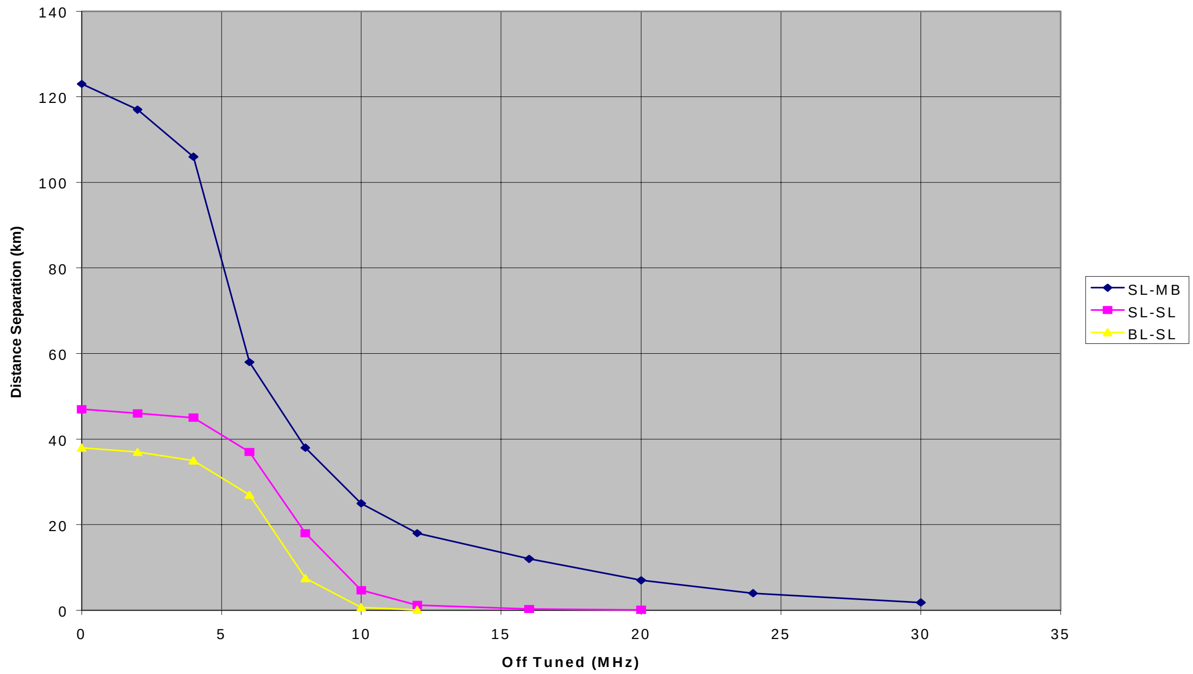

Figure C-9. Frequency-Distance Separation for AN/TRC-170 to a TRR

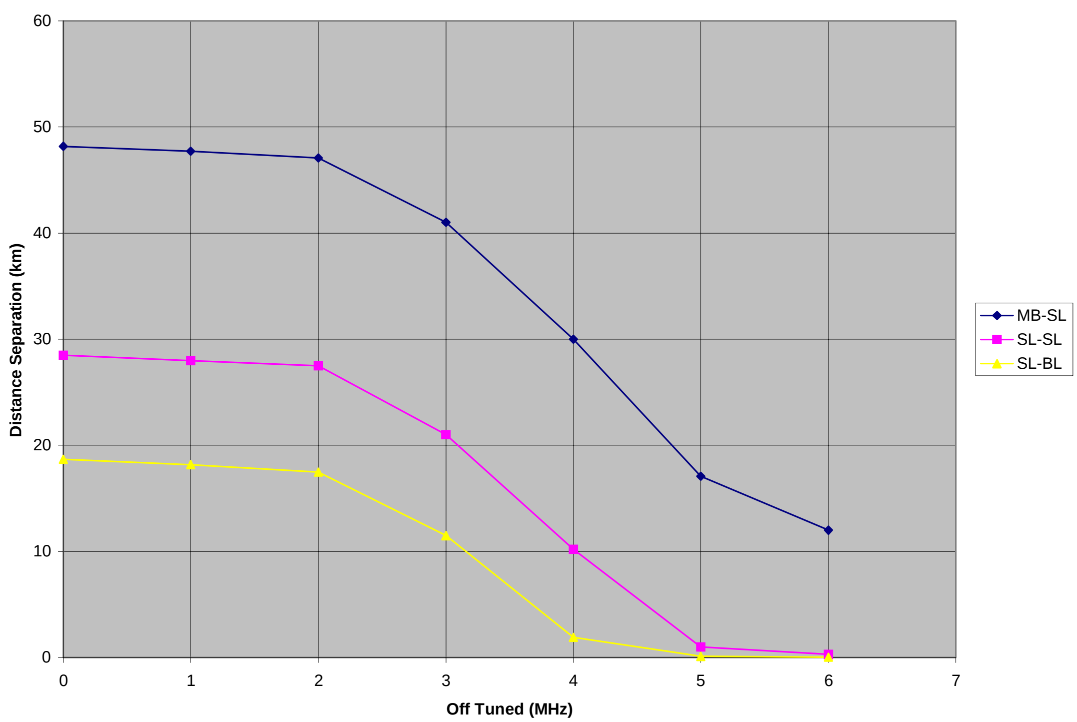

Figure C-10. Frequency-Distance Separation for a TRR to AN/TRC-170

The frequency separation requirements for AN/TRC-170 transmitters and TRR receivers are in the range of 12 to 18 MHz for co-located radios (distance separations of approximately 200 meters) with sidelobe or backlobe antenna orientations. The frequency-distance separation requirements for the AN/TRC-170 high power mode are larger (by a factor of two or three) than the separation requirements for LOS microwave radios and additional spectrum will be required to provide compatible frequency assignments.

AN/GRC-222. The AN/GRC-222 is a high traffic digital radio that operates in a LOS mode of propagation. The AN/GRC-222 has a capacity to 18.72 mbps of data using 8-level phase shift keying (PSK) modulation. The radio parameters of the AN/GRC-222 are provided in Table C-31, and the results of the analysis are provided in Figures C-11 and C-12. The collocated frequency-separation requirement between the AN/GRC-222 and a TRR receiver is approximately 8 MHz.

Table C-31. Parameters of the AN/GRC-222 J/F 12/6204

Frequency range	4400 – 5000 MHz
Transmit power	0.8 W
Emission Bandwidth (MHz)*	5.8 (-3dB), 7.6 (-20dB), 12.2 (-60dB)
Antenna gain	33 dBi (mainbeam)
Antenna height	30 m
Receiver bandwidth (MHz)*	12.0 (-3dB), 19.0 (-20dB), 46.0 (-60dB)
Receiver noise figure	7 dB (assumed)
Receiver sensitivity*	-66 dBm @ 18720 Kb/s and BER = 10E-5
Receiver noise power*	-91 dBm (assumed)
Interfering signal threshold*	-97 dBm (assumed)
Cable losses	6 dB @ 4700 MHz (assumed)
Waveform	7M00G2D, 8 PSK
*18720 kb/s	

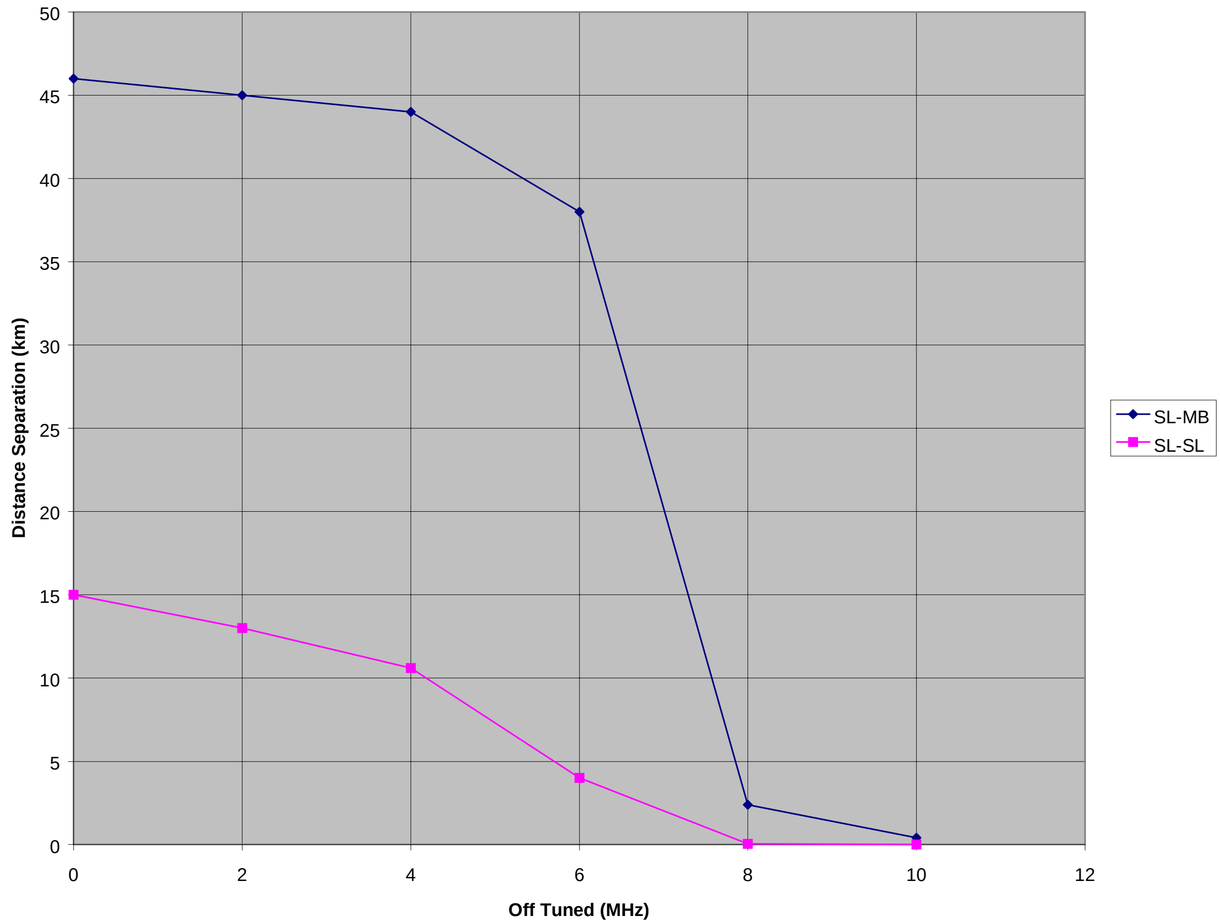

Figure C-11. Frequency-Distance Separation for AN/GRC-222 to a TRR

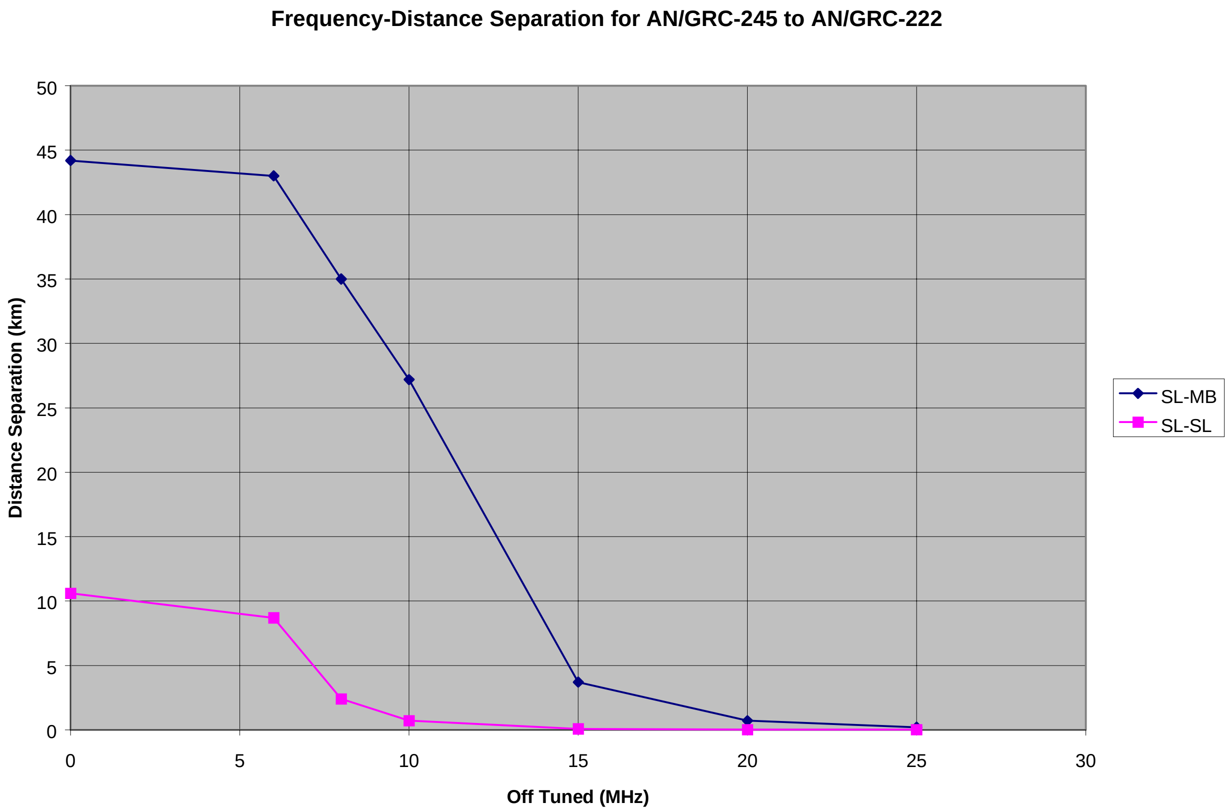

Figure C-12. Frequency-Distance Separation for a TRR to AN/GRC-222

Cooperative Engagement Capability (CEC). CEC is a system that provides the means to conduct coordinated Anti-Air Warfare (AAW) area defense. All Cooperating Units (CU) that participate in a CEC network exchange sensor data in near real time to form an identical composite track and identification air surveillance picture on each CU. This sensor cooperation function allows targets to be detected and compositely tracked that a single individual sensor could not track. The composite air picture provides the means for a battle force to accomplish optimized weapon system assignments and the coordinated engagements of threats. CEC is implemented via a Cooperative Engagement Processor (CEP) and a Data Distribution System (DDS). The CEP is a computer system responsible for forming the composite track and identification data base, and for coordinating engagements. The DDS is an radio frequency (RF) network responsible for the secure, environmentally resistant transfer of sensor and weapon data among the CUs. CEC is currently being deployed aboard Navy E-2C aircraft and the major Navy surface combatants, carriers, and amphibious class ships. CEC is also now in development for deployment with the USA PATRIOT, USAF AWACS, and USMC AN/SPS-59 radar systems. The parameters for CEC are provided in Table C-32.[5]

Table C-32. Parameters of the Cooperative Engagement Capability (CEC) from FCC-00-63

Frequency	4929 MHz and Below
Emission Bandwidth	22 MHz
Maximum Transmit Power (EIRP)	630 kW
Out-of-Band Emissions	+/- 7.65 MHz (-3 dBc), +/- 12.1 MHz (-30 dBc)
Transmitter Noise	+/- 25.6 MHz Less Than –145 dBc/Hz

The analysis of CEC interference to a relocated TRR concluded that band sharing and band segmentation are not feasible. For band sharing, the separation distance required to reduce CEC in-band signals to a maximum allowed interference level was determined to be beyond the RF horizon, which could exceed 200 NM for airborne CEC platforms. Since both TRR and CEC may operate in close proximity, that separation distance is not acceptable. For band segmentation, the distance may reduce to 30 nmi (55 km), which is again unacceptable. Most significant, for band segmentation, CEC may have to incur a 250 MHz reduction in usable spectrum. That spectrum reduction would have significant and unacceptable impacts on CEC combat readiness and operation.

C.7.1.2 4400-4940 MHz Band Assessment

Battle Space management doctrine and tactics will require collocation of CEC and TRR aboard Navy ships and ashore elements of Marine and Army Air Defense radars and Missile Batteries, among other things. However, relocation of TRR systems from the 1755-1850 MHz band into the 4400-4940 band would preclude simultaneous use of CEC and TRR during, among other things, carrier battle group operations, amphibious operations, and joint operations ashore. It is contrary to battle space management doctrine and tactics to forgo the simultaneous use of critical warfighting systems. Trade-offs between use of anti-air warfare systems (like CEC) and systems for the exchange of tactical data (TRR) are unacceptable.

If AN/TRC-170 systems and the TRR systems both operate in this same frequency band, additional spectrum would be required to provide larger guardbands around the AN/TRC-170 emissions. An additional spectrum requirement of 50 MHz would be necessary to provide the guardband with CEC.

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[5] Federal Communications Commission, *FCC Proposes Licensing and Service Rules for the 4.9 GHz Spectrum Band*, NPRM FCC-00-63, 29 February 2000.

Accommodating the TRR in the 4400-4940 MHz band could require a 200 to 250 MHz reduction in CEC spectrum and have a significant impact on CEC combat readiness and operations. The major operational impact of a decrease in RF spectrum is a decrease in the number of CUs that can simultaneously participate in a CEC network. Each CU increases the warfighting effectiveness of the battle force by providing: (1) sensors that uniquely contribute to the formation and update of a composite track and identification data base, and/or (2) weapon systems that uniquely contribute to target engagement based on that composite data base. The decrease in bandwidth, then, degrades the overall warfighting capabilities of a CEC network, the individual combatants that comprise the network, and the individual combatants that must be purposely omitted from the network.

C.7.2 Operational Impact

Vacating the entire 1755-1850 MHz band is not an option for the Army. This band is a key element of Army battlefield communication networks for the foreseeable future, including the new HCLOS radio. Alternate frequency bands above the mid 2 GHz area may not be suitable for tactical microwave systems. The 1700 MHz band is used for mobile communications because the propagation characteristics allow for better penetration of foliage, use of inexpensive coaxial cables instead of expensive wave guides, and have a wide beam width allowing for quicker path alignment. These characteristics are critical to tactical mobile communications units because of their mission to provide the Army with the ability to relocate command centers quickly. Moving the communications network to a higher frequency band would negate many of these factors, thus decreasing the operational utility of the system. Otherwise, over the air training exercises would be severely restricted at most of the training locations available to the Army. The operational implications from the inability to train in the US would directly impact combat operations. Deployment and maintenance of the ACUS/MSE system during a crisis and network management of large brigade/division/corps level units will be degraded because of the lack of trained operators.

Vacating the entire 1755-1850 MHz band is unacceptable for the Marine Corps until new frequency space is identified and a new system is developed. No existing materiel solutions are available for fielding until at least the 2010 time frame. Operational impacts are worse than Option 1, as no capability would remain for amphibious and battlefield training.

APPENDIX D – POTENTIAL FOR INTERFERENCE BETWEEN IMT-2000 ENVIRONMENT AND AIR COMBAT TRAINING SYSTEMS (1755-1850 MHZ)

The 1755-1850 MHz frequency band is used by Air Combat Training Systems (ACTS) such as the Air Force's Air Combat Maneuvering Instrumentation (ACMI) and the identical Navy Tactical Air Combat Training System (TACTS). These existing ACTS systems transmit data to the aircraft on either 1830 or 1840 MHz and receive data from the aircraft on either 1778 MHz or 1788 MHz. Phase-modulated ranging tones and 198.4 kb/s data, using frequency shift keying, are transmitted. Point-to-point links in this band are also used to communicate the data from remote sites to a central location.

Current plans call for existing ACTS to be operating well past 2010. Under the current plan, the Joint Tactical Combat Training System (JTCTS) would not begin replacing existing ACTS until after 2006, with a replacement schedule into at least the 2010 time frame. The JTCTS data links operate air-to-ground, ground-to-air, and ground-to-ground, and can tune across the band 1710-1850 MHz in 5 MHz increments. The JTCTS data link signal structure is l6-ary, orthogonal signaling, with 0.351, 0.703, and 1.406 Mb/s data rates combined with either 5.63 or 22.5 Mc/s pseudorandom spreading codes.

This appendix addresses the possible interference between IMT-2000 base and mobile stations and the ACTS, also described as the TACTS/ACMI and the JTCTS operating in the frequency band 1755-1850 MHz.

D.1 OPERATIONAL MISSION OVERVIEW

The mission of the Air Force ACTS ranges, as prescribed in Air Combat Command (ACC) regulation 23-24, is to "maximize the combat readiness, capability, and survivability of participating units by providing realistic training in a combined air, ground, and electronic threat environment while providing for a free exchange of ideas between forces." Specifically, the range objectives are to force the crewmember to cope with an action-reaction sequence of threat events that (1) reflects the realities of imperfect intelligence and the limitations of operational plans, (2) yields an opportunity to practice handling larger amounts of information under stress, and (3) provides recognition that other players are influencing the scenario, the threat, and the outcome.

The ACTS 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 and post mission reconstruction capabilities to enhance debriefing of combat aircrews. 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.

Live air combat training is essential in order to expose pilots and combat systems operators to the complexities and stresses under which they are expected to execute their intended missions in actual combat. A key part of this training is the capability to provide accurate feedback directly to the aircrews and the probable or actual results of their actions. The required training environment and feedback capability can only be provided with special instrumentation such as ACTS and JTCTS. The time-related data, provided by this instrumentation—aircraft instantaneous position, velocity vector and accelerations, maneuvering history, and combat system activity history—forms the only possible objective information for feedback. This data supports weapons engagements performed with simulated weapons fly-outs and endgame results, instead of utilizing real weapons for obvious safety reasons and the prohibitive cost of expending actual weapons in a training situation. The ability to provide this type of support ensures each flight hour flown is maximized in terms of effectiveness and cost efficiency.

Without the training feedback from ACTS, aircrews may develop the habit of launching their air-to-air or air-to-ground weapons "out of the envelope" or not maintaining radar-lock throughout the simulated launch of a weapon. These bad habits can be deadly in air combat. Aircrews can deploy and fly in support of the combatant commanders without ACTS training, but in the words of one Air Force fighter pilot, "It's like sending a little league baseball player straight into the big leagues. With little or no training and experience, the player will most likely strike out. In our case, we don't strike out, we get shot down." In addition, both the Air Force and Navy systems are used by allied nations during training in the US. This opportunity to train in coalition operations is invaluable as air operations over Kosovo showed.

In the early 1990s, the Navy began development of a system that would not only replace and upgrade their "legacy" TACTS but also provide a capability to take the TACTS function to sea with a carrier battlegroup. Subsequently, the Office of the Secretary of Defense (OSD) mandated expansion of the Navy's Tactical Combat Training System (TCTS) program to cover Joint Air Force and Navy requirements for the next-generation ACTS. The initial focus of the Joint TCTS (JTCTS) program is on development and production of the mobile ("rangeless") configuration, which does not impact the continental US (CONUS)-based IMT-2000 deployment. Development and production of the fixed range configuration (and replacement of all the legacy ACTS within CONUS) is not currently scheduled until the 2008-2017 time frame. While some existing "fixed" ranges may be replaced by rangeless capability, Major Training Centers (MTCs) of all services provide infrastructure that are planned to be preserved and modernized with JTCTS derived "fixed applications."

TACTS is the primary tool at the Navy Fleet Replacement Squadron (FRS) and Marine Training Squadron level, where the aircrews first learn how to fly and fight with the specific aircraft they will operate in the Fleet. ACTS is essential to the advanced tactical training—Strike-Fighter Advanced Readiness Program (SFARP), Fighter Advanced Readiness Program (FARP), and Top Gun—that the F/A-18 and F-14 aircrews go through as their squadrons prepare for eventual carrier deployment. TACTS is critical to the ability of the Naval Strike and Air Warfare Center (NSAWC) and Marine Aviation Weapons And Tactics Squadron One (MAWTS-1) to prepare and evaluate the ability of carrier air wings and Marine aviation tactical squadrons to carry out complex coordinated combat operations. Similar Air Force schools and large air exercises like Red Flag at Nellis Range rely on ACMI systems to conduct similar training regimen.

JTCTS systems will be fielded more widely in the future to support more robust "joint" training, as the Services become more interdependent. JTCTS will fulfill the same functions as ACTS with added flexibility to support the rangeless training concept with fewer constraints than what is currently associated with the ACTS ground infrastructure.

D.2 SYSTEM DESCRIPTIONS

Technical characteristics of the TACTS/ACMI and JTCTS, together with relevant operational assumptions, are given in the following paragraphs.

D.2.1 TACTS/ACMI Characteristics

D.2.1.1 System Characteristics

Characteristics of the TACTS/ACMI system are given in Tables D-1, D-2, and D-3. Values are those in the frequency allocation applications,[1,2,3,4] unless noted otherwise. Unique radio frequency (RF) parameters of some of the Air Force ACTS ranges are not considered in this analysis. Certain parameters of the internal AIS units were not available. The values were estimated based on the corresponding parameters of the Airborne Instrumentation Subsystem (AIS) pod units, and the shaded cells of Tables D-1 and D-2 indicate these parameters. For transmitter emission bandwidths and receiver IF bandwidths, as well as harmonic and spurious levels, the DD Form 1494 values were used instead of the specified values.[5] It was felt the specified values represented a limit not to be exceeded, while the 1494 values more closely represented actual system characteristics. TACTS/ACMI frequencies and the link types associated with their use are listed in Table D-4.

D.2.1.2 Operational Considerations

In an earlier analysis for the Air Force Frequency Management Agency (AFFMA),[6] ground-to-air separation distances of 78 and 35 km were used. These values correspond to 48.5 mi (42.1 nmi) and 21.75 mi (18.9 nmi) respectively. The specified nominal maximum range appears to be 65 nmi.[7] The separation distances of 78 km (42.1 nmi) and 35 km (18.9 nmi) were used in the TACTS/ACMI portion of this analysis.[8]

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[1] Application for Equipment Frequency Allocation (DD Form 1494) for AN/TSQ-T4 Master Station and subsequent Notes to Holders, J/F 12/4321, Washington, DC: MCEB, April 1975.

[2] Application for Equipment Frequency Allocation (DD Form 1494) for AN/TSQ-T4 Remote Stations and subsequent Notes to Holders, J/F 12/4322, Washington, DC: MCEB, April 1975.

[3] Application for Equipment Frequency Allocation (DD Form 1494) for AN/TSQ-T4 Up Link and subsequent Notes to Holders, J/F 12/4323, Washington, DC: MCEB, April 1975.

[4] Application for Equipment Frequency Allocation (DD Form 1494) for TACTS, ACMI AIS Pods and subsequent Notes to Holders, J/F 12/4324/2, Washington, DC: Naval Air Systems Command, May 1987.

[5] Fred Williar, Naval Air Systems Command, e-mail to Allan Baker, IITRI, Subject: More TACTS Data, Patuxent River NAS, MD, September 27, 2000.

[6] Wayne Wamback, The Potential for Interference Between IMT-2000 Systems and US DoD Systems Operating in the Frequency Band 1755-1850 MHz, Annex 2, Alexandria, VA: AFFMA, 28 February 2000.

[7] James E. Keeler, AAC/WMRR, e-mail to J. Don Simmons, Civ AAC/WMRR, *Subject: DoD Forms for 1755 – 1850 MHz IMT-2000 Study*, September 13, 2000.

[8] Fred Williar, Naval Air Systems Command, e-mail to Allan Baker, IITRI, *Subject: TACTS AIS Data*, Patuxent River NAS, MD, September 27, 2000.

Table D-1. TACTS/ACMI Transmitter Characteristics

Transmitter Characteristic	TIS Master	TIS Remote	TIS Uplink	AIS Downlink (Pod)[a]	AIS Downlink (Internal)[d]
Power (W)	20	1 or 5[b]	5 [c]	20	10-15 (min)[e]
Modulation Type	FSK,PM	FSK,PM	FSK,PM	FSK,PM	FSK,PM
Modulation Indices	0.9,0.3,0.3	0.9,0.3,0.3	9,3,3	9,3,3	8.2,2.7,2.7
Carrier Deviation (FSK)	± 74.4 kHz	± 74.4 kHz	± 74.4 kHz	± 74.4 kHz	± 74.4 kHz
Data Rate (kb/s)	198	198	198	198	198
Widest Emission Bandwidth (MHz)					
-3 dB	0.6	0.6	3.0	2.0	3.0
-20 dB	0.8	0.8	7.0	8.0	7.0
-60 dB	2.1	2.1	12.0	12.0	12.0
Harmonic Attenuation (dB)	70	70	70	85	85
Spurious Attenuation (dB)	70	70	70	70	70

[a]The calibration transponder at the master station is electronically identical to the AIS pod.
[b]Depends on manufacturer. Cubic Corp. uses 1 W, ADT uses 5 W (Ref. 5).
[c]20 W at Tyndall ACMI and Yukon MDS ranges (Ref. 5).
[d]Data consolidated from Ref. 8.
[e]15 W applies to AISI(K) (Ref. 8).

Table D-2. TACTS/ACMI Receiver Characteristics

Receiver Characteristic	TIS Master	TIS Remote	TIS Downlink	AIS[a] (Pod)	AIS (Internal)[d]
Sensitivity (dBm)	-95 (BER = $1x10^{-5}$)	-95 (BER = $1x10^{-5}$)	-95 (BER = $1x10^{-5}$)	-99 (10 dB S/N) (BER = $1x10^{-5}$)	-95 dBm (100% response), -99 dBm (50% response)
Noise Level[e] (dBm)	-110	-110	-110	-111	-111
IF Bandwidth[b] (MHz)					
-3 dB	1.5	1.5	1.5	1.2	1.2
-20 dB	5.0	5.0	5.0	3.0	3.0
-60 dB	12.0	12.0	12.0	8.0	8.0
Receiver Selectivity[c] (MHz)					
-3 dB	1.5	1.5	1.5	1.2	1.2
-20 dB	2.9	2.9	2.9	3.0	3.0
-60 dB	7.4	7.4	7.4	6.8	6.8
Spurious Response (dB)	60	60	85	85	85

[a]The calibration transponder at the master station is electronically identical to the AIS pod.
[b]Second IF bandwidth
[c]Bandwidth of combined first and second IF stages.
[d]Data consolidated from Ref. 8.
[e]Calculated using 2.7 dB noise figure, from Ref. 5.

Table D-3. TACTS/ACMI Antenna Characteristics

Antenna Characteristic	TIS Master	TIS Remote	TIS Uplink/ Downlink	AIS (Pod)	AIS (Internal)
Type	Parabolic (Dipole Arrays)/ Broad Beamwidth	Parabolic	Crossed Dipole Array	Dipole	Dipole
Gain (dBi)	28,24, 20[d]/14.5	26	3.0	0	0
Polarization	V & H	V,H	RHCP	RHCP	RHCP
Height (ft)	75 (300 max)[e]	100-150	160 (100-150)[e]	30,000[a,c]	55,000-60,000[a,b]

[a]Maximum altitude above mean sea level
[b]From Reference 8.
[c]Reference 5 gives a range of 10,000 to 30,000 ft. This reference also states that the tracking instrumentation subsystem (TIS) is specified to track aircraft within altitudes of 500 ft. to 40,000 ft above the range floor.
[d]Different values are given. The 20-dB value is given in Reference 1. Although a broad beamwidth is usually desired, the antenna gain may depend on the installation.
[e]Antenna height is site-dependent.

Table D-4. TACTS/ACMI Frequencies and Usage

Type of Link	Frequencies (MHz)
Master-to-Remote	1768 or 1769
AIS-to-Remote (Downlink)	1788 “A” Pod or 1778 “B” Pod
Remote-to-Master	1797, 1802, 1807, 1812, 1817, 1822
Remote-to-AIS (Uplink)	1840 “A” Pod or 1830 “B” Pod

The maximum number of aircraft is stated to be 36 (Reference 7). For the Nellis ACTS and the Alaska Upgrade (AAU), as many as 100 aircraft can be supported. In this analysis, the effect of the number of aircraft flying at a given time was not considered.

Altitudes of 5000 m (16,400 ft) and 9000 m (29,530 ft) were used in Reference 6. A somewhat higher maximum altitude of 40,000 feet above range floor is given in Reference 5, and altitudes of 55,000 to 60,000 feet are given for the internal AIS equipment (Reference 8). The 9000 m (approximately 30,000 ft) altitude was used in this analysis.

A representative sample of TACTS and ACMI training center sites is shown in Figure D-1.

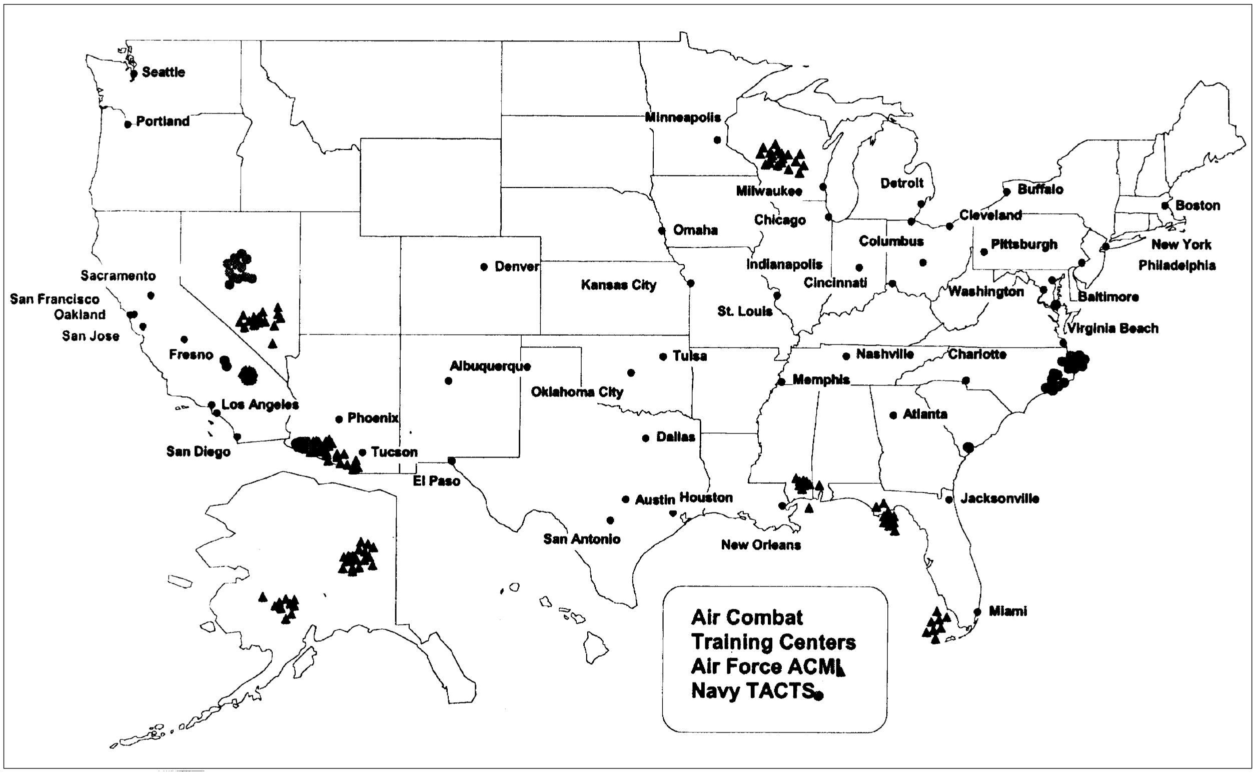

Figure D-1. Representative Sample of Air Combat Training Center Sites

D.2.2 JTCTS Characteristics

D.2.2.1 System Characteristics

Tables D-5, D-6, and D-7 contain characteristics of the JTCTS. Characteristics were obtained from the frequency allocation application,[9] SRI International reports[10,11] and material from the system manufacturer which was provided by SRI International.[12,13] The high-power mode of operation (67.6 W) was assumed. The shaded boxes contain assumed values.

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[9] Application for Equipment Frequency Allocation (DD Form 1494) for Joint Tactical Combat Training System (JTCTS) Instrumentation Data Network, (Stage 4), J/F 12/06999/2, Patuxent River, MD, NAWCAD, 10 July 1998.

[10] David Hanz, Results from Phase 1a of the GSM-1800/JTCTS Datalink Signal Compatibility Test Program, Special Report 10240-99-SR-110, Menlo Park, CA: SRI International, November 1999.

[11] US DoD Air Combat Training Systems Development Roadmap for Next Generation & Spectrum Compatibility Issues, dated 12 January 2000. Briefing given by D. Hanz of SRI International, 11 September 2000.

[12] Raytheon Systems Company, *JTCTS Data Link Overview*, Slide Package, undated, attachment to D. Hanz, SRI International, e-mail to A. Baker, IITRI/JSC, September 25, 2000. *Subject: Reference Material #1.*

[13] Dave Hanz, SRI International, e-mail to Allan Baker, IITRI, *Subject: More Reference*, 25 September 2000, with attachment Raytheon Specification G644379 8 February 1996 CAGE Code 49956 Rev. A: 31 December 1996.

Table D-5. JTCTS Transmitter Characteristics

Transmitter Characteristic	Narrowband	Wideband
Power (W)	7.6 or 67.6	7.6 or 67.6
Tuning	Frequencies are selectable from 1710-1850 MHz in 5-MHz increments (1755-1850 MHz in US&P).	
Modulation Type	OQPSK with DS spread spectrum, 16-ary orthogonal Walsh signaling	
Data Rate (kb/s)	351.5625, 703.125, 1406.25	351.5625, 703.125, 1406.25
Chip Rate (Mc/s)	5.63	22.5
Protocol	TDMA-100 ms frame, Primary IDN: 25 slots/frame Secondary IDN: 10 slots/frame	
Error Detection and Correction	Reed-Solomon FEC Short Data Slots: (116,100) Long Data Slots: (128,100) Relay Slots: (56,40)	
Emission Bandwidth (MHz)		
-3 dB	2.1	4.8
-20 dB	5.63	22.5
-60 dB	22.5	90
Harmonic Attenuation (dB)		
(2 & 3)	70	70
Other	80	80
Spurious Attenuation (dB)	80	80

Table D-6. JTCTS Receiver Characteristics

Receiver Characteristic		
Sensitivity (dBm)	-106.5 @ 14.1 dB E_b/N_o, 351.56 kb/s, RS coding	
Noise Figure (dB)	4.5	
Receiver Noise Level, dBm[b]	-114.0 (352.6 kb/s), -111.0 (703 kb/s), -108 dBm (1406 kb/s)	
First IF Bandwidth (MHz)	Narrowband[c]	Wideband
-3 dB	22.5	22.5
-20 dB	45	45
-60 dB	60	60
Implementation Losses (dB)	2	
Spurious Response (dB)	60	
Image Rejection (dB)	100	
Intermediate Frequency (MHz)	400	
[a]It is expected that additional selectivity is present, at the second IF or baseband [b]In bandwidth equal to the bit rate. [c]No additional filtering is used for the narrowband mode.[14]		

[14] David Hanz, SRI International, e-mail to Allan Baker, IITRI/JSC, 9 October 2000, Subject: JTCTS Characteristics.

Table D-7. JTCTS Antenna Characteristics

Antenna Characteristic	Instrumentation Data Link (Aircraft Fuselage Mounted)	Instrumentation Data Link (Aircraft Pod Mounted)	Ship-to-Shore Link
Type	¼ λ monopole blade	½ λ crossed dipoles	Stacked dipole array
Gain (dBi)	2	6	8
Polarization	V	H,V	V
Height (ft)	30,000	30,000	

D.2.2.1.2 Operational Considerations

In Reference 6, ground-to-air separation distances of 78 and 35 km were used for both the TACTS/ACMI and JTCTS analyses. These values correspond to 48.5 mi (42.1 nmi) and 21.75 mi (18.9 nmi) respectively. However, it is realized that for the JTCTS, the ground-to-air links are secondary and tertiary links. The primary link is the air-to-air link, with a maximum distance of 150 nmi (278 km). A separation distance of this magnitude plus a smaller one (78 km or approximately 50 mi) were used in the analysis.

The maximum number of aircraft is stated to be 100 for JTCTS, according to discussions at a 25 September 2000 meeting with Naval Air Systems Command (NAVAIR) and SRI International personnel and to Reference 7. Typical numbers of aircraft may be somewhat less. In this analysis, the effect of the number of aircraft flying at a particular time was not considered.

Altitudes of 5000 m (16,400 ft) and 9000 m (29,530 ft) were used in Reference 6. Some of the material provided for the TACTS system indicates that maximum altitudes may be higher (e.g., 40,000 to 60,000 feet). However, after coordination with JTCTS engineering and operational personnel, an altitude of 9000 m (approximately 30,000 ft) was used in both the TACTS/ACMI and JTCTS parts of the analysis.

D.3 COST ISSUES

D.3.1 Aircraft Combat Training Systems

The DoD is developing the next generation air combat training system to replace the existing ACTS equipment. This system, called the Joint Tactical Combat Training System (JTCTS), is a Global Positioning System (GPS)-based system. JTCTS, as designed, utilizes the 1755-1850 MHz band. However, JTCTS can be retuned to a segment of the 1755-1850 MHz band or relocated to another band of comparable spectrum, given one's availability. This is the key assumption regarding DoD proposed mitigation approach for tactical aircraft training systems under the full-band loss option. If a comparable band in S-band is not made available a much more expensive, complicated, and yet to be defined alternative, will be required.

The proposed DoD mitigation plan for ACTS is to retune to the segmented band or relocate to an alternate JTCTS band, accelerate immediately the development work necessary to reconfigure JTCTS equipment to the operating band, and then to accelerate to the extent possible fielding of the system considering the large number of aircraft affected and the number of ranges that utilize TACTS/ACMI equipment. The acceleration can be large, as in the 2006 IMT-2000 build-out case, or more gradual in the 2010 case. Given the current JTCTS program, relocating and fielding JTCTS for all legacy ACTS in 2006 is high risk (questionable feasibility) or in 2010 is medium to high risk even with immediate funding. Table D-8 shows the cost impact of relocating JTCTS under the 2010 option assuming total band loss to DoD.

Table D-8. Joint Tactical Combat Training System (JTCTS) (TY$M)

	FY02	FY03	FY04	FY05	FY06	FY07	To Complete	Total
JTCTS Acceleration	15.2	55.7	44.8	68.6	48.6	34.8	173.0	440.7

D.4 OPTION 1 – FULL BAND SHARING

D.4.1 TACTS/ACMI Technical Assessment

D.4.1.1 Interference from IMT-2000 into TACTS/ACMI Airborne Receivers

The calculation of aggregate IMT-2000 interference into the TACTS/ACMI and JTCTS airborne receivers was done in a manner similar to that in Reference 6, which was based on the levels used in Recommendation ITU-R M.687-2.[15] Two training ranges were selected, Cherry Point Marine Corps Air Station (MCAS), in the eastern US, and Nellis Air Force Base (AFB) in the western US. Both training ranges were within LOS of at least one major metropolitan area. For each training range, a point within the boundary of the flight area was selected, and metropolitan areas within the radio line of sight (LOS) of this point were selected. The assumed aircraft receiver altitude was 9000 m (approximately 30,000 ft). For each city, the equivalent area was calculated, and the propagation loss was calculated using the

[15] International Telecommunication Union, International Mobile Telecommunications-2000 (IMT-2000), Recommendation ITU-R M.687-2, 1997.

JSC Spherical Earth Model (SEM)[16] with the modified free space option. Antenna heights used were 40 m for the IMT-2000 base stations and 9000 m for the airborne receiver. For these antenna heights and an assumed smooth earth, the radio LOS was calculated to be approximately 260 miles.

The total power at the airborne receiver was calculated using Equation D-1 (Adapted from Reference 6):

$$I(\text{dBW/Hz}) = \sum_{i=1}^{n} P_d \, P_{mi} \, D_{pl} \, l_{pi} \qquad \text{(D-1)}$$

where:

- P_d = power density per square kilometer per Hertz generated by IMT-2000 stations in an urban environment. Given by Reference 15 as 38 μW/km²/Hz
- P_{mi} = population of the ith visible metropolitan area, in millions
- D_{pl} = average inverse population density, in km^2 per million
- l_{pi} = path loss from the ith metropolitan area, equal to $10^{-L/10}$, where L is the path loss from the JSC SEM, in dB

Values of P_m used were the populations of the Ranally Metropolitan Areas, taken from the Rand McNally Commercial Atlas and Marketing Guide.[17] The values used are population estimates for 1 January 1999.

In Reference 6, the average population density was determined by averaging the population densities of the metropolitan areas or central cities for eight world cities. The average ratio was calculated to be 144.2 km^2/million.

As in Reference 6, a factor for environmental losses, 10 dB, was subtracted from the results of Equation D-1. Use of a lesser value, such as 0 dB, was also considered.

The results of the calculations using Equation D-1 are given in Tables D-9 and D-10 for Nellis AFB and Cherry Point, respectively.

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16 David Eppink and Wolf Kuebler, *TIREM/SEM Handbook*, ECAC-HDBK-93-076, Annapolis, MD: DoD ECAC, March 1994.
17 Rand McNally & Co., *Rand McNally 2000 Commercial Atlas & Marketing Guide*, 131st Edition, 2000, pp. 124-125.

Table D-9. Power Levels from Nearby Cities, Nellis AFB ACMI Range

City	Distance		Population (Metro Area) (mil.)	Equiv. Area (km^2)	Path Loss, dB	Received Power Density (dBW/Hz)
	Miles	km				
Las Vegas, NV	58	93	1.2575	181.3	137	-158.6
Los Angeles, CA	260	418.4	13.11	1890.5	169.7	-181.1
Bakers-field, CA	234	376.6	0.404	58.24	149.1	-175.6
Fresno, CA	253	407.1	0.726	104.7	159.7	-183.7
Riverside, CA	234	376.6	1.536	221.5	149.1	-169.8

The total power density is -158.2 dBW/Hz; with a 10-dB factor for environmental losses, it is -168.2 dBW/Hz.

Table D-10. Power Levels from Nearby Cities, Cherry Point MCAS

City	Distance		Population (Metro Area) (mil.)	Equiv. Area (km^2)	Path Loss, dB	Received Power Density (dBW/Hz)
	Miles	km				
Richmond, VA	200	322	.861	124.1	147.7	-171.0
Norfolk, VA	140	225	1.006	144.9	144.6	-167.2
Newport News, VA	140	225	0.476	68.6	144.6	-170.4
Fayetteville, NC	135	217	0.319	46.1	144.3	-171.9
Charlotte, NC	240	386	1.215	175.3	149.3	-171.1
Charleston, SC	240	386	0.4782	69.1	149.3	-175.1
Columbia, SC	260	418	0.4924	71.0	169.4	-195.1
Raleigh, NC	140	225	0.6733	97.1	144.6	-168.9
Durham, NC	140	225	0.3273	47.2	144.6	-172.1

The total power was calculated to be -161.4 dBW/Hz; with a 10-dB factor for environmental losses, it is -171.4 dBW/Hz.

Results of the interference calculations are given in Table D-11 for TACTS/ACMI air-to-ground separation distances of 35 and 78 km, for the aggregate interfering signal without environmental losses, the interfering signal with 10 dB losses, and the interfering signal attenuated by 10 dB, with the 10 dB loss factor. The 10-dB attenuation may approximate a situation where the IMT-2000 system is near the beginning of its full-scale implementation.

The results in Table D-11 show that the TACTS/ACMI link margins are degraded to -22 to -29 dB, with the full aggregate interfering signal, with 10 dB of environmental losses. With 10 dB less interfering power than predicted with the full operational implementation, link margins are still degraded to -12 dB at the 35 km TACTS/ACMI transmitter-to-receiver separation distance and -19 dB at the 78-km separation distance. Since a number of factors could cause the calculated numbers to be higher than those shown, the results suggest that sharing in a full IMT-2000 environment is not feasible.

Table D-11. TACTS/ACMI Airborne Receiver Link Margins With and Without IMT-2000 Interference

Aircraft Altitude	9000 m	9000 m
Distance from Ground Transmitter	78 km	35 km
Range Between A/C and Ground Transmitter	78.52 km	36.14 km
Ground Transmitter Power	7 dBW	7 dBW
Transmit Antenna Gain	0 dBi	0 dBi
Transmitter System Losses	2 dB	2 dB
Transmitter Data Rate (198.4 kb/s)	53.0 dB/Hz	53.0 dB/Hz
Transmit E_b	-48 dBW	-48 dBW
Free Space Path Loss (1800 MHz)	135.4 dB	128.7 dB
Airborne Receiver Antenna Gain	0 dBi	0 dBi
Rx Noise (3 dB NF)	-201 dBW/Hz	-201 dBW/Hz
E_b/N_o	17.6 dB	24.3 dB
Criterion (E_b/N_o for BER = 10^{-5})	13.35 dB	13.35 dB
Margin (No Interference)	4.2 dB	10.9 dB
I_o	-158 dBW/Hz	-158 dBW/Hz
$E_b/(N_o + I_o)$	-25.4 dB	-18.7 dB
Degraded Below Criterion	38.8 dB	32.1 dB
I_o	-168 dBW/Hz	-168 dBW/Hz
$E_b/(N_o + I_o)$	-15.4 dB	-8.7 dB
Degraded Below Criterion	28.8 dB	22.1 dB
I_o	-178 dBW/Hz	-178 dBW/Hz
$E_b/(N_o + I_o)$	-5.4 dB	1.3 dB
Degraded Below Criterion	18.8 dB	12.1 dB
I_o	-188 dBW/Hz	-188 dBW/Hz
$E_b/(N_o + I_o)$	4.6 dB	11.3
Degraded Below Criterion	8.8 dB	2.1 dB

D.4.1.2 Interference from IMT-2000 into TACTS/ACMI Ground-Based Receivers

To analyze interference from IMT-2000 into TACTS/ACMI ground-based receivers, the required separation distance to preclude interference into a ground receiver from a single IMT-2000 base and mobile transmitter was calculated. The IMT-2000 parameters used in the calculations are given in Tables A-4 and A-5. The TACTS/ACMI ground receiver and antenna parameters are given in Tables D-1, D-2, and D-3.

As was assumed in Reference 6, TACTS/ACMI operations are link-margin limited. The volume of space usable for flight training is determined by the available link margin. It was assumed that the maximum range between ground-based and airborne equipment, which determines the maximum aircraft-to-aircraft separation, cannot be reduced by more than ten percent due to interference from IMT-2000 systems. This condition equates to an allowed degradation in the TACTS/ACMI link margin of approximately 1 dB and an I/N of –6 dB. It is noted, as in Reference 6, that the full amount of interference degradation is made available to IMT-2000, rather than only ten percent of the total interference budget, as is often considered reasonable.

Interference between ground-based transmitters and receivers was calculated using Equation D-2:

$$I = P_T + G_T + G_R - L_P - L_S - L_{SP} - FDR \qquad \text{(D-2)}$$

where

I	=	interference power in receiver, in dBm
P_T	=	transmitter power, in dBm
G_T	=	transmitter antenna gain in direction of receiver, in dBi
G_R	=	receiver antenna gain in direction of transmitter, in dBi
L_P	=	propagation loss, in dB
L_S	=	system losses, in dB
L_{SP}	=	processing loss of interference in a spread spectrum receiver, in dB
FDR	=	frequency-dependent rejection, in dB.

The interference power I was set to a maximum allowable value, the interference threshold I_t, which is set for the TACTS/ACMI receivers at 6 dB below the receiver noise level, and Equation D-2 was rearranged to form Equation D-3:

$$L_P = P_T + G_T + G_R - L_S - L_{SP} - FDR - I_t \qquad \text{(D-3)}$$

where quantities are as previously defined.

The factor L_{SP}, for a direct-sequence spread spectrum receiver such as those used for CDMA versions of the IMT-2000, is given by Equation D-4:

$$L_{SP} = 10 \log (R_c/R_d) \qquad \text{(D-4)}$$

where:

R_c	=	chip rate of receiver, chips/s
R_d	=	data rate of system, bits/s.

Frequency-dependent rejection (FDR) for the ontune cases considered here is given by Equation D-5:

$$FDR = 10 \log (B_t/B_r) \quad \text{for } B_t > B_r$$
$$0 \quad \text{for } B_t \leq B_r \qquad \text{(D-5)}$$

where:

B_t = transmitter 3-dB emission bandwidth, in Hertz

B_r = receiver bandwidth, in Hertz.

The receiver bandwidth for use in Equation D-5 was assumed equal to the chip rate, for code division multiple access (CDMA) IMT-2000 receivers and other direct-sequence spread-spectrum receivers. For time division multiple access (TDMA) receivers, the receiver bandwidth and bit rate were assumed equal for this analysis, at 30 kHz for the IS-136 and 176 kHz for the Groupe Speciale Mobile (GSM) system, and the L_{SP} term is not applicable.

The required separation distance to preclude interference was calculated using the required propagation loss from Equation D-3 and the JSC Inverse Smooth Earth Model. Antenna heights used were 40 m and 1.5 m for the IMT-2000 base station and mobile transmitters respectively, and 30 m for the TACTS/ACMI receivers. The required separation distances are given in Table D-12. The distances shown are the maximum for all versions of the IMT-2000 listed in Tables A-4 and A-5. For one case, the wideband CDMA, a FDR of 3 dB would lower the separation distances slightly. For the other three IMT-2000 versions, the FDR is 0 dB. TACTS/ACMI antenna gain values of 26 dBi and 0 dBi were used. The 26 dBi gain represents either the master or the remote station in a ground-to-ground interaction. The 0-dBi gain represents the remote station used as a TIS uplink. It is expected that the 3-dBi gain shown in Table D-3 would be reduced by 3 dB for polarization differences between the right-hand circular polarization of the TACTS/ACMI antenna and the linear polarization of the interfering signal.

Table D-12. Distances, in km, from IMT-2000 Transmitters to Preclude Interference to TACTS/ACMI Ground-Based Receivers

TACTS/ACMI Antenna Gain (dBi)	IMT-2000 Station	
	Mobile	Base
0	20.0	70.1
26	38.9	146.1

D.4.1.3 Interference from TACTS/ACMI Ground-Based Transmitters into IMT-2000 System

Separation distances to be maintained by IMT-2000 receivers from TACTS/ACMI ground transmitters to preclude interference were calculated using the path loss from Equation D-3 and the inverse SEM propagation model. Parameters for the IMT-2000 receivers are taken from Tables A-4 and A-5 and parameters for the TACTS/ACMI transmitters and antennas were taken from Tables D-1 and D-3. For the IMT-2000 receiver interference criteria, the two values in Tables A-4 and A-5 were used, plus an additional, higher value, corresponding to the desired signal 20 dB above the receiver sensitivity level. It was felt that the two higher thresholds used would represent a range of realistic received signal levels. Separation distances for each interference threshold and TACTS/ACMI transmitter-antenna combination are given in Table D-13. For the highest interference threshold, only one value, the worst-case, was calculated. Distances for the other IMT-2000 versions are expected to be slightly less, as was the case for the lower thresholds.

For the narrowband TACTS/ACMI signals, the Master Station (MS) and TIS ground-to-ground links, the separation distances for the CDMA WB and NB IMT-2000 implementations are slightly smaller than for the TDMA implementation. This is because the CDMA implementations offer some processing loss to the narrowband TACTS/ACMI signal, due to the correlation of the desired signal and subsequent narrowband filtering in the receiver. The separation distances for both TDMA implementations were practically identical.

Table D-13. Distances, in km, from TACTS/ACMI Ground-Based Transmitters to Preclude Interference to IMT-2000 Receivers

TACTS/ACMI Antenna Gain and Tx Power	IMT-2000 Station					
	Mobile			Base		
	CDMA WB	CDMA NB	TDMA	CDMA WB	CDMA NB	TDMA
IMT-2000 Interference Criterion I/N = -6 dB						
MS 26 dBi/20 W	46	48.4	50.7	132.1	157.9	180.3
TIS 26 dBi/1 W	38.5	41.3	43.2	85.1	98.4	110
G/A 0 dBi/5 W	25.2	25.9	26	63.2	63.9	64
IMT-2000 Interference Criterion for S = Sensitivity + 10 dB						
MS 26 dBi/20 W	36.9	39.8	41.8	80	90.8	101
TIS 26 dBi/1 W	27.9	31.4	33.7	66	69.7	72.5
G/A 0 dBi/5 W	11.9	12.7	12.8	49.2	50.1	50.2
IMT-2000 Interference Criterion for S = Sensitivity + 20 dB						
MS 26 dBi/20 W			35.3			74.6
TIS 26 dBi/1 W			26.0			64.3
G/A 0 dBi/5 W			5.7			39.1

D.4.1.4 Interference from TACTS/ACMI Airborne Transmitters into IMT-2000 System

The required separation distances between an airborne TACTS/ACMI transmitter (at 9000 m altitude) and IMT-2000 base and mobile stations were calculated in a manner similar to those for the ground-based ACTS transmitters. For each value of required path loss, the JSC inverse smooth-earth propagation model was used to calculate the required separation distance. For the IMT-2000 base stations, a 2.5-degree downtilt angle was assumed and a maximum antenna gain, at the horizon or above, of 5 dBi was used in the analysis. Results of the calculations are shown in Table D-14. Because of the relatively wide bandwidth of the AIS downlink signal, little processing gain is realized by the CDMA implementations, and the separation distances for the three versions are not significantly different. The required separation distances for the base stations approach LOS for the lowest interference threshold, and they are in the neighborhood of 180 km for the middle interference threshold. These distances could significantly reduce the area of IMT-2000 usage near TACTS/ACMI training ranges.

Table D-14. Required Separation Distances, in km, to Preclude Interference from TACTS/ACMI Airborne Transmitters into IMT-2000 Receivers

IMT-2000 Station					
Mobile			Base		
CDMA WB	CDMA NB	TDMA	CDMA WB	CDMA NB	TDMA
IMT-2000 Interference Criterion I/N = -6 dB					
318.9	320.1	322.7	404.4	405.4	405.5
IMT-2000 Interference Criterion for S = Sensitivity + 10 dB					
57.1	63.5	64.3	162.8	180.6	182.7
IMT-2000 Interference Criterion for S = Sensitivity + 20 dB					
14.7	16.9	17.1	47.8	53.2	53.9

D.4.2 JTCTS Technical Assessment

D.4.2.1 Interference from IMT-2000 into JTCTS Airborne Receivers

The JTCTS data link signal structure is 16-ary, orthogonal signaling, with 0.351, 0.703, and 1.406 Mb/s data rates combined with either 5.63 or 22.5 Mc/s pseudorandom spreading codes. Symbol rates are 89.9, 175.8, and 351.5 kb/s. The required E_s/N_o, including Reed-Solomon forward error-correcting code gain, is 11.0 dB.

Table D-15 contains the calculations of the JTCTS link margins for the aircraft altitude of 9000 m (approximately 30,000 feet), and two separation distances, in the absence of interference. The first separation distance, 78 km, is the same as used in the TACTS/ACMI analysis. The second distance, 150 nmi (277.8 km) represents the specified maximum separation distance for the JTCTS air-to-air link

(Reference 12), which is its primary communications link. In the absence of interference, link margins vary, depending on the symbol rate, from 16 to 22 dB for the 78-km distance, and from 5 to 11 dB for the 278-km distance.

It was assumed that the JTCTS was subjected to the same aggregate IMT-2000 interference levels as those calculated earlier for the TACTS/ACMI systems. Table D-16 shows the received $Es/(N_o + I_o)$ and resulting link margins in the presence of the aggregate IMT-2000 RF environment. With I_o = -168 dBW/Hz, negative link margins of from –10 to –16 dB result, depending on the data rate, for the 78 km distance. For the 150 nmi (278 km) separation, the link margins are 11 dB less, from –21 to –27 dB. For a 10-dB lower aggregate interference level, expected to occur before a mature usage rate is developed, negative link margins exist for all but the lowest symbol rate (87.9 ksps) at the 78 km separation, and at all symbol rates at the 278 km separation.

Comparison of the results for the JTCTS and TACTS/ACMI systems show that the JTCTS link margins are somewhat higher in the presence of interference, than are those of the TACTS/ACMI. However, the effect is still such that, even with an incomplete buildup of the IMT-2000 environment, operation of the systems at typical training ranges will be degraded.

Table D-15. JTCTS Airborne Receiver Link Margins Without IMT-2000 Interference

Aircraft Altitude	9000 m	9000 m
Distance from Tx	78 km	277.8 km (150 nmi)
Transmitter Power	18.3 dBW	18.3 dBW
Transmit Antenna Gain	2 dBi	2 dBi
Tx System Losses	2 dB	2 dB
Transmit Symbol Rate		
87.9 ksps	49.5 dBHz	49.5 dBHz
175.8 ksps	52.5 dBHz	52.5 dBHz
351.6 ksps	55.5 dBHz	55.5 dBHz
Transmit Energy per Symbol		
87.9 ksps	-31.2 dBW	-31.2 dBW
175.8 ksps	-34.2 dBW	-34.2 dBW
351.6 ksps	-37.2 dBW	-37.2 dBW
Free Space Path Loss (1800 MHz)	135.4 dB	146.4 dB
Airborne Receiver Antenna Gain	2 dBi	2 dBi
Received E_s		
87.9 ksps	-164.6 dBW	-175.6 dBW
175.8 ksps	-167.6 dBW	-178.6 dBW
351.6 ksps	-170.6 dBW	-181.6 dBW
Rx N_o (4.5 dB NF)	-199.5 dBW/Hz	-199.5 dBW/Hz
E_s/N_o		
87.9 ksps	34.9	23.9
175.8 ksps	31.9	20.0
351.6 ksps	28.9	17.9
Implementation Losses	2.0 dB	2.0 dB
Required E_s/N_o	11.0 dB	11.0 dB
Margin		
87.9 ksps	21.9 dB	10.9 dB
175.8 ksps	18.9 dB	7.9 dB
351.6 ksps	15.9 dB	4.9 dB

Table D-16. JTCTS Airborne Receiver Link Margins and Degradation Due to IMT-2000

Aircraft Altitude	9000 m	9000 m
Distance from Transmitter	78 km	277.8 km
Received E_s/N_o		
87.9 ksps	-164.6 dB	-175.6 dB
175.8 ksps	-167.6 dB	-178.6 dB
351.6 ksps	-170.6 dB	-181.6 dB
I_o	-158 dBW/Hz	-158 dBW/Hz
$E_s/(N_o + I_o)$		
87.9 ksps	-6.6 dB	-17.6 dB
175.8 ksps	-9.6 dB	-20.6 dB
351.6 ksps	-12.6 dB	-23.6 dB
Margin		
87.9 ksps	-19.6 dB	-30.6 dB
175.8 ksps	-22.6 dB	-33.6 dB
351.6 ksps	-25.6 dB	-36.6 dB
I_o	-168 dBW/Hz	-168 dBW/Hz
$E_s/(N_o + I_o)$		
87.9 ksps	3.4 dB	-7.6 dB
175.8 ksps	0.4 dB	-10.6 dB
351.6 ksps	-2.6 dB	-13.6 dB
Margin		
87.9 ksps	-9.6 dB	-20.6 dB
175.8 ksps	-12.6 dB	-23.6 dB
351.6 ksps	-15.6 dB	-26.6 dB
I_o	-178 dBW/Hz	-178 dBW/Hz
$E_s/(N_o + I_o)$		
87.9 ksps	13.4 dB	2.4 dB
175.8 ksps	10.4 dB	-0.6 dB
351.6 ksps	7.4 dB	-3.6 dB
Margin		
87.9 ksps	0.4 dB	-10.6 dB
175.8 ksps	-2.6 dB	-13.6 dB
351.6 ksps	-5.6 dB	-16.6 dB
I_o	-188 dBW/Hz	-188 dBW/Hz
$E_s/(N_o + I_o)$		
87.9 ksps	23.4 dB	12.4 dB
175.8 ksps	20.4 dB	9.4 dB
351.6 ksps	17.4 dB	6.4 dB
Margin		
87.9 ksps	10.4 dB	-0.6dB
175.8 ksps	7.4 dB	-3.6 dB
351.6 ksps	4.4 dB	-6.6 dB

D.4.2.2 Interference from IMT-2000 into JTCTS Ground-Based Receivers

As was done for the TACTS/ACMI, it was assumed for the JTCTS that the maximum range between ground and air stations (which in turn determines the maximum aircraft-to-aircraft separation) cannot be reduced by more than about 10 percent due to interference from IMT-2000 systems. This condition equates to an allowed degradation in the JTCTS link margin of approximately 1 dB and an interference-to-noise power ratio criterion of –6 dB. It again is noted that the full amount of interference degradation is made available to IMT-2000, rather than apportioning only 10 percent of the total interference budget to this system, as is sometimes considered reasonable. Although a high (26 dBi) antenna gain was not given in the JTCTS system description, it was assumed that an antenna of this type could be used in a tertiary, or ground-to-ground, link.

All IMT-2000 transmitters considered were narrower in bandwidth than the narrower-bandwidth JTCTS chip rate. A processing loss equal to the ratio of the chip rate to the data rate was applied to the interfering signal level, as described earlier. For each chip rate, the separation was the same for each data rate considered. This is due to the processing loss compensating for the change in noise level. The processing loss is proportional to the data rate, while the noise power, and hence the interference threshold, is inversely proportional to the data rate. See Table D-17.

Table D-17. Separation Distances, in km, from JTCTS Ground Receivers to Preclude Interference from IMT-2000 Transmitters

JTCTS Antenna Gain, (dBi)	JTCTS Receiver Chip Rate (MChips/s)	Data Rate, Mb/s	IMT-2000 Station	
			Mobile	Base
0	5.63	0.3516	13.0	65.4
		1.406	13.0	65.4
	22.5	0.3516	8.1	58.7
		1.406	8.1	58.7
26	5.63	0.3516	33.8	117.3
		1.406	33.8	117.3
	22.5	0.3516	29.6	89.5
		1.406	29.6	89.5

D.4.2.3 Interference from JTCTS Ground-Based Transmitters into IMT-2000 System

Separation distances which may need to be maintained by IMT-2000 receivers to preclude interference from JTCTS ground transmitters were calculated in a manner similar to those corresponding distances for the TACTS/ACMI ground transmitters. The JSC inverse SEM propagation model was used, with the JTCTS characteristics of Tables D-5 and D-7 and the IMT-2000 characteristics of Tables A-4 and

A-5. Separation distances were calculated for both the narrowband and wideband JTCTS signal, and each of the four IMT-2000 variations considered, for both mobile and base stations. Results are given in Tables D-18 and D-19. In Table D-18, the separation distances for each version of the IMT-2000, against the wideband JTCTS signal, were the same. In Table D-19, the wideband CDMA version gave slightly more processing loss to the narrowband JTCTS signal, resulting in slightly smaller separation distances, when compared to the other versions, whose separation distances were identical.

Table D-18. Distances, in km, from JTCTS Wideband Ground-Based Transmitters to Preclude Interference to IMT-2000 Receivers

JTCTS Antenna Gain (dBi)	IMT-2000 Station	
	Mobile	Base
IMT-2000 Interference Criterion I/N = -6 dB		
0	32.1	71.3
12	40.3	93.4
26	48.1	154.2
IMT-2000 Interference Criterion for S = Sensitivity + 10 dB		
0	20.8	58.6
12	30.2	68.5
26	39.5	89.2
IMT-2000 Interference Criterion for S = Sensitivity + 20 dB		
0	11.7	48.9
12	22.1	60.0
26	32.8	71.4

Table D-19. Distances, in km, from JTCTS Narrowband Ground-Based Transmitters to Preclude Interference to IMT-2000 Receivers

JTCTS Antenna Gain (dBi)	IMT-2000 Station			
	Mobile		Base	
	WB CDMA	Others	WB CDMA	Others
IMT-2000 Interference Criterion I/N = -6 dB				
0	33.5	35.2	72.3	74.4
12	41.1	42.5	97.1	105.7
26	48.7	50.6	161.7	178.8
IMT-2000 Interference Criterion for S = Sensitivity + 10 dB				
0	21.8	23.9	59.6	61.8
12	31.1	32.8	69.4	71.5
26	40.2	41.7	92.5	100.4
IMT-2000 Interference Criterion for S = Sensitivity + 20 dB				
0	12.6	14.8	50.0	52.4
12	23.1	25.1	60.9	63.0
26	33.5	35.2	72.3	74.4

D.4.2.4 Interference from JTCTS Airborne Transmitters into IMT-2000 System

The interference from airborne JTCTS transmitters into IMT-2000 receivers was calculated using the same approach and path loss model as was done in a preceding section for the TACTS/ACMI system. As in the preceding section, results are given for both narrowband and wideband JTCTS waveforms. Results are given in Tables D-20 and D-21. Again, for the wideband JTCTS waveform, distances are equal for all IMT-2000 versions, while for the narrowband JTCTS waveform, the wideband CDMA IMT-2000 implementation results in a slightly lower separation distance.

Tables D-20 and D-21 show that the required separation distances are quite high (100 to 400 km), even for the higher interference thresholds. They are higher than those shown for the TACTS/ACMI transmitters, primarily because of the higher EIRP of the JTCTS equipment. Depending on the interference criterion used, coordination to line of sight distances may be necessary to avoid interference from the airborne system to the IMT-2000 receivers.

Table D-20. Required Separation Distances, in km, to Preclude Interference from JTCTS Wideband Airborne Transmitters into IMT-2000 Receivers

IMT-2000 Station					
Mobile			Base		
CDMA WB	CDMA NB	TDMA	CDMA WB	CDMA NB	TDMA
IMT-2000 Interference Criterion I/N = -6 dB					
343.6	343.6	343.6	415.9	415.9	415.9
IMT-2000 Interference Criterion for S = Sensitivity + 10 dB					
187.0	187.0	187.0	399.7	399.7	399.7
IMT-2000 Interference Criterion for S = Sensitivity + 20 dB					
55.2	55.2	55.2	157.3	157.3	157.3

Table D-21. Required Separation Distances, in km, to Preclude Interference from JTCTS Narrowband Airborne Transmitters into IMT-2000 Receivers

IMT-2000 Station					
Mobile			Base		
CDMA WB	CDMA NB	TDMA	CDMA WB	CDMA NB	TDMA
IMT-2000 Interference Criterion I/N = -6 dB					
346	351.4	351.4	417	420	420
IMT-2000 Interference Criterion for S = Sensitivity + 10 dB					
212	283.7	283.7	400	402	402
IMT-2000 Interference Criterion for S = Sensitivity + 20 dB					
62.8	84.1	84.1	179	238	238

D.4.3 Mitigation Techniques

Possible methods to mitigate interference between IMT-2000 and ACTS equipment include the following. These techniques were generally found to be not practical or operationally unacceptable.

- Coordination of antenna orientation of IMT-2000 base stations with the location of the training ranges. The mainbeams of the IMT-2000 antennas should not point in the direction of training range ground stations or of major flight activity, and the IMT-2000 base stations should not be illuminated by the mainbeams of high-gain ACTS ground station antennas.
- Coordination of training range aircraft training schedules with IMT-2000 operations, such that IMT-2000 power levels, frequencies, or antenna orientations could be adjusted to avoid mutual interference.
- Use of polarization diversity between IMT-2000 base stations and ACTS equipment, to reduce interference levels for mainbeam-to-mainbeam interactions between IMT-2000 and ACTS equipment.

D.4.4 Results – Option 1

1. Because of the large separation distances needed to avoid interference from airborne ACTS transmitters to IMT-2000 receivers, and because of the effect of the aggregate IMT-2000 ground environment on the link margins of the airborne ACTS receivers, sharing of the two systems, without frequency separation, does not appear feasible.

2. Interference between airborne ACTS transmitters and IMT-2000 receivers and between the aggregate IMT-2000 environment and ACTS airborne receivers seem to be the worst, or most limiting, cases, for band sharing.

3. A 10 dB reduction of aggregate interference power, as might be associated with an incomplete buildup of a mature IMT-2000 environment, still results in negative link margins for TACTS/ACMI and JTCTS airborne receivers.

4. For ground-to-ground interactions, separation distances to avoid interference appear to be of the same order of magnitude for ACTS-to-IMT-2000 and IMT-2000-to-ACTS interactions. Effects on system operation depend on interference thresholds used and the location of the ACTS ground equipment.

D.4.5 Operational Impact

Full band sharing of the 1755-1850 MHz spectrum with ACTS and IMT-2000 is not considered to be a viable option. As reported in the DoD IMT-2000 Technical Working Group Interim Report, the results of the full band sharing electromagnetic compatibility (EMC) assessment indicates that significant undesired interactions may occur both to and from ACTS. Distance separations needed to preclude interference can be substantial, particularly in the case of airborne platforms. Overseas ACTS ranges experiencing undesired interactions from cellular phone communications confirm this assessment. Coordination and scheduling of shared spectrum between DoD training ranges and IMT-2000 is not possible due to mission classification, complex range operations, and allowing immediate support of unplanned training exercises. Also, training missions continue to require increased range airspace. Operational limitations and constraints cannot be placed on missions supporting warfighter training. Spectrum sharing would further negatively impact-training operations by restricting tethered RF connectivity & operations of ACTS pods with the range ground system infrastructure. It would also restrict available range airspace, which negatively affects training in the use of simulated munitions systems. It limits training mission scheduling and live monitoring capabilities. It would constrain ACTS interoperability and compatibility. Sharing would limit or preclude large-scale joint training exercises and limit migration to rangeless air-to-air operational training.

Under the program of record, JTCTS will not be deployed in CONUS by 2003. It is anticipated that under full band sharing in this time frame, all current TACTS/ACMI would be forced to cease operation. The absence of instrumentation to support live tactical training would result in direct loss of readiness for combat forces. The ability to observe, evaluate, and provide feedback for complex, multi-faceted training exercises would be virtually eliminated. Losing the instrumentation capabilities would remove the source of objective information. Lack of simulation capabilities would negate the ability to determine force attrition in real-time for realistic evaluation of tactics and tactical execution.

Under current plans the replacement of legacy TACTS/ACMI by JTCTS will not begin until post 2006 although fixed range development will be ongoing. In the 2006 time frame some data link modifications could be made, and if started soon enough, an acceleration of the program to replace the legacy TACTS/ACMI could make significant progress by 2006—but complete conversion of legacy systems by that time frame is not considered achievable. However, even with a conversion to JTCTS, there are no mitigation techniques that could be implemented in either JTCTS, legacy TACTS/ACMI, or IMT-2000 in the same geographic region.

D.5 OPTION 2 – BAND SEGMENTATION/PARTIAL BAND SHARING

The analysis described in the previous sections assumed no separation in frequency between the IMT-2000 and ACTS systems. If the present band is segmented, with separate but adjacent segments allocated separately to ACTS and IMT-2000 systems, the effect of frequency separation between the two systems becomes of importance.

Two proposed methods for operating within the 1755 to 1850 MHz band were examined briefly, and the feasibility of satisfactory operation of the ACTS and IMT-2000 equipment was assessed.

In the first plan (Option 2A), the 1755-1805 MHz portion of the band remains allocated to ACTS. The rest of the band is allocated to IMT-2000 systems. In the second plan (Option 2B), ACTS and IMT-2000 are allowed to operate in the present band. The ACTS systems operate as they presently do, and the IMT-2000 systems must operate in the 1755-1790 MHz portion of the band and coordinate in the areas where ACTS operates and where interference is a possibility. The 1790-1850 MHz portion of the band is retained for use by ACTS systems.

D.5.1 Option 2A – 1755-1805 MHz Retained

D.5.1.1 TACTS/ACMI Technical Assessment

Under plan 1 (Option 2A), the TACTS/ACMI would lose six of the 11 frequencies now available to it across the 1768 to 1840 MHz range. It would lose use of the 1840 MHz (A) or 1830 MHz (B) ground-to-air link transmit frequencies, and four of the six frequencies (1807, 1812, 1817, and 1822 MHz) used for transmitting from the remote ground transmitters to the master receiver. Typically, the TACTS/ACMI uses eight or more frequencies for its necessary functions. Loss of all but the 1755-1805 MHz portion of the band does not appear feasible for satisfactory operation of the present TACTS/ACMI system.

A short EMC analysis to determine the feasibility of modifying the TACTS/ACMI to operate in the 1755-1805 MHz band was performed. Minimum frequency and distance separations such that an interference threshold was not exceeded were calculated. The interference thresholds used were the same as those in the sharing analysis. The minimum frequency separation to avoid interference between adjacent ranges was calculated to be 5 MHz, for the AIS transmitter and TIS downlink receiver. It was also determined that a frequency separation of 4.8 MHz from the band edge is necessary to avoid interference from the AIS transmitter to IMT-2000 base station receivers at the band edge, with no distance constraints.

Frequency and distance separation constraints are expected to be similar between the AIS transmitter and remote ground receivers, as between the A/G downlink transmitter and G/A downlink receiver.

It is assumed that the master station transmitter frequency is 3 MHz from the band edge, and the "B" downlink frequency is 5 MHz removed from that. Further, the "A" uplink frequency is assumed to be 5 MHz removed from the upper band edge, with the remote transmitter frequencies at least 5 MHz from the uplink or downlink frequencies. With these assumptions, the frequency plan of Table D-22 is possible.

Table D-22. Possible TACTS/ACMI Frequency Plan for 1755-1805 MHz

Frequency, MHz	Link Description
1758	Master to Remotes
1763	AIS-to-Remote Downlink "B"
1768	AIS-to-Remote Downlink "A"
1773	Remote-to-Master 1
1778	Remote-to-Master 2
1783	Remote-to-Master 3
1788	Remote-to-Master 4
1795	Remote-to-AIS Uplink B
1800	Remote-to-AIS Uplink A

Using the arrangement of Table D-22, four remote G/G frequencies are available, compared to the six presently used. The possibility of compressing six G/G frequencies into the 27 MHz of available spectrum between the downlink "A" and uplink "B" frequencies was not analyzed. Also, a more detailed EMC analysis of the TACTS/ACMI components should be conducted. The frequency separation between collocated AIS transmitters and receivers is reduced from 52 MHz to 32 MHz. A 4 dB increase in transmitter-to-receiver isolation from that now employed, to compensate for decreased rejection due to offtuning, would be necessary.

Without modification of the TACTS/ACMI emission bandwidth or receiver selectivity characteristics, the electromagnetic interference (EMI) margin of the modified system will be reduced from that of the present system. A major modification of the TACTS/ACMI, such as using GPS for position determination, would allow the bandwidths of the air-to-ground (A/G) and ground-to-air (G/A) signals to be reduced from 3 MHz to a value closer to the present data rate, 198 kHz. Thereby, the amount of spectrum needed would be reduced further. Also, since multilateration is no longer needed, the number of ground-to-ground (G/G) frequencies would be reduced from the six presently used to one or two.

D.5.1.2 JTCTS Technical Assessment

The JTCTS normally uses one to three frequencies between 1710 and 1850 MHz. This range is further restricted to 1755-1850 MHz in the US and Possessions. One frequency is used for air-to-air communications, the primary link. A second frequency is often used for the secondary link, for ground-to-air communications. The third frequency is used for a tertiary data link for ground to ground communications. This link is not always used.

In conversations with JTCTS engineers at SRI International, it has been stated that it may be possible for the JTCTS to operate with two 22.5 MHz channels separated by 5 MHz at the –20 dB points of the spectrum. The total occupied bandwidth for the wideband mode would be approximately 22.5 x 2 + 5 = 50 MHz. The third frequency, for the tertiary link, could be reassigned to a different, probably a higher, band. It may be possible that the two channels can operate without mutual interference, as has been stated. However, the effect of JTCTS interactions with IMT-2000 equipment near the edges of the band must also be investigated. A preliminary assessment of the effects of frequency separation was made by generating frequency-distance curves for JTCTS-to-IMT-2000 and IMT-2000-to-JTCTS interactions. The curves generated are for wideband CDMA and wideband JTCTS versions. The middle CDMA interference threshold was used, corresponding to a desired signal 10 dB above sensitivity. These curves are given as Figures D-2 and D-3. Although conservative interference thresholds were used in generating these curves, they show that, at the band edges, 11.25 MHz from the JTCTS wideband center frequency, significant separation distances are needed to avoid interference. Further investigations of these interactions would be necessary to determine the feasibility of this band segmenting plan.

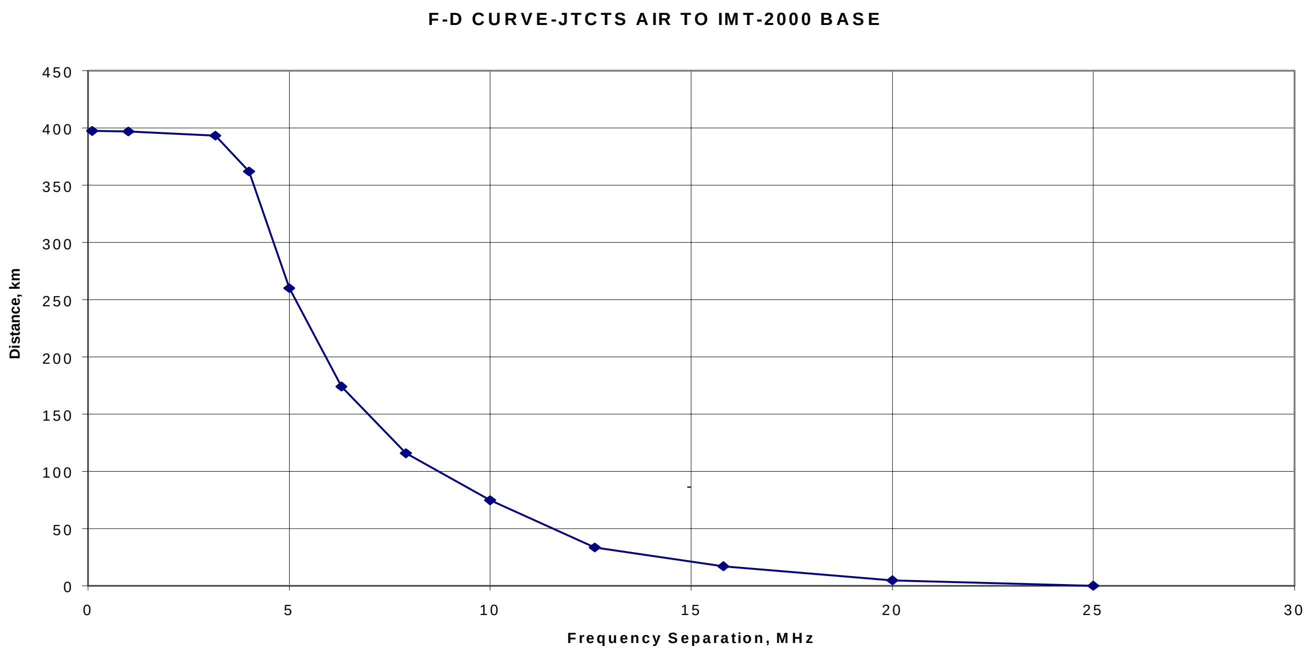

Figure D-2. Frequency-Distance Curve for JTCTS Airborne to IMT-2000 Interaction

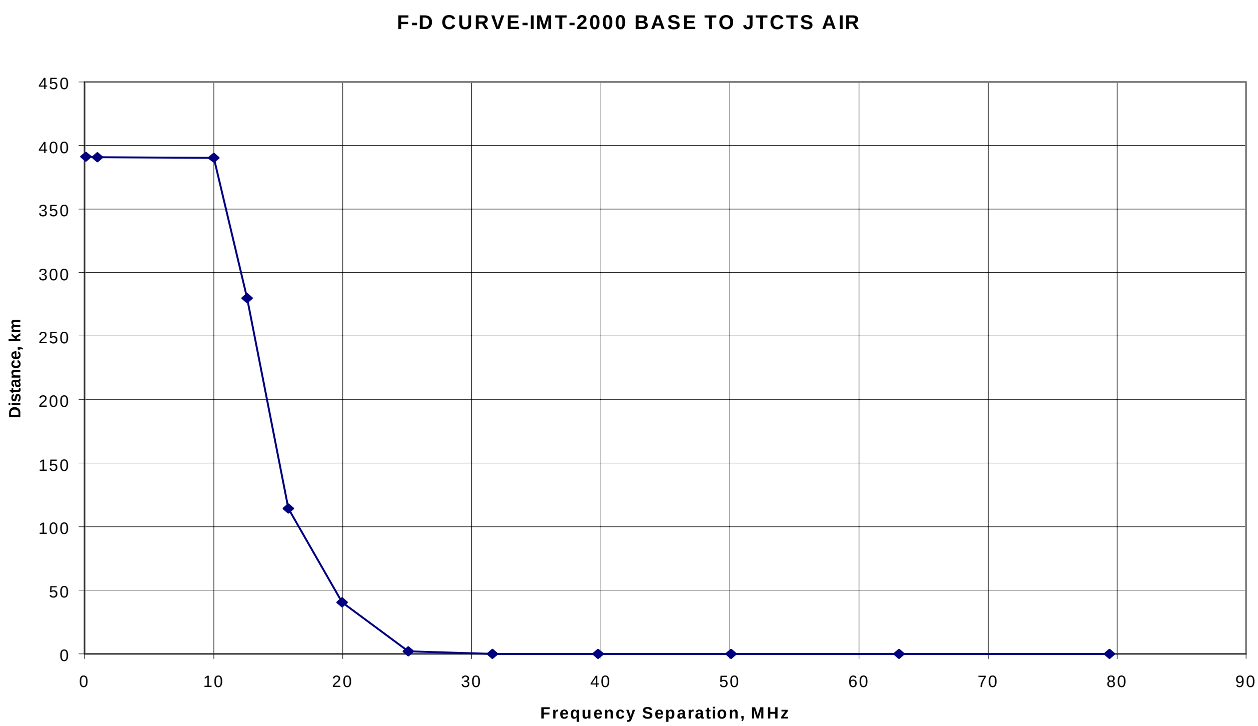

Figure D-3. Frequency-Distance Curve for IMT-2000 to JTCTS Airborne Interaction

D.5.1.3 Operational Impact

Interference with the ACTS data link will occur dependent on frequency, location, and transmitter power of future IMT-2000 equipment. The RF interference will adversely affect system operation. Interference with uplink frequencies (1830 and 1840 MHz) will render ACTS airborne instrumentation inoperative while interference with ACTS ground-to-ground RF links could vary with portions of the range becoming inoperative. Additionally, there is no current way to limit system operation to a portion of the band, therefore it must be assumed ACTS operation will adversely affect IMT-2000 systems. This would likely cause severe restrictions to TACTS/ACMI emissions thus significantly reducing system utility.

If the ACTS loses access to the 1805-1850 MHz band in 2006, the impacts would be similar to those described for 2003 unless modification to the existing frequency plan is pursued. A remanufacture of existing TACTS/ACMI hardware (updating for obsolescence and technology advances) could make operation of the legacy systems within a reduced bandwidth feasible. It is estimated the fielding of the proposed ACTS modifications could be accomplished for all ranges by 2006. However, operational training will be impacted because of range downtime during installation and checkout of the modifications. Each range will be completely down for at least 1-3 months with limited capability up to 6 months due to modification of range equipment. A moderate schedule risk is assessed in modifying all the ACTS ranges by 2006. For 2010, the assessment is the same as the assessment for provided 2006 except that risk is reduced based on additional time to deploy.

The operational impact can be minimized if no spectrum conflicts arise with other Government systems and all the mitigation efforts are completely implemented by 2006 (schedule risk) or if turnover of 1805-1850 MHz band can be delayed at sites where mitigation measures have not been completed by 2006.

The replacement of the legacy ACTS by JTCTS is scheduled to begin after 2006. The 2010 time frame may allow for an accelerated JTCTS program to provide replacement ACTS, provided actions are taken sufficiently early. A modification program for the legacy ACTS could also be completed by that time frame—but that would be moot if all systems have been replaced by JTCTS. Any loss of current system use or functionality would impact the training and readiness of the aircrews, with the impact directly related to the historical tactical training role/function of the system at a given site.

D.5.2 Option 2B – Phased Segmentation to 1790-1850 MHz Retained

D.5.2.1 TACTS/ACMI Technical Assessment

In Option 2B, which involves coordination within the same band, IMT-2000 systems would be forced to coordinate their operation in areas where present ACTS systems operate and interference is a possibility. In the first segment of the band to be made available, 1710 to 1755 MHz, no TACTS/ACMI frequencies exist, and JTCTS does not normally operate in this range in the US and Possessions. For the other segments (1755 to 1780 and 1780 to 1790 MHz), airborne and ground-based TACTS/ACMI frequencies are used. The results of the previous sharing analysis show that, for the airborne ACTS transmitters, coordination distances to avoid interference to an IMT-2000 receiver are sometimes at line-of-sight distances (400 km for 9000 m altitude). Distances needed to avoid interference from aggregate IMT-2000 environments to an airborne ACTS receiver are more difficult to calculate. However, with a single metropolitan area the size of Las Vegas, NV, and ignoring the effects of other cities, preliminary calculations indicate that separation distances of the same magnitude or larger may be needed.

The possibility of modifying the TACTS/ACMI such that all frequencies, A/G, G/A, and G/G, are within the 1790-1850 MHz band, and sharing is not necessary, was also considered. The analysis, results, and frequency plan described in Section 5.1.2.1 apply to this case also, with one exception. That is, the amount of spectrum available between the downlink "A" and uplink "B" frequencies, for remote (G/G) links, is increased from 27 to 37 MHz. Allowing 10 MHz for protection between G/G and A/G or G/A links, 27 MHz are left. This amount of spectrum allows for six G/G frequencies separated by 5 MHz, which is the present arrangement. The frequency separation between collocated AIS transmitters and receivers is reduced from 52 to 42 MHz. A 2 dB increase in transmitter-to-receiver isolation, to compensate for decreased rejection due to offtuning, would be necessary. As with the 1755-1805 MHz band the EMI margin would be reduced when compared to that of the present system, with the present emission bandwidth and receiver characteristics. Further modification of the TACTS/ACMI, to provide position determination by GPS, would reduce the bandwidth of the A/G and G/A emissions, and greatly reduce the number of G/G frequencies needed.

D.5.2.2 JTCTS Technical Assessment

Although JTCTS is capable of operating in the first part of the band to be shared in this option, 1710-1755 MHz, it does not normally operate in this segment in the US and Possessions. For the rest of the proposed shared band, 1755 to 1780 and 1780 to 1790 MHz, separation distances needed to avoid interference from the airborne JTCTS and IMT-2000 receivers, as well as from an aggregate environment of IMT-2000 transmitters to the JTCTS receiver, are estimated to approach line of sight magnitudes. Operation in the 1790-1850 MHz band, the part left unshared, would allow at most two of the three data links to operate compatibly.

D.5.2.3 Operational Impact

Under this option, if IMT 2000 build out is contained below 1755 MHz until perhaps the 2006 time frame, there would be little impact to DoD operations during that time as ACTS frequencies begin above 1755 MHz. As IMT 2000 equipment is deployed to use frequencies above 1755 MHz, impacts to TACTS/ACMI would occur. Under the program of record, the replacement of the legacy TACTS/ACMI by JTCTS will not yet have begun in 2006 although fixed range development will be ongoing. The 2006 time frame may allow for the replacement of legacy TACTS/ACMI only by a drastically accelerated JTCTS program, but the schedule realism for replacement of all legacy TACTS/ACMI by either the current JTCTS or a modified JTCTS in that time frame is questionable. If started soon enough, a simple modification program for the legacy TACTS/ACMI could allow it to keep operating in 1780-1850 MHz band. This would allow sufficient time (i.e., until 2010) for all legacy TACTS/ACMI to be replaced by JTCTS. The ground-to-ground microwave links can be relocated once suitable spectrum is identified. Operational impact is none if no spectrum conflicts arise with other Government systems and all the mitigation efforts are completely implemented by 2006 (schedule risk) or if turnover of 1755-1780 MHz band can be delayed at sites where mitigation measures have not been completed by 2006. Any loss of current system use or functionality would impact the training and readiness of the aircrews, with the impact directly related to the historical tactical training role/function of the system at a given site.

The replacement of the legacy ACTS by JTCTS is scheduled to begin after 2006. The 2010 time frame may allow for an accelerated JTCTS program to provide replacement of ACTS, provided actions are taken sufficiently early. A modification program for the legacy ACTS could also be completed by that time frame—but that would be moot if all systems have been replaced by JTCTS. Any loss of current system use or functionality would impact the training and readiness of the aircrews, with the impact directly related to the historical tactical training role/function of the system at a given site.

D.5.3 Results – Option 2

1. Of the band-segmenting plans proposed, plan 1 (Option 2A) involves use of only the 1755-1805 MHz portion of the band. Operation of the present TACTS/ACMI does not appear feasible with this plan. Operation of a modified TACTS/ACMI may be feasible, with a reduced number of G/A

link frequencies and/or reduced EMI margin. Further, modification of TACTS /ACMI to use GPS for position determination would greatly reduce the number of required G/G frequencies. Operation of the JTCTS may be possible with reassignment of one of the three channels. Interactions of JTCTS with IMT-2000 equipment in adjacent bands need to be investigated further before feasibility of this option can be demonstrated.

2. Segmentation plan 2 (Option 2B) involves coordination of IMT-2000 operations in regions where ACTS systems presently operate and interference is possible. For the portions of the band above 1755 MHz, preliminary analysis, as discussed in this report, indicates that, because of the use of airborne ACTS transmitters and receivers, coordination distances from flight areas may exceed 400 km, making partial band sharing with this plan difficult to implement. Operation of a TACTS/ACMI modified such that all frequencies are within the 1790-1850 MHz band may be feasible, with a somewhat reduced EMI margin, or with position determination using GPS.

3. Interference problems exist in implementing both segmenting Options 2A and 2B, with the present TACTS/ACMI. With Option 2A, operation of the present TACTS/ACMI is not feasible. With Option 2B, partial band sharing with the present TACTS/ACMI would lead to required separation distances approaching radio line-of-sight. Modifications of TACTS/ACMI may make operation in the restricted bands feasible, for both Options 2A and 2B. For both Options 2A and 2B, operation of JTCTS, with the tertiary data link assigned to a different band, may be feasible. However, further investigation is needed to verify this conclusion.

D.6 OPTION 3 – PARTIAL BAND SEGMENTATION/OTHER BAND COMBINATION

D.6.1 Technical Assessment

In the analysis described here, the effects of loss of part of the 1755-1850 MHz band are treated. Operation is permitted for ACTS in the 1755-1805 MHz (or 1790-1850 MHz) portion of the band, while the remainder of the band is reallocated to IMT-2000 use. The focus of this analysis was on the 1755-1805 MHz portion of the band. Both the 1755-1805 and 1790-1850 MHz portions of the band are in the frequency ranges of the TACTS/ACMI and JTCTS. Although the 1790-1850 MHz portion is 10 MHz larger than the 1755-1805 MHz portion considered, most of the conclusions should be generally applicable to both plans. The ground-to-air (G/A), air-to-ground (A/G), and air-to-air (A/A) links are assumed to remain in the 1755-1805 (or 1790-1850) MHz band, while the ground-to-ground (G/G) links of each system are moved in frequency to higher bands. The two bands considered for G/G fixed point-to-point communication are 4400-4940 MHz and 7250-8400 MHz. Feasibility, self-interference, and interference to and from incumbent systems in the band were considered.

D.6.1.1 TACTS/ACMI

D.6.1.1.1 SELF-COMPATIBILITY ANALYSIS

For each system, the reduced available bandwidth means not only that components of the system must be reassigned to another band, but also that the frequency separations between those components remaining in the band are reduced. In both the TACTS/ACMI and JTCTS systems at present, the A/G and G/A (or A/A) link frequencies are generally near the band edge, with G/G link frequencies in the gap between the two sets. Under the proposed partial segmenting plan, the frequency gap is removed and the A/G, G/A, and/or A/A links are much closer together. This situation increases the potential for interference, both within the collocated transceivers and between adjacent ranges.

The TACTS/ACMI A/G and G/A links presently use four frequencies in the 1755-1850 MHz range. The two uplink frequencies (1840 MHz and 1830 MHz) are called A and B frequencies, respectively, and are separated by 10 MHz to avoid mutual interference problems at adjoining training ranges. The two downlink frequencies, 1788 and 1778 MHz, are also A and B frequencies, and are separated for the same reason. The transmit and receive frequencies are separated by 52 MHz to allow for isolation between the collocated airborne or ground-based transmitter and receiver.

The feasibility of using a set of four frequencies with reduced separation to fit within the 1755-1805 MHz band was investigated. A frequency plan for the 50-MHz band segment was proposed for study. The G/A frequencies are 1763 MHz (B) and 1773 MHz (A) and the A/G frequencies are 1787 MHz (B) and 1797 MHz (A). The 10-MHz frequency separation between B and A frequencies is preserved, the separation between transmitter and receiver frequencies is reduced from 52 to 24 MHz, and the separation from band edges is reduced from 15 to 8 MHz.

Frequency Separations Needed for Adjacent Ranges. Calculations of necessary frequency and distance separation to avoid interference were made. For the AIS transmitter and TIS receiver, it was found that 5 MHz separation is needed between adjacent ranges, to avoid the necessity of a specified distance separation.

Frequency Separation or Isolation Needed for Simultaneous A/G and G/A Communication. For the collocated transmitter and receiver, airborne or ground-based, with the

52-MHz separation used at present, a rejection of 82.3 dB due to off-tuning was calculated. An additional 77.7 dB of isolation is needed to avoid interference. Reducing the frequency separation to 24 MHz leads to a 76 dB value of FDR, or a 84 dB loss needed from other isolation. This value is 6.3 dB more than that attained at present. If TACTS/ACMI were redesigned to use GPS for position determination, the bandwidths of the A/G and G/A signals could be reduced from 3 MHz to a value closer to that of the present data rate, 198 kHz, and further reduce the amount of spectrum needed in the reduced band.

Analysis of System EMI at Band Edges with IMT-2000 Equipment. For the TACTS/ACMI AIS transmitter, a frequency separation of 4.8 MHz from the band edge is necessary for no distance constraints to avoid interference to IMT-2000 base station receivers at the band edge. Again the IMT-2000 interference threshold assumes the desired signal is 10 dB above the sensitivity level. The frequency plan for the TACTS/ACMI in the 1755-1805 MHz band, postulated earlier, assumes an 8-MHz frequency separation from the edge of the band. Hence the interference is below the IMT-2000 threshold.

Analysis of EMC with Other Systems in the 1755-1850 MHz or 1790-1850 MHz Band. The 1755-1850 MHz band is currently shared by TACTS/ACMI with tactical radio relay links and missile video and control links. Reduction of the available spectrum from 95 MHz to 50 (or 60) MHz means, for the TACTS/ACMI systems, that the G/G links would migrate to other bands. The A/G, and G/A links, because one or both ends are on an aircraft at an altitude that may reach 30,000 feet or more, may cause or suffer interference out to distances approaching radio line of sight (390 km at 30,000 ft.). EMC of the TACTS/ACMI with itself is difficult to attain in this band, especially when adjacent ranges are considered. For the JTCTS, self-compatibility, when adjacent ranges are considered, has not been predicted to be attainable through frequency separation alone. For the TACTS/ACMI, although EMC with itself is predicted to be attainable, interference from or to other systems in this band, such as tactical radio and missile control links, would add to a compatibility situation that is marginal at best.

D.6.1.1.2 Issues of Moving Ground-to-Ground Links to Other Bands

Issues of moving G/G links to higher bands are similar for both TACTS/ACMI and JTCTS. The exception to this rule is that TACTS/ACMI uses a large number, up to 20 or more, of ground-to-ground links to provide position location by multilateration, while JTCTS uses only one ground-to-ground link to transmit data to the control station for monitoring or other purposes. The main part of the analysis will be included under the TACTS/ACMI section, with exceptions to the conclusions noted for JTCTS.

Issues associated with moving the ground-to-ground links of the TACTS/ACMI and JTCTS to other frequency bands include feasibility, e.g., propagation phenomena and hardware issues that may affect link redesign, and potential EMC problems with equipment presently in the band of concern. These issues were explored for the 4400-4940 MHz and 7250-8400 MHz bands.

Feasibility Assessment—Fade Margin and Link Length. An approximation of the relationship between link reliability, fade margin, link length, and frequency is given by Equation D-6:[18]

$$U_{ndp} = a\,b\,(2.5 \times 10^{-6})\,f\,D^{3}\,10^{-F/10} \qquad \text{(D-6)}$$

Where:

U_{ndp}	=	annual outage probability (1 - reliability)
a	=	terrain factor
b	=	climate factor
F	=	fade margin, to the "minimum acceptable" point, in dB
D	=	path length, in miles
f	=	frequency, in GHz

The product of a and b equals 0.25, for a normal or average path.

A previous Electromagnetic Compatibility Analysis Center (ECAC) report dealt with site selection of proposed ACMI facilities at Holloman AFB, NM.[19] The length of the master-to-remote paths varies from 8 to 50 km (5 to 31 mi). For a 50 km (31 mi) path, and a link reliability of 99.99 percent (U_{ndp} = 0.0001), use of Equation D-6 results in a 25.3 dB fade margin needed for 1.8 GHz. To preserve the same link reliability with the same fade margin at 4.4 GHz, the link length would have to be reduced from 50 km to 36.6 km (22.75 mi). To retain the same link length, and hence the same tower sites, the fade margin would have to be increased to 29 dB. As an example, increasing the fade margin could be accomplished by increasing the effective radiated power output by 3.7 dB, or more than doubling the power.

To operate in the 7.25-8.4 GHz band, use of Equation D-6 shows that a 50 km link would have to be reduced to 30.8 km (19.1 mi) to preserve a 99.99 percent link reliability with a 25.3 dB fade margin, as

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[18] GTE Lenkurt Incorporated, *Engineering Considerations for Microwave Communications Systems,* San Carlos, CA, 1975, pp. 59-60.

[19] John Covert, *ACMI Siting and EMC Study for Holloman Air Force Base,* ECAC-CR-79-007, Annapolis, MD: DoD ECAC, January 1979.

predicted to occur at 1.8 GHz. To retain the same link length, the fade margin would have to be increased from 25.3 dB to 31.7 dB. As an example, increasing the fade margin could be accomplished by increasing the effective radiated power, by about 6 dB, or a factor of x4.

Feasibility Assessment—Power, Noise Figure, and Antenna Gain Considerations. The TACTS/ACMI TIS remotes use transmitters with 1 to 5 watts (30-37 dBm) of power. Transmitter powers in this range appear to be readily available throughout the frequency ranges from 1 to 8 GHz.[20] If the link lengths were kept the same and the fade margin increased, say, to 29 dB as calculated above, this would be an increase of 4 dB. A total of 20 log (4800/1800) = 8.5 dB of additional path loss would be expected. The antenna gain for a parabolic antenna of a given size would increase by 8.5 dB also. Use of matching high-gain antennas on each end of the link could increase the total coupling gain by 8.5 dB, so the transmitter power would not need to be increased.

The TACTS/ACMI receivers at 1.8 GHz have noise figures in the order of 2-3 dB. While Reference 20 shows a number of available receivers with noise figures in that range at 2 GHz, they are much less common at higher frequencies. At 4 GHz, they range from 5 to 8 dB, and at 8 GHz, from 8 to 8.5 dB. More recent manufacturers' data, however, shows that low-noise amplifiers with noise figures less than 2 dB are readily available, at least in commercial versions, for frequencies at and above 10 GHz.[21]

To provide the increased fade margin needed, an increase of 6.4 dB in received power would be needed. At the higher frequency, an increase in 12.7 dB in antenna gain could be realized for a given antenna size. If matching antennas were used on each end of the link, the coupling loss would be decreased by this amount, making up for the necessary 6.4 dB increase in received power to attain the same link reliability. As was stated previously, amplifiers with noise figures less than or equal to the 2.3 dB known to be used by the TACTS/ACMI systems should be readily available.

Self-Interference Potential. Issues associated with interference between the ACTS links should be no different than for their present configuration. With the TACTS/ACMI, the problem at certain ranges, such as Fallon, which lists 23 links,[22] using six frequencies among them, is expected to be severe but apparently tractable. If more bandwidth is available, however, the resulting increase in frequency resources would lessen the problem. A proposed modification to TACTS/ACMI, to use GPS for

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[20] *MSN Microwave Radio System Matrix,* Microwave Systems News, June 1980, pp. 92-108.

[21] Manufacturers Data from JCA Technology and MITEQ, *Microwaves & RF,* September 2000.

[22] Mike Ryan, Mid-Atlantic Area Frequency Coordination Office, Naval Air Warfare Center Aircraft Division, facsimile to Bob Martin and Al Baker, JSC/IITRI, , Patuxent River, MD, October 2000.

position determination, would also reduce the number of links to one, eliminating the potential for self-interference.

Self-interference potential in the 7250-8400 MHz band should be similar to that described for the 4400-4940 MHz band. Because the band is larger (1150 MHz) than at 4400 MHz (540 MHz) more frequency resources may be available than at the lower band, as well as in the present 95-MHz band (1755-1850 MHz).

EMC with Incumbent Equipment—4400-4940 MHz. The AN/TRC-170 and AN/GRC-222 are tactical radios used in both line-of-sight (LOS) and troposcatter modes. They use high-gain antennas, and compatibility of the ACTS fixed G/G links with these systems should be attainable using a combination of frequency and distance separation and antenna pointing discrimination.

The Light Airborne Multipurpose System (LAMPS) is operated primarily in an ocean environment and is not expected to interact with G/G links at training ranges under most conditions. For CEC, band sharing is not possible between CEC and the relocated ground-to-ground links that support an air combat training system for sites where both systems operate simultaneously. Band segmentation would, among other things, preclude fully integrated training with an attendant and unacceptable reduction in readiness.

Other equipment in the 4400-4940 MHz range includes threat simulators, which are assigned frequencies in the 4900-4990 MHz range at the Naval Air Station (NAS) Oceana training range (Reference 22). In selecting operating frequencies for the ACTS G/G links, the part of this segment overlapping the 4400-4940 MHz frequency range would need to be avoided.

EMC with Incumbent Equipment—7250-8400 MHz. Equipment presently in this band includes point-to-point communications links, and earth-to-space and space-to-earth communications links. According to Reference 22, a number of frequency assignments associated with US Navy training ranges are in this band. These assignments include those for threat simulators at NAS Oceana (7800-8500 MHz) and MCAS Yuma (7950-8020 MHz). A number of microwave links are also operating at frequencies throughout the 7250-8400 MHz range. Frequency assignments for these links include five at Cherry Point, 15 at Camp Lejeune, and nine at Fallon. EMC with these existing threat simulators and any associated airborne jammers, as well as with the existing point-to-point links at the three bases mentioned would have to be considered. Since a number of bands appear to be used for these point-to-point links at different ranges, it may be feasible to reassign the existing point-to-point links to a band higher than 7250-8400 MHz, in order to effect common TACTS/ACMI or JTCTS frequencies.

D.6.1.2 JTCTS

D.6.1.2.1 Self-Compatibility Analysis

The present JTCTS, when the maximum number of frequencies are used, consists of three links, the primary channel, or air-to-air link, the secondary channel, or ground-to-air link, and the tertiary channel, or ground-to-ground link. Each channel can be tuned to a center frequency between 1710 MHz and 1850 MHz (in 5-MHz increments) (In the US and possessions, the frequency range of operation is 1755-1850 MHz.) However, an example of spectrum usage that has been proposed has the primary and secondary channels near each edge of the range, with the tertiary channel frequency between the other two (Reference 11). With a 50-MHz frequency range available, the tertiary channel will be reassigned to another band, and it has been proposed that the remaining channels will be assigned so that their -20 dB emission levels are at the band edges. For the JTCTS wideband mode, the -20 dB points are at 11.25 MHz from the center frequencies. Therefore, the center frequencies of the primary and secondary links will be separated by 27.5 MHz. The analysis in this section was conducted assuming the JTCTS wideband mode was used.

Provisions for Adjacent Ranges. Calculations were made of the distance separations necessary to avoid interference, for the JTCTS G/A transmitter to the JTCTS air-to-air receiver, with a 27.5 MHz separation between frequencies. The interference threshold used was an interference-to-noise ratio of -6 dB, which leads to a 10 percent decrease in maximum communications range. This frequency separation allows the transmitter spectrums for both transmitters to be 20 dB down at the edge of the 1755-1805-MHz band. With this frequency separation, 76 km distance separation is needed to avoid interference. The same distance separation applies to the cases of an airborne transmitter and a ground based receiver, and to an airborne transmitter to an airborne receiver. A frequency separation of 35 MHz is necessary to lower the distance to 20 km. The above distance assumed all transmitters used the high-power wideband mode of JTCTS. If the low-power mode is used, the separation distance at 27.5 MHz frequency separation is lowered to 25 km, and a 28.4 MHz frequency separation is needed at 20 km.

Several TACTS/ACMI ranges on the east coast are approximately 100 nmi (185 km) apart and use alternating A and B frequency sets.[23] At 185 km a 22.8 MHz frequency separation is necessary, to avoid interference between two JTCTS systems. While this separation would allow two air-to-air links in the same band, interference to the ground-to-air links of the adjacent range, if present, would occur.

[23] James C. Hodges, *Frequency Management and Avoidance of Mutual Interference Between the TACTS and ACMI Ranges in the Eastern United States,* SRI International, 12 December 1983.

Frequency separation between adjacent ranges is not practical if both primary (A/A) and secondary (G/A) links occupy the same band.

Two other ideas are being explored for using JTCTS at adjacent ranges.[24] They are: using different spreading codes that are nearly orthogonal to provide additional isolation, and using timing discrimination between adjacent ranges, where combined usage of the two ranges does not exceed the maximum capacity of the system.

If it is possible to control the relative timing of the transmitted signals, the coded signals can be made nearly orthogonal, the effect of the added signal will be minimal, and only the noise added by the channel will be significant.[25] It may be possible to control this relative timing in cases where two ranges have access to a common control center, as is the case for the present two-master-station Charleston TACTS range (Reference 23). However, most adjacent ranges do not at present operate with common control elements. If the timing between two adjacent ranges is not controlled, the interfering signal will appear to be noiselike. It will be equivalent to that analyzed in this study, and will be subject to the same frequency and distance constraints to avoid interference. The presence of dispersion due to multipath also degrades the orthogonality and increases the noise-like nature of the interfering signal.

The second technique mentioned requires timing discrimination at adjacent ranges and also assumes that the combined usage of the two ranges would not exceed the total capacity of the system (100 aircraft). For example, it is not envisioned that either the Yuma or Goldwater ranges would ever use more than 50 aircraft each during a training operation (Reference 24). The time-division multiple access scheme would provide enough time slots for aircraft in the two ranges. They could conceivably be run as one range (all on the same primary frequency) with a subset of data being routed to each. This technique would depend on the ability to coordinate the timing between the two ranges. A detailed examination of the feasibility of timing coordination was not conducted in this study.

Frequency Separation or Isolation Needed for Simultaneous A/A and G/A Communication. For the high-power transmitter situation, a 76-km separation in distance is needed to avoid interference at a 27.5 MHz frequency separation from the G/A transmitter to the A/A receiver, or from the A/A transmitter to a ground-based receiver. If operation in the low-power mode is used, as is presently being suggested for the secondary link (Reference 24), the necessary distance separation is

[24] David Hanz, SRI International, e-mail to Allan Baker, JSC/DWD, *Re: Additional Questions on JTCTS*, Menlo Park, CA, 6 December 2000.

[25] B. Paris, "Access Methods," Chapter 79 of J. Gibson, ed., *The Communications Handbook*, IEEE Press, 1999.

reduced to 25 km. The significance of this interference would depend on the period of time the secondary link is transmitting, and the airborne operations that are occurring during this time.

Analysis of System EMI at Band Edges with IMT-2000 Equipment. If the JTCTS signal is 11.25 MHz from the edge of the band, 42.4 km separation is needed from the IMT-2000 base station receivers at the band edge frequencies, to avoid interference. If no distance separation is observed, a frequency separation of 18.8 MHz is necessary. The interference threshold used assumed the desired signal was 10 dB above the sensitivity level. These distances may be significant, with training ranges near populated areas.

Analysis of EMC with Other Systems in the 1755-1850 MHz or 1790-1850 MHz Band. The 1755-1850 MHz band is currently shared by JTCTS with tactical radio relay links and missile video and control links. Reduction of the available spectrum from 95 MHz to 50 (or 60) MHz means, for the JTCTS systems, that the G/G, or tertiary, link would migrate to another band. The A/A and G/A links, because one or both ends are on an aircraft at an altitude that may reach 30,000 feet or more, may cause or suffer interference out to distances approaching radio line of sight (approximately 390 km at 30,000 ft.). EMC of the JTCTS with itself is difficult to attain in this band, especially when adjacent ranges are considered. For the JTCTS self-compatibility, when adjacent ranges are considered, has not been predicted to be attainable through frequency separation alone. If the interference margin is completely taken up by self-interference, addition of interference from other systems would lead to an incompatible situation..

D.6.1.2.2 Issues of Moving Ground-to-Ground Links to Other Bands

Feasibility Assessment—Fade Margin and Link Length. For the JTCTS, since position determination is done by the Global Positioning System (GPS) and not through multilateration, only one microwave link is needed for the tertiary link, to transmit data for monitoring purposes. The amount of equipment to be changed in frequency is therefore much less than for TACTS/ACMI. The power, antenna gain, and fade margin effects are expected to be the same. Modifications to TACTS/ACMI to use GPS for position determination have been suggested also. If such a modification were implemented, the number of microwave links needed for that system would also be decreased.

Feasibility Assessment—Power, Noise Figure, and Antenna Gain Considerations. The JTCTS receiver noise figure is 4.5 dB. Receivers with noise figures in this range in the 4 GHz band appear to be readily available.

Self-Interference Potential. With the JTCTS, if only one link is used, the potential for self-interference between ground-to-ground links should not exist.

EMC With Incumbent Equipment-4400-4940 MHz. For the JTCTS G/G link, the EMC situation with incumbent equipment in the 4400-4940 MHz band is similar to that with TACTS/ACMI, only with a single link instead of multiple links.

EMC With Incumbent Equipment-7250-8400 MHz. As was the case for the 4400-4940 MHz band, for the JTCTS G/G link, the EMC situation with incumbent equipment in the 7250-8400 MHz band is similar to that with TACTS/ACMI, only with a single link instead of multiple links.

D.6.1.3 Results – Option 3

1. It appears to be possible for the A/G and G/A links of TACTS/ACMI to operate in the 1755-1805 MHz (or 1790-1850 MHz) band compatibly, both within the same range and between adjacent ranges.
2. Operation of the A/A and G/A links of JTCTS within these restricted frequency bands may be feasible within the same training range, although some distance separation is necessary to avoid interference to IMT-2000 receivers at the band edges. Compatibility between adjacent ranges has not been demonstrated, and may not be attainable through frequency separation alone.
3. Because of the reduced spectrum available for all systems, and because the links remaining in the band have airborne transmitters and receivers, compatibility with equipment remaining in the band is expected to be made much more difficult to attain.
4. It appears to be feasible to move the G/G links of TACTS/ACMI and JTCTS to either the 4400-4940 MHz or 7250-8400 MHz band. Some equipment at training ranges is assigned frequencies in these ranges, including threat simulators and point-to-point microwave links. EMC problems with this equipment are expected to be tractable.
5. Redesigning the TACTS/ACMI to use GPS instead of multilateration for position determination would reduce the A/G and G/A signal bandwidths from 3 MHz to a value nearer the data rate (198 kHz) and make compatibility with itself and other systems easier to attain. It would also greatly reduce the number of G/G links to be redesigned to operate in another band.

D.6.2 Operational Impact

Interference with the ACTS data link will occur dependent on frequency, location, and transmitter power of future IMT-2000 equipment. The RF interference will adversely affect system operation. Interference with uplink and downlink frequencies will render ACTS airborne instrumentation inoperative while interference with ACTS ground-to-ground RF links could vary with portions of the range becoming inoperative. Additionally, there is no current way to limit system operation to a portion of the band, therefore it must be assumed ACTS operation will adversely affect IMT-2000 systems. This would likely cause severe restrictions to TACTS/ACMI emissions thus significantly reducing system utility.

If the ACTS loses access to parts of the 1755-1850 MHz band in 2006, the impacts would be similar to those described for 2003 unless modification to the existing frequency plan is pursued. A remanufacture of existing TACTS/ACMI hardware (updating for obsolescence and technology advances) could make operation of the legacy systems within a reduced bandwidth feasible. It is estimated the fielding of the proposed ACTS modifications could be accomplished for all ranges by 2006. However, operational training will be impacted because of range downtime during installation and checkout of the modifications. Each range will be completely down for at least 1-3 months with limited capability up to 6 months due to modification of range equipment. A moderate schedule risk is assessed in modifying all the ACTS ranges by 2006. For 2010, the assessment is the same as the assessment for provided 2006 except that risk is reduced based on additional time to deploy.

The operational impact can be minimized if no spectrum conflicts arise with other Government systems and all the mitigation efforts are completely implemented by 2006 (schedule risk) or if turnover of 1805-1850 MHz band can be delayed at sites where mitigation measures have not been completed by 2006. The operational impact may be further minimized if ground-to-ground links can be successfully relocated to other frequency bands. Compatibility with incumbent systems in the bands supporting relocation may be a major issue.

The replacement of the legacy ACTS by JTCTS is scheduled to begin after 2006. The 2010 time frame may allow for an accelerated JTCTS program to provide replacement ACTS, provided actions are taken sufficiently early. A modification program for the legacy ACTS could also be completed by that time frame—but that would be moot if all systems have been replaced by JTCTS. Any loss of current system use or functionality would impact the training and readiness of the aircrews, with the impact directly related to the historical tactical training role/function of the system at a given site.

D.7 OPTION 4 – VACATING THE 1755-1850 MHZ BAND

In Option 4, the 1755-1850 MHz band is unavailable, and all equipment must be redesigned to operate in other frequency bands that are allocated to their functions. For this option, both 2200-2290 MHz and 4400-4940 MHz were considered for moving the A/G, A/A, and G/A links. The two bands considered in Option 3, 4400-4940 MHz and 7250-8400 MHz, were again considered for the G/G links. Again, feasibility, self-interference, and interference to and from incumbent systems in the band were considered.

D.7.1 TACTS/ACMI Assessment

D.7.1.1 OPTION 4A – Move A/G and G/A Links to 2200-2290 MHz Band, and Move G/G Links to 4400-4940 or 7250-8400 MHz Band

With Option 4A, the entire 1755-1850 MHz band is no longer available for ACTS use. Instead of remaining in a reduced (50 MHz) portion of the present band, the A/G and G/A links of the TACTS/ACMI will be moved to a higher band. Two candidate bands were considered for this study. They are the 2200-2290 MHz and 4400-4940 MHz bands. For relocation of a system, especially one with airborne components, a number of issues must be addressed. The two primary categories of issues include the feasibility of redesigning equipment to perform its function in the new band, and potential EMC problems with equipment already using the band. The 2200-2290 MHz band was considered as a prime candidate for relocation. Because it is closest in frequency to the present band, it is expected to present a minimum number of redesign problems. However, it is already occupied by a number of systems considered to be of prime importance to the DoD and others. In addition, compatibility with other systems operating on board the platforms (aircraft or ship) where the system is installed, need to be investigated.

Systems presently residing in the 2200-2290 MHz band include Space-Ground Link Subsystem (SGLS) downlink receivers, missile telemetry links, threat simulators, and the NASA Goldstone Deep Space Network (DSN) and Space Tracking and Data Network (STDN) receivers located near one of the training ranges, at Fort Irwin, CA. At the Beaufort MCAS, eight microwave links are assigned frequencies from 2208 to 2285 MHz. On aircraft and ships, interference from the harmonics of collocated Joint Tactical Information Distribution System (JTIDS) and Tactical Air Navigation (TACAN) transmitters need to be considered. In addition, the effect of harmonics of the redesigned ACTS transmitter on collocated receivers needs to be assessed.

The effects of moving the G/G links to the 4400-4940 MHz or 7250-8400 MHz band has been treated in the previous section. For the 4400-4940 MHz band, an additional EMC issue has been created, because harmonics of transmitters in the 2200-2290 MHz band lie within this frequency range.

Feasibility Assessment. In the 2200-2290 MHz band, the free-space propagation loss is 1.9 dB higher than in the 1755-1850 MHz band. For G/A and A/G links, omnidirectional antennas are desirable, and no additional antenna gain can be achieved at the higher frequency, as may be the case with a dish antenna. Therefore, to maintain the same maximum communications range, the transmitter power needs to be raised by 1.9 dB. The TACTS/ACMI airborne transmitter power needs to be increased from 20 to about 30 watts. This power level is lower than the present JTCTS transmitter power of 67.6 watts, and therefore is considered to be feasible.

Self-Compatibility. In the analysis for the 1755-1850 MHz band, self-compatibility within this band segment was predicted for the TACTS/ACMI A/G and G/A links. Self-compatibility should still be attainable in a similar (50-MHz) portion of the 2200-2290 MHz band. For the case of interference to adjacent ranges, the additional transmitter power should be cancelled by the revised path loss.

EMC with Incumbent Equipment—SGLS Downlink Receivers. The Air Force Satellite Control Network (AFSCN) provides telemetry, tracking, commanding, control, and communications functions for manned and unmanned DoD and non-DoD satellite operations and other space vehicle missions. The terrestrial components of the AFSCN include operations control nodes, common-user control nodes, remote ground facilities, remote tracking stations, and automated remote tracking stations. One element of the AFSCN is the SGLS, which provides telemetry, tracking, and commanding (TT&C), as well as data and voice communications. The SGLS uplink operates between 1760-1845 MHz and the downlink operates between 2200-2290 MHz.

The SGLS downlink signal format can include any combination of ranging code and three subcarriers (carrier 1), telemetry (carrier 2), and wideband data (carrier 3). Selected downlink signal parameters relevant to this assessment are provided in Table D-23 below. Certain space vehicles may include a special S-band communications package that accommodates three carriers on a standard SGLS link. This is referred to as the M2P1 configuration and provides additional voice and data communications. For the terminals examined in this analysis, a review of the M2P1 characteristics shows the standard SGLS downlink to be more susceptible to interference than the M2P1 downlink. Consequently, the M2P1 receiver analysis is not presented here.

Table D-23. Nominal SGLS Downlink Signal Characteristics

Nominal SGLS Earth Station Parameter	Value
3 dB Bandwidth/Bit Rate	Carrier 1 1.024 MHz subcarrier PCM telemetry 7.8 bps -128 kbps 1.25 MHz subcarrier Voice 100 Hz - 3.5 kHz Analog data 100 Hz - 20 kHz 1.7 MHz subcarrier PCM/PAM telemetry 125 bps - 256 kbps PAM telemetry to 20 kHz 2.05 kHz Carrier 2 128 - 1024 kbps Carrier 3 0.2 - 10 MHz

AFSCN earth stations that receive the SGLS downlink signals are limited in number and are normally fixed facilities located at government controlled sites. A list of the fixed terminals is given in Appendix B. The fixed terminals generally include large, high gain, directional antennas. Within the control network there are smaller, transportable terminals that function as remote tracking stations and may be used for range operations and special events. These transportable terminals were the initial focus of this assessment as these terminals are the most likely to be near an uncontrolled environment, have lower link margins due to smaller antennas, and consequently may be more subject to interference.

The transportable terminals include the S-band transportable ground station (STGS), the transportable S-band terminal (TST), and the transportable space test and evaluation resource (TSTR). Of these terminals, the TST has the smallest antenna, the lower figure of merit, lowest link margin, and has the lowest interference thresholds. This analysis was performed on carrier 1 (Telemetry) and carrier 2 (1024 kbps) of the TST, using information on link margin and the resulting interference threshold taken from an earlier JSC analysis.[26] Other information was taken from the system frequency allocation application.[27] Separation distances for these terminals were expected to be representative. Relevant SGLS parameters for a number of TST functions are included in Table D-24 below.

[26] Lloyd Apirian, Ben Benedick, and Ray Dizon, *Siting Analysis Supporting Proposed AFSCN MCC Relocation to Kirtland AFB,* JSC-CR-95-015, Annapolis, MD: DoD JSC, May 1995.

[27] *Application for Equipment Frequency Allocation (DD Form 1494) for Space Ground Link Subsystem (SGLS),* J/F 12/1520/4, Washington, DC, 11 December 1967.

Table D-24. SGLS Link Budget Values

Item	TST Carrier 1			TST Carrier 2	
	Telemetry	Comm	Ranging	512 kb/s	1024 kb/s
Effective Received Power (dBm)	-110.6	-113.2	-108.1	-101.1	-101.1
Effective Noise Temperature (dBk)	22.9	22.9	22.9	22.9	22.9
N_0 (dBm/Hz)	-175.7	-175.7	-175.7	-175.7	-175.7
Bandwidth (dBHz)	45.0	43.0	60.0	57.1	60.1
E_b/N_0 (dB) C/N_0 (dB)	20.1	22.1	67.6	17.5	14.5
E_b/N_0 Required (dB) C/N_0 Required (dB)	9.6	-23.0	47	9.6	9.6
Link Margin (dB)	10.5	25.1	20.6	7.9	4.9
Required Margin (dB)	3.0	3.0	3.0	3.0	3.0
Excess Margin (dB)	7.5	22.0	17.6	4.9	1.9
N (dBm)	-130.7	-132.7	-115.7	-118.6	-115.6
I/N_{th} (dB)	6.7	8.5	17.5	3.2	-2.6
Interference threshold, I_{th}, dBm	-124.0	-110.7	-98.2	-115.4	-118.2

For the TACTS/ACMI A/G links, if no frequency coordination is assumed, a separation distance of 383 km is necessary to avoid interference to the TST downlink receiver using Carrier 1, and 392 km to avoid interference to the TST downlink receiver using Carrier 2. To avoid distance separation constraints, 5 MHz and 12 MHz separations are necessary from Carriers 1 and 2, respectively, for the situations analyzed. The SGLS downlink uses frequencies at 5 MHz intervals throughout the 2200-2290 MHz band (Reference 26).

EMC with Incumbent Equipment—Missile Telemetry Links. Various systems, such as the AN/DKT-XX series, the Aydin Vector T-series, etc. are used to telemeter the performance data of a missile weapon back to a monitoring station. A typical example is the T-802, used in the Advanced Medium Range Air-to-Air Missile (AMRAAM). This system has a transmitter with a nominal bandwidth of 2.4 MHz and an output power of about 4 watts. An omnidirectional antenna is normally used. The telemetry signals are received by range ground terminals, using receivers typified by the Defense Electronics TR-109. As these systems are generally one-way data links, there is no associated receiver on board the missile.

For telemetry use at missile test ranges, the band is divided into 89 one-MHz channels, from 2200.5 MHz to 2289.5 MHz. The missile telemetry systems are used principally on or near DoD training and weapons ranges. In some circumstances the missiles will be launched from one range and fly into an impact on another range.

At one of the major ACTS training ranges, Nellis AFB, NV, a number of frequencies throughout the 2200-2290 MHz range are assigned to specific telemetry transmitters. A large number of frequencies are assigned to the AN/DKT-37D. Information on this transmitter was obtained from the frequency allocation application[28] and frequency-distance separation criteria for avoidance of its interference to the TACTS/ACMI and JTCTS receivers were calculated. An similar analysis was performed of the effects of the TACTS/ACMI and JTCTS airborne transmitters on a typical ground-based telemetry receiver, the Microdyne Model 1100R. Information on this receiver was also taken from its frequency allocation application.[29] For each receiver, an interference threshold of 6 dB below the noise level was used.

For the TACTS/ACMI AIS transmitter interfering with the ground-based telemetry receiver, a 5 MHz frequency separation or a 392 km distance separation is needed to avoid exceeding the interference threshold. The AN/DKT-37D missile transmitter is relatively low power (2 W) and narrowband (0.5 MHz). Therefore the required separation distances and frequencies to avoid interference to the ACTS receivers are somewhat smaller compared to the ACTS-to-telemetry receiver distance. For the TACTS/ACMI AIS receiver, the minimum separation distance is 308 km, and the minimum frequency separation is 3 MHz.

Cosite Equipment at Subharmonics and Harmonics for the F/A-18 Aircraft. An assessment of the potential interference from equipment collocated with the ACTS on a typical aircraft, the F/A-18, was performed. The 2200-2290 MHz band contains second harmonics of Tactical Air Navigation/Distance Measuring Equipment (TACAN/DME) and Joint Tactical Information Distribution System (JTIDS) frequencies. Both of these equipments are located on the F/A-18 aircraft. The 2200-2290 MHz band is also a fourth subharmonic of the band occupied by the collocated AN/APN-202 beacon.

The JSC Aircraft inter-Antenna Propagation with Graphics (AAPG) computer program[30] was used to model the F/A-18 aircraft to determine the path loss between antennas on the aircraft structure. The

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[28] *Application for Equipment Frequency Allocation (DD Form 1494) for AN/DKT-37 Telemetry*, J/F 12/5971, Washington, DC, MCEB, 23 April 1985.

[29] *Application for Equipment Frequency Allocation (DD Form 1494) for Microdyne Corporation Model 1100R Receiver*, J/F 12/2702, Washington, DC, MCEB, 3 January 1969.

[30] W. Klocko, D. Katz, P. Hussar, and E. Smith-Rowland, *User Guide for AAPG 2000*, JSC-UM-98-094, Annapolis, MD: DoD JSC, March 1999.

amount of frequency-dependent rejection (FDR) was then calculated using Equation D-7, derived from Equation E-3 with L_s and $L_{SP} = 0$.

$$FDR = P_t + G_t + G_r - L_p - I_t \qquad \text{(D-7)}$$

where L_p is the path loss from AAPG 2000 and other quantities are as previously defined. An interference threshold 6 dB below receiver noise, which results in a loss of ten percent of communications range, was used for the ACTS systems. The value of FDR from Equation D-7, the transmitter emission spectrum, and the receiver selectivity characteristics were then input to the JSC Frequency-Dependent Rejection Calculation (FDRCAL) model to determine the amount of frequency separation necessary for the interference threshold I_t not to be exceeded.

Cosite Equipment—TACAN/DME. Use of the AAPG model resulted in a path loss of 39 dB between the TACTS fuselage-mounted antenna (on the nose wheel door) used for the internal TACTS and the lower TACAN/DME antenna, which is also used for JTIDS. Characteristics of the TACAN component of the AN/USQ-140 were used in the analysis.[31] For TACAN/DME interference to the TACTS, 63 MHz separation between the TACAN/DME harmonic and the TACTS frequency is needed for I_t not to be exceeded. For example, if the TACTS receiver operates on 2250 MHz, TACAN/DME interrogator frequencies between 1093 and 1156 MHz must be avoided. Any interrogation channels above 69 would cause the threshold to be exceeded. Channels 1-16 and 60-69, which are designated for use by the military services for tactical purposes, lie outside this range. Blanking of the TACTS receiver by the TACAN transmitter could also be investigated.

Cosite Equipment—JTIDS. To avoid JTIDS harmonic interference to TACTS, JTIDS harmonics must be separated by 31.6 MHz from the TACTS frequency. JTIDS transmitter characteristics were those of the AN/USQ-140(V) taken from the frequency allocation application (Reference 31). For example, for TACTS operation at 2250 MHz, JTIDS frequencies between 1109 and 1141 MHz need to be avoided. A loss of 10 of the 51 available JTIDS frequencies would occur. As with TACAN, blanking of the TACTS receiver when JTIDS transmits could be investigated.

Cosite Equipment—AN/APN-202. The AN/APN-202 may operate in the 8800-9500 MHz frequency range, although it often receives on 9310 MHz. A path loss of 48.5 dB was calculated using

[31] *Application for Frequency Allocation (DD Form 1494) for Joint Tactical Information Distribution System, Multi Functional Information Distribution System (JTIDS/MIDS),* J/F 12/4413/4 (Draft).

AAPG-2000. The resulting TACTS harmonic is calculated to be -87.5 dBm. This value is 22.5 dB below the AN/APN-202 sensitivity of -65 dBm, which was used as the interference threshold. Therefore, no interference problem is expected.

Other Collocated Systems. Other collocated systems that may be affected by the reassigned TACTS AIS transmitter include the AN/ALQ-165 jammer and the AN/ALR-067 countermeasures warning and control system (CWCS). Compatibility with these systems will be assessed in the classified supplement.

Goldstone Deep Space Network and GSTDN Receivers (Ft. Irwin only). The NASA Deep Space Network (DSN) receiver at Goldstone, CA is located within the boundaries of Fort Irwin. The Air Warrior/National Training Center Integration System (AW/NTC-IS) is also located there. One of the components of the AW/NTC-IS is an ACMI. If this ACMI is moved in frequency to the 2200-2290 MHz band, the DSN receivers will have to be protected.

The primary S-band frequency range used for Deep Space spacecraft communication at Goldstone is 2290-2300 MHz, adjacent to the proposed 2200-2290 MHz band. These frequencies must be protected during sensitive events. However, the receivers are capable of operating from 2200-2300 MHz,[32] and a number of authorized frequencies of low-earth-orbit (LEO) satellites are listed in the Goldstone Authorized Frequency Database.[33] These frequencies must also be protected.

An assessment of the effects of the ACMI remote and airborne systems on the Goldstone receiver was done in a manner similar to that done in an earlier analysis.[34] For the Goldstone receivers, an interference threshold of -192 dBm/Hz and an antenna gain of 32 dBi were used. For the ACMI AIS transmitter at a 9000 km altitude, 432 km of distance separation would be needed to avoid exceeding the interference threshold. At a point 60 dB down from the maximum peak of the emission spectrum, at ±6 MHz from the carrier frequency, the minimum separation distance would be 106 km. For the ACMI TIS remote G/A link transmitter, the corresponding separation distances are 93 km and 22 km for the on-tune and -60 dB points, respectively.

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[32] Goddard Space Flight Center, *Mission Requirements and Data Systems Support Forecast*, Document 501-803, Greenbelt Maryland, August 1996, p. 7-14.

[33] "NTIA S-Band Authorized Frequencies at Goldstone," [NTIA Web page], 19 May 1999 [cited 29 November 2000]. Available from http://gts.gdscc.nasa.gov/GFACSEC/GFACFreqs.htm; INTERNET.

[34] J. Colaw, V. Casto, and G. Goodwyn, *EMC Analysis of the ASET-IV Equipment at Ft. Irwin, Hohenfels, and Ft. Chaffee (U)*, ECAC-CR-91-037, Annapolis, MD: DoD ECAC, August 1991, (SECRET) (Declassify on: OADR).

Threat Simulators. A description of threat simulators operating in this band and EMC issues with a relocated TACTS/ACMI are included in the *classified* supplement to this report.

Other Incumbent Equipment. Other equipment operating in the 2200-2290 MHz band includes point-to-point microwave links at one of the training ranges, Beaufort MCAS. Of the six training ranges described in Reference 22, only one has microwave links in this band. If the TACTS/ACMI A/G and G/A links were to move to this band, compatibility with these links is expected to be an issue. It may be desirable to reassign the microwave link frequencies to a higher band.

EMC with Other Systems That May Migrate to This Band. Other systems considering migration to this band include weapons control data links. The ACTS coexisted with these systems in a similar sized piece of spectrum in the 1755-1800 MHz band. Only the A/A, A/G, and G/A links would move to the 2200-2290 MHz band, so the compatibility situation would be somewhat simpler than in the present band, if other equipment were not already in the band. However, the existence of other systems, such as the SGLS downlink receiver, missile telemetry links, and threat radar simulators, already severely limits the amount of interference-free spectrum available. The addition of weapons control data links, along with ACTS, would only add more interference possibilities to an extremely crowded band.

D.7.1.2 OPTION 4B – Move A/G and G/A Links to 4400-4940 MHz Band, and Move G/G Links to 4400-4940 or 7250-8400 MHz Band

With Option 4B, as with Option 4A, the entire 1755-1850 MHz band is no longer available for ACTS use. Instead of remaining in a reduced (50 MHz) portion of the present band, the A/G and G/A links of the TACTS/ACMI will be moved to a higher band. For relocation of a system, especially one with airborne components, a number of issues must be addressed. The two primary categories of issues include the feasibility of redesigning equipment to perform its function in the new band, and potential EMC problems with equipment already using the band. Along with the 2200-2290 MHz band, the 4400-4940 MHz band was considered as a candidate for relocation. Because it is farther in frequency from the present band, it is expected to present more redesign problems than the 2200-2290 MHz band. Although the 4400-4990 MHz band offers more spectrum than the 2200-2290 MHz band, it is also already occupied by a number of systems considered to be of prime importance to the DoD and others. As with the lower band, compatibility with other systems operating on board the platforms (aircraft or ship) where the system is installed, need to be investigated.

Major systems presently residing in the 4400-4940 MHz band include the AN/TRC-170 and AN/GRC-222 tactical line-of-sight and troposcatter radios, the US Navy Light Airborne Multipurpose System (LAMPS) and Cooperative Engagement Capability (CEC). Other systems in the band include HAVE NAP, which is used on the B-52 aircraft, the Integrated Target Control System (ITCS), which is used at the Atlantic Fleet Warfare Training Facility (AFWTF), and UAV links, such as the Pioneer UAV. As with the 2200-2290 MHz band, on aircraft and ships, interference from the harmonics of collocated Joint Tactical Information Distribution System (JTIDS) and Tactical Air Navigation (TACAN) transmitters need to be considered. In addition, the effect of harmonics of the redesigned ACTS transmitter on collocated receivers needs to be assessed. Threat simulators have also been assigned frequencies in the 4900-4990 MHz range at the NAS Oceana training range.

The effects of moving the G/G links to the 4400-4940 MHz or 7250-8400 MHz band has been treated in the previous section. For G/G links in the 4400-4940 MHz band, an additional EMC issue has been created, because all links of the ACTS systems, A/G, G/A, and A/A would have to coexist in this band.

Feasibility Assessment. To maintain the same communications range at 4.4 GHz with omnidirectional antennas, the transmitter powers would have to be increased by 7.8 dB. The TACTS/ACMI AIS transmitter would have to be increased in power from 20 to 121 watts. Devices in this power range for 2200-2290 MHz are apparently available, although not built to military specifications. Going to the higher frequency band adds an extra level of difficulty, and it is not known if transmitters at this power level can meet the power and weight constraints of fighter aircraft. It may be possible to use lower power, with the addition of a high-gain antenna with tracking capabilities at the ground station. The feasibility of this arrangement and the ability to track maneuvering aircraft would need to be determined.

Self-Compatibility. In the analysis for the 1755-1850 MHz band, self-compatibility within this band segment was predicted for the TACTS/ACMI A/G and G/A links. Self-compatibility for these links should still be attainable in a similar (50-MHz) portion of the 4400-4940 MHz band. For the case of interference to adjacent ranges, the additional transmitter power needed should be cancelled by the revised path loss. If the G/G links were also to be in this band, more than 72 MHz would be needed, as was the case for 1755-1850 MHz band.

EMC with Incumbent Equipment—AN/TRC-170/AN/GRC-222. Frequency and distance separations necessary to avoid interference from the TACTS/ACMI AIS transmitter to the AN/TRC-170 receiver in the line-of-sight (LOS) and troposcatter configurations were calculated using characteristics and thresholds from an earlier analysis.[35] For the LOS mode, an interference threshold of -76 dBm, corresponding to a reliability of 99.99% for a link length of 20 km, was used. For the troposcatter mode, a threshold of -100 dBm, corresponding to 99.99% reliabiliity for a link length of 100 km, was used. Thresholds were determined from Figures 1 and 2 of Reference 35. Calculations for the AN/TRC-170 mainbeam (44 dBi), near-sidelobe (10 dBi) and backlobe (0 dBi) gains were made. Results are given in Table D-25. Distance separations in Table D-25 assume no off-tuning, and frequency separations assume a 1 km separation distance. Values in parentheses are for the power raised by the amount to achieve the same communications range at 4600 MHz as at 1800 MHz.

Table D-25. Distance and Frequency Separations Necessary to Avoid Interference From TACTS/ACMI AIS Transmitter to AN/TRC-170 Receivers

Mode	AN/TRC-170 Gain, dBi	Distance, Km	Frequency, MHz
LOS	0	0	0
	10	8	2
	44	386	6
Troposcatter	0	60 (155)	4 (4.7)
	10	192 (384)	5 (5.9)
	44	404 (410)	12.7 (19.1)

From Table D-25 it can be seen that a reasonable amount of frequency separation between TACTS/ACMI and AN/TRC-170 equipment should be observed, especially when the TACTS/ACMI aircraft may fly through the mainbeam of the AN/TRC-170 transmitter antenna.

EMC with Incumbent Equipment—Pioneer UAV. The Pioneer unmanned aerial vehicle (UAV) has RF links at UHF and C band. There is a primary C band link at 4 GHz and an alternate link at 5 GHz. The 4430-4590 MHz frequency range supports the primary uplink and 4750-4950 MHz supports the downlink. The downlink data may be video, infrared sensor information, or telemetry data, and the uplink is command data. In CONUS, use of the Pioneer UAV generally occurs at the test ranges of the Southwest or at sea. Pioneer flights take place on an intermittent basis. Two methods of addressing compatibility issues with Pioneer are coordinating times of Pioneer flights with ACTS training missions, and using the alternate (5 GHz) link.

EMC with Incumbent Equipment—AGM-142 (HAVE NAP). The AGM-142 missile is operational on B-52 aircraft. Training missions for this missile can occur anywhere over the US, but generally in

[35] Suresh Agarwal, *Analysis of the AN/TRC-170 When Deployed As Part of the Tactical Air Control System*, ECAC-PR-78-071, Annapolis, MD, DoD ECAC, December 1978.

Western regions. Live launches usually occur at White Sands Missile Range and at the Utah Test and Training Range. Maintenance and checkout is usually performed at Barksdale AFB, LA. Specific frequency ranges and other characteristics of this system are classified. The AGM-142 will not be addressed further in this study.

EMC with Incumbent Equipment—LAMPS. Compatibility issues with LAMPS are described in the *classified* supplement.

EMC with Incumbent Equipment—CEC. CEC is a system that provides the means to conduct coordinated Anti-Air Warfare (AAW) area defense. All Cooperating Units (CU) that participate in a CEC network exchange sensor data in near real time to form an identical composite track and identification air surveillance picture on each CU. This sensor cooperation function allows targets to be detected and compositely tracked that a single individual sensor could not track. The composite air picture provides the means for a battle force to accomplish optimized weapon system assignments and the coordinated engagements of threats. CEC is implemented via a Cooperative Engagement Processor (CEP) and a Data Distribution System (DDS). The CEP is a computer system responsible for forming the composite track and identification data base, and for coordinating engagements. The DDS is an RF network responsible for the secure, environmentally resistant transfer of sensor and weapon data among the CUs. CEC is currently being deployed aboard Navy E-2C aircraft and the major Navy surface combatants, carriers, and amphibious class ships. CEC is also now in development for deployment with the USA PATRIOT, USAF Airborne Warning and Control System (AWACS), and USMC AN/SPS-59 radar systems. The parameters for CEC are provided in Table C-30.

EMC with Incumbent Equipment—Threat Simulators. Threat simulators in the 4900-4990 MHz frequency range have been assigned frequencies at the NAS Oceana training range (Reference 22). This band overlaps part of the 4400-4940 MHz band. At Oceana, and at other ranges that may use threat simulators in this band, assignment of ACTS frequencies in the 4900-4940 MHz range should be avoided. A list of threat radars in the 4400-4940 MHz band is given in the *classified* supplement.

Cosite Equipment at Subharmonics and Harmonics for the F/A-18 Aircraft. An assessment of the potential interference from equipment collocated with the ACTS on a typical aircraft, the F/A-18, was performed. The 4400-4940 MHz band contains fourth harmonics of Tactical Air Navigation/Distance Measuring Equipment (TACAN/DME) and Joint Tactical Information Distribution System (JTIDS) frequencies. Both of these equipments are located on the F/A-18 aircraft. The 4400-4940 MHz band is also a second subharmonic of the band occupied by the collocated AN/APN-202 beacon and AN/APG-65/73 fire control radar.

As was done for the 2200-2290 MHz band, the JSC Aircraft inter-Antenna Propagation with Graphics (AAPG) computer program was used to model the F/A-18 aircraft to determine the path loss between antennas on the aircraft structure. An analysis to determine the frequency constraints on the fundamental emitter to avoid potential interference from its harmonic was then performed.

Cosite Equipment—TACAN/DME. Use of the AAPG model resulted in a path loss of 45 dB between the TACTS fuselage-mounted antenna (on the nose wheel door) used for the internal TACTS and the lower TACAN/DME antenna, which is also used for JTIDS. For TACAN/DME interference to the TACTS, 31.6 MHz separation between the TACAN/DME harmonic and the TACTS frequency is needed for I_t not to be exceeded. For example, if the TACTS receiver operates on 4600 MHz, TACAN/DME interrogator frequencies above 1142 MHz must be avoided. Any interrogation channels above 118 would cause the threshold to be exceeded.

Cosite Equipment—JTIDS. To avoid JTIDS harmonic interference to TACTS, JTIDS harmonics must be separated by 8.8 MHz from the TACTS frequency. A rejection value of 80 dB was assumed for the fourth harmonic (Reference 31). For example, for TACTS operation at 4600 MHz, JTIDS frequencies between 1148 and 1152 MHz need to be avoided. A loss of two of the 51 available JTIDS frequencies would occur.

Cosite Equipment—AN/APN-202. The TACTS, in the 4400-4940 MHz band, lies at the second subharmonic of the AN/APN-202 beacon frequency range. The TACTS second harmonic is calculated to be -87.5 dBm, 22.5 dB lower than the AN/APN-202 sensitivity of -65 dBm. Interference to the AN/APN-202 is not expected.

Cosite Equipment—Fire Control Radar. The TACTS, in the 4400-4940 MHz band, lies at the second subharmonic of the AN/APG-65/73 radar tuning range. An assessment of interference to the radar is included in the classified supplement.

Cosite Equipment—AN/APN-194 Radar Altimeter. The AN/APN-194 Doppler radar altimeter operates at a center frequency of 4300 MHz. At least 61 dB rejection of the TACTS AIS signal is necessary for the signal to be below the -85 dBm sensitivity level of the AN/APN-194. This rejection should be attainable at a frequency separation of less than 100 MHz. At least 101 dB of rejection is needed for the AN/APN-194 signal peak power to be below the TACTS AIS interference threshold. If this amount of FDR is not attainable, because of the low duty cycle of the altimeter, (.00072), blanking of the TACTS receiver may be a feasible mitigation technique.

Other Collocated Systems. Other collocated systems that may be affected by the reassigned TACTS AIS transmitter include the AN/ALQ-165 jammer and the AN/ALR-067 CWCS. Compatibility with these systems will be assessed in the classified supplement.

Compatibility with Other Systems Migrating to This Band. The 4400-4940 MHz band contains more spectrum (540 MHz) compared to the lower bands, so compatibility with the additional equipment, such as weapons control data links, that may migrate to the 4400-4940 MHz band would be more readily achieved than at the lower bands. This situation would occur even if the G/G links were moved to the band. However, the presence of the systems already in the band may negate most of the advantage given by the wider bandwidth.

D.7.2 JTCTS A/A and G/A Links Technical Assessment

D.7.2.1 OPTION 4A – Move G/A and A/A Links to 2200-2290 MHz Band, and Move G/G Links to 4400-4940 or 7250-8400 MHz Band

With Option 4A, the entire 1755-1850 MHz band is no longer available for ACTS use. Instead of remaining in a reduced (50 MHz) portion of the present band, the G/A and A/A links of the JTCTS will be moved to a higher band. Two candidate bands were considered for this study. They are the 2200-2290 MHz and 4400-4940 MHz bands. For relocation of a system, especially one with airborne components, a number of issues must be addressed. The two primary categories of issues include the feasibility of redesigning equipment to perform its function in the new band, and potential EMC problems with equipment already using the band. The 2200-2290 MHz band was considered as a prime candidate for relocation. Because it is closest in frequency to the present band, it is expected to present a minimum number of redesign problems. However, it is already occupied by a number of systems considered to be of prime importance to the DoD and others. In addition, compatibility with other systems operating on board the platforms (aircraft or ship) where the system is installed, need to be investigated.

Systems presently residing in the 2200-2290 MHz band include Space Ground Link Subsystem (SGLS) downlink receivers, missile telemetry links, threat simulators, and the NASA Goldstone Deep Space Network (DSN) and Space Tracking and Data Network (STDN) receivers located near one of the training ranges, at Fort Irwin, CA. At the Beaufort MCAS, eight microwave links are assigned frequencies from 2208 to 2285 MHz. On aircraft and ships, interference from the harmonics of collocated Joint Tactical Information Distribution System (JTIDS) and Tactical Air Navigation

(TACAN) transmitters need to be considered. In addition, the effect of harmonics of the redesigned ACTS transmitter on collocated receivers needs to be assessed.

The effects of moving the G/G links to the 4400-4940 MHz or 7250-8400 MHz band has been treated in the previous section. For the 4400-4940 MHz band, an additional EMC issue has been created, because harmonics of transmitters in the 2200-2290 MHz band lie within this frequency range.

Feasibility Assessment. As was the case for the TACTS/ACMI, the JTCTS transmitter powers would have to be increased by 1.9 dB, or, in the case of JTCTS, to 105 watts. According to JTCTS program consultants (Reference 24), high power devices for this band are available, but they do not meet military specifications for packaging or temperature range. Although individual parts may need to be screened, implementation is believed to be feasible.

Self-Compatibility. In the analysis for the 1755-1805 MHz band, it was found that compatibility within the same range could be attained at a 20-km distance between G/A and A/A links, if the frequency separation between the two links was 35 MHz or more. Compatibility could therefore be attained in a 58-MHz portion of the 2200-2290 MHz band. Compatibility between links of adjacent ranges requires an additional 22.8 MHz for each link. Adding the additional 45.6 MHz to the 58 MHz needed for compatibility within the same range results in 103.6 MHz, greater than 90 MHz. Therefore, even if compatibility with other systems within the band were of no concern, compatibility between adjacent ranges cannot be achieved by frequency separation alone in the 2200-2290 MHz band.

EMC with Incumbent Equipment—SGLS Downlink Receivers. An analysis of interference from the JTCTS air-to-air link to the SGLS downlink receivers was conducted in a manner similar to that described for the TACTS/ACMI air-to-ground link transmitter. For TST Carrier 1, a 392 km distance separation is needed for no frequency separation constraints, and for TST Carrier 2, 402 km separation is needed. The frequency separation constraints are somewhat larger than for the TACTS/ACMI, because of the wider bandwidth of the JTCTS. For Carrier 1, 27 MHz separation is needed at minimal distance, and for Carrier 2, 37 MHz separation is needed.

EMC with Incumbent Equipment—Missile Telemetry Links. An analysis for required frequency and distance separations between the JTCTS airborne transmitter and a ground-based telemetry receiver, the Microdyne 1100R, and between the AN/DKT-37 missile telemetry transmitter and the JTCTS airborne receiver was conducted, using methodology similar to that used for the TACTS/ACMI equipment described above.

For the JTCTS A/A transmitter interfering with the ground-based telemetry receiver, a 35-MHz frequency separation or a 401 km distance separation is needed to avoid exceeding the interference threshold. The larger frequency separation and separation distance for the JTCTS, as compared to the TACTS/ACMI, are due to its broader bandwidth and higher power level. The JTCTS high power and wideband modes were assumed for this analysis. To avoid the missile telemetry transmitter signal exceeding the interference threshold of the JTCTS airborne receiver, a distance separation of 117 km or a frequency separation of 27 MHz must be maintained.

Cosite Equipment at Subharmonics and Harmonics for the F/A-18 Aircraft. An investigation of JTCTS transceiver interference effects from and to collocated transmitters and receivers on the F/A-18 aircraft was performed in the same manner as described for the TACTS/ACMI. The results are discussed below.

Cosite Equipment—TACAN/DME. To avoid TACAN/DME interference to JTCTS, about 100 MHz of frequency separation would be needed. The increased frequency separation, compared to TACTS, is largely due to the wider bandwidth of the JTCTS receiver. All TACAN/DME channels above 50 would cause harmonics above the threshold level. The military-only channels 1-16 would continue to generate harmonics below the interference threshold.

Cosite Equipment—JTIDS. To avoid JTIDS harmonic interference to JTCTS, about 63 MHz frequency separation is needed. JTIDS frequencies between 1093 and 1157 MHz would cause the interference threshold to be exceeded for the hypothetical situation of JTCTS operating at 2250 MHz. Of the 51 JTIDS frequencies, 21 would exceed the interference threshold.

Cosite Equipment—AN/APN-202. The second harmonic of the JTCTS at the AN/APN-202 receiver input is calculated to be -71.2 dBm, lower than the -65 dBm sensitivity of the AN/APN-202 receiver. Interference to the AN/APN-202 from JTCTS in the 2200-2290 MHz band is not expected to be a problem.

Other Collocated Systems. Other collocated systems that may be affected by the reassigned JTCTS airborne transmitter include the AN/ALQ-165 jammer and the AN/ALR-067 CWCS. Compatibility with these systems will be assessed in the classified supplement.

Collocated Shipboard Systems. The JTCTS, when used for exercises at sea, is expected to have a transmitter and possibly a receiver on board ship. Compatibility of these systems with other shipboard equipment would need to be assessed.

Goldstone Deep Space Network and GSTDN Receivers (Ft. Irwin only). An assessment of the effects of the JTCTS airborne transmitter on the Goldstone receiver was done in a manner similar to that described above for the ACMI systems. At a 9000 m altitude, 439 km of separation is needed to avoid exceeding the interference threshold with no offtuning, and 309 km separation is needed at the -60 dB spectral level, ± 11.25 MHz.

Threat Simulators. A description of threat simulators operating in this band and EMC issues with a relocated JTCTS are included in the *classified* supplement to this report.

Other Incumbent Equipment. Other equipment operating in the 2200-2290 MHz band includes point-to-point microwave links at one of the training ranges, Beaufort MCAS. Of the six training ranges described in Reference 22, only one has microwave links in this band. If the JTCTS A/A and G/A links were to move to this band, compatibility with these links is expected to be an issue. It may be desirable to reassign the microwave link frequencies to a higher band.

EMC with Other Systems That May Migrate to This Band. As with the TACTS/ACMI, addition of weapons control data links, or other systems, to this band due to overall reduction of spectrum available to DoD only adds more interference possibilities to an already overcrowded band.

D.7.2.2 OPTION 4B – Move G/A and A/A Links to 4400-4940 MHz Band, and Move G/G Links to 4400-4940 or 7250-8400 MHz Band

With Option 4B, as with Option 4A, the entire 1755-1850 MHz band is no longer available for ACTS use. Instead of remaining in a reduced (50 MHz) portion of the present band, G/A and A/A links of the JTCTS will be moved to a higher band. For relocation of a system, especially one with airborne components, a number of issues must be addressed. These issues for the JTCTS are much the same as for the TACTS/ACMI, described earlier. The two primary categories of issues include the feasibility of redesigning equipment to perform its function in the new band, and potential EMC problems with equipment already using the band. Because the 4400-4940 MHz band is farther in frequency from the present band, it is expected to present more redesign problems than the 2200-2290 MHz band. Although the 4400-4990 MHz band offers more spectrum than the 2200-2290 MHz band, it is also already occupied by a number of systems considered to be of prime importance to the DoD and others. As with the lower band, compatibility with other systems operating on board the platforms (aircraft or ship) where the system is installed, need to be investigated.

Major systems presently residing in the 4400-4940 MHz band have been listed in the TACTS/ACMI discussion, and will be repeated here for convenience. They include the AN/TRC-170 and AN/GRC-222 tactical line-of-sight and troposcatter radios, the US Navy Light Airborne Multipurpose System (LAMPS) and Cooperative Engagement Capability (CEC). Other systems in the band include HAVE NAP, which is used on the B-52 aircraft, the Integrated Target Control System (ITCS), which is used at the Atlantic Fleet Warfare Training Facility (AFWTF), and UAV links, such as the Pioneer UAV. As with the 2200-2290 MHz band, on aircraft and ships, interference from the harmonics of collocated Joint Tactical Information Distribution System (JTIDS) and Tactical Air Navigation (TACAN) transmitters need to be considered. In addition, the effect of harmonics of the redesigned ACTS transmitter on collocated receivers needs to be assessed. Threat simulators have also been assigned frequencies in the 4900-4990 MHz range at the NAS Oceana training range.

The effects of moving the G/G links to the 4400-4940 MHz or 7250-8400 MHz band has been treated in the previous sections. For G/G links in the 4400-4940 MHz band, an additional EMC issue has been created, because all links of the ACTS systems, A/G, G/A, and A/A would have to coexist in this band.

Feasibility Assessment. To operate without reduced communications range in the 4400-4940 MHz band, the JTCTS transmitter would have to be increased in power to 400 watts. According to JTCTS program consultants (Reference 24), for aircraft using the pod version of the JTCTS, the prime power available at the wing station is not sufficient to provide this amount of transmitter power. Operating the JTCTS at this frequency band with omnidirectional antennas, as is necessary for the air-to-air link, may not be feasible.

Self-Compatibility. According to analyses referred to for the 2200-2290 MHz band, 103 MHz was predicted to be necessary for compatibility of both G/A and A/A links in the same range and adjacent ranges. Although this amount of spectrum was not available in the lower bands, it should be available, barring interference problems with incumbent systems, in the 4400-4940 MHz band. If compatibility with incumbent systems can be managed, the available spectrum should be able to include the tertiary (G/G) link as well.

EMC with Incumbent Equipment—AN/TRC-170/AN/GRC-222. Frequency and distance separations necessary to avoid interference from the JTCTS airborne transmitter to the AN/TRC-170 receiver in the line-of-sight (LOS) and troposcatter configurations were calculated using the methods described for the TACTS/ACMI analysis. The results are given in Table D-26. Frequency separations to be observed are somewhat larger than for the TACTS/ACMI AIS. Frequency separations of up to 20 MHz should be observed, even if the mainbeam of the AN/TRC-170 is avoided. In Table D-26, numbers in parentheses are for the JTCTS transmitter power raised to meet the same communications range as at 1800 MHz.

Table D-26. Distance and Frequency Separations Necessary to Avoid Interference From JTCTS Airborne Transmitter to AN/TRC-170 Receivers

Mode	AN/TRC-170 Gain, dBi	Distance, Km	Frequency, MHz
LOS	0	5	2.2
	10	33 (86)	6 (11.2)
	44	393	29
Troposcatter	0	171 (383)	14 (18.9)
	10	385 (391)	20 (26.5)
	44	411 (416)	67 (69)

EMC with Incumbent Equipment—LAMPS. Compatibility issues with LAMPS are described in the *classified* supplement.

EMC with Incumbent Equipment—CEC. Compatibility issues between the JTCTS and the CEC are described in the *classified* supplement.

EMC with Incumbent Equipment—Threat Simulators. As mentioned earlier,threat simulators in the 4900-4990 MHz frequency range have been assigned frequencies at the NAS Oceana training range (Reference 22). This band overlaps part of the 4400-4940 MHz band. At Oceana, and at other ranges that may use threat simulators in this band, assignment of ACTS frequencies in the 4900-4940 MHz range should be avoided. A list of threat radars in the 4400-4940 MHz band is given in the classified supplement.

Cosite Equipment at Subharmonics and Harmonics for the F/A-18 Aircraft. An investigation of JTCTS transceiver interference effects from and to collocated transmitters and receivers on the F/A-18 aircraft was performed in the same manner as described for the TACTS/ACMI. The results are discussed below.

Cosite Equipment—TACAN/DME. To avoid TACAN/DME interference to JTCTS, about 54.5 MHz of frequency separation would be needed. The increased frequency separation, compared to TACTS, is largely due to the wider bandwidth of the JTCTS receiver. For JTCTS operation at mid-band (4600 MHz), all TACAN/DME channels above 112 would cause harmonics above the threshold level.

Cosite Equipment—JTIDS. To avoid JTIDS harmonic interference to JTCTS, 27.4 MHz of frequency separation is needed. JTIDS frequencies between 1143 and 1157 MHz would cause the interference threshold to be exceeded for the hypothetical situation of JTCTS operating at 4600 MHz. Of the 51 JTIDS frequencies, five would exceed the interference threshold.

Cosite Equipment—AN/APN-202. The JTCTS, in the 4400-4940 MHz band, lies at the second subharmonic of the AN/APN-202 beacon frequency range. The JTCTS second harmonic is calculated to be -71.2 dBm, 6.2 dB lower than the AN/APN-202 sensitivity of -65 dBm. Interference to the AN/APN-202 is not expected.

Cosite Equipment—Fire Control Radar. The JTCTS, in the 4400-4940 MHz band, lies at the second subharmonic of the AN/APG-65/73 radar tuning range. An assessment of interference to the radar is included in the classified supplement.

Cosite Equipment—AN/APN-194 Radar Altimeter. The AN/APN-194 Doppler radar altimeter operates at a center frequency of 4300 MHz. At least 72 dB rejection of the JTCTS signal is necessary for the signal to be below the -85 dBm sensitivity level of the AN/APN-194. This rejection should be attainable at a frequency separation of less than 100 MHz. At least 98 dB of rejection is needed for the AN/APN-194 signal peak power to be below the JTCTS interference threshold. If this amount of rejection is not attainable through frequency separation, the low duty cycle of the altimeter, (.00072), may allow blanking of the JTCTS receiver as a feasible mitigation technique.

Other Collocated Systems. Other collocated systems that may be affected by the reassigned JTCTS airborne transmitter include the AN/ALQ-165 jammer and the AN/ALR-067 CWCS. Compatibility with these systems will be assessed in the classified supplement

Compatibility with Other Systems Migrating to This Band. The same situation applies to the JTCTS as to TACTS/ACMI. As this band contains more spectrum (540 MHz) compared to the lower bands, compatibility with the additional equipment, such as weapons control data links, in the band would be more readily achieved than at the lower bands. This situation would occur even if the G/G links were moved to the band. However, the presence of the systems already in the band may negate most of the advantage given by the wider bandwidth. Since the JTCTS uses more transmitter power and receiver bandwidth, compatibility appears to be more difficult to achieve than is the case with TACTS/ACMI.

D.7.3 Results – Option 4

1. It is generally feasible to redesign the TACTS/ACMI or JTCTS airborne transmitters to attain the present system ranges at 2200-2290 MHz.
2. A number of systems operating in the 2200-2290 MHz band would present compatibility problems and possibly operational constraints. They include:
   a. Missile telemetry links, at Nellis AFB and elsewhere
   b. SGLS fixed and transportable S-band downlink terminals
   c. NASA Goldstone DSN and GSTDN receivers, at Fort Irwin, CA
   d. Threat radar simulators (see classified supplement)
   e. Point-to-point microwave links (Beaufort MCAS)
3. Use of the redesigned system at 2200-2290 MHz on a typical fighter aircraft presents potential cosite EMC problems with other systems on that aircraft. These systems include:
   a. TACAN/DME interrogators
   b. JTIDS
   c. Jammers
   d. Radar Warning Receivers
4. It is probably not feasible to redesign the JTCTS transmitter to operate in the 4400-4940 MHz band with a 150-nmi range to be installed on present-day fighter aircraft.
5. The number of systems already operating in the 4400-4940 MHz band is somewhat smaller than at 2200-2290 MHz. These systems include:
   a. Tactical point-to-point and troposcatter radios
   b. Unmanned aerial vehicles
   c. Cooperative Engagement Capability (CEC) (See classified supplement)
   d. Threat simulators (See classified supplement)
6. The CEC is expected to be the primary contender for spectrum in this band.
7. As with the 2200-2290 MHz band, use of the redesigned system on a fighter aircraft, if feasible, presents a number of cosite interference problems, similar to the ones mentioned for 2200-2290 MHz.
8. EMC issues with G/G links, migrating to the 4400-4940 MHz or 7250-8400 MHz band, are expected to be tractable, as was the case for Option 3.

D.7.4 Operational Impact

One option presented by the Air Force is to upgrade all ACTS ranges and AIS pods with a GPS tracking capability and replace existing RF hardware with new, state of the art, digital equipment. AIS pod uplink and downlink frequencies could also be moved to the 2200-2290 MHz band. Use of GPS for position determination will reduce the bandwidth of the uplinks and downlinks, from greater than 7 MHz to less than 1.2 MHz and also eliminate the use of multiple frequency assignments for ground-to-ground communications resulting in reduced total bandwidth required for ACTS ranges. Moving the TACTS/ACMI to a different band could not be implemented by 2003 or likely by 2006. Therefore, vacating the current band in those time frames would impose unacceptable impact to combat training. One of the above options for moving to an alternate frequency band could possibly be implemented by 2010. However, unless continued operation of legacy TACTS/ACMI is assured in the interim, operational impacts would be severe.

By 2003, JTCTS will not yet be deployed in the US and it would be difficult to make any significant modifications to the legacy TACTS/ACMI.Operational impact to US forces is the same as in Option 1. In 2010,the replacement of the legacy TACTS/ACMI by JTCTS will have just begun (2008).The 2010 time frame may allow for an accelerated JTCTS program to provide replacement TACTS/ACMI. A modification program for the legacy TACTS/ACMI could also be completed by that time frame—but that would be moot if all systems have been replaced by JTCTS. Operational impact is none if no spectrum conflicts arises with other systems and all the mitigation efforts are completely implemented by 2010 or if turnover of 1755-1850 MHz can be delayed at sites where mitigation measures have not been completed by 2010. Compatibility issues with incumbent systems in the 2200-2290 and 4400-4940 MHz frequency bands may prevent the implementation of this option.

APPENDIX E – OTHER SYSTEMS

The operations of a number of additional Department of Defense (DoD) systems rely on spectrum between 1755 and 1850 MHz in addition to those of the four primary DoD functional capabilities. Long-range, low-capacity (data rate), point-to-point microwave system operations represent a majority of the systems. These systems primarily operate at fixed locations and employ directional antennas. A number of mobile operations are also authorized in this band although few are considered to represent dominant uses. Two mobile systems, the Combat Identification for the Dismounted Soldier (CIDDS) and the Land Warrior Wireless Local Area Network (WLAN), are developmental systems whose operations also are dependent on spectrum in this band segment. CIDDS entered into development in 1997 and the low-rate initial production of fifty units will be tested in FY01. Current program documentation indicates approximately 100,000 CIDDS units will be procured to outfit dismounted soldiers of all three military services. Land Warrior is a first-generation integrated fighting system for dismounted soldiers. Current program documentation indicates a minimum of 41,000 units, with a potential increase to 71,000 units, are to be produced commencing in calendar 2003. A number of Unmanned Aerial Vehicles (UAVs), such as the Pointer (FQM-151A) and the Exdrone (BQM-147A), are also authorized in this band. These systems transmit video and status data from the UAV to the ground control system (GCS) using analog frequency modulated (FM) video and data on subcarriers. Fixed point-to-point microwave, CIDDS, the Land Warrior WLAN, and UAVs are believed to represent significant other uses of the 1755 to 1850 MHz band.

Technical, cost, and operational impact analyses have been provided for each of the aforementioned systems. Impact assessments associated with the 1755 to 1850 MHz band reallocation have also been provided for the Aberdeeen Test Center (ATC) telemetry system and the Nellis Air Force Base TCM-601 television ordnance scoring system (TOSS).

E.1 POTENTIAL FOR INTERFERENCE TO AND FROM FIXED POINT-TO-POINT COMMUNICATIONS

The 1755-1850 MHz band is considered to be the Federal Government's general purpose, long-range, low-capacity, point-to-point microwave band. These systems provide a small number of voice, digital control, or monitoring channels through which information is routed to and from remote locations. Typical uses for this band include backbone communications at military test and training ranges, and supervisory control and data acquisition (SCADA) for electrical power generation, locks, and dams. Most of these microwave systems are capable of operation between 1710 and 1900 MHz. Originally allocated to operate between 1710 and 1855 MHz, the lower band segment was to be reallocated in accordance with the Omnibus Budget Reconciliation Act of 1993 (OBRA-93) between January 1999 and January 2004. Recently, the Federal Communications Commission (FCC) published their intent to reassign the lower band segment by 30 September 2002, although a small number of special operations were exempted from reassignment.[1] Exempted operations include those at 333 Federal power agency (FPA) sites and 111 additional sites located outside 25 densely-populated US cities where emergency, disaster response, safety-of-life, and other critical operations exist.

E.1.1 Operational Mission Overview

Point-to-point microwave systems whose operations require access to spectrum in the 1755-1850 MHz band are employed by the DoD for the transmission of voice and data communications to and from military hydrologic and range facilities. While their data throughput is minimal, compared to the throughput of other current-day transmission media, their relative importance remains quite high due to the nature of their mission. Dams are employed to protect lives and property of downstream inhabitants and, in some instances, are also employed to generate electrical power. River locks are employed to facilitate shipborne navigation between and along United States (US) waterways. Most of the point-to-point communications that have hydrologic-related functions are operated by the Army Corps of Engineers (ACE). All three services also rely on point-to-point microwave systems for backbone communications at military operating areas in the continental US (CONUS). It is through such communications networks that range telemetry data and voice communications are routed to facilities where the particular test or exercise is being scored or monitored. Most installations of microwave systems that employ spectrum in this band are legacy in nature. Typical replacement media include point-to-point systems that employ higher regions of radio frequency (RF) spectrum and fiber-optic cable. Figure E-1 depicts the locations of military point-to-point communications systems in CONUS.

E.1.2 System Descriptions

Typical characteristics of DoD point-to-point microwave systems, which require spectrum in the 1755-1850 MHz are contained in Table E-1.

[1] Policy Statement, *Principles for Reallocation of Spectrum to Encourage the Development of Telecommunications Technologies for the New Millenium*, FCC 99-354, Washington, DC: Federal Communications Commission, 22 November 1999.

Table E-1. Typical DoD Point-to-Point Microwave System Characteristics[2]

Frequency Range	1700 to 1900 MHz
Average Power	1 to 10 watts
Bandwidth	0.5 to 10 MHz
Transmission Capacity	24 to 600 channels
Transmit/Receive Spacing (common antenna)	20 to 50 MHz
Antenna Gain	28 to 34 dBi
Antenna Height	10 to 100 m

Excluding systems employed by ACE, which are discussed in further detail hereafter, the majority of DoD microwave operations are located in the Desert Southwest (e.g., Arizona, California, Nevada, New Mexico, and Utah) and the Southeast (e.g., Alabama, Florida, Georgia, North Carolina, and South Carolina). Including ACE operations, locations where all three military services are authorized by permanent frequency assignment to employ fixed point-to-point microwave systems in CONUS are depicted in Figure E-1.

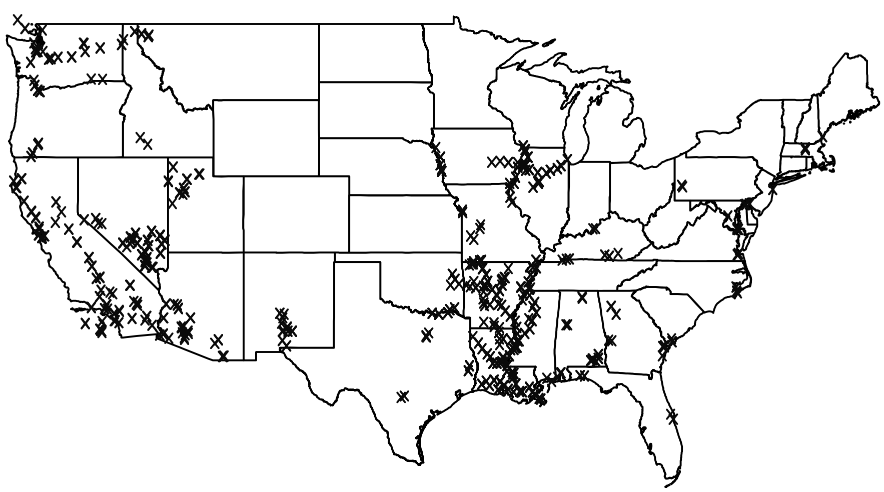

Figure E-1. DoD 1755 to 1850 MHz Point-to-Point Communications Locations

[2] R. Matheson, *Spectrum Usage for the Fixed Services*, NTIA Report 00-378, Washington, DC: US Department of Commerce, March 2000.

E.1.3 Army Corps of Engineers

Officially a branch of the military, fully 80% of the works performed by the ACE represent civilian efforts.[3] They manage an intracoastal and inland network of 12,000 miles of commercial navigation channels. They also operate more than 200 locks and dams for navigation. More than two billion tons of commerce are moved on these waterways annually. The ACE also operates 368 reservoirs for flood control, from which one fourth of the nation's hydropower is produced. The $20 billion investment in flood control during the 1990s was credited with the prevention of $168 billion in flood damage. One of the means they employ to support this widespread network of facilities throughout the US are point-to-point microwave communications systems. ACE maintains 346 permanent frequency assignments within the 1755 to 1850 MHz band to support these operations. ACE operations in this band represent approximately one-half of the DoD fixed point-to-point microwave system operations that are authorized in this band by permanent frequency assignment.

E.1.3.1 Operational Mission Overview

ACE operates a nationwide 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. This system provides microwave links where no commercial communications connectivity exists. This system is essential to ACE operations because it allows 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. The system helps ensure the safety and integrity of the nation’s waterways and helps prevent catastrophic events that could cost lives and economic damage as well as environmental damage.

ACE employs fixed point-to-point microwave communications systems to accomplish a number of functions in CONUS. Information provided within permanent frequency assignments recorded for these operations indicate their majority support backbone communications; the remainder support civil works, miscellaneous microwave, administrative, energy control and utilities, hydrologic, survey, construction, and contingency functions. Additional information indicates these assignments support remote hydropower and ship-traffic control, and ACE inter-district voice and data connections. Several indicate they were coordinated with the Department of Energy (DOE). The CONUS region that is most densely populated with ACE operations is the Mississippi River basin. The second and third most densely

[3] “US Army Corps of Engineers Home Page,” [USACE Web Page], Washington, DC: USACE, 12 December 2000 [cited 19 December 2000]. Available from http://www.usace.army.mil/; INTERNET.

populated regions include the Sierra Nevada and Northern Coastal Ranges in California, and the Columbia Plateau in Washington, respectively. Locations where the ACE is authorized by permanent frequency assignment to employ fixed point-to-point microwave systems in CONUS are depicted in Figure E-2.

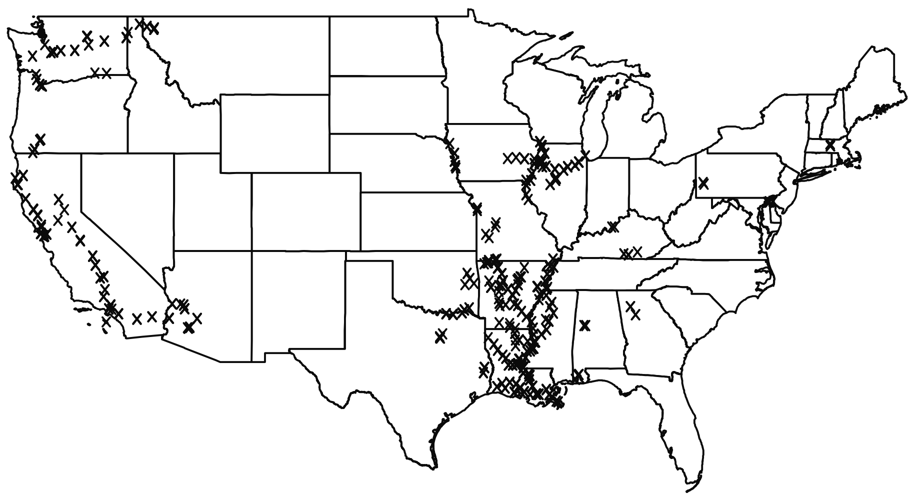

Figure E-2. Army Corps of Engineers 1755 to 1850 MHz Point-to-Point Communications Locations

E.1.3.2 Technical Assessment

Sharing between fixed ACE point-to-point microwave and IMT-2000 systems was determined on a one-to-one basis. Distances beyond which compatible operations of these systems could be attained were calculated for all receiver and transmitter pairings. IMT-2000 base and mobile configurations were assessed. The fixed point-to-point microwave antenna and IMT-2000 base station antennas were all assessed as having a two-step antenna pattern comprised of mainbeam and median gain levels.

Fully 90% of the fixed ACE point-to-point microwave communications systems are manufactured by the Motorola Corporation and Granger Associates. The Motorola K16RBF, Motorola K26RBF, Granger 6015-AE, and Granger 6018A microwave systems constitute the majority of these systems. Of these four, the technical characteristics of the Granger 6015-AE were deemed representative of the median system characteristics identified in permanent frequency assignment data for all ACE systems. The characteristics of this system are identified in Table E-2. The interference threshold for this system, an I/N level of –6dB, was based on ITU-R F.1334, which limits the degradation due to interference in a fixed service receiver to +1 dB.

Table E-2. ACE Fixed Point-to-Point Microwave Characteristics[4, 5]

Frequency Range	1700 to 1850 MHz
Mean Power	10 watts
Emission Designator	2M17F8E
Emission Bandwidth (MHz)	0.5 (-3 dB), 1.8 (-20 dB), 2.9 (-40 dB), and 4.0 (-60 dB)
IF Bandwidth (MHz)	4.5 (-3dB), 7.0 (-20 dB), and 25 (-60 dB)
Receiver Noise Figure	7 dB
Receiver Sensitivity	-94 dBm (30 dB S/N)
Receiver Noise Power	-108 dBm
Transmission Capacity	72 channels
Transmit/Receive Spacing	20 MHz
Antenna Gain	29 dBi (Mainbeam); -6 dBi (>30 degrees off-axis)
Antenna Height	80 m

The technical parameters for the IMT-2000 radios are presented elsewhere in this report. The IMT-2000 receiver thresholds were modified in the same manner described in the Tactical Radio Relay Assessment of Interference.

As was done in previous sections, an assessment was performed to quantify the distance separation at which compatible on-tune operations of fixed point-to-point microwave and IMT-2000 systems would exist. The necessary propagation loss to ensure compatible operations for mainbeam (MB) and median sidelobe (SL) antenna-to-antenna couplings was calculated by summing the corresponding transmitter power, transmitter and receiver antenna gain, and frequency dependent rejection. The corresponding receiver interference threshold was subtracted from this value to ascertain the minimum propagation path loss at which compatible operations would exist. Next, the Spherical Earth Model (SEM) was employed to calculate the distance separation between transmitter and receiver antennas, which would produce the minimum propagation path loss for the corresponding transmitter and receiver antenna pair. Lastly, the frequency dependent rejection term was varied to introduce effects relating to off-tuned operations of the two systems. The IMT-2000 (transmitter) to fixed point-to-point microwave (receiver) distance separation values beyond which compatible operations would exist are contained in Table E-3. The fixed point-to-point microwave (tranmitter) to IMT-2000 (receiver) distance separation values beyond which compatible operations would exist are contained in Table E-4.

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[4] *Granger Model 6015-3A/E/72 Microwave Terminal*, Application for Equipment Frequency Allocation (DD Form 1494) J/F 12/5441,14 September 1984.

[5] Manufacturer's Brochure, *1800 MHz Terminals – Model 6015/AE*, Santa Clara, CA: Granger Associates, n.d.

Table E-3. IMT-2000 Transmitter to Fixed Point-to-Point Microwave Receiver Distance Separations Beyond Which Compatible Operations Would Exist

Transmitter-to-Receiver Coupling		Distance Separation for Compatible Operations (km)			
IMT-2000	6015-AE	CDMA(NB)	CDMA(WB)	ISM-136	GSM
Base MB	MB	131	131	131	131
Base MB	SL	71	71	71	71
Base SL	MB	91	91	91	91
Base SL	SL	59	59	59	59
Mobile	MB	41	41	41	41
Mobile	SL	11	11	11	11

Table E-4. Fixed Point-to-Point Microwave Transmitter to IMT-2000 Receiver Distance Separations Beyond Which Compatible Operations Would Exist

Transmitter-to-Receiver Coupling		Distance Separation for Compatible Operations (km)			
6015-AE	IMT-2000	CDMA(NB)	CDMA(WB)	ISM-136	GSM
MB	Base MB	160	137	178	178
MB	Base SL	105	94	115	115
MB	Mobile	62	58	64	64
SL	Base MB	76	72	79	79
SL	Base SL	64	60	67	67
SL	Mobile	29	25	32	32

A review of the results in these two tables yields several interesting findings. The separation distances of most consequence are tied to operations of the fixed point-to-point microwave system. Irrespective of the IMT-2000 system, larger distance separations are required for compatible operations of both system classes in all cases of antenna coupling from the 6015-AE transmitter but for the lone exception involving the mainbeam of the 6015-AE receiver. Thus, the technical characteristics of fixed-point-to-point microwave systems will dictate the minimum distance at which compatible operations will exist. Lastly, simultaneous on-tune operations of both system classes are not projected to be compatible without significant distance separation.

The employment of frequency separation will surely decrease the distance separations at which compatible operations could exist. It will not, however, enable both classes of systems to operate without some form of coordination between their fixed operations. Given the modeling of the transmitter and receiver bandwidth characteristic fall-off curves below –60 dB, the maximum attenuation realizable for a frequency separation of 95 MHz is on the order of -73 dB. This amount of attenuation is more than sufficient to decrease the required separation distance values for compatible operations cases involving sidelobe coupling between directional antennas and omnidirectional mobile antennas below 3 km. For mainbeam-to-mainbeam coupling between directional antennas, however, it is not sufficient to decrease the required separation distance values much below 25 km.

E.1.3.2.1 Results Option 1 – Full Band Sharing. A frequency separation on the order of 5 MHz would decrease the required separation to approximately 10 km for transmitter to receiver couplings between the 6015-AE mainbeam and mobile IMT-2000 systems. A frequency separation between 25 and 30 MHz would decrease the required distance separation between a 6015-AE and an IMT-2000 base station to approximately 10 km, given mainbeam-to-sidelobe coupling. While these separations in distance and frequency are not prohibitive, their significance will depend on the proliferation of IMT-2000 devices in regions where fixed-point-to-point microwave antennas are located. It may not be practical to continue operations of ACE point-to-point microwave systems along the populated portions of the Mississippi River, but the converse might prove true along the Columbia plateau or along the Sierra Nevada Range.

Since the microwave links tend to be in remote areas, sharing should not present a problem. For those links near population centers or IMT-2000 systems, frequency sharing could be coordinated; otherwise the link will have to be relocated in the spectrum.

E.1.3.2.2 Results Option 2 – Band Segmentation/Partial Band Sharing. Fixed point-to-point communications systems could, most likely, coexist in the 1755 to 1850 MHz band, if larger segments of the band were retained on an exclusive basis. Retention of these segments on a shared basis is less feasible. Irrespective of how the band is shared, the concerns involving frequency separation, outlined in Option 1, *Full Band Sharing*, must still be addressed. The simultaneous operations of fixed point-to-point microwave systems and IMT-2000 base stations would have to be coordinated on a one-on-one basis to preclude interference effects.

Consideration must be given to the microwave system requirement that distinct transmit and receive frequencies are required for each point-to-point link. These frequencies are typically separated by 20 to 50 MHz, as denoted in Table E-1. Segments to be retained must accommodate this channel separation requirement. They must also accommodate multiple transmit and receive links at sites where more than two microwave systems are in use.

Additionally, the permanent frequency assignments for a significant number of 1755 to 1850 MHz ACE links denote their second frequency lies within the 1710 to 1755 MHz band. While this lower band segment was reallocated in accordance with OBRA-93, it has yet to be reassigned, and the former population of users has been allowed to retain use of their assignments until the 1710 to 1755 MHz band is reassigned. Band segments to be retained must also accommodate the pending loss of assignments in the lower adjacent band.

Of final note, most of the 1710 to 1855 MHz fixed point-to-point microwave systems in use today are legacy equipment from the 1970s and 1980s. Crystal oscillators and other components that may be required to retune their transmit and receive frequencies might not be commercially available any more.

Band segmentation is acceptable as long as the microwave system is capable of operating in that portion of the band.

E.1.3.2.3 Results Option 3 – Partial Band Segmentation/Other Band Combination (if viable). In a variation of Option 2, *Band Segmentation/Partial Band Sharing*, an opportunity does exist to employ spectrum between 1700 and 1710 MHz. This segment is currently allocated to the Government Fixed and Meteorological-Satellite (space-to-Earth) Services on a shared basis with similar Nongovernment services. By footnote (G118), Government fixed stations may be authorized in the 1700 to 1710 MHz band only if spectrum is not available in the 1710 to 1850 MHz band. It is likely this small segment of spectrum could be employed to accommodate displaced users of the 1710 to 1850 MHz bands, who could not readily be accommodated in band segments that are retained on an exclusive or shared basis between 1755 and 1850 MHz.

Additional issues are similar to those discussed under Results for Option 2.

E.1.3.2.4 Results Option 4 – Vacate 1755-1850 MHz. A significant amount of frequency spectrum is already allocated to the Government on an exclusive basis for Fixed Service operations in higher frequency ranges. The 4400 to 4990 MHz and 7125 to 8500 MHz bands are already employed by the DoD for fixed point-to-point microwave communications in CONUS. The median 1755 to 1850 MHz ACE point-to-point link length is 40 km. Fully 84% of these links are less than 64 km in length. Based on engineering judgement, point-to-point microwave equipment from the two alternate bands could replace existing 1710 to 1850 MHz equipment without the installation of additional antenna towers for links of 64 km or less in length. The remainder, whose length is between 64 and 120 km, are potentially long enough to require the installation of an additional antenna to complete the link. A scan of permanent frequency assignments for the 4400 to 4990 MHz band indicates all three DoD services employ the Terra-Com TCM-602 and TCM-620. A similar scan of the 7125 to 8500 MHz band indicates the DoD employs the Terra-Com TCM-604 (Air Force, Army, and Navy), Collins MW-518 (Air Force, Army, and Navy), Collins MDR-8-5N (Air Force), and the Alcatel MDR-4308 (Air Force and Navy). Much like the equipment DoD already employs in the 1755 to 1850 MHz band, most are legacy equipment from the 1970s and 1980s. A quick search of point-to-point microwave equipment, whose form and functions might suffice as replacement equipment, indicates the systems identified in Table E-5 are commercially available today. Lastly, consideration should also be given to the replacement of RF-based links with cable-based links. The use of fiber optic cable might prove to be a viable alternative for replacement of RF links in less remote regions of the CONUS.

Table E-5. Commercially Available Point-to-Point Microwave Equipment (commercial brochures and web pages)

Corporation	Model	Frequency Range	Purpose
Harris Corporation	Constellation™	7125 to 8275 MHz	Point-to-Point Digital
Alcatel	9647LH	4400 to 5000 MHz	Long Haul Digital Links
	9674LH	7125 to 7700 MHz	Long Haul Digital Links
	9681LH	7700 to 8400 MHz	Long Haul Digital Links
	MDR-6X07/08	7125 to 8500 MHz	Long Haul/Low Capacity
	MDR-4X05	4500 to 5000 MHz	Medium Capacity Digital
	MDR-4X08	7100 to 8500 MHz	Medium Capacity Digital

Vacating the band is an unnecessary option unless sharing or segmentation does not work. This should apply to individual links and not the microwave system as a whole. Those links situated in a high density IMT-2000 environment may need to be relocated in the spectrum. During any relocation, the current link must be kept operational until the new link is ready for cutover, to prevent remote facilities from being unmonitored.

E.2 POTENTIAL FOR INTERFERENCE TO AND FROM LAND WARRIOR

Land Warrior is a twenty-first century fighting system for military operations in urban terrain. Under development since 1991 by the US Army and Marine Corps, this system will integrate digital technologies into dismounted forward combat troops at the squad, platoon, and company level. Land Warrior incorporates advanced weaponry, communications, and intelligence systems into a composite, soldier-based fighting system. The primary subsystems include the M-16/M-4 Modular Carbine, integrated helmet assembly, protective clothing and integrated equipment, computer/radio, and software. The Land Warrior Wireless Local Area Network (WLAN) is designated as the communications portion of this system. A pre-production version of the system was successfully demonstrated in calendar year 2000; production quantities of Land Warrior are scheduled for delivery starting in calendar year 2003.

E.2.1 Operational Mission Overview

Land Warrior represents the next generation of combat capability for the soldier. The Land Warrior system is a close combat fighting system for infantrymen, combat medics, combat engineers, forward observers, and scouts. As a system, the soldier can both send and receive voice, video images, map overlay information, operational plan diagrams, etc. The system also provides situation awareness (SA) information among all team members, improves survivability, and increases lethality while reducing the soldier's load. The current maneuver forces have no such capability today at the lowest echelons.

Land Warrior is designed to enhance the 'situational awareness' of dismounted troops. Currently, this is accomplished through voice communications or hand signals. Land Warrior will supplement ordinary voice communications with video imagery and data transmissions. The resultant combination of communications capabilities will enable the squad leader to monitor troop progress and mission success. Conversely, Land Warrior will offer troops the capability to receive information formerly available to the squad leader alone. The Land Warrior WLAN is the sole communications subsystem through which all voice, data , and video imagery will be transmitted and received.

E.2.2 System Descriptions

The technical characteristics of the Land Warrior WLAN are identified in Table E-6. One parameter bears additional discussion. The LAN is basically a commercial-off-the-shelf item. The key difference is that its baseband has been downconverted to the 1750 to 1850 MHz band. The IEEE 802.11 channelization scheme it employs was devised to support direct-sequence spread spectrum wireless telephony in the 2400 to 2483.5 MHz industrial, scientific, and medical (ISM) band. These operations are type-certified in accordance with FCC Part 15. Eleven channels, spaced at 5-MHz intervals, constitute this channel plan between 2412 and 2462 MHz.[6] The frequency range of the downconverted Land Warrior WLAN channel plan lies between 1772 and 1822 MHz. In accordance with IEEE 802.11, a diphase binary phase-shift keyed modulation is applied with an 11-megachip per second chipping rate and a 1-megabit per second (Mb/s) bit rate. In practice, no more than three channels are available for use in close proximity to one another and the channel throughput is reduced from 11 Mb/s to something on the order between 2 and 5 Mb/s.[7]

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[6] *"The IEEE 802.11 Wireless LAN Standard"* [The Wireless LAN Association Web Page], Willoughby, OH, 2000 [cited 4 December 2000]. Available from http://www.wlana.com/learn/; INTERNET.

[7] J. Conover, *"Wireless LANS Work Their Magic"* [Network Computing – The Technology Solution Center Web Page], CMP Media, Incorporated, 10 July 2000 [cited 21 December 2000]. Available from http://www.networkcomputing.com/1113/1113f2.html; INTERNET.

Table E-6. Land Warrior WLAN Characteristics[8]

Frequency Range:	1750 to 1850 MHz
Mean Power:	2 watts
Emission Designator	20M0G9W
Emission Bandwidth (MHz)	10 (-3 dB), 20 (-20 dB), 35 (-40 dB), and 40 (-60 dB)
IF Bandwidth (MHz):	17 (-3dB), and 35 (-60 dB)
Receiver Noise Figure	7 dB
Receiver Sensitivity	-100 dBm (30 dB S/N)
Receiver Noise Power	-103 dBm
System Capacity:	11 overlapped channels (IEEE 802.11 channelization)
Antenna Gain:	6 dBi (Omnidirectional)
Antenna Height	1.5 m

E.2.3 Technical Assessment

Sharing between the Land Warrior WLAN and IMT-2000 systems was determined on a one-to-one basis. Distances beyond which compatible operations of these systems could be attained were calculated for all receiver and transmitter pairings. IMT-2000 base and mobile configurations were assessed. The IMT-2000 base station antennas was assessed as having a two-step antenna pattern comprised of mainbeam and median gain levels. The Land Warrior WLAN and IMT-2000 mobile station antennas were both assessed as having an omnidirectional antenna pattern.

The technical parameters for the IMT-2000 radios are presented elsewhere in this report. The IMT-2000 receiver thresholds were modified in the same manner described in the Tactical Radio Relay Assessment of Interference.

As was done in previous sections, an assessment was performed to quantify the distance separation at which compatible on-tune operations of the Land Warrior WLAN and IMT-2000 systems would exist. The necessary propagation loss to ensure compatible operations for mainbeam (MB) and median sidelobe (SL) antenna-to-antenna couplings was calculated by summing the corresponding transmitter power, transmitter and receiver antenna gain, and frequency dependent rejection. The corresponding receiver interference threshold was subtracted from this value to ascertain the minimum propagation path loss at which compatible operations would exist. Next, the Spherical Earth Model (SEM) was employed to calculate the distance separation between transmitter and receiver antennas, which would produce the minimum propagation path loss for the corresponding transmitter and receiver antenna pair.

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[8] *Land Warrior WLAN*, Application for Equipment Frequency Allocation (DD Form 1494) J/F 12/7786, October 2000.

Lastly, the frequency dependent rejection term was varied to introduce effects relating to off-tuned operations of the two systems. The IMT-2000 (transmitter) to Land Warrior WLAN (receiver) distance separation values beyond which compatible operations would exist are contained in Table E-7. The Land Warrior WLAN (transmitter) to IMT-2000 (receiver) distance separation values beyond which compatible operations would exist are contained in Table E-8.

Table E-7. IMT-2000 Transmitter to Land Warrior WLAN Receiver Distance Separations Beyond Which Compatible Operations Would Exist

Transmitter-to-Receiver Coupling		Distance Separation for Compatible Operations (km)			
IMT-2000	Land Warrior WLAN	CDMA(NB)	CDMA(WB)	ISM-136	GSM
Base MB	Mobile	38	38	38	38
Base SL	Mobile	28	28	28	28
Mobile	Mobile	2.5	2.5	2.5	2.5

Table E-8. Land Warrior WLAN Transmitter to IMT-2000 Receiver Distance Separations Beyond Which Compatible Operations Would Exist

Transmitter-to-Receiver Coupling		Distance Separation for Compatible Operations (km)			
Land Warrior WLAN	IMT-2000	CDMA(NB)	CDMA(WB)	ISM-136	GSM
Mobile	Base MB	34	34	34	34
Mobile	Base SL	23	23	23	23
Mobile	Mobile	5	5	5	5

The employment of frequency separation does reduce the distance separations beyond which compatible operations of the two systems would exist, albeit not very much. Table E-9 contains several discrete combinations of frequency and distance separation which would ensure compatible simultaneous operations. Note: the separations contained in Table E-9 pertain to the transmitter/receiver pairings which require the furthest separations. A review of the data indicates IMT-2000 base stations could not operate in close proximity to ranges where the Land Warrior WLAN is to be employed without prior frequency planning and coordination. Whereas off-frequency tuning will decrease the separation distance beyond which the two mobile stations could operate compatibly, its effects are minimal. However, on-tune operations of IMT-2000 mobile stations should be of little consequence to Land Warrior operations provided these two systems are separated by a small distance.

Table E-9. Frequency and Distance Separations Beyond Which Simultaneous Operations of the Land Warrior WLAN and IMT-2000 Would Exist

Frequency Separation (MHz)	Distance Separation (km)		
	Base MB	Base SL	Mobile
0.0	38	27	5
4.5	38	27	4.5
5.0	38	27	4.1
6.0	38	27	3.1
7.0	38	27	2.5
8.0	38	26	2.4
9.0	32	22	1.7
10.0	25	16	1.5
15.0	6	2.0	0.6
20.0	2.4	0.5	0.2

E.2.3.1 Results Option 1 – Full Band sharing

Simultaneous on-tune operations of IMT-2000 and the Land Warrior WLAN might be practicable if certain geographic constraints can be established. IMT-2000 base stations must not be installed within 40 km of the perimeter of military test and training facilities where Land Warrior WLAN operations will be authorized. The likelihood this requirement could be fulfilled is reasonable. Additionally, IMT-2000 connectivity must be prohibited within the confines of these same facilities. The likelihood this requirement could be fulfilled is far from certain as it may be impossible to police such a prohibition. While potentially practicable, full band sharing poses too much risk.

Potential risk mitigation techniques applicable to full or partial band sharing would require the Army, in conjunction with the IMT-2000 industry, to develop acceptable frequency use coordination procedures and implement them in software in the Integrated System Control (ISYSCON) (used by tactical forces during training and to coordinate sharing with line-of-sight (LOS) radio networks) and Spectrum XXI (for use by Army frequency managers to work frequency assignments). Although this option appears attractive, the restrictions for sharing, such as limiting operations, locations, and link length, may inhibit the full use of this system by the Army. The restrictions may end up being unworkable at some locations and would require software supportability through ISYSCON and Spectrum XXI. If the Army wants to train as it fights, limiting the size and scope of the training exercises is counterproductive. Large-scale maneuver of forces for training is already limited to specific locations. Also, Army Guard and Reserve unit training at home locations will be similarly affected.

E.2.3.2 Results Option 2 – Band segmentation/partial band sharing

Simultaneous operations of IMT-2000 and the Land Warrior WLAN in segregated portions of spectrum are more practicable than full band sharing. The amount of frequency separation that will be required to ensure compatible operations will depend on the relative location where Land Warrior WLAN operations are authorized. If the location of these operations is well within the perimeter of a military test or training facility, no further coordination would be required; otherwise, some form of coordination may be required to ensure IMT-2000 base station operations do not pose conflicts. No matter the location, IMT-2000 mobile operations must still be prohibited within the immediate vicinity of the area where Land Warrior WLAN operations are authorized.

One requirement that must still be addressed is the number of Land Warrior WLAN channels that will be required to support a given test or exercise. As was stated previously, no more than three Institute of Electrical and Electronics Engineers (IEEE) 802.11 channels are available for collocated use irrespective of band segmentation. The implementation of band segmentation could further reduce the number of available channels such that the full capability of the Land Warrior WLAN is unattainable during test and training operations. The likelihood that multiple Land Warrior WLANs will be required to operate in the same environment must be ascertained.

The 50-MHz block would give the current Land Warrior radio reduced room to operate and will continue to require close frequency coordination in ISYSCON and Spectrum XXI for sharing the band with LOS radio networks.

E.2.3.3 Results Option 3 – Partial band segmentation/Other band combination (if viable*)*

The current design of the Land Warrior WLAN is such that it is only capable of tuning within the 1772 to 1822 MHz sub-band. Given the current system design, it would not be possible to combine the use of band segments in adjacent spectrum with band segments in the 1755 to 1850 MHz to fulfill Land Warrior WLAN operational requirements.

This option frees up 10 MHz more, but the same restrictions and coordination issues apply. See Option 2.

E.2.3.4 Results Option 4 – Vacate 1755-1850 MHz

The current Land Warrior WLAN frequency band is a compromise between competing requirements. The band must support omnidirectional connectivity between soldiers. Spectrum below 2000 MHz most readily accommodates this requirement without the use of complicated antenna arrays. Such arrays would be prohibitively difficult to integrate into the vest that houses the bulk of the Land Warrior system on the warfighter’s body. The use of spectrum below 1000 MHz would pose a similar difficulty as the antenna size would be too large to integrate effectively and factors associated with body loading would be a concern. To minimize development costs and risk, a choice was made to employ a commercial-off-the-shelf (COTS) RF assembly as the heart of the baseband local area network (LAN) system. Initially designed to operate in the 2400 to 2483.5 MHz band, the frequency band of this assembly is downconverted to reach the 1755 to 1850 MHz band. System weight is already nearing its maximum level. No more batteries can be integrated without surpassing the Land Warrior system weight requirement, yet power remains to be a concern as the LAN subsystem just meets its range requirement of 1.3 kilometers. The resultant choice of Government exclusive spectrum between 1755 and 1850 MHz successfully fulfilled the majority of these system requirements.

Little spectrum exists between 1000 and 2000 MHz to accommodate the Government Mobile Services on a primary or secondary basis. Excluded through recent or pending reallocation initiatives in accordance with OBRA-93 mandates are 1427 to 1429 MHz, and 1710 to 1755 MHz. Included are 1350 to 1400 MHz, 1432 to 1435 MHz, and 1435 to 1535 MHz.

The 1350 to 1400 MHz band is allocated to the Government Mobile Services on a primary basis between 1350 and 1390 MHz and on a secondary basis between 1390 and 1400 MHz. Both domestically and internationally, spectrum in the lower and upper adjacent bands is not allocated to accommodate the Mobile Services on any basis.

Thus, there is insufficient spectrum to accommodate all eleven channels of the COTS baseband RF assembly. As was discussed under band segmentation options, no more than three of eleven IEEE 802.11 channels are available for collocated use given the full operational band is available for use. The use of any sub-band could further reduce the number of available channels even further. The full capability of the Land Warrior system might be unattainable if multiple Land Warrior WLAN nets are required to operate in the same environment simultaneously.

The 1432 to 1435 MHz is much too small in bandwidth to accommodate a single Land Warrior WLAN channel.

The 1435 to 1535 MHz band is allocated to the Government Mobile Services on a primary basis between 1435 and 1525 MHz and on a secondary basis between 1525 and 1535 MHz. Unfortunately, aeronautical telemetry (ATM) is the only Mobile Service authorized in these band segments. In accordance with US footnote 78 (US 78), the frequencies between 1435 and 1535 MHz will be assigned for ATM and associated telecommand operations for flight testing of manned or unmanned aircraft and missiles, or their major components. Permissible usage is defined to include telemetry associated with launching and reentry into the earth's atmosphere as well as an incidental orbiting prior to reentry of manned objects undergoing flight tests. The DoD test and evaluation (T&E) community has become increasingly defensive of the spectrum that remains to support ATM operations in CONUS. They contend their spectrum requirements will exceed the amount of spectrum allocated to their operations in the next few years given the projected amount of data they expect to download during future single aircraft and multiple-aircraft flight tests. Insufficient spectrum will result in increased aircraft development program costs when testing schedules are slipped or stretched in duration. The allocation status of this band must be satisfactorily addressed before any attempt is made to expand the existing allocation to include the ground-based mobile services, even for an operation so low-powered and short-range as the Land Warrior WLAN. On a more positive note, spectrum between 1427 and 1525 MHz is allocated internationally to the Mobile Services on a primary basis, which would be conducive to Land Warrior WLAN outside the continental US (OCONUS) operations.

Fully vacating the band is not acceptable for the Land Warrior, since it will require redesigning of the radio. Depending upon the new band, this may have a severe impact on the ability of the system to meet its required 1.3 km operating range (on open, flat, uncluttered terrain). However, if the Land Warrior was forced to migrate to another portion of the spectrum, then the optimum plan/schedule for implementing such a move is now. The system is fast paced and will be building 41,000 units beginning in FY03. Any move decision would delay the schedule about six months. The radio and antenna will have to be redesigned and system testing reaccomplished. Evolutionary growth of the system through field testing will be interrupted if Land Warrior is forced to move to another band. The impact to current operations is none, but the impact to our future soldiers is unknown at this time and requires further study.

E.3 POTENTIAL FOR INTERFERENCE TO AND FROM CIDDS

Combat identification is the ability to differentiate friend, foe, or neutral, with high confidence, beyond engagement range, and in sufficient time to support successful engagement and weapon release decisions. Several means by which combat identification is performed include RF interrogation, laser interrogation, and electronic surveillance measures. Dismounted ground-maneuver forces traditionally have employed vision-oriented means to perform combat identification. The range at which positive identification can be reliably accomplished through visual means, relative to the range of the forces weaponry, is considered to be marginal in daylight conditions and inadequate in darkness, foul weather, or when vision is compromised by obscurants or smoke. The CIDDS system is being developed to improve the ability of dismounted forces to aid in the determination of friendly and unfriendly dismounted forces. An engineering and manufacturing development (E&MD) program since 1997, this program will culminate in the delivery of fifty CIDDS units prior to the initiation of low-rate initial production (LRIP). Current projections indicate as many as 100,000 CIDDS units will be procured at the outset to full-scale production.[9]

E.3.1 Operational Mission Overview

The purpose of CIDDS is to help prevent friendly forces from firing on friendly forces, otherwise known as fratricide. CIDDS represents a huge leap forward in reducing fratricide among our forces. CIDDS is a laser interrogate, RF response system designed to provide identification of friendly forces by individual and automatic weapons users to a range of 1000 meters or more, depending on visual conditions. The system is used by forward combat forces, in both open terrain and urban areas. The laser interrogation signal message identifies a set of random frequency channels for the transponder to use in its response. The CIDDS is to be employed by combat, combat support, and combat service support soldiers. The CIDDS will be used to supplement existing target identification procedures, enhance Situational Awareness, and help prevent the attack of friendly soldiers which may have been attacked under existing rules of engagement. The combination of existing target identification techniques and CIDDS will reduce fratricide and increase soldier survivability. Fratricide represented a not so insignificant portion of the combat deaths experienced in Operation DESERT STORM. Any opportunity to reduce this potential loss of life is considered critical to the combatant commanders.

CIDDS is a secure laser interrogation and RF response system which will permit the warfighter to ascertain whether a targeted individual is friendly or unknown. In concert with existing visual-based means, CIDDS will complement target identification procedures, but will not be employed as the sole determinant for target identification. Warfighters from all three DoD services may eventually be equipped with CIDDS to support a broad gamut of military operations. Employable as a stand-alone capability or an integral capability within the Land Warrior System, CIDDS will fill a long-lasting identification gap, and, it is hoped, increase survivability while reducing fratricide.

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[9] "Combat ID Dismounted Soldier," [USA PM CI Web Page], Ft Monmouth, NJ, August 2000 [cited 20 November 2000]. Available from http://peoiews.monmouth.army.mil/ci/; INTERNET.

E.3.2 System Descriptions

The CIDDS system has two major component groups.[10] The weapon-mounted subsystem contains an infrared (IR) laser interrogator, radio receiver, IR aiming laser, and Multiple Integrated Laser Engagement System-compatible laser. The helmet-mounted subsystem contains laser detectors, flat-patch antennae, and a radio transmitter. When a soldier spots a target, he activates the CIDDS laser. The laser interrogator directs its beam towards the unknown target. If the target is CIDDS-equipped (i.e., friendly), their helmet-mounted laser detectors will decode the interrogating signal, and enable an encoded radio response from the CIDDS radio transmitter, thus identifying the target as friendly. The helmet transmitter employs redundant transmissions on three frequencies to increase the probability of identification.[11] The combined interrogation and response time is less than one second. The weapon-borne radio receiver of the interrogating soldier and the helmet-borne transmitter of the responding soldier are the two CIDDS components which employ the 1755 to 1850 MHz band. The weapon-borne receiver employs a directional receive antenna; the helmet-borne transmitter employs four patch antennas whose combined coverage approximates an omnidirectional pattern. The technical characteristics of CIDDS are identified in Table E-10.

Table E-10. CIDDS Characteristics

Frequency Range:	1755 to 1850 MHz
Mean Power:	1 watts
Emission Designator	37K8F1D
Emission Bandwidth (kHz)	19 (-3 dB), 53 (-20 dB), 161 (-40 dB), and 506 (-60 dB)
IF Bandwidth (kHz):	25 (-3dB), 150 (-20dB), and 500 (-60 dB)
Receiver Noise Figure	7 dB
Receiver Sensitivity	-108 dBm (0.01 bit error rate; 16 dB S/N)
Receiver Noise Power	-129 dBm
Channelization:	From 1755.0125 MHz in 25 kHz increments
Antenna Gain (transmit):	+2 dBi
Antenna Gain (receive):	+6 dBi (mainbeam); –3 dBi (sidelobe)
Antenna Height	1.5 m

[10] *"Combat Identification Systems"* [Motorola Corporation Integrated Systems Division Web Page], Scottsdale, AZ, 2000 [cited 27 December 2000]. Available from http://www.motorola.com/GSS/SSTG/ISD/ws/cidds.html; INTERNET.

[11] *Combat Identification for the Dismounted Soldier*, Application for Equipment Frequency Allocation (DD Form 1494) J/F 12/7554, 12 August 1998.

E.3.3 Technical Assessment

Sharing between CIDDS and IMT-2000 systems was determined on a one-to-one basis. Distances beyond which compatible operations of these systems could be attained were calculated for all receiver and transmitter pairings. IMT-2000 base and mobile configurations were assessed. The IMT-2000 base station antennas were assessed as having a two-step antenna pattern comprised of mainbeam and median gain levels. The CIDDS helmet-borne transmit antenna and IMT-2000 mobile station antennas were both assessed as having omnidirectional antenna patterns. The CIDDS weapon-borne receive antenna was modeled as having a two-step antenna pattern due to reflect its directionality.

The technical parameters for the IMT-2000 radios are presented elsewhere in this report. The IMT-2000 receiver thresholds were modified in the same manner described in the Tactical Radio Relay assessment of interference.

As was done in previous sections, an assessment was performed to quantify the distance separation at which compatible on-tune operations of CIDDS and IMT-2000 systems would exist. The necessary propagation loss to ensure compatible operations for mainbeam (MB) and median sidelobe (SL) antenna-to-antenna couplings was calculated by summing the corresponding transmitter power, transmitter and receiver antenna gain, and frequency dependent rejection. The corresponding receiver interference threshold was subtracted from this value to ascertain the minimum propagation path loss at which compatible operations would exist. Next, the Spherical Earth Model (SEM) was employed to calculate the distance separation between transmitter and receiver antennas, which would produce the minimum propagation path loss for the corresponding transmitter and receiver antenna pair. Lastly, the frequency dependent rejection term was varied to introduce effects relating to off-tuned operations of the two systems. The IMT-2000 (transmitter) to CIDDS (receiver) distance separation values beyond which compatible operations would exist are contained in Table E-11. The CIDDS (transmitter) to IMT-2000 (receiver) distance separation values beyond which compatible operations would exist are contained in Table E-12.

Table E-11. IMT-2000 Transmitter to CIDDS Receiver Distance Separations Beyond Which Compatible Operations Would Exist

Transmitter-to-Receiver Coupling		Distance Separation for Compatible Operations (km)			
IMT-2000	CIDDS	CDMA(NB)	CDMA(WB)	ISM-136	GSM
Base MB	Mobile MB	48	44	60	55
Base SL	Mobile MB	36	32	50	44
Mobile	Mobile MB	5	4	10	7
Base MB	Mobile SL	40	36	53	48
Base SL	Mobile SL	28	25	42	36
Mobile	Mobile SL	3	2	7	4

Table E-12. CIDDS Transmitter to IMT-2000 Receiver Distance Separations Beyond Which Compatible Operations Would Exist

Transmitter-to-Receiver Coupling		Distance Separation for Compatible Operations (km)			
CIDDS	IMT-2000	CDMA(NB)	CDMA(WB)	ISM-136	GSM
Mobile	Base MB	36	32	51	43
Mobile	Base SL	25	21	39	32
Mobile	Mobile	6	4	12	9

The separation distances beyond which compatible on-tune operations will result are relatively large, when compared to the assessment of Land Warrior WLAN compatibility, for all couplings involving IMT-2000 base station operations. The distance separations beyond which compatible on-tune operations of IMT-2000 mobile station and CIDDS will result are significantly less and appear to be more readily attainable. Given these results, it appears unlikely that simultaneous on-tune operations can be authorized without some form of prior geographic coordination.

The employment of frequency separation does reduce the distance separations beyond which compatible operations of the two systems would exist. Table E-13 contains several discrete combinations of frequency and distance separation which would ensure compatible simultaneous operations. Note: the separations contained in Table E-13 pertain to the transmitter/receiver pairings which require the furthest separations, irrespective of transmitter and receiver assignation as well as IMT-2000 modulation. No attempt was made to differentiate between the mainbeam and sidelobe gain levels of the CIDDS receive antenna in Table E-13 as its beamwidth (60 degrees), coupled with its mobility, were assumed representative of an omnidirectional antenna pattern in this summary of off-tuned results.

Table E-13. Frequency and Distance Separations Beyond Which Compatible Operations of CIDDS and IMT-2000 Would Exist

Frequency Separation (MHz)	Distance Separation (km)		
	Base MB	Base SL	Mobile
0.0	60	50	12
2.0	29	19	2.1
3.0	10	5	0.7
4.0	4.9	1.3	0.3
5.0	3.6	0.8	0.2
6.0	3.1	0.7	0.2

A review of the data indicates IMT-2000 base and mobile stations could not operate in close proximity to ranges where CIDDS is to be employed without prior frequency planning and coordination. However, frequency separation considerably decreases the separation distance beyond which the two mobile stations could operate compatibly.

E.3.3.1 Results Option 1 – Full Band sharing

Simultaneous operations of IMT-2000 and CIDDS might be practicable if certain geographic or frequency constraints can be established. For on-tune operations, IMT-2000 base stations must not be installed within 60 km and IMT-2000 mobile stations must not be employed within 12 km of military test and training facilities where CIDDS operations will be authorized. For off-tuned operations, these distance requirements would be relaxed considerably although IMT-2000 connectivity must be prohibited within several kilometers of CIDDS operating areas given frequency separations of several megahertz. The likelihood either of these requirements could be fulfilled is far from certain as it may be impossible to police a prohibition on IMT-2000 use on military bases. While potentially practicable, full band sharing poses too much risk.

Full band sharing may be acceptable but would require the Army, in conjunction with the IMT-2000 industry, to develop acceptable frequency use coordination procedures and implement them in software on the ISYSCON (for use by the tactical forces during training and to coordinate sharing with the line of sight radio network) and Spectrum XXI (for use by Headquarters Army and installation spectrum managers to work day-to-day issues). Some adaptation would be needed to the CIDDS system to ease the frequency selection and assignment process. However, although this option looks attractive, frequency use and location restrictions may inhibit the Army's CIDDS training.

If the amount of frequencies available limits the size and scope of the training exercises, or if the propagation restrictions forces limits where in the training ranges CIDDS can be used, this will reduce effective CIDDS training. Limiting operations, locations, link lengths, and size of the exercise would be counterproductive to the purpose of the training. Large-scale maneuver of forces for training is already limited to certain locations in the US. The major operational concern with this option is that if CIDDS is limited to a single RF channel, it will affect performance and may actually increase the probability of fratricide. CIDDS relies on frequency agility to decrease RF collisions and increase probability of correct identification.

E.3.3.2 Results Option 2 – Band segmentation/partial band sharing

Simultaneous operations of IMT-2000 and CIDDS in segregated portions of spectrum are more practicable than full band sharing. The amount of frequency separation that will be required to ensure compatible operations will depend on the relative location where CIDDS operations are authorized. If the location of these operations is well within the perimeter of a military test or training facility, little further coordination would be required; otherwise, some form of coordination will be required to ensure IMT-2000 base station operations do not pose conflicts. One unknown of this estimation is CIDDS frequency reuse. Each CIDDS equipment requires three discrete relatively-narrow (38 kHz occupied bandwidth) channels for response to interrogation. The total number of frequencies that will be required to support a large-scale training exercise is unknown. Attempts to segment the 1755 to 1850 MHz band to accommodate CIDDS operations must include consideration for the sum total spectrum required to stage the operation as well as the upper and lower guardbands to ensure compatibility with IMT-2000 operations.

Partial band sharing would pose the same risks as full band sharing and are not recommended for consideration for the same reasons.

The use of 50 MHz gives the current CIDDS radio some room to operate without having to shift bands but will continue to require close frequency coordination in ISYSCON for sharing the band with LOS radio networks. See Option 1.

E.3.3.3 Results Option 3 – Partial band segmentation/Other band combination (if viable)

The current design of CIDDS is such that it is only capable of tuning within the 1772 to 1822 MHz sub-band. Given the current system design, it would not be possible to combine the use of band segments in adjacent spectrum with band segments in the 1755 to 1850 MHz to fulfill CIDDS operational requirements.

Additional issues are similar to those discussed under Results for Option 2.

E.3.3.4 Results Option 4 – Vacate 1755-1850 MHz

The current CIDDS frequency band is a compromise between competing requirements. The band must support omnidirectional connectivity between soldiers, but must be capable of supporting the use of small, weapon-borne, directional antennas for receipt of responses to laser interrogation. Spectrum below 2000 MHz most readily accommodates omnidirectional connectivity. Spectrum above 1000 MHz most readily accommodates the use of small, directional antennas. CIDDS must also be interoperable with the combat identification capability of the Land Warrior system, which shares use of this band. The resultant choice of Government exclusive spectrum between 1755 and 1850 MHz successfully fulfilled the majority of these system requirements.

Little spectrum exists between 1000 and 2000 MHz to accommodate the Government Mobile Services on a primary or secondary basis. Excluded through recent or pending reallocation initiatives in accordance with OBRA-93 mandates are 1427 to 1429 MHz, and 1710 to 1755 MHz. Included are 1350 to 1400 MHz, 1432 to 1435 MHz, and 1435 to 1535 MHz.

The 1350 to 1400 MHz band is allocated to the Government Mobile Services on a primary basis between 1350 and 1390 MHz and on a secondary basis between 1390 and 1400 MHz. The same tactical radio-relay systems that operate in the 1755 to 1850 MHz band employ this band. Compatibility concerns with these systems are considered doubtful for this reason. Fixed-frequency long-range surveillance radars also employ this band, but conflicts with the aforementioned radio-relay operations have already been deconflicted in CONUS and it is likely CIDDS equipment will be employed at the same military training areas where radio-relay operations are authorized. Airborne target control and range applications datalinks employ this band, too. While these systems are not electronically identical to the weapons datalinks and air combat training systems in use in the 1755 to 1850 MHz band, their operations are believed to be representative of one another and their collocated operations may prove equally benign to one another. The one contrary note is that the 1350 to 1400 MHz band will not support operations of the Land Warrior system with which CIDDS must be interoperable.

The 1432 to 1435 MHz band is not capable of adequately supporting CIDDS operations in providing accuracy of correct identification (ID). The same radio relay and datalink systems whose operations were addressed in the previous paragraph employ this band as well.

The 1435 to 1535 MHz band is allocated to the Government Mobile Services on a primary basis between 1435 and 1525 MHz and on a secondary basis between 1525 and 1535 MHz. Unfortunately, aeronautical telemetry (ATM) is the only Mobile Service authorized in these band segments. In accordance with US footnote 78 (US 78), the frequencies between 1435 and 1535 MHz will be assigned for ATM and associated telecommand operations for flight testing of manned or unmanned aircraft and missiles, or their major components. Permissible usage is defined to include telemetry associated with launching and reentry into the earth's atmosphere as well as an incidental orbiting prior to reentry of manned objects undergoing flight tests. The DoD test and evaluation (T&E) community has become increasingly defensive of the spectrum that remains to support ATM operations in CONUS. They contend their spectrum requirements will exceed the amount of spectrum allocated to their operations in the next few years given the projected amount of data they expect to download during future single aircraft and multiple-aircraft flight tests. Insufficient spectrum will result in increased aircraft development program costs when testing schedules are slipped or stretched in duration. The allocation status of this band must be satisfactorily addressed before any attempt is made to expand the existing allocation to include the ground-based mobile services, even for an operation so low-powered and short-range as CIDDS. On a more positive note, spectrum between 1427 and 1525 MHz is allocated internationally to the Mobile Services on a primary basis, which would be conducive to CIDDS OCONUS operations.

Vacating the band will require a re-engineering effort on CIDDS, which is due to begin field testing in Summer 2001. Delaying the deployment of CIDDS will increase the opportunity that our front line soldiers will continue to fight without a fratricide prevention system.

E.4 POTENTIAL FOR INTERFERENCE BETWEEN IMT-2000 AND UNMANNED AERIAL VEHICLES

A number of UAVs, such as the Pointer (FQM-151A) and the Exdrone (BQM-147A), currently use spectrum between 1755 and 1850 MHz. These systems transmit video and status data from the UAV to the GCS using analog FM video and data on subcarriers.

This section addresses the potential for interference between IMT-2000 base and mobile stations and the UAV systems operating in the 1755 to 1850 MHz band, identifies possible electromagnetic interference (EMI) interactions, and offers recommendations on how to obtain electromagnetic compatibility (EMC).

For this assessment, systems that operate within the 1350 to 1380, 2200 to 2290, and 4400 to 4940 MHz frequency bands and are located within 200 nmi of China Lake were identified using the JSC Frequency

Usage database. After compiling a complete listing of systems, the list was reduced to a number of key systems. Mitigation techniques and interference link budget analyses were completed to determine if the IMT-2000 systems operating in the 1755 to 1850 MHz band would interfere with the UAVs and to determine if migrating the UAVs to a different frequency band, such as the 1350 to 1380, 2200 to 2290, or 4400 to 4940 MHz band, would result in possible EMI.

E.4.1 Operational Mission Overview

The Pointer UAV is a production-ready, electric, hand launched UAV designed for remote monitoring and surveillance. The 8.5 pound UAV transmits real-time video to the pilot and observer on the ground as well as remote viewing stations, using a black and white color, or thermal cameras. A variety of alternative payloads such as air pollution sensing, chemical weapons detection, and unexploded land mine detection are currently being developed. The Pointer can carry a 1.5 pound payload and can operate for 60 minutes on a non-rechargeable battery, or for 45 minutes with a rechargeable battery. The Pointer has an operational range of 5-10 km.

E.4.2 System Descriptions

Characteristics of the FQM-151A and BQM-147A systems are identified in Tables E-14 and E-15. The data values were obtained from the frequency allocation applications, unless noted otherwise. Parameters of the BQM-147A downlink receiver were not available; however, the values were estimated to be the same as those for the FQM-151A downlink receiver. For transmitter emission bandwidths and receiver intermediate frequency (IF) bandwidths, as well as harmonic and spurious levels, the DD Form 1494 values were used instead of the specified values. The specified values represented a limit not to be exceeded, while the 1494 values more closely represented actual system characteristics. The BQM-147A specified, nominal maximum range is 50 km (31.1 mi, 27.0 nm), and the FQM-151A communications range is 5 km (3.1 mi, 2.7 nm). The potential number of aerial vehicles in simultaneous operation is three and five for BQM-147A and FQM-151A, respectively. Altitudes of 10,000 ft (3048 m) and 1,000 ft (305 m) were used for the BQM-147A and FQM-151A, respectively. The IMT-2000 parameters used in the calculations are identified in Tables A-4 and A-5.

Table E-14. BQM-147A and FQM-151A Airborne Transmitter Characteristics

Transmitter Characteristics		
Platform	BQM-147A	FQM-151A
Frequencies in MHz	1755 – 1850 MHz	1737.5, 1787.5, and 1837.5 MHz
Power in W	10	1
Emission Bandwidth in MHz		
-3 dB	3.0	8.7
-20 dB	15.0	19.9
-60 dB	29.1	40.7
Harmonic Attenuation in dB	65	55
Spurious Attenuation in dB	80	55
Antenna Characteristics		
Type	Yagi	Dipole
Gain in dBi	2	2
Polarization	V	V
Height in ft	10,000	1,000

Table E-15. BQM-147A and FQM-151A Ground Receiver Characteristics

Receiver Characteristics		
Platform	BQM-147A	FQM-151A
Sensitivity in dBm	*	-76 (20 dB S/N)
Noise Level in dBm	*	-96.0
RF Bandwidth in MHz		
-3 dB	*	150
-20 dB	*	210
-60 dB	*	280
1st IF Receiver Selectivity in MHz		
-3 dB	*	60
-20 dB	*	90
-60 dB	*	135
2nd IF Receiver Selectivity in MHz		
-3 dB	*	20
-20 dB	*	24
-60 dB	*	28
Spurious Response in dB	*	60
Antenna Characteristics		
Type	Yagi	Yagi
Gain in dBi	15	14
Polarization	V	V
Height in ft	6	6
* BQM-147A data not available, assumed identical to FQM-151A		

E.4.3 Option 1 – Full Band Sharing

E.4.3.1 Technical Assessment

To analyze interference from IMT-2000 into BQM-147A and FQM-151A ground-based receivers, the required separation distance to preclude interference into a ground receiver from a single IMT-2000 base and mobile transmitter was calculated. The BQM-147A and FQM-151A operational range is link-margin limited. It was assumed that the maximum range between ground-based and airborne equipment, which determines the maximum aircraft-to-aircraft separation, cannot be reduced by more than ten percent due to interference from IMT-2000 systems. This condition equates to an allowed degradation in the UAV link margins of approximately 1 dB and an I/N of -6 dB.

Interference between ground-based transmitters and receivers was calculated using Equation E-1:

$$I = P_T + G_T + G_R - L_P - L_S - FDR \qquad \text{(E-1)}$$

where

I	=	interference power in receiver, in dBm
P_T	=	transmitter power, in dBm
G_T	=	transmitter antenna gain in direction of receiver, in dBi
G_R	=	receiver antenna gain in direction of transmitter, in dBi
L_P	=	propagation loss, in dB
L_S	=	system losses, in dB
FDR	=	frequency-dependent rejection, in dB.

The interference power (I) was set to a maximum allowable value, the interference threshold I_t, which for the BQM-147A and FQM-151A GCS receiver is 6 dB below the receiver noise level.

Equation E-1 was rearranged to:

$$L_P = P_T + G_T + G_R - L_S - FDR - I_t \qquad \text{(E-2)}$$

where

L_P	=	propagation loss, in dB
P_T	=	transmitter power, in dBm
G_T	=	transmitter antenna gain in direction of receiver, in dBi
G_R	=	receiver antenna gain in direction of transmitter, in dBi
L_S	=	system losses, in dB
FDR	=	frequency-dependent rejection, in dB
I	=	interference power in receiver, in dBm.

Frequency-dependent rejection (FDR) for the on-tune cases considered here is given by Equation E-3:

$$FDR = 10 \log (B_t/B_r) \quad \text{for } B_t > B_r$$
$$0 \quad \text{for } B_t \leq B_r \qquad (E\text{-}3)$$

where

B_t = transmitter 3-dB emission bandwidth, in Hertz

B_r = highest-order intermediate frequency 3-dB receiver bandwidth, in Hertz.

The required separation distances to preclude interference between the IMT-2000 mobile and base receivers verses the BQM-147A and FQM-151A airborne transmitters, and the BQM-147A and FQM-151A GCS receivers verses the IMT-2000 mobile and base transmitters, were calculated using the required propagation loss from Equation E-2 and the JSC Inverse Smooth Earth Model (ISEM). Antenna heights used were: 40 m for the IMT-2000 base station transmitter and receiver, 1.5 m for the IMT-2000 mobile transmitter and receiver, 2 m for the BQM-147A and FQM-151A receivers, 3048 m for the BQM-147A transmitter, and 305 m for the FQM-151A transmitter.

E.4.3.2 Results

The required separation distances between the IMT-2000 mobile and base transmitters and the BQM-147A, FQM-151A GCS receivers are given in Table E-16. The required separation distances between the BQM-147A and FQM-151A airborne transmitters and the IMT-2000 mobile and base receivers are given in Table E-17.

Table E-16. Distances, in km, from IMT-2000 Transmitters to Preclude Interference to BQM-147A and FQM-151A GCS Receivers

Platform	IMT-2000 Station	
	Mobile	Base
BQM-147A	1.2	29.2
FQM-151A	1.2	28.4

Table E-17. Distances, in km, from BQM-147A and FQM-151A Airborne Transmitters to Preclude Interference to IMT-2000 Receivers

	IMT-2000 Station					
	Mobile			Base		
	CDMA WB	CDMA NB	TDMA	CDMA WB	CDMA NB	TDMA
Platform	IMT-2000 Interference Criterion I/N = -6 dB					
BQM-147A	236.2	235.8	222.3	269.5	270.2	260.9
FQM-151A	65.6	65.1	53.0	99.5	100.4	89.4
Platform	IMT-2000 Interference Criterion for S = Sensitivity + 10 dB					
BQM-147A	185.6	184.6	97.1	242.1	243.1	92.8
FQM-151A	30.1	29.6	9.7	32.6	35.3	9.3
Platform	IMT-2000 Interference Criterion for S = Sensitivity + 20 dB					
BQM-147A	107.7	162.5	30.6	102.9	111.5	29.2
FQM-151A	10.8	10.4	3.1	10.3	11.2	2.9
NB = Narrow Band WB = Wide Band I/N = Interference to Noise ratio						

E.4.3.3 Operational Impact

Sharing would be acceptable and possibly workable but would require the Army, in conjunction with the IMT-2000 industry, to develop frequency use coordinating procedures. There may some restrictions for use that may limit the effectiveness of the system. Given the nature of the Pointer UAV and its concept of operations for close in aerial surveillance, coordination with other civilian users seems possible.

E.4.4 Options 2 and 3 – Band Segmentation/Partial Band Sharing/Other Band Combination

E.4.4.1 Technical Assessment

It was proposed to segment the current 1755 to 1850 MHz frequency band to allow concurrent operations of the UAV systems and IMT-2000 equipment. In subsection E.4.3, the IMT-2000 and UAV systems were assumed to be on-tune. Here, the 1755 to 1805 MHz portion of the band would remain allocated to UAV systems, and either the 1805 to 1850 MHz or 1755-1790 MHz portion would be allocated to the IMT-2000 systems.

E.4.4.2 Results

If the 1755 to 1850 MHz frequency band is segmented into adjacent bands, where one segment is strictly allocated to the UAV systems and the other segment is allocated to the IMT-2000 systems, the effect of frequency separation between the two systems decreases the minimum required separation to preclude EMI. With the reduction in bandwidth, only two BQM-147A and FQM-151A can operate simultaneously. Use of two aerial vehicles will require channel spacing of at least 21 MHz, resulting in minimal spectrum remaining for other systems. Frequency separation of at least 10 MHz and 14 MHz is required between UAV systems and mobile and base stations, respectively, to achieve compatible IMT-2000 operations.

Option three consisted of utilizing a portion of the 1755-1850 MHz frequency for shared IMT-2000 and UAV use and utilizing a separate band for UAV use. The single air-to-ground data link mission can only be accomplished in one contiguous band. Therefore, option three is not feasible.

E.4.4.3 Operational Impact

The 50 MHz would give the Pointer UAV video and telemetry space to operate without having to shift bands. It will still require close frequency coordination for sharing the remaining portions of the band with other DoD systems.

E.4.5 Option 4 – Vacate 1755-1850 MHz

E.4.5.1 Migrating to the 1350-1390 MHz Frequency Band

The systems located within the electromagnetic environment (EME) are listed in Table E-18. The analyzed 1350 to 1390 MHz systems are identified below.

Table E-18. Systems Located Within the EME

Nomenclature	Number of systems active
AN/GRC-226	7
AN/GRC-226 (V)	2
AN/GRC-50	10
AN/PPQ-2	3
AN/TPS-59	2
Gulf Range Drone Control System (GRDCUS)	3
Nuclear Detonation Detection System (NDS)	7
QUC101002	17
QUC1011002	1

Table E-19 lists transmitter characteristics of primary 1350 to 1390 MHz systems, and Table E-20 lists the receiver characteristics of the 1350 to 1390 MHz systems.

Table E-19. 1350-1390 MHz Systems Transmitter Characteristics

Transmitter Characteristics						Antenna Characteristics	
Platform	Frequency (MHz)	Power (W)	Emission Bandwidth (MHz)			Gain (dB)	Polarization
			-3 dB	-20 dB	-60 dB		
AN/FPS-108 NB	1175-1375	16.8×10^6	5.0	10.0	200	47.9	V
AN/FPS-108 WB	1175-1375	16.8×10^6	190	200	300	47.9	V
AN/FPS-117 NB	1215-1400	4×10^3	0.625	0.8	4.6	39.1	V
AN/FPS-117 WB	1215-1400	4×10^3	1.25	1.8	19.2	39.1	V
AN/FPS-124	1218-1398	700	3.0	19.0	597	30.9	V
AN/GRC-103	1350-1849	120	0.3	0.7	3.0	16	V
AN/GRC-226	1350-1850	5	1.0	2.0	6.0	20	V
AN/MRC-142	1350-1850	3	0.45	1.05	3.16	20.3	V
Air Route Surveillance Radar (ARSR)	1215-1400	93×10^3	1.09	1.61	8.87	32	V
GPS L3	1350-1400						V
Multi-Object Tracking and Control System (MTACS)	1350-1850	400	10.0	22.0	50.0	2.1	V

Table E-20. 1350-1390 MHz Systems Receiver Characteristics

Receiver Characteristics											
Platform	Noise Figure (dB)	RF Bandwidth (MHz)			1st IF Receiver Selectivity (MHz)			2nd IF Receiver Selectivity (MHz)			Antenna Gain (dBi)
		-3 dB	-20 dB	-60 dB	-3 dB	-20 dB	-60 dB	-3 dB	-20 dB	-60 dB	
AN/FPS-108 NB	7	225	300	1000	68	90	137	18	47	121	47.9
AN/FPS-108 WB	7	225	300	1000	68	90	137	18	47	121	47.9
AN/FPS-117 NB	7	284	452	1350	20	40	120	20	40	120	39.7
AN/FPS-117 WB	7	284	452	1350	20	40	120	20	40	120	39.7
AN/FPS-124	7	218	303	630	10	32	320	2.4	6.4	12.3	30.2
AN/GRC-103	7	7	12	27	0.75	2.0	4.2				16
AN/GRC-226	7	30	45	110	0.85	2.0	6.0				20
AN/MRC-142	8	8.0	35	80	2.0	4.4	8.0	0.8	0.9	1.0	20.3
ARSR	7	58	71	121	0.69	1.9	5.3	0.69	1.9	5.3	32
GPS L3	7										
MTACS	3.2	22	36	110	12	30	60				0

E.4.5.1.1 Technical Assessment. To analyze interference from the BQM-147A and FQM-151A transmitters into incumbent 1350 to1390 MHz receivers, and interference from the incumbent 1350 to 1390 MHz transmitters into the BQM-147A and FQM-151A receivers, the required separation distances to preclude interference were calculated. It was assumed that the incumbent 1350 to 1390 MHz receivers, the BQM-147A receiver and the FQM-151A receiver, were noise limited. This condition equates to an allowed degradation in the link margins of approximately 1 dB and an I/N of -6 dB. The assessment methodology is similar to that described previously. The required propagation loss was determined from Equation E-3, and the required separation distance was calculated using the standard free-space path loss equation shown in Equation E-4, rather than using ISEM, since the operational altitude was unknown for the incumbent 1350 to 1390 MHz systems.

$$L_P = 20Log_{10}(F_r) + 20Log_{10}(D) + 32.45 \quad \text{(E-5)}$$

where

L_P = propagation loss, in dB
F_r = receiver frequency, in MHz
D = separation distance between the transmitter antenna and the receiver antenna, in km

E.4.5.1.2 Results. The required separation distances between the incumbent 1350 to 1390 MHz transmitters and the BQM-147A and FQM-151A receivers are contained in Table E-21 (for 10 MHz and 20 MHz of transmitter/receiver frequency separation). The required separation distances between the BQM-147A and FQM-151A transmitters and the incumbent 1350 to 1390 MHz receivers are contained in Table E-22 (for 10 MHz and 20 MHz of transmitter/receiver frequency separation).

Table E-21. Required Separation Distances (km) for 1350-1390 MHz Receivers

	Receiver Platforms			
	FQM-151A	BQM-147A	FQM-151A	BQM-147A
Incumbent Systems	Frequency Off Tune			
	10	10	20	20
Transmitter: NGTCS	BRH	BRH	BRH	BRH
Transmitter: RAJPO	BRH	BRH	14.8	14.8
Transmitter: TAS MK-23	BRH	BRH	BRH	BRH
Transmitter: AN/FPS-108 NB	BRH	BRH	BRH	BRH
Transmitter: AN/FPS-108 WB	BRH	BRH	BRH	BRH
Transmitter: AN/FPS-117 NB	BRH	BRH	BRH	BRH
Transmitter: AN/FPS-117 WB	BRH	BRH	BRH	BRH
Transmitter: AN/FPS-124	BRH	BRH	BRH	BRH
Transmitter: AN/GRC-103	BRH	BRH	91.1	91.1
Transmitter: AN/GRC-226	BRH	BRH	16.6	16.6
Transmitter: AN/MRC-142	BRH	BRH	16.0	16.0
Transmitter: ARSR	BRH	BRH	BRH	BRH
Transmitter: MTACS	BRH	BRH	216.7	216.7
Transmitter: AN/TPS-59	BRH	BRH	127.7	127.7
BRH = Beyond Radio Horizon				

Table E-22. Required Separation Distances (km) for 1350-1390 MHz Tramsmitters

	Transmitter Platforms			
	FQM-151A	BQM-147A	FQM-151A	BQM-147A
Incumbent Systems	Frequency Off Tune			
	10	10	20	20
Receiver: NGTCS	11.8	37.6	11.8	37.6
Receiver: RAJPO	6.0	9.1	0.1	0.4
Receiver: TAS MK-23	79.2	73.1	1.2	5.4
Receiver: AN/FPS-108 NB	BRH	BRH	BRH	BRH
Receiver: AN/FPS-108 WB	BRH	BRH	BRH	BRH
Receiver: AN/FPS-117 NB	BRH	BRH	118.3	207.9
Receiver: AN/FPS-117 WB	BRH	BRH	118.3	207.9
Receiver: AN/FPS-124	205.0	258.1	3.0	12.1
Receiver: AN/GRC-103	29.0	27.0	0.4	1.9
Receiver: AN/GRC-226	46.1	43.0	0.9	3.3
Receiver: AN/MRC-142	40.4	36.9	0.6	2.7
Receiver: ARSR	207.3	191.3	3.1	13.9
Receiver: MTACS	26.8	60.8	1.0	1.5
Receiver: AN/TPS-59	BRH	BRH	9.7	39.2
BRH = Beyond Radio Horizon				

Modifications to the BQM-147A and FQM-151A transmitters and receivers would be necessary to migrate the systems to the 1350 to 1390 MHz band. There are several high-power radars currently operating in this band; thus, even with 20-MHz frequency separation, some systems would require a beyond radio horizon (BRH) separation distance, and the BQM-147A and FQM-151A would require forward error correction (FEC) to maintain a marginal communications link.

E.4.5.2 Migrating to the 2200-2290 MHz Frequency Band

The systems located within the EME are listed in Table E-23. The analyzed 2200 to 2290 MHz systems are identified below. Table E-24 lists the transmitter characteristics of the 2200 to 2290 MHz systems, and Table E-25 lists the receiver characteristics of the 2200 to 2290 MHz systems.

In addition to the incumbent 2200 to 2290 MHz systems listed in Table E-25, the National Aeronautics and Space Administration (NASA) maintains a Deep Space Network (DSN) at Goldstone, CA, near Fort Irwin, CA. The DSN 2200 to 2290 MHz receiver front-ends have very low noise characteristics (-192 dB/Hz) and use a 32-dBi parabolic dish antenna to track spacecraft from horizon to 90^{o} zenith.

Table E-23. Systems Located Within the EME

Nomenclature	Number of Systems	Nomenclature	Number of Systems	Nomenclature	Number of Systems
AAC AR3605S	1	CXS 610 XPNDR	2	MOT TDRSS XPNDR	1
AN/DKT-023 (V)	4	DRA DESIGN	2	NASA DESIGN	4
AN/DKT-031 (V)	4	EOS AM/TDRSS	4	NASA DSN DESIGN	2
AN/DKT-038	1	ESA DESIGN	5	NASA NEAR EARTH TR	9
AN/DKT23	6	FASDSN TELEMETRY	3	NASA SMEX XPNDR	4
AN/DKT-23	1	FECLR42000	6	NASA XPNDR	12
AN/DKT30	2	GENTRANSPONDER	4	NASA/ESA DESIGN	1
AN/DKT-30	1	GERMAN SATELLITE	2	PHI GOES	3
AN/DKT-31	60	GRA60183A/24	2	PHI GOES XPNDR	1
AN/DKT-31(V)	4	HUGT802	16	RAYRTT-601	2
AN/DKT37	2	ISAS DESIGN	1	RCA TRANSMITTER	1
AN/DKT-37	16	L3 COMM CSX-600B	8	RCAMULTIBNDTRNSL	1
AN/DKT37D	19	LOCCTS905	1	RIETRANSPONDER	12
AN/DKT-49	4	LOCCTS-905	3	SEOTTS1A	3
AN/DKT-56	10	LOE CTS-905	1	SMWTTX135-5A	4
AN/DKT-73	18	LOE CXS-600A STDN	1	SOVXM-LTA	4
AN/DKT-80	91	LOE LORAL CONIC	1	SPACE INNOVATIONS	2
AN/DNQ1	1	LOECONIC LC-CTS-10	2	ST-402-S	3
APIT1478D	8	LOECTS515C5	2	STD NEAR EARTH XPN	4
API-T1478D	4	LOECTS905	9	STDN XPNDR	7
AYD ST408S	1	LOECTS-905	1	TDC1098V	3
AYDST402S	12	MCCM903	1	TDE/TAP TRANSMITTE	1
AYDST408S	2	MCCT1025S	1	TELTR2202	3
AYDST409	4	MCCT4X-2	1	TERTCM601	3
AYDT105	12	MCCT4X-S	4	TRW TRANSPONDER	14
AYDT105S	3	MCCT-60	1	TRW XPNDR	1
AYDT400	1	MCCT70	2	TRWTLMTX	1
AYDVECTORT-805S	1	MCCT702	1	TRWTRANSPONDER	2
CANADIAN DESIGN	2	MCCT705	2	TRWTWIDEBAND	1
CEL TLM XMTR	1	MCCT705HR	12	TSC TR2400	3
CIN MODEL TTC 701	1	MCCT705S	4	TSCTR 2202	3
CNC L-3 COMM	1	MCCT802	10	TTSDR2D	1
CNCAIM9X ATE	7	MCCTV1205	1	VEC105S	1
CNCCTMUHF302	9	MCOT702	1	VECST405S	3
CNCCTMUHF310	1	MCT TDRSS NE	3	VECT-1025	11
CNCCTMUHF401	1	MDC1400MR	3	VECT-102S	13
CNCCTS402	24	MICROCOMT70	1	VECT1055	11
CNCCTS705	13	MODEL CXS-600 STDN	3	VECT105S	11
CNCCTS905	4	MOT 2ND	1	VECT-105S	4
CNCSA2747-1	2	MOT MODEL USB	1	VECT110S	5
CONIC CXS-600B	2	MOT STDN XPNDR	2	VECT1O2S	2
CUB TR-38	1	MOT TDRSS TRNSPDR	7	VECT402L	2

Table E-24. 2200-2290 MHz Systems Transmitter Characteristics

Transmitter Characteristics							Antenna Characteristics
Platform	Power (W)	Modulation Type	Emission Bandwidth (MHz)				Gain (dBi)
			-3 dB	-20 dB	-40 dB	-60 dB	
AN/DKT-xx	2	FSK	0.100	0.200	0.400	0.980	5
AN/DKT-37D(v)	2	FM	0.250	0.600	N/A	1.2	0
AN/DKT-31(v)	5	PAM NRZ	0.600	1.28	N/A	1.6	2
Loral CXS-800	5	BPSK NRZ-L	3.8	6.9	11.2	17	0
AN/DKT-27 (MOD)	5	N/A	RF1				
			0.400	1.9	N/A	3.7	5
			RF2				
			0.200	1	N/A	2.5	0
AN/DKT-56	2	FM	0.100	0.200	0.400	0.980	
AN/DKT-23	2-5	PAM FM	1.6	4.8	N/A	9.6	5
PROG 777	1	PCM PM	2	5	N/A	8	5.3
DMSP	3.7	PM weather data	2	13.5	37	38.7	1
DMSP	3.7	PM weather data	0.157	0.480	N/A	5.6	1
DMSP	2	PM telemetry	0.930	6.8	9.8	12.4	4
Aydin Vector T/ST 400	20	FM	5.8	5.9	N/A	13	0
NRZ – Non-Return-to Zero (modulation) NRZ – Non-Return-to-Zero-Level							

Table E-25. 2200-2290 MHz Systems Receiver Characteristics

Receiver Characteristics											
Platform	Noise Figure (dB)	RF Bandwidth (MHz)			1st IF Receiver Selectivity (MHz)			2nd IF Receiver Selectivity (MHz)			Antenna Gain (dBi)
		-3 dB	-20 dB	-60 dB	-3 dB	-20 dB	-60 dB	-3 dB	-20 dB	-60 dB	
AN/DKT-xx	10	6	N/A	N/A	4	6.1	12	1	1.5	3	20.9
AN/DKT-37D(v)	10	6	N/A	N/A	4	6.1	12	1	1.5	3	20.9
AN/DKT-31(v)	10	6	N/A	N/A	4	6.1	12	1	1.5	3	20.9
Loral CXS-800	10	6	N/A	N/A	4	6.1	12	1	1.5	3	20.9
AN/DKT-27 Modified (MOD)	10	6	N/A	N/A	4	6.1	12	1	1.5	3	20.9
AN/DKT-56	10	6	N/A	N/A	4	6.1	12	1	1.5	3	20.9
AN/DKT-23	10	6	N/A	N/A	4	6.1	12	1	1.5	3	20.9
PROG 777	10	6	N/A	N/A	4	6.1	12	1	1.5	3	20.9
DMSP	8	100	N/A	N/A	10	12	100	N/A	N/A	3	20.9
DMSP	8	20	50	100	2	5	10	0.200	0.500	3	20.9
DMSP	8	22	50	130	17	23	29	4	7.9	3	20.9
Aydin Vector T/ST 400	10	225	350	500	45	86	292	20	24	3	20.9

E.4.5.2.1 Technical Assessment. To analyze interference from the BQM-147A and FQM-151A transmitters into incumbent 2200 to 2290 MHz receivers, and interference from the incumbent 2200 to 2290 MHz transmitters into the BQM-147A and FQM-151A receivers, the required separation distances to preclude interference were calculated. It was assumed that the incumbent 2200 to 2290 MHz receivers, the BQM-147A receiver and the FQM-151A receiver, were noise limited. This condition equates to an allowed degradation in the link margins of approximately 1 dB and an I/N of -6 dB. The assessment methodology is similar to that described previously. The required propagation loss was determined from Equation E-3, and the required separation distance was calculated using Equation E-4, rather than using ISEM, since the operational altitude was unknown for the incumbent 2200 to 2290 MHz systems.

E.4.5.2.2 Results. The required separation distances between the incumbent 2200 to 2290 MHz transmitters and the BQM-147A, FQM-151A receivers are contained in Table E-26 (for 10 MHz and 20 MHz of transmitter/receiver frequency separation). The required separation distances between the BQM-147A and FQM-151A transmitters and the incumbent 2200 to 2290 MHz receivers are contained in Table E-27 (for 10 MHz and 20 MHz of transmitter/receiver frequency separation).

In addition to the incumbent systems, the minimum separation distances were calculated using Equation E-2 and Equation E-4 for interference from the UAV to the DSN receivers. Results are provided in Table E-27.

Table E-26. Distances, in km, from Incumbent 2200-2290 MHz Airborne Transmitters to Preclude Interference to BQM-147A and FQM-151A Ground Receivers

	Receiver Platforms			
	BQM-147A	FQM-151A	BQM-147A	FQM-151A
Incumbent Systems	Frequency Off Tune			
	10 MHz	10 MHz	20 MHz	20 MHz
Transmitter: AN/DKT-xx	BRH	BRH	1.7	1.7
Transmitter: AN/DKT-37D (v)	167	167	0.8	0.8
Transmitter: AN/DKT-31 (v)	BRH	BRH	1.3	1.3
Transmitter: PROG 777				
Transmitter: AN/DKT-27 (MOD)	BRH	BRH	0.5	0.5
Transmitter: AN/DKT-56	168	168	0.9	0.9
Transmitter: AN/DKT-23	BRH	BRH	2.3	2.3
Transmitter: PROG 777	227	227	1.1	1.1
Transmitter: DMSP	263	263	6.9	6.9
Transmitter: DMSP	254	254	3.9	3.9
Transmitter: DMSP	270	270	1.5	1.5
Transmitter: Aydin Vector T/ST 400	BRH	BRH	2.9	2.9
BRH = Beyond Radio Horizon				

Table E-27. Distances, in km, from BQM-147A and FQM-151A Airborne Transmitters to Preclude Interference to Incumbent 2200-2290 Receivers

	Transmitter Platform			
	BQM-147A	FQM-151A	BQM-147A	FQM-151A
Incumbent Systems	Frequency Off Tune			
	10 MHz	10 MHz	20 MHz	20 MHz
Receiver: AN/DKT-xx	23.2	23.5	1.6	0.3
Receiver: AN/DKT-37D (v)	23.2	23.5	1.6	0.3
Receiver: AN/DKT-31 (v)	23.2	23.5	1.6	0.3
Receiver: AN/DKT-27 (MOD)	19.3	19.6	1.3	0.3
Receiver: AN/DKT-56	23.2	23.2	1.6	0.3
Receiver: AN/DKT-23	23.2	23.2	1.6	0.3
Receiver: DMSP	BRH	BRH	BRH	BRH
Receiver: DMSP	18.4	18.9	1.35	0.3
Receiver: DMSP	166	288	9.6	2.5
Receiver: Aydin Vector T/ST 400	2	2	0.2	0.02
Receiver: DSN	BRH*	BRH*		
BRH = Beyond Radio Horizon * - On Tune, FDR was 0 dB				

By maintaining at least 10-MHz frequency separation, the BQM-147A and FQM-151A can operate within a reasonable separation distance from the incumbent 2200 to 2290 MHz systems. To migrate to the 2200 to 2290 MHz frequency band and maintain a link margin, the BQM-147A and FQM-151A must increase either the transmitter antenna gain, transmitter power, or receiver antenna gain by 1.9 dB. Failure to maintain this link margin could result in up to a 24% reduction in communication range.

E.4.5.3 Migrating to the 4400-4940 MHz Frequency Band

The systems located within the EME are listed in Table E-28. The analyzed 4400 to 4940 MHz systems are identified below.

Table E-29 lists the transmitter characteristics of the 4400 to 4490 MHz systems, and Table E-30 lists the receiver characteristics of the 4400 to 4940 MHz systems.

E.4.5.3.1 Technical Assessment. To analyze interference from the BQM-147A and FQM-151A transmitters into incumbent 4400 to 4940 MHz receivers, and interference from the incumbent 4400 to 4940 MHz transmitters into the BQM-147A and FQM-151A receivers, the required separation distances to preclude interference were calculated. It was assumed that the incumbent 4400 to 4940 MHz receivers, the BQM-147A receiver and the FQM-151A receiver, were noise limited. This condition equates to an allowed degradation in the link margins of approximately 1 dB and an I/N of -6 dB. The analysis methodology is similar to that described previously. The required propagation loss was determined from Equation E-3, and the required separation distance was calculated using Equation E-4, rather than using ISEM, since the operational altitude was unknown for the incumbent 4400 to 4940 MHz systems.

E.4.5.3.2 Results. The required separation distances between the incumbent 4400 to 4940 MHz transmitters and the BQM-147A and FQM-151A receivers are contained in Table E-31 (for 10 MHz and 20 MHz of transmitter/receiver frequency separation). The required separation distances between the BQM-147A and FQM-151A transmitters and the incumbent 4400 to 4940 MHz receivers are contained in Table E-32 (for 10 MHz and 20 MHz of transmitter/receiver frequency separation).

Table E-28. 4400-4940 MHz Systems Located Within the EME

Nomenclature	Number of Systems	Nomenclature	Number of Systems	Nomenclature	Number of Systems
AAC AR3605S	1	CUB TR-38 TRANSPON	1	MOT TDRSS XPNDR	1
AN/DKT-023 (V)	4	CXS 610 XPNDR	2	NASA DESIGN	4
AN/DKT-031 (V)	4	DRA DESIGN	2	NASA DSN DESIGN	2
AN/DKT-038	1	EOS AM/TDRSS	4	NASA NEAR EARTH TR	9
AN/DKT23	6	ESA DESIGN	5	NASA SMEX XPNDR	4
AN/DKT-23	1	FASDSN TELEMETRY	3	NASA XPNDR	12
AN/DKT30	2	FECLR42000	6	NASA/ESA DESIGN	1
AN/DKT-30	1	GENTRANSPONDER	4	PHI GOES	3
AN/DKT-31	60	GERMAN SATELLITE	2	PHI GOES XPNDR	1
AN/DKT-31(V)	4	GRA60183A/24	2	RAYRTT-601	2
AN/DKT37	2	HUGT802	16	RCA TRANSMITTER	1
AN/DKT-37	16	ISAS DESIGN	1	RCAMULTIBNDTRNSL	1
AN/DKT37D	19	L3 COMM CSX-600B	8	RIETRANSPONDER	12
AN/DKT-49	4	LOCCTS905	1	SEOTTS1A	3
AN/DKT-56	10	LOCCTS-905	3	SMWTTX135-5A	4
AN/DKT-73	18	LOE CTS-905	1	SOVXM-LTA	4
AN/DKT-80	91	LOE CXS-600A STDN	1	SPACE INNOVATIONS	2
AN/DNQ1	1	LOE LORAL CONIC	1	ST-402-S	3
APIT1478D	8	LOECONIC LC-CTS-10	2	STD NEAR EARTH XPN	4
AN/GRC-222	1	LOECTS515C5	2	STDN XPNDR	7
AN/TRC-170	1	LOECTS905	9	TDC1098V	3
API-T1478D	4	LOECTS-905	1	TDE/TAP TRANSMITTE	1
AYD ST408S	1	MCCM903	1	TELTR2202	3
AYDST402S	12	MCCT1025S	1	TERTCM601	3
AYDST408S	2	MCCT4X-2	1	TRW TRANSPONDER	14
AYDST409	4	MCCT4X-S	4	TRW XPNDR	1
AYDT105	12	MCCT-60	1	TRWTLMTX	1
AYDT105S	3	MCCT70	2	TRWTRANSPONDER	2
AYDT400	1	MCCT702	1	TRWTWIDEBAND	1
AYDVECTORT-805S	1	MCCT705	2	TSC TR2400	3
CANADIAN DESIGN	2	MCCT705HR	12	TSCTR 2202	3
CEL TLM XMTR	1	MCCT705S	4	TTSDR2D	1
CIN MODEL TTC 701	1	MCCT802	10	VEC105S	1
CNC L-3 COMM	1	MCCTV1205	1	VECST405S	3
CNCAIM9X ATE	7	MCOT702	1	VECT-1025	11
CNCCTMUHF302	9	MCT TDRSS NE	3	VECT-102S	13
CNCCTMUHF310	1	MDC1400MR	3	VECT1055	11
CNCCTMUHF401	1	MICROCOMT70	1	VECT105S	11
CNCCTS402	24	MODEL CXS-600 STDN	3	VECT-105S	4
CNCCTS705	13	MOT 2ND	1	VECT110S	5
CNCCTS905	4	MOT MODEL USB	1	VECT1O2S	2
CNCSA2747-1	2	MOT STDN XPNDR	2	VECT402L	2
CONIC CXS-600B	2	MOT TDRSS TRNSPDR	7		

Table E-29. 4400-4940 MHz Systems Transmitter Characteristics

Transmitter Characteristics							Antenna Characteristics
Platform	**Power (W)**	**Modulation Type**	**Emission Bandwidth (MHz)**				**Gain (dBi)**
			-3 dB	**-20 dB**	**-40 dB**	**-60 dB**	
AN/TRC-97	1000	FM	0.780	1	N/A	1.5	9
AN/TRC-97	1000	FM	0.966	1.5	N/A	2	38
Pioneer SR RPV	30 (TCU) 10 (PCS)	SS PSK	12.5	32.5	37	60	30
Pioneer SR RPV	30	FM	2	13.5	25.3	38.7	30
TUAV BMS D/V Link	3	FM	0.0745	0.1008	0.242	0.7366	29
TUAV BMS D/V Link	10	FM	3	15	23	29	5.5
Pioneer SR Remotely Piloted Vechicle (RPV) (MOD)	2000 (ship,land) 4000 (air)	FM SS	11	17.7	36.9	73.8	21
Pioneer SR RPV (MOD)	2000 (ship,land) 4000 (air)	FM SS	11	17.7	36.9	73.8	21
PCS – Portable Communications System SS – Spread Spectrum TCU – Tracking and Communications Unit							

Table E-30. 4400-4940 MHz Systems Receiver Characteristics

<table>
<tr><th colspan="12">Receiver Characteristics</th></tr>
<tr><th rowspan="2">Platform</th><th rowspan="2">Noise Figure (dB)</th><th colspan="3">RF Bandwidth (MHz)</th><th colspan="3">1st IF Receiver Selectivity (MHz)</th><th colspan="3">2nd IF Receiver Selectivity (MHz)</th><th rowspan="2">Antenna Gain (dBi)</th></tr>
<tr><th>-3 dB</th><th>-20 dB</th><th>-60 dB</th><th>-3 dB</th><th>-20 dB</th><th>-60 dB</th><th>-3 dB</th><th>-20 dB</th><th>-60 dB</th></tr>
<tr><td>AN/TRC-97</td><td>7</td><td>20</td><td>40</td><td>120</td><td>1.5</td><td>2.8</td><td>8</td><td>0.220</td><td>1.2</td><td>N/A</td><td>38</td></tr>
<tr><td>AN/TRC-97</td><td>7</td><td>20</td><td>40</td><td>120</td><td>1.5</td><td>2.8</td><td>8</td><td>0.220</td><td>1.2</td><td>N/A</td><td>38</td></tr>
<tr><td>Pioneer SR RPV</td><td>7</td><td>180</td><td>205</td><td>280</td><td>30</td><td>45</td><td>100</td><td>1.2</td><td>4.5</td><td>10</td><td>34</td></tr>
<tr><td>Pioneer SR RPV</td><td>7</td><td>66</td><td>100</td><td>190</td><td>32</td><td>60</td><td>280</td><td>22</td><td>40</td><td>84</td><td>10</td></tr>
<tr><td rowspan="4">TUAV BMS D/V Link</td><td rowspan="4">2</td><td rowspan="4">225</td><td rowspan="4">350</td><td rowspan="4">500</td><td rowspan="4">45</td><td rowspan="4">86</td><td rowspan="4">292</td><td colspan="3">2nd</td><td rowspan="4">5.5</td></tr>
<tr><td>7</td><td>8</td><td>25</td></tr>
<tr><td colspan="3">3rd</td></tr>
<tr><td>20</td><td>24</td><td>30</td></tr>
<tr><td>TUAV BMS D/V Link</td><td>3.5</td><td>225</td><td>350</td><td>500</td><td>45</td><td>86</td><td>292</td><td>20</td><td>24</td><td>30</td><td>29</td></tr>
<tr><td rowspan="4">Pioneer SR RPV (MOD)</td><td rowspan="4">8</td><td colspan="3">1st</td><td rowspan="4">25</td><td rowspan="4">50</td><td rowspan="4">150</td><td colspan="3">2nd</td><td rowspan="4">20</td></tr>
<tr><td>810</td><td>950</td><td>1680</td><td>15.3</td><td>21</td><td>50</td></tr>
<tr><td colspan="3">2nd</td><td colspan="3">3rd</td></tr>
<tr><td>30</td><td>42.5</td><td>70</td><td>2.2</td><td>3</td><td>7</td></tr>
<tr><td rowspan="4">Pioneer SR RPV (MOD)</td><td rowspan="4">6</td><td colspan="3">1st</td><td rowspan="4">25</td><td rowspan="4">50</td><td rowspan="4">150</td><td rowspan="4">0.728</td><td rowspan="4">1.2</td><td rowspan="4">1.6</td><td rowspan="4">3.7</td></tr>
<tr><td>810</td><td>950</td><td>1680</td></tr>
<tr><td colspan="3">2nd</td></tr>
<tr><td>30</td><td>42.5</td><td>70</td></tr>
</table>

Table E-31. Distances, in km, from Incumbent 4400-5000 MHz Airborne Transmitters to Preclude Interference to BQM-147A and FQM-151A Receivers

	Receiver Platform			
	BQM-147A	FQM-151A	BQM-147A	FQM-151A
Incumbent Systems	Frequency Off Tune			
	10 MHz	10 MHz	20 MHz	20 MHz
Transmitter: AN/TRC-97	BRH	BRH	BRH	BRH
Transmitter: AN/TRC-97	BRH	BRH	BRH	BRH
Transmitter: Pioneer SR RPV	BRH	BRH	BRH	BRH
Transmitter: TUAV BMS D/V Link	263.4	263.4	6.9	6.9
Transmitter: TUAV BMS D/V Link	254.5	254.5	3.9	3.9
Transmitter: Pioneer SR RPV (MOD)	270.4	270.4	1.5	1.5
Transmitter: Pioneer SR RPV (MOD)	BRH	BRH	29.5	29.5
BRH = Beyond Radio Horizon				

Table E-32. Distances, in km, from BQM-147A and FQM-151A Airborne Transmitters to Preclude Interference to Incumbent 4400-5000 Receivers

	Transmitter Platforms			
	BQM-147A	FQM-151A	BQM-147A	FQM-151A
Incumbent Systems	Frequency Off Tune			
	10 MHz	10 MHz	20 MHz	20 MHz
Transmitter: AN/TRC-97	134.6	213.4	9.9	2.8
Transmitter: AN/TRC-97	134.6	137.8	9.9	2.1
Transmitter: Pioneer SR RPV	104.4	93.1	6.6	1.6
Transmitter: TUAV BMS D/V Link	BRH	BRH	BRH	BRH
Transmitter: TUAV BMS D/V Link	18.4	18.9	1.4	0.3
Transmitter: Pioneer SR RPV (MOD)	288.6	166.1	9.6	2.5
Transmitter: Pioneer SR RPV (MOD)	4.6	4.7	0.3	0.1
BRH = Beyond Radio Horizon				

Maintaining a link margin and migrating to the 4400 to 4940 MHz frequency band would require a 8.1 dB increase of transmitter antenna gain, transmitter power, or receiver antenna gain. If modifications are not completed, the communication range could be reduced up to 61%. This requirement may be prohibitive without extensive modifications. At this frequency band the increased transmitter power and very directional antennas with tracking systems cost more and may be weight prohibitive. Since the beam width of an antenna is proportional to the gain, a higher gain antenna will have a narrower beam width, which may not be feasible for some systems.

This option is not attractive to the Army since a new band would have to be found and a determination made to the availability of appropriate transmitter modules of the size and weight needed for the Pointer UAV. Overall operational impact is minimal since only four models have been fielded, so far. However, a change will require a delay in the continued fielding, delaying use by Army infantry units, Air Force security forces, and NASA launch facilities monitoring.

E.5 US ARMY ABERDEEN TEST CENTER

E.5.1 Operational Mission

The ATC Range Telemetry System provides a multi-link radio telemetry communication capability throughout the many test ranges and facilities of the Aberdeen Test Center (ATC). It consists of several fixed receiving stations located at the high-usage ranges/test areas and many transportable (vehicle housed) receiving stations which are emplaced at any of the multitude of ATC test areas or remote test sites when required to support testing projects. Transmitters are installed on the items being tested on the ranges and communicate the various data (video, high-rate vetronics, analog, digital) to the receiving station. 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.

E.5.2 OPTION 1 – FULL BAND SHARING

This is not a workable solution. Telemetry transmits continuously during the work day. Interference from IMT-2000 users operating at the same frequencies would disrupt the acquisition of data in support of the testing of military vehicles and equipment, essentially shutting down the test range. This inhibits the development and testing on new combat applications for combat units.

E.5.3 OPTION 2 – BAND SEGMENTATION/PARTIAL BAND SHARING

This band contains approximately 50% of the assets of the ATC range telemetry. Inside this band a portion of the equipment cannot be modified to operate in the band segment and must be replaced; other equipment can be adapted or tuned and made usable. Additional frequencies must be made available and selected to eliminate interference with the current frequencies.

E.5.4 OPTION 3 – PARTIAL BAND SEGMENTATION/OTHER BAND COMBINATION (IF VIABLE)

See Option 2.

E.5.5 OPTION 4 – VACATE 1755-1850 MHZ

Unless additional spectrum is allocated and new equipment is procured and fielded, range operations will be affected adversely. Also, the propagation characteristics of any new band for relocation needs to carefully studied. The current band allows the use of wide beam width antennas, helical antennas resistant to wind and water movement, use of non-expensive radar-slaved antennas for tracking aircraft, and foliage penetration.

E.6 TCM-601

E.6.1 OPERATIONAL MISSION

The TCM-601 (TOSS) provides a television ordinance scoring capability to range users in support of exercise and test missions at Nellis Range. For the year 2001, sixteen one-week sessions will occur for Red Flag exercises alone. The average number of missions using TOSS at Nellis Range exceeds 50,000 per year for both US and Allied forces. TOSS is a field-proven, accurate weapons scoring system with a night scoring system using infrared cameras. Scoring can be done for live or inert conventional weapons. The operational employment of TOSS provides scoring for over 21 targets with over 100 aim points. There is no planned replacement for this system.

E.6.2 OPTION 1 – FULL BAND SHARING

Since the TOSS system can not share with IMT-2000, the system would be rendered non-operational. Without the feedback from TOSS, range scoring would revert to manual methods. This inability to produce near-instantaneous feedback negatively affects the quality of crew training. Training missions involving multiple bombing runs would not have the benefit of feedback from previous ordnance drops to correct any deficiencies before the next drop.

E.6.3 OPTION 4 – VACATE 1755-1850 MHZ

TOSS has no planned replacement system. Until a replacement system is developed and fielded, TOSS must remain operational to ensure quality training is maintained. The only workaround is manual range scoring which reverts aircrew training back to 1950s technology.

E.7 COST ISSUES FOR OTHER SYSTEMS

E.7.1 Army Corps of Engineers

The primary DoD user of point-to-point microwave links in the band is the ACE. They have over 300 links, mostly in very isolated regions, throughout the US. Under either the band segmentation option or the band vacation option these links would be relocated to 6 GHz, requiring more towers and replacing virtually of the equipment. Refer to Table E-33 for reimbursement cost data.

Table E-33. Army Corps of Engineers Point-to-Point Microwave Links (TY$M)

	Service	FY02	FY03	FY04	FY05	FY06	FY07	To Complete	Total
Reimbursement Cost	Army	0.0	0.0	0.0	0.0	0.0	0.0	125.0	125.0

E.7.2 Land Warrior/CIDDS

The Land Warrior and CIDDS Army programs are still in the development phase. The modification to either program would be much more extensive if the entire band was lost versus the band segmentation options. Since both systems are planning to begin production in the FY02-03 period, delaying their modification will only cause a much larger fraction of the equipment being procured to require retrofitting—a much more expensive process than initiating the modification prior to the production start. For this reason, the cost for delaying the modification of these systems to be more coincident with either a 2006 or 2010 introduction of IMT-2000 systems is not included in Table E-34. Instead, only the most economical, (i.e., earliest possible modification), plan is presented for the band segmentation and total band loss options for these systems.

Table E-34. Land Warrior and CIDDS Systems (TY$M)

	Service	FY02	FY03	FY04	FY05	FY06	FY07	To Complete	Total
Land Warrior (Band Segmentation Options)	Army	1.1	0.0	0.0	0.0	0.0	0.0	0.0	1.1
Land Warrior (Band Vacation Options)	Army	5.3	0.0	0.0	0.0	0.0	0.0	0.0	5.3
CIDDS (Band Segmentation Options)	Army	1.1	2.0	0.7	0.0	0.0	0.0	0.0	3.8
CIDDS (Band Vacation Options)	Army	32.4	16.7	1.8	0.2	0.2	0.2	7.0	58.5

E.7.3 Miscellaneous Systems

Many small systems also utilize the 1755-1850 MHz band, from perimeter security systems to scoring systems for combat training. Each of these will require modification to some extent in either the band segmentation or band vacation options. Because by and large these systems utilize non-developmental commercial equipment they typically require replacement regardless of the loss of some or all of the band. They, of course, would not have any significant cost associated with the band sharing option. Table E-35 represents the costs to replace these systems under both the segmentation and total band loss options. The various fixed point-to-point microwave links mentioned in the table do not include any of the links associated with the Army Corps of Engineers, ACTS ranges, TOSS, MSE, or TRI-TAC systems that have been addressed previously. Of course, for the various introduction dates some or all of these replacement costs could be deferred but typically at higher cost. Therefore, for economic reasons immediate replacement was assumed regardless of the IMT-2000 introduction date.

Table E-35. Miscellaneous Equipment Cost Data (TY$M)

	Service	FY02	FY03	FY04	FY05	FY06	FY07	To Complete	Total
Tayburn Video Data Link	Army	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4
AN/DSQ-024A/B Scoring System	Army	1.8	0.0	0.0	0.0	0.0	0.0	0.0	1.8
AN/DSQ-040 Miss Distance Indicator	Army	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Thru Sight Video (TSV) System	Army	1.5	0.0	0.0	0.0	0.0	0.0	0.0	1.5
GTE Lenkurt 79F1 Microwave Radio	Army	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Simplex Microwave Data Link	Army	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Conic CTM-UHF-402V Video Transmitter	Army	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AN/DSQ(XMG-1) Missile Scoring Set	Army	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Security Video Systems	AF	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Security Video Systems	Navy	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3
ATC Range Telemetry System	Army	2.1	1.0	0.0	0.0	0.0	0.0	0.0	3.1
Dynamically Reconfigured Real Time Software	Army	7.7	0.0	0.0	0.0	0.0	0.0	0.0	7.7
Various Fixed Mircrowave Links	All	45.0	0.0	0.0	0.0	0.0	0.0	0.0	45.0
Total Reimbursement		**60.3**	**1.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**61.3**

APPENDIX F – MOBILE VIDEO/CONTROL LINKS

(This classified appendix is bound separately.)

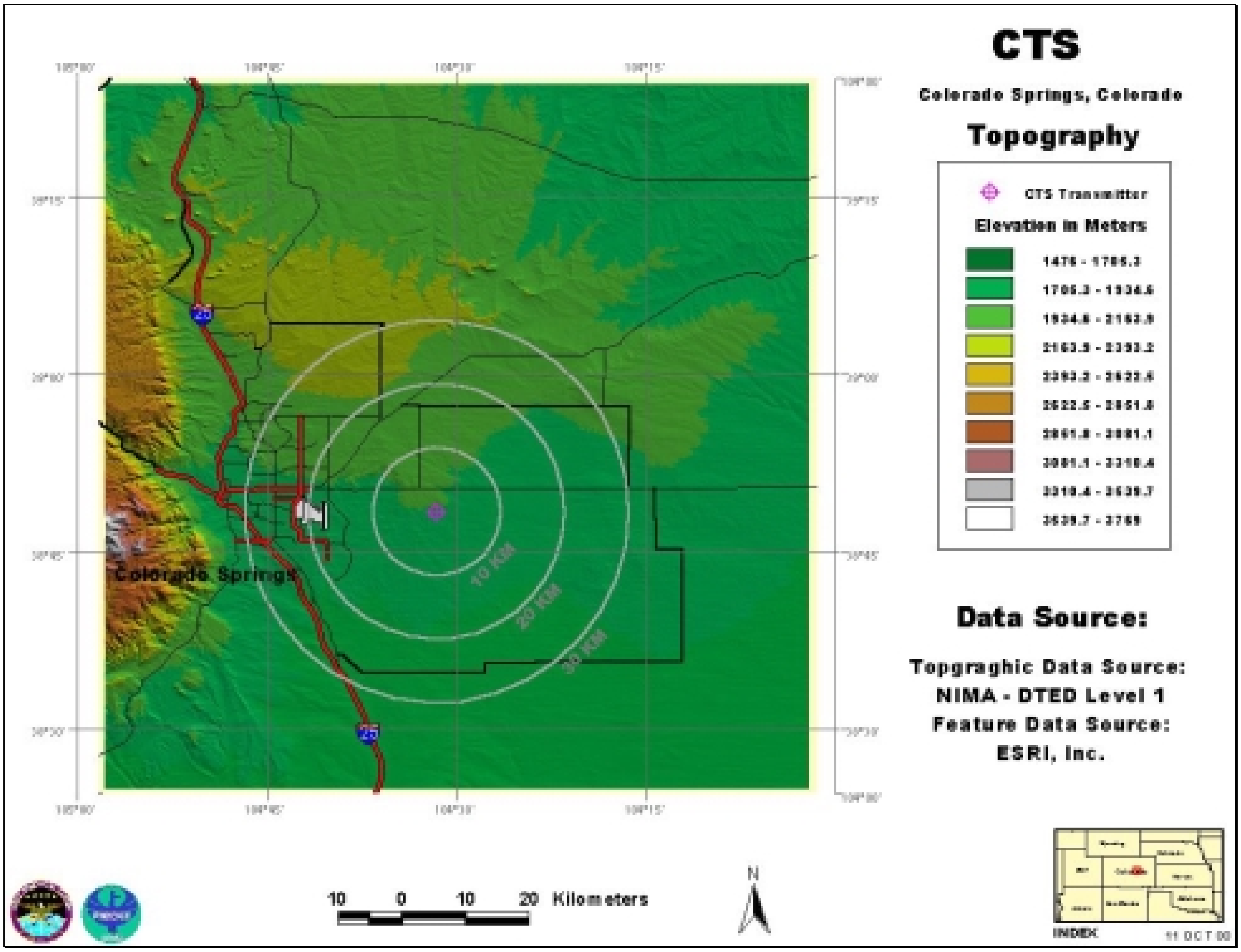
APPENDIX G – DISCUSSION OF MITIGATION METHODS

Individual system design considerations, environmental site planning, cooperative frequency planning, and other cooperative measures can often mitigate the potential for harmful interference between radio frequency systems. The implementation of interference mitigation measures can greatly enhance opportunities for spectrum sharing. The assessments contained in Appendices B through E and the classified supplement include suggested means to mitigate possible harmful interference, if undesired interactions were predicted. A complete exploration and quantification of the technical, cost, and operational impact of the indicated mitigation measures was not possible given the uncertainty of some International Mobile Telecommunications for the Year 2000 (IMT-2000) technical parameters and schedule limitations on this assessment. The operational risks associated with possible mitigation measures are either addressed in the appendices and results or require further investigation. Many of the techniques were found not to be practical or operationally acceptable. It is important to note that costs for these mitigation techniques have not been calculated. Employing any of these techniques would require a cost assessment and may dramatically alter the cost estimates presented earlier.

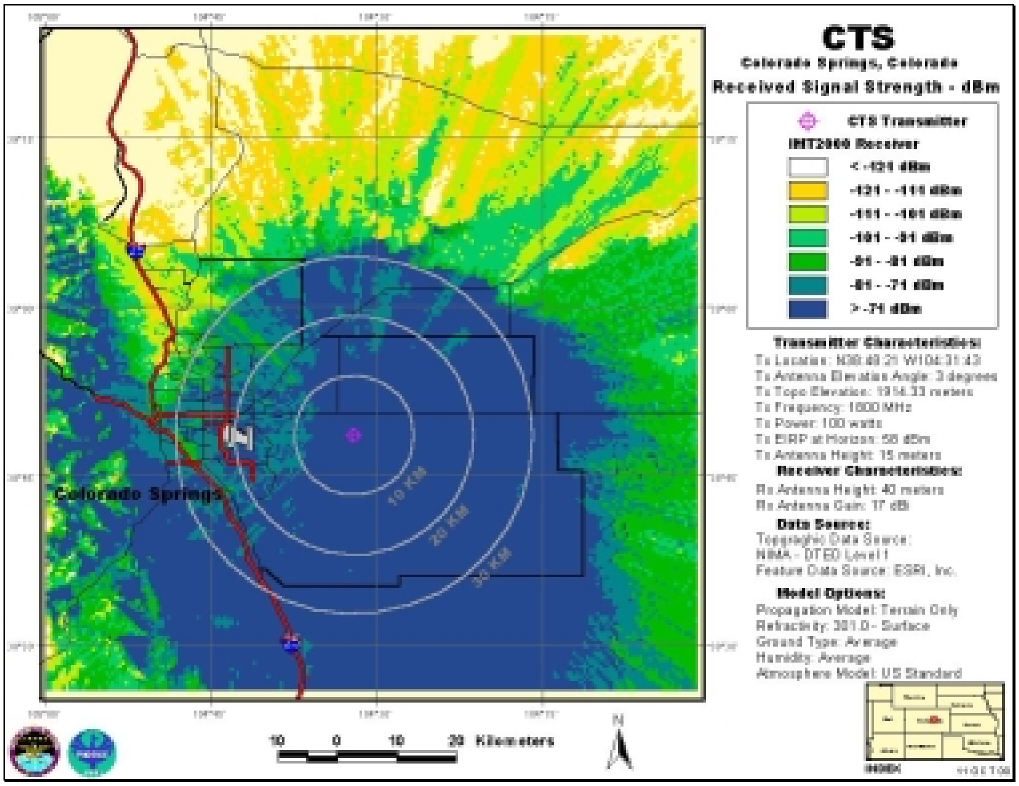
- In selected areas, implement an IMT-2000 network design that eliminates base station mainbeam illumination of Department of Defense (DoD) operational areas.
- In selected areas, implement an IMT-2000 network design using minimally acceptable transmitter power levels.
- In selected areas, investigate possible IMT-2000 base station antenna nulling.
- Relocate the satellite operations (SATOPS) uplink antennas and/or SATOPS transmission off-loading.
- Implement SATOPS antenna elevation angle restrictions.
- Reduce the out-of-beam energy of the SATOPS antennas.
- Investigate SATOPS signal blockage, use of radio frequency absorptive material, and antenna redesign.
- Investigate SATOPS power management.
- Identify keep-out zones for IMT-2000 mobile units around designated DoD sites.
- Consider polarization discrimination between SATOPS antennas and IMT-2000 base station antennas.
- Implement cooperative scheduling of SATOPS transmissions with IMT-2000 network operations centers, allowing real-time frequency management.
- Investigate segmenting the 1755-1850 MHz frequency band; however, segmentation of the 1755-1850 MHz band may result in spectrum spillover into adjacent bands.

- Investigate cross-polarization between IMT-2000 base stations and tactical radio relay to reduce the level of interference interactions.
- Investigate the possibility of using less conservative interference thresholds by insuring that neither IMT-2000 systems nor DoD systems operate near minimally acceptable signal levels.
- Coordinate antenna orientation of IMT-2000 base stations with the location of the test ranges. The mainbeams of the IMT-2000 antennas should not point in the direction of training range ground stations or of major flight activity, and the IMT-2000 base stations should not be illuminated by the mainbeams of high-gain Air Combat Training Systems (ACTS) ground station antennas.
- Use polarization diversity between IMT-2000 base stations and ACTS equipment, to reduce interference levels for mainbeam-to-mainbeam interactions between IMT-2000 and ACTS equipment.

ATTACHMENT 1



Topography Around CTS, Colorado Springs, Colorado



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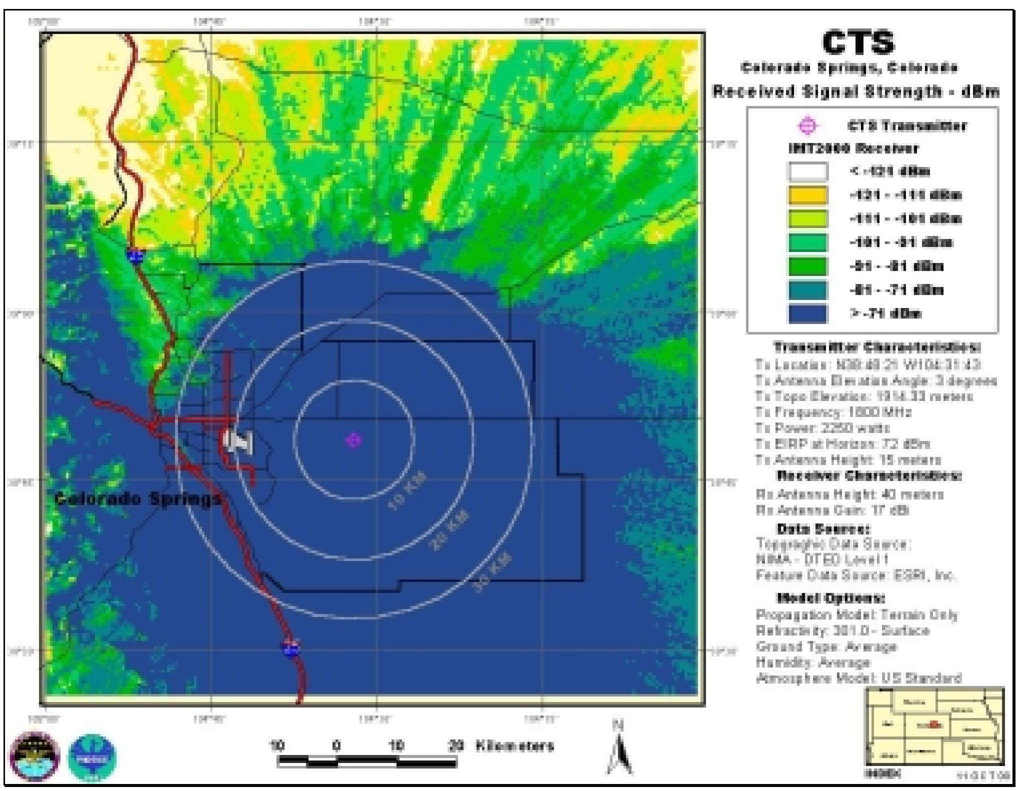

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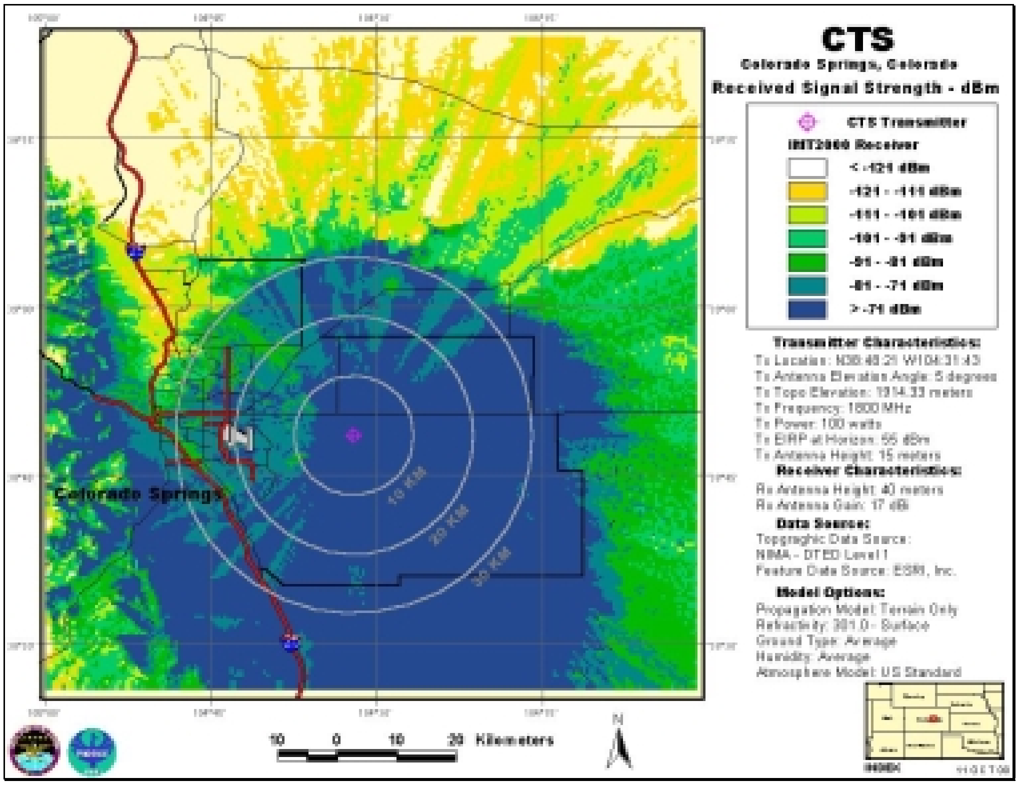

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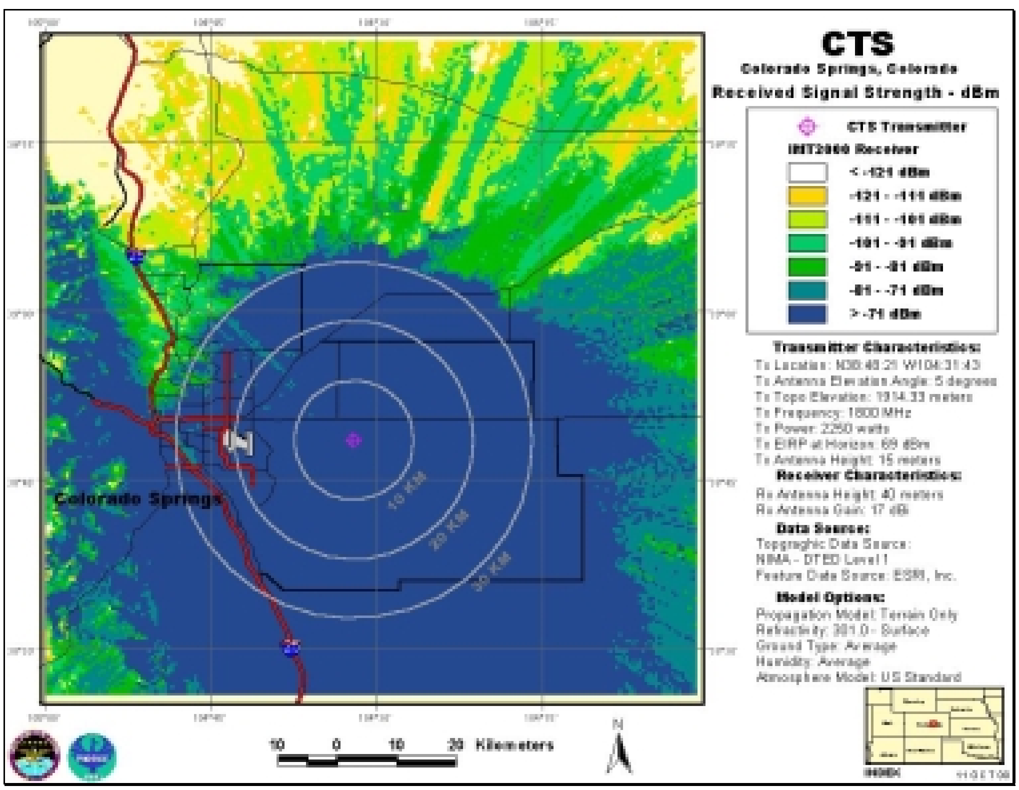

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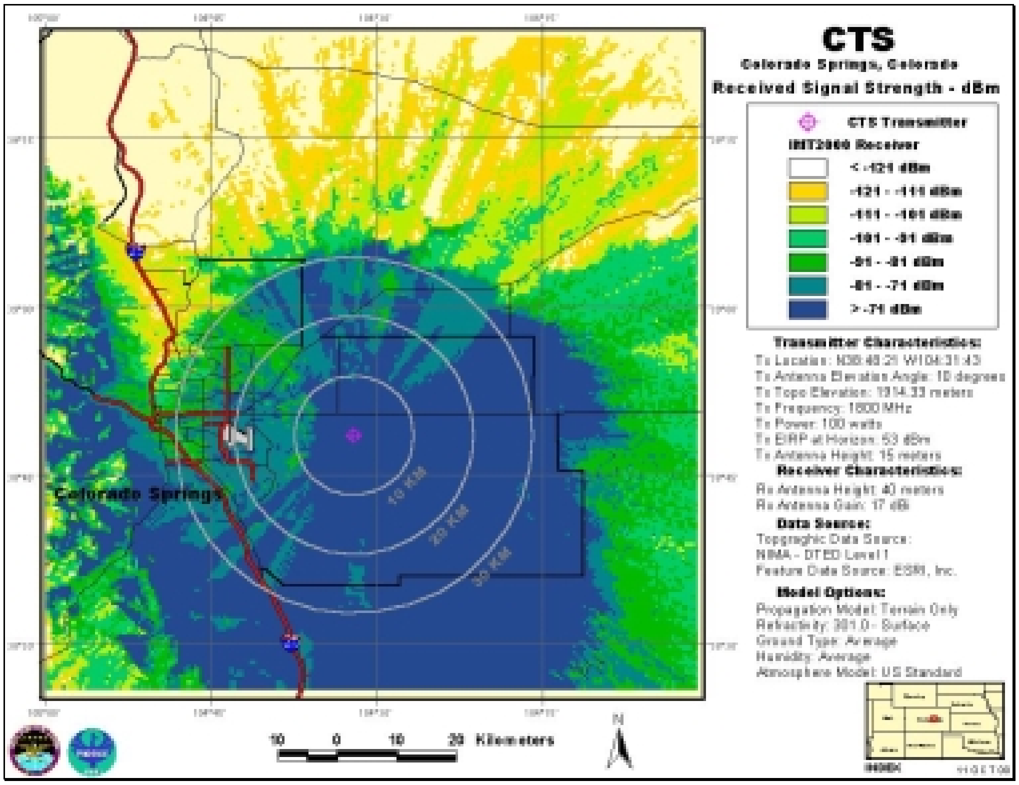

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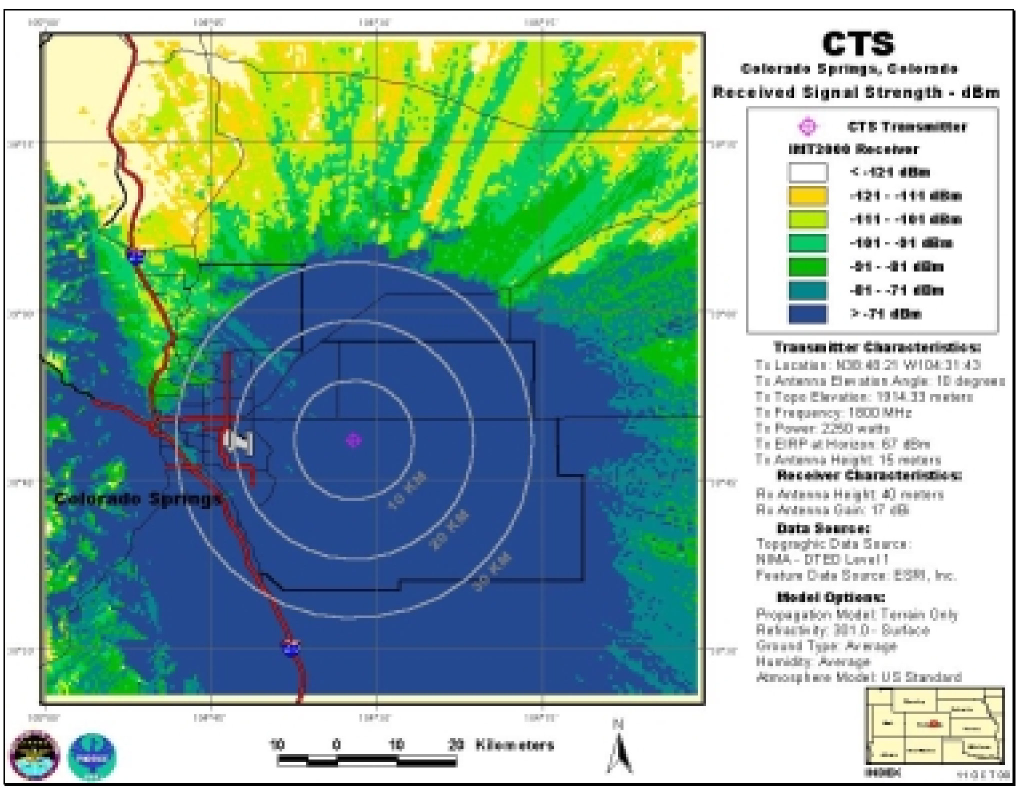

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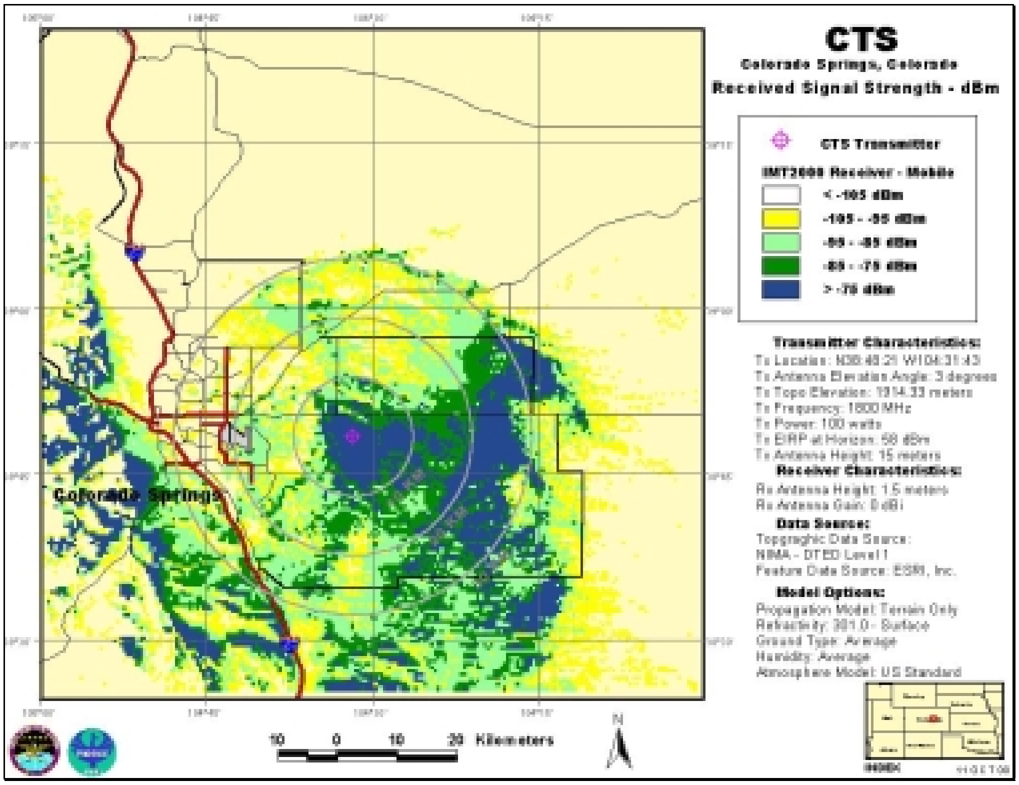

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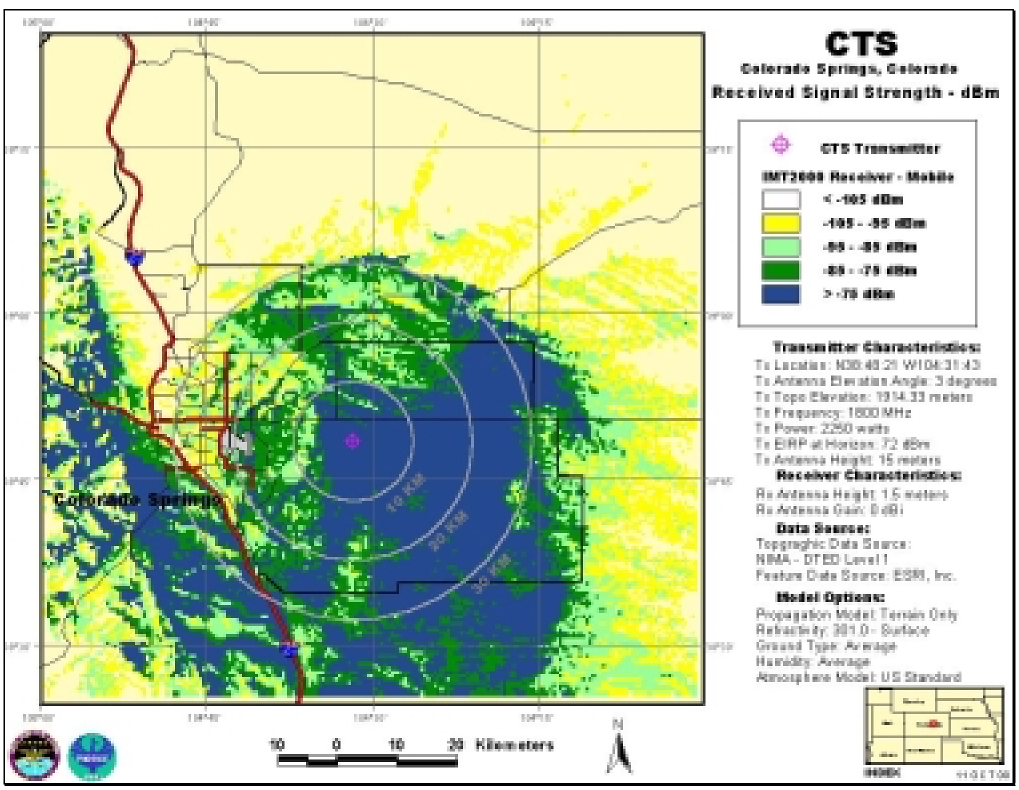

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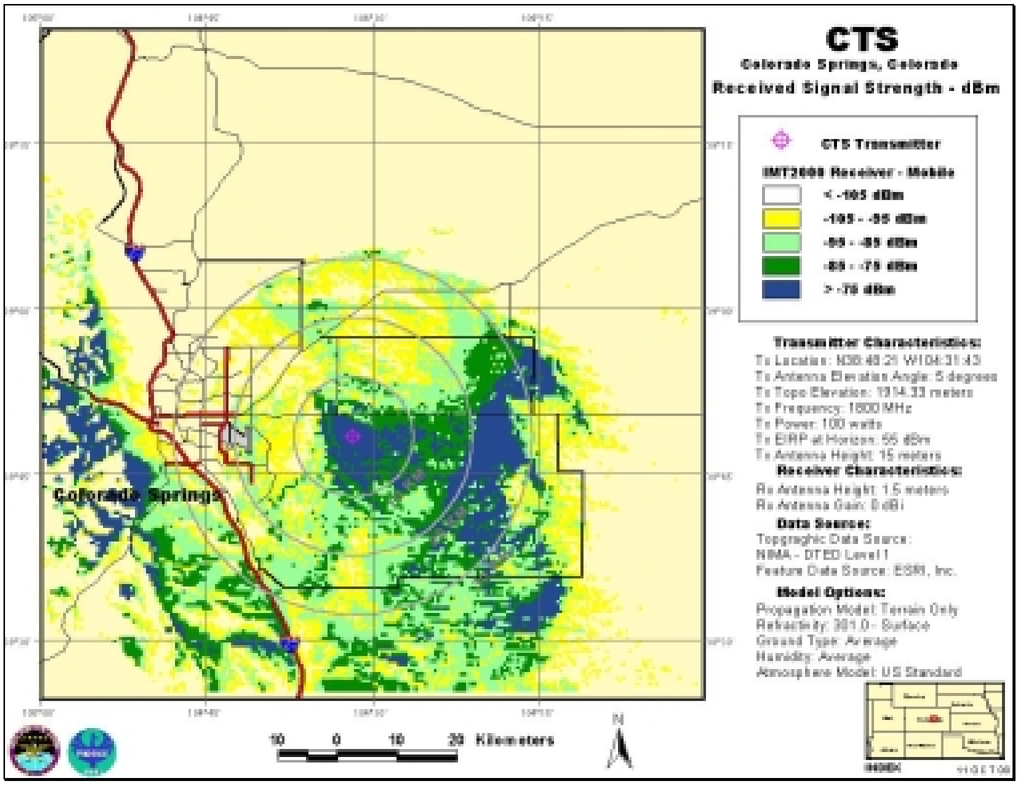

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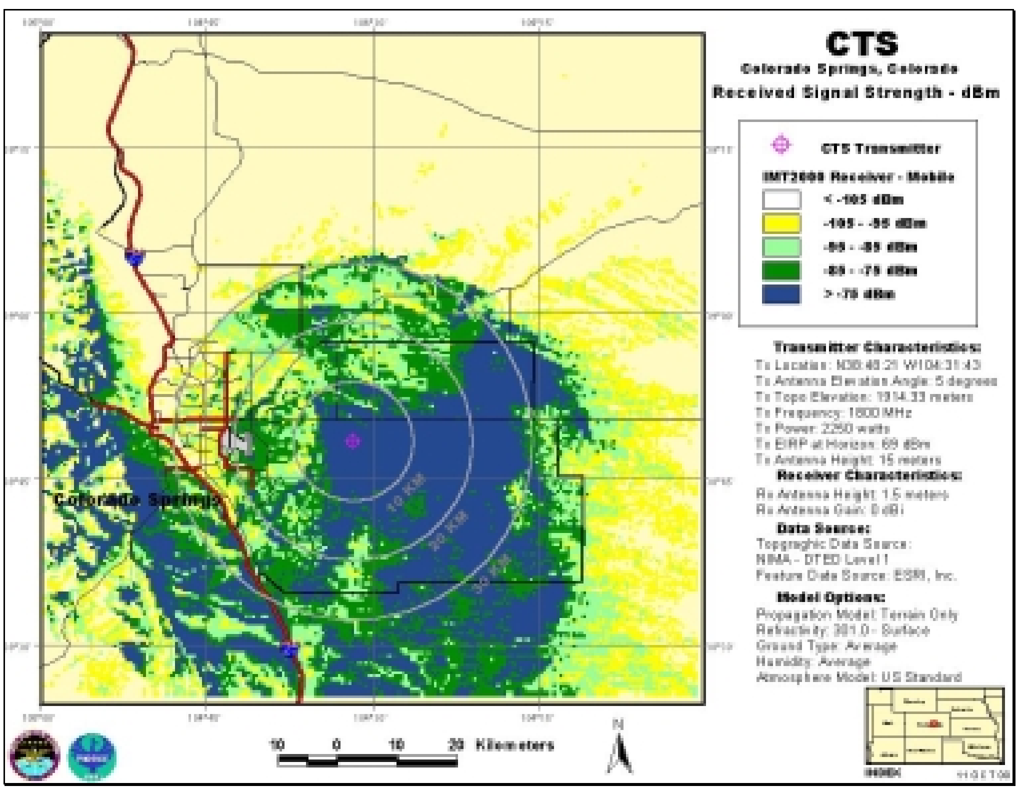

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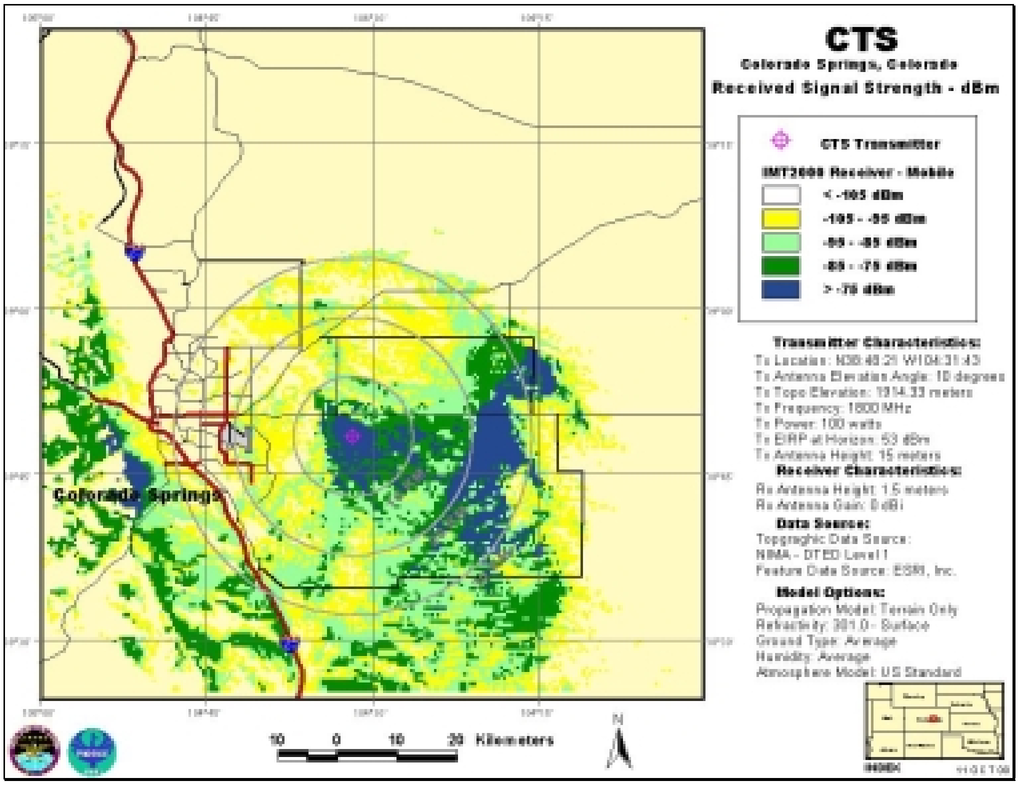

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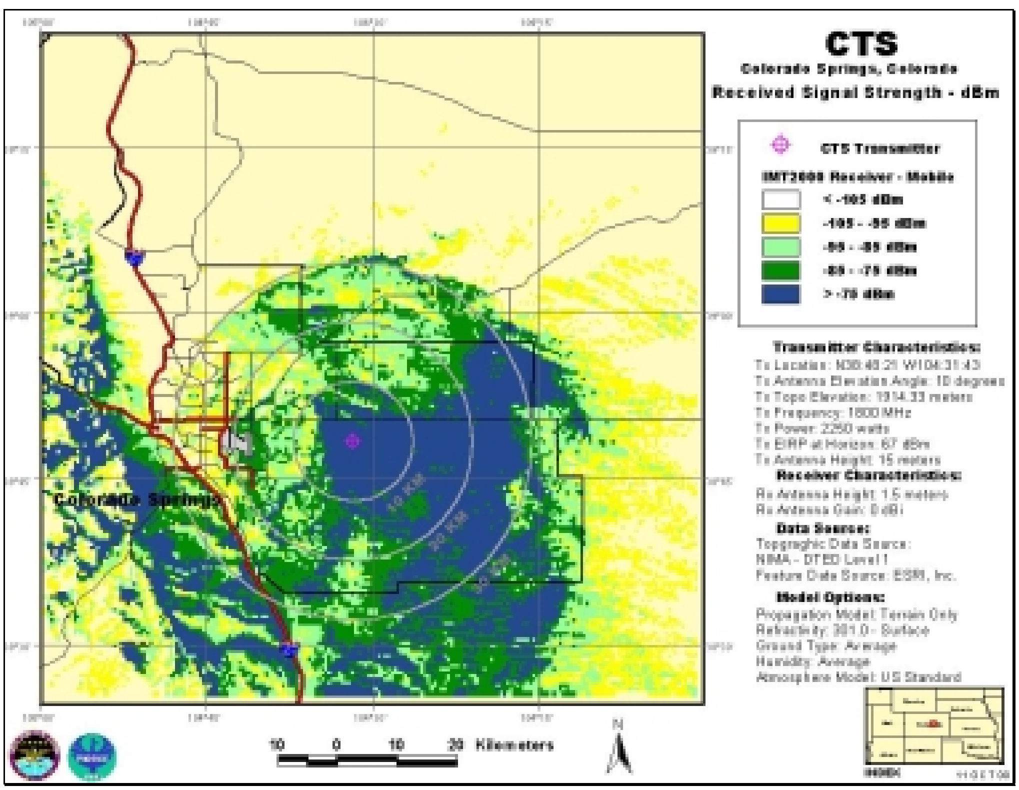

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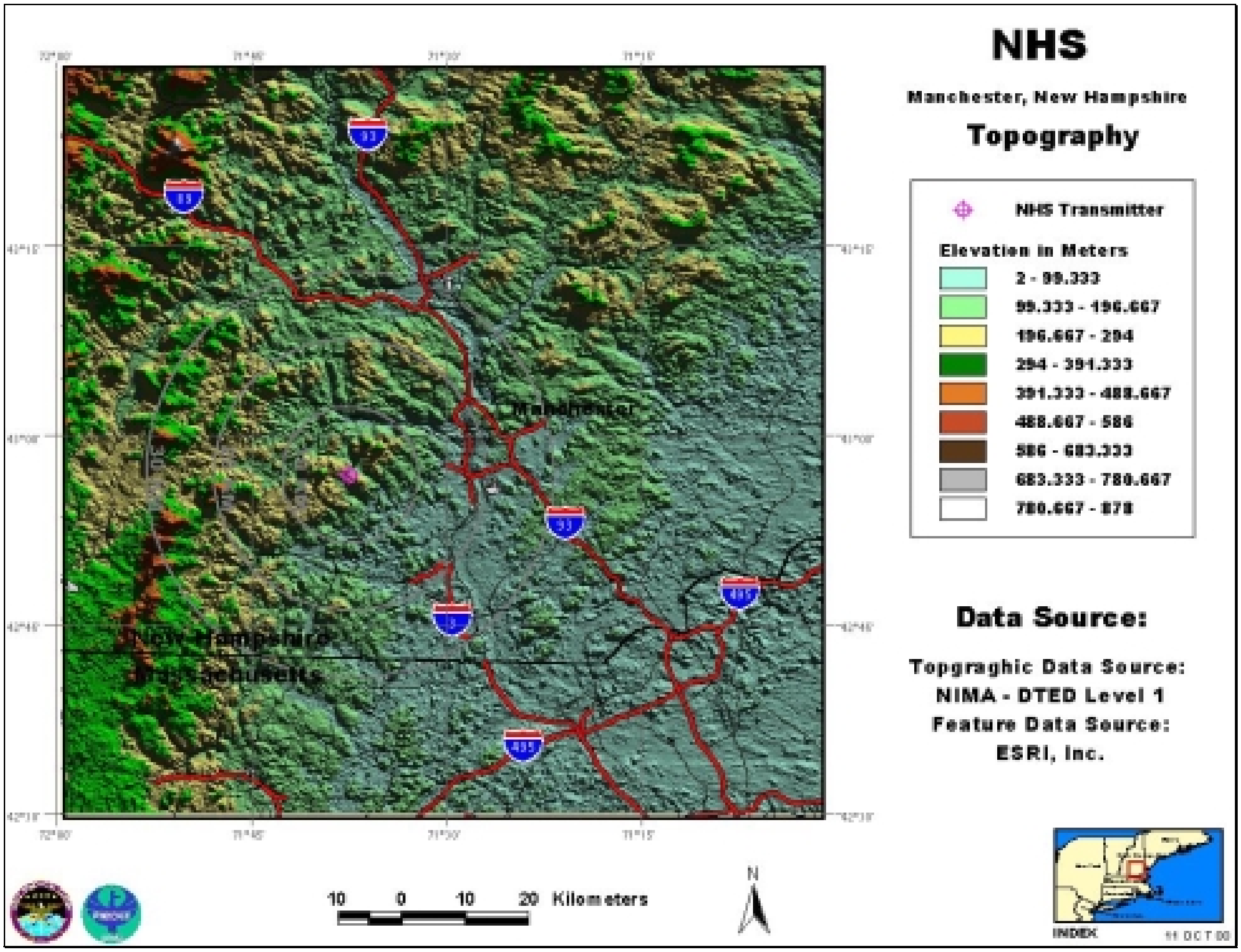
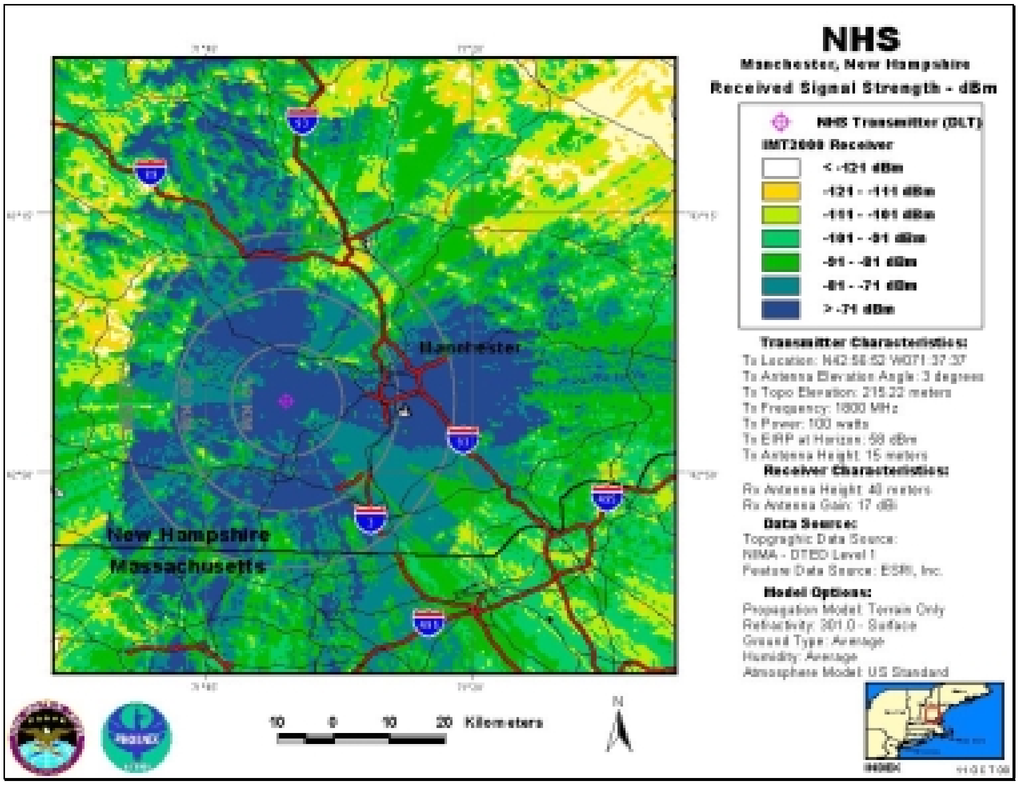


Topography Around NHS, Manchester, New Hampshire



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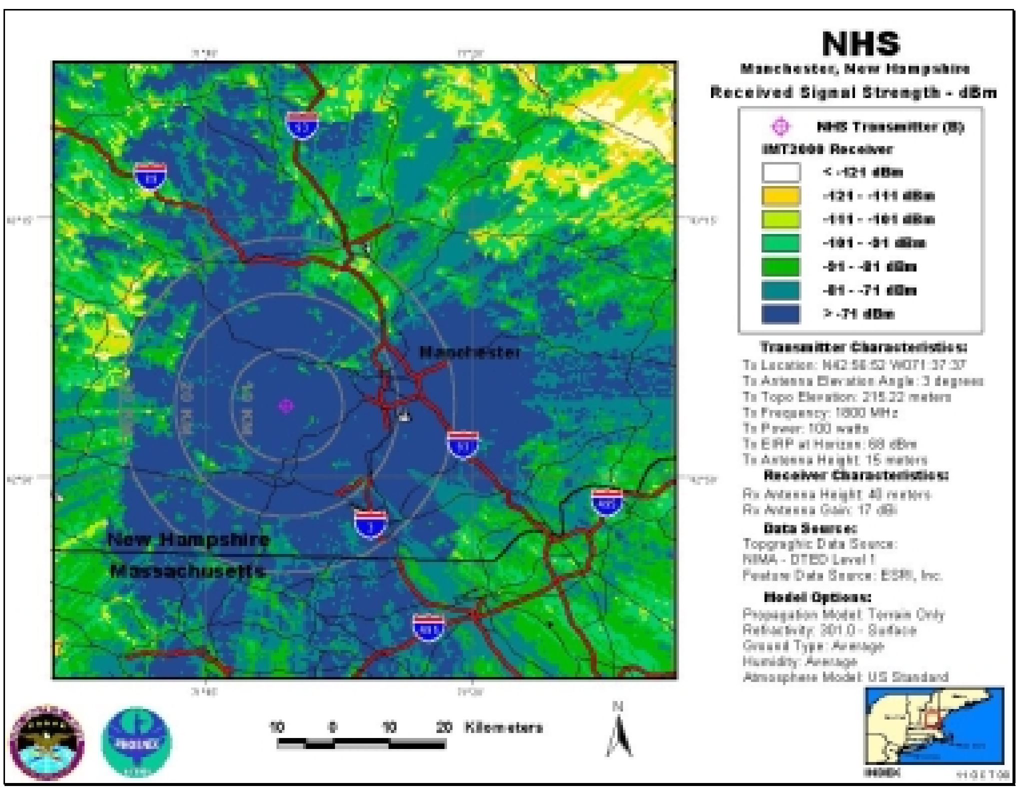

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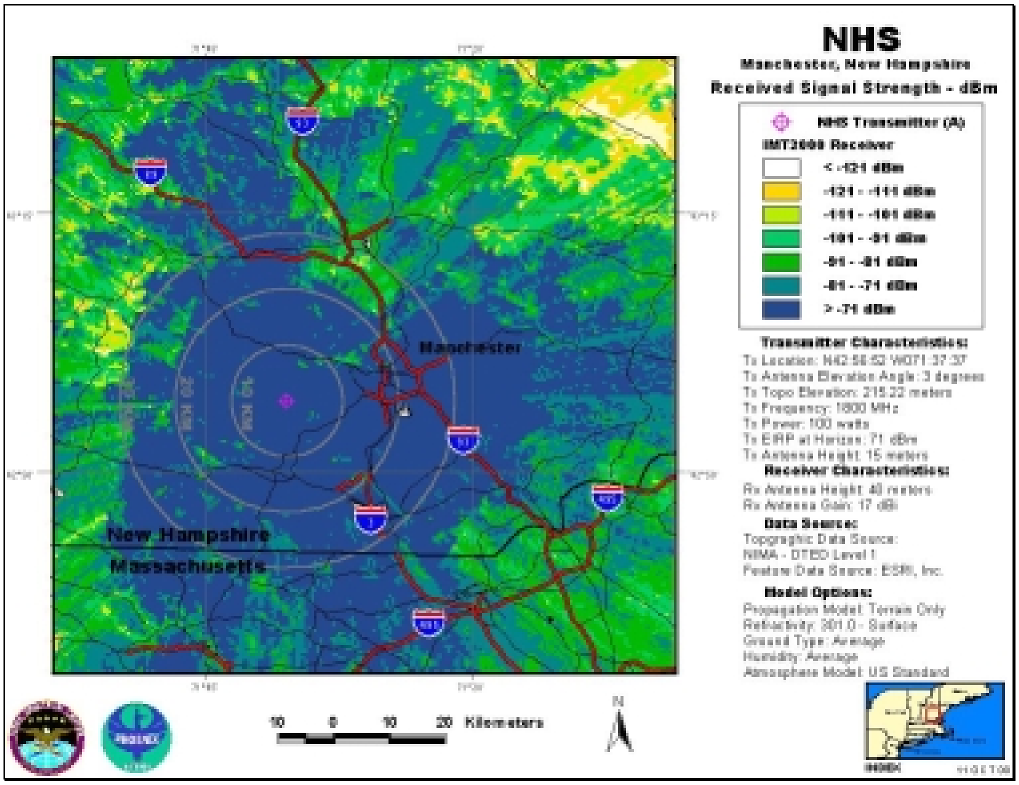

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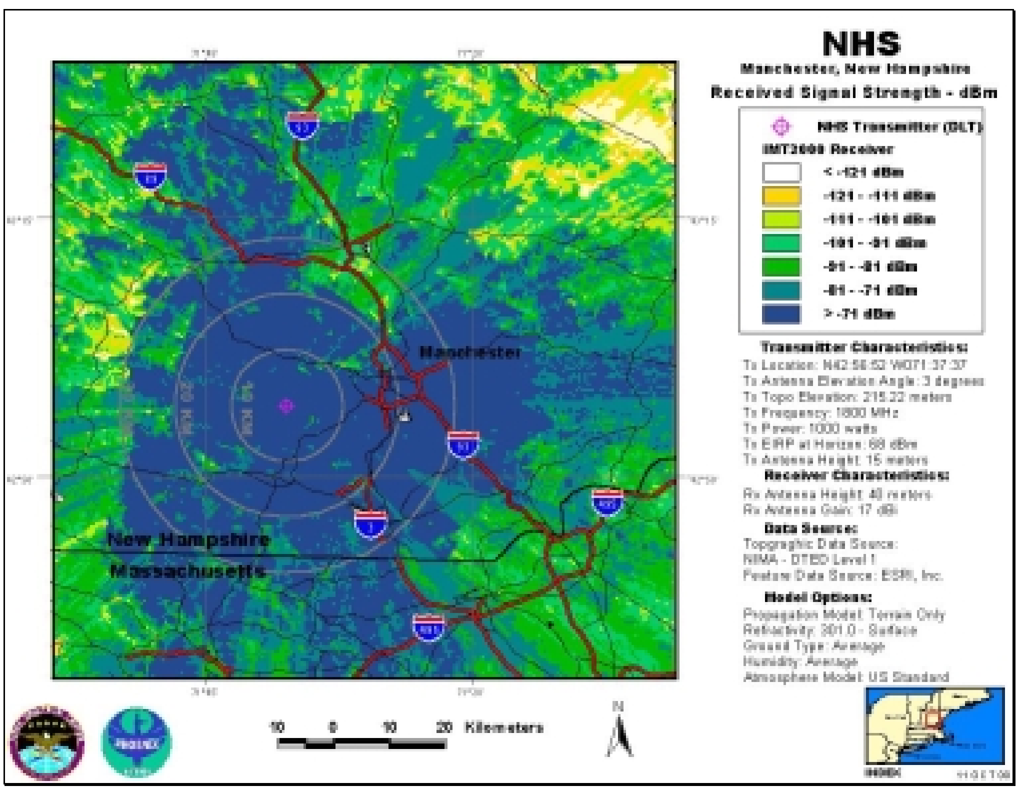

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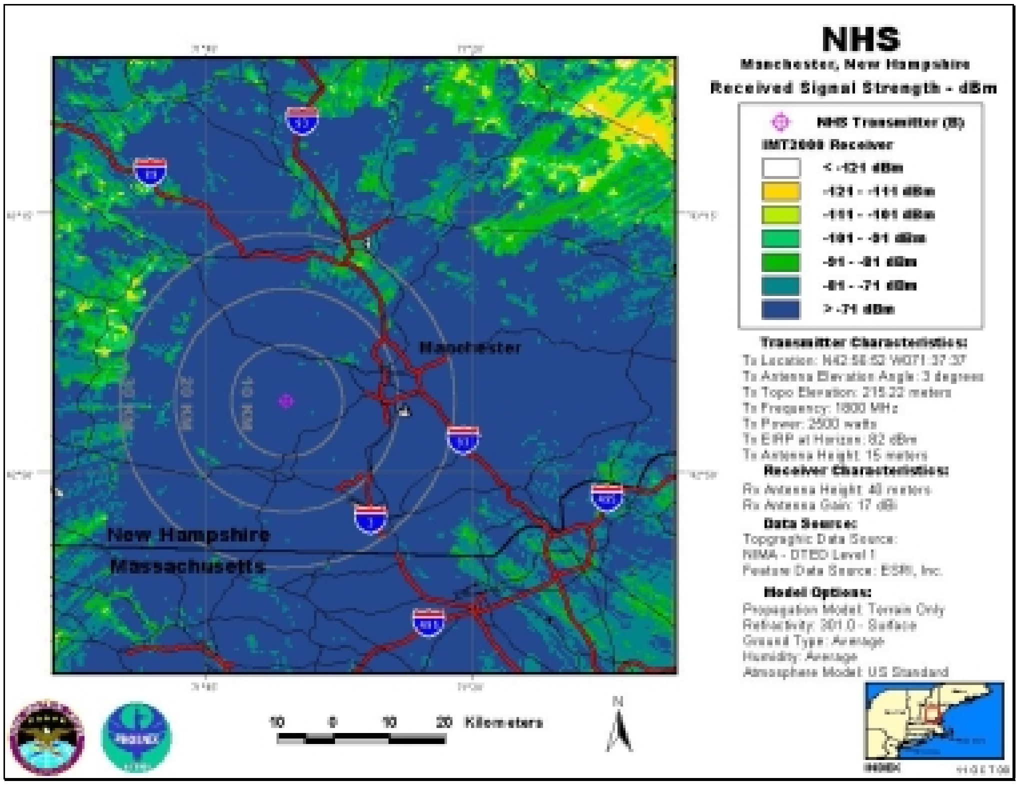

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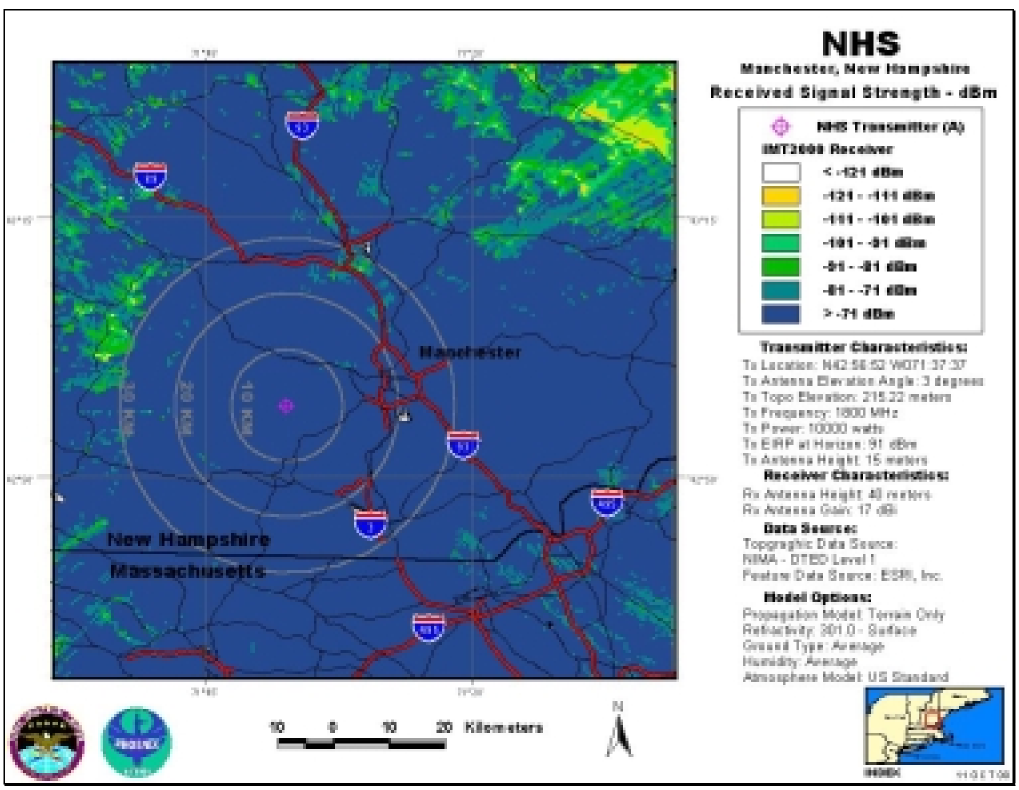

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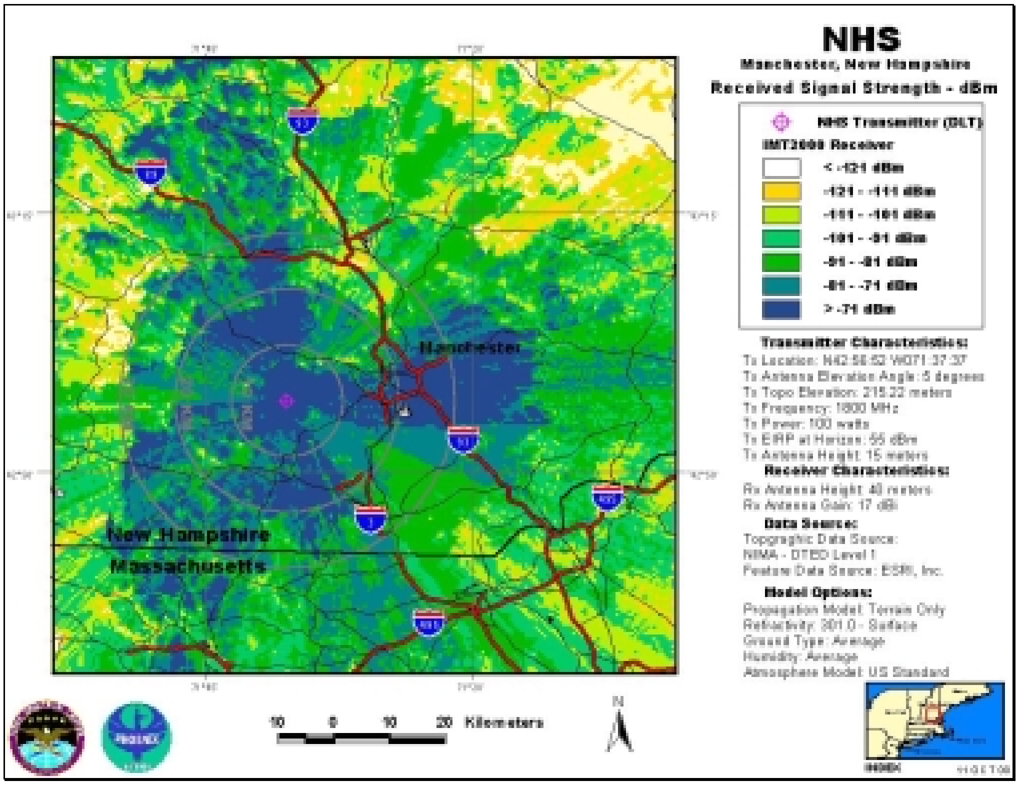

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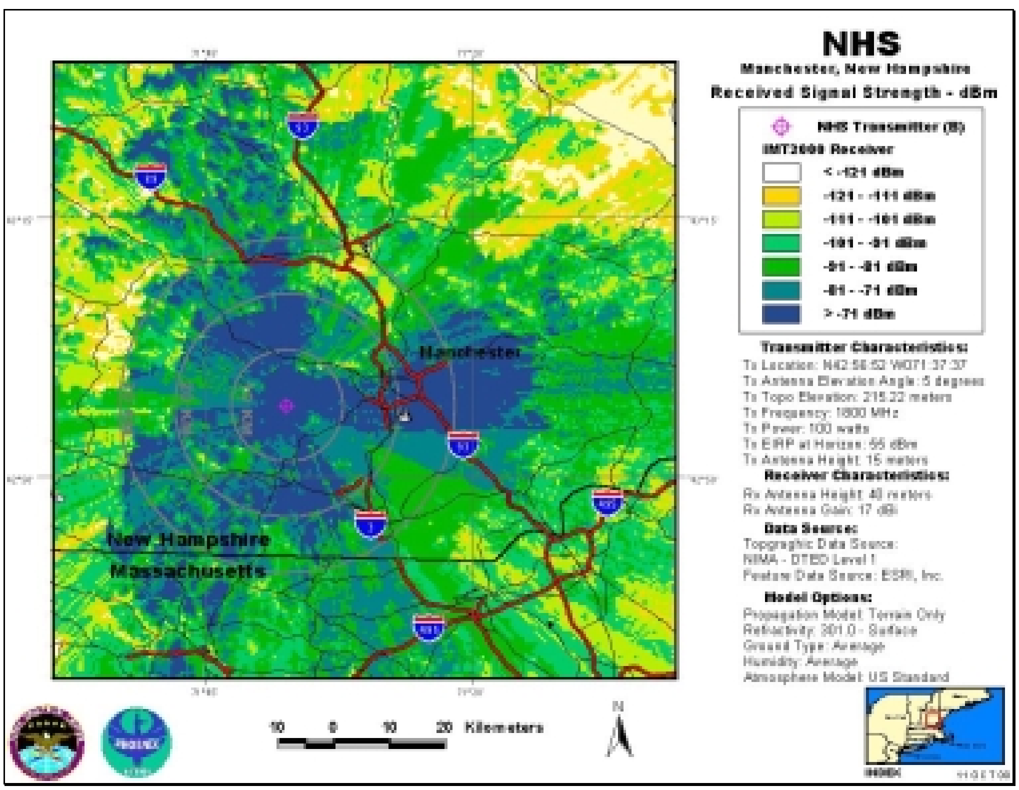

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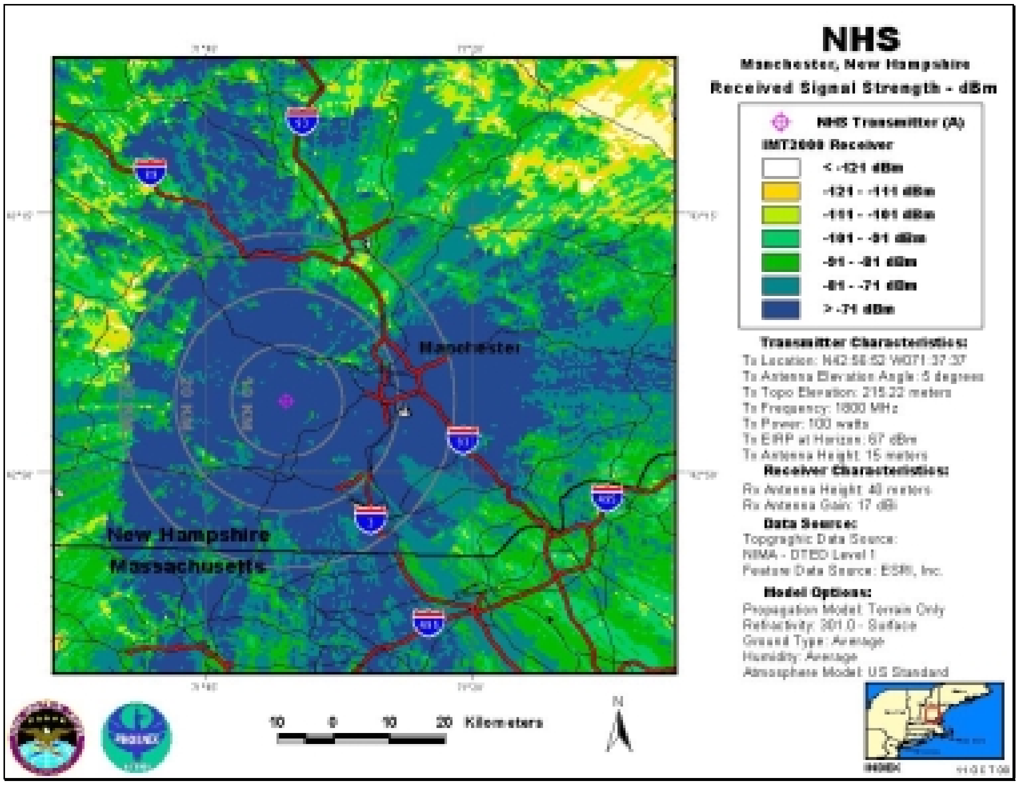

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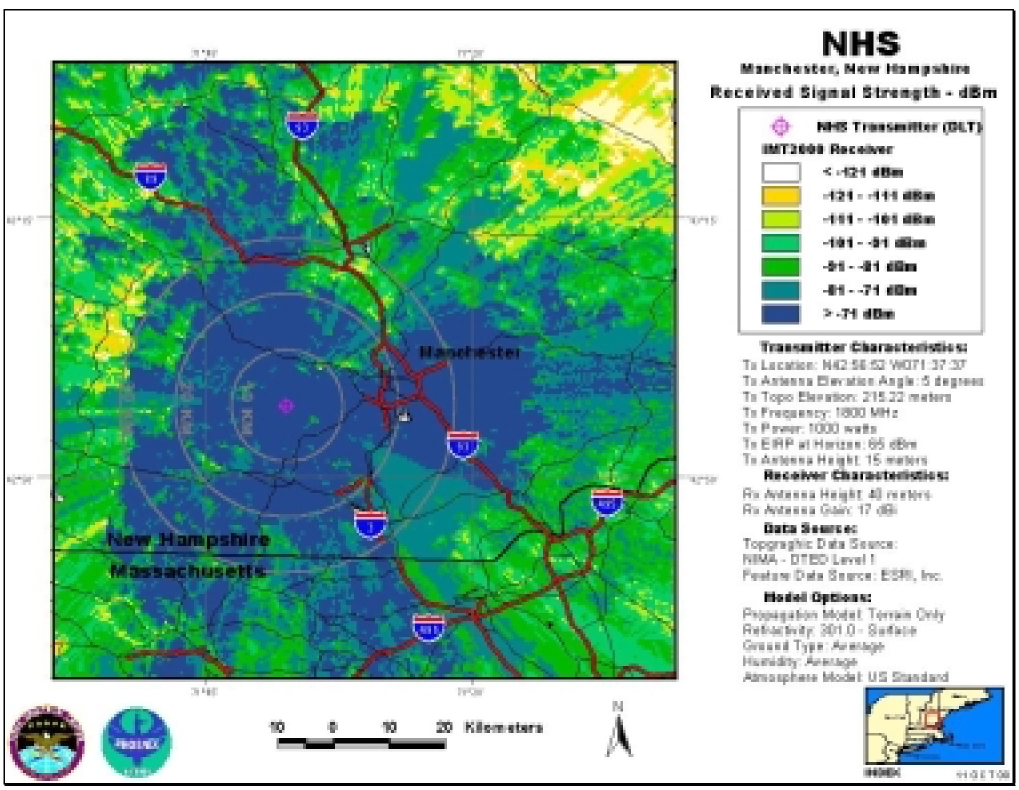

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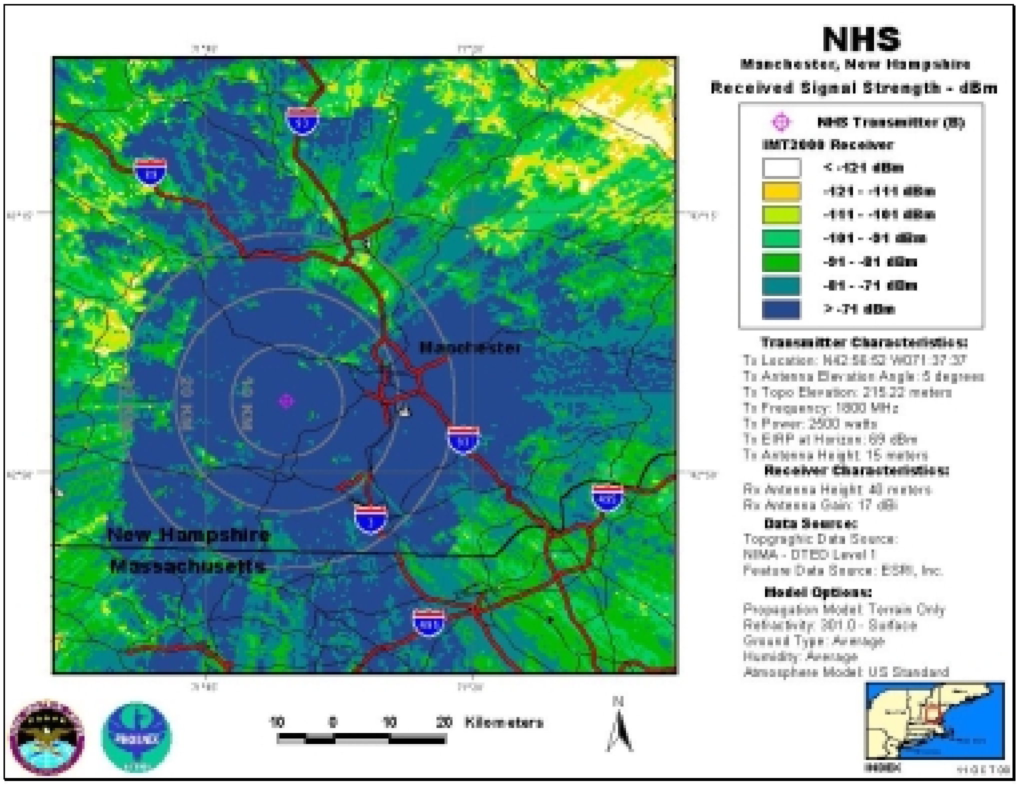

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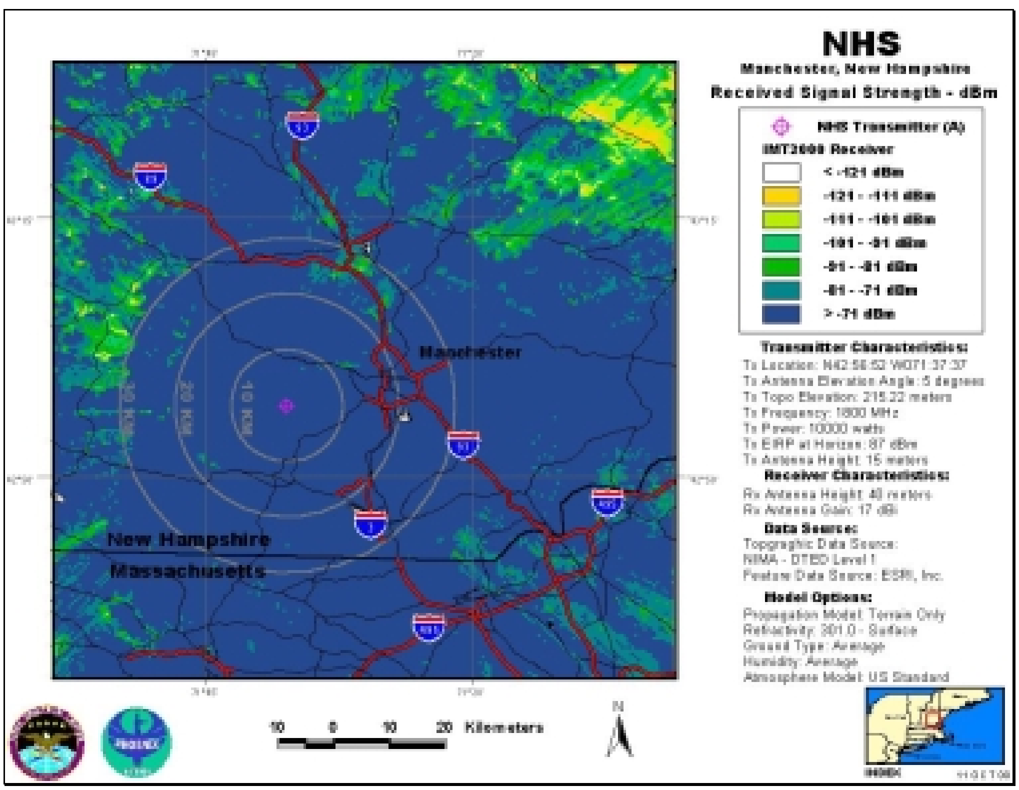

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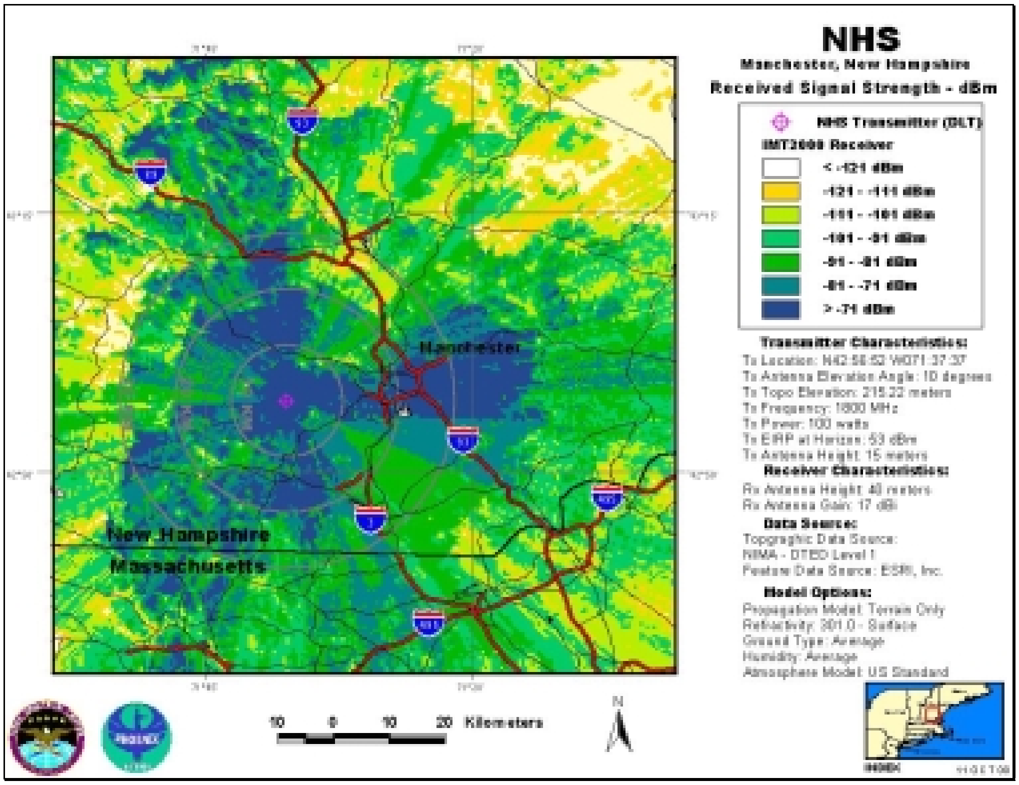

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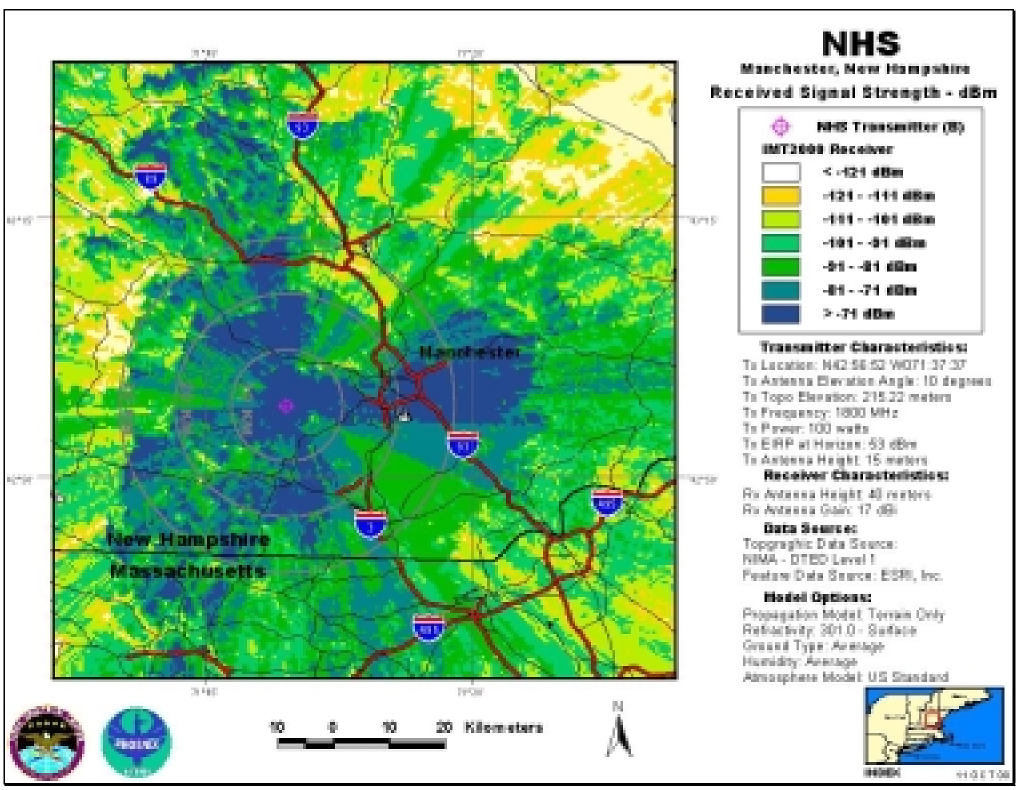

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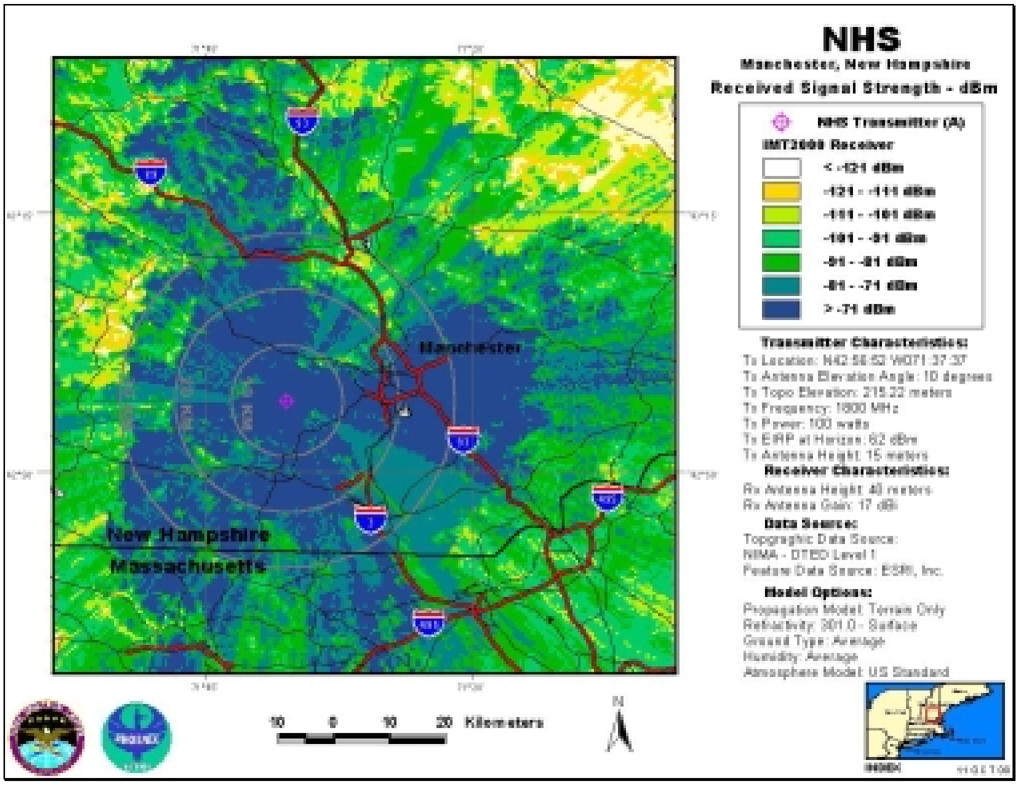

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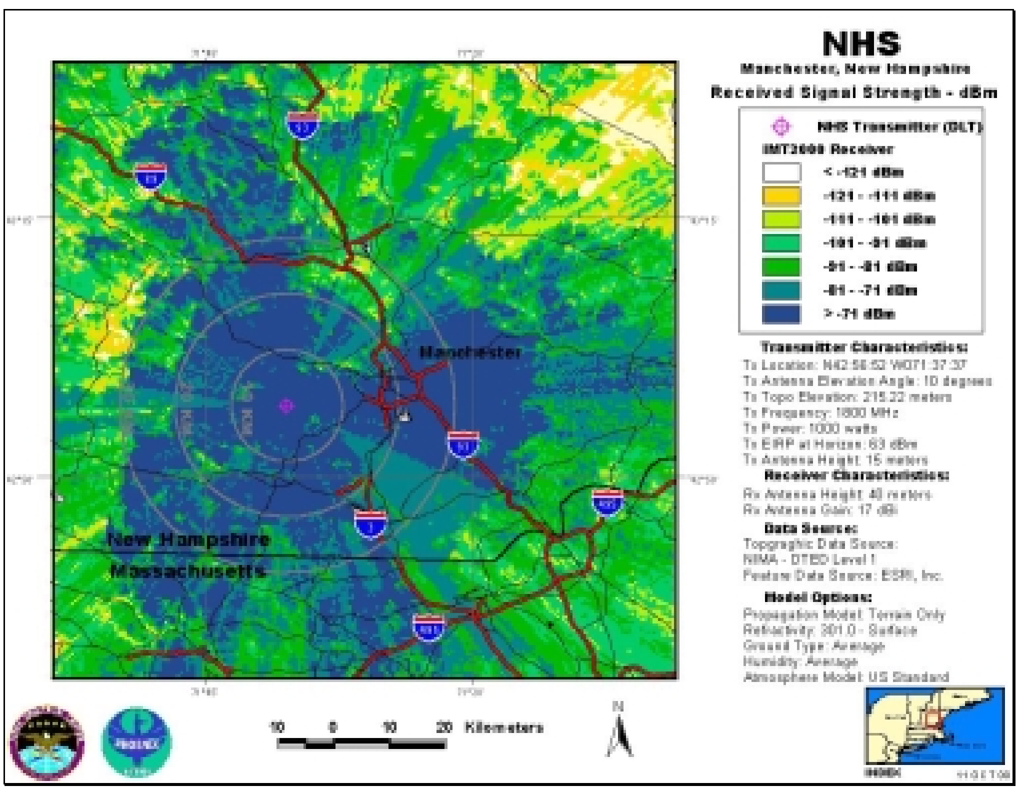

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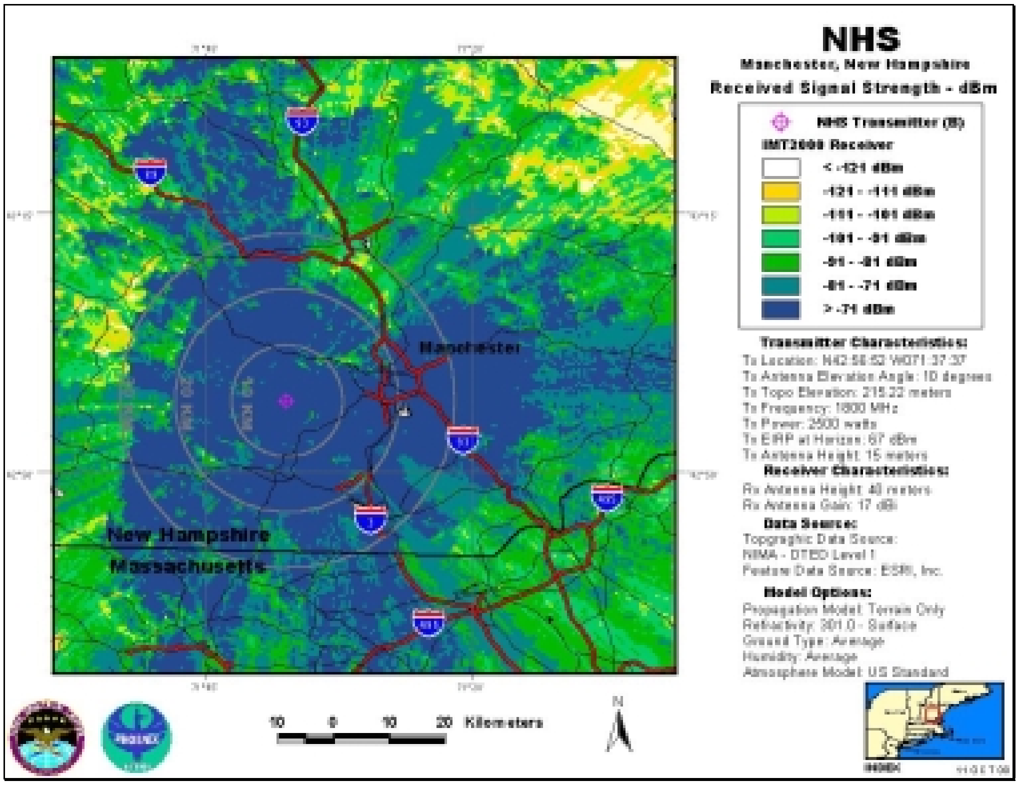

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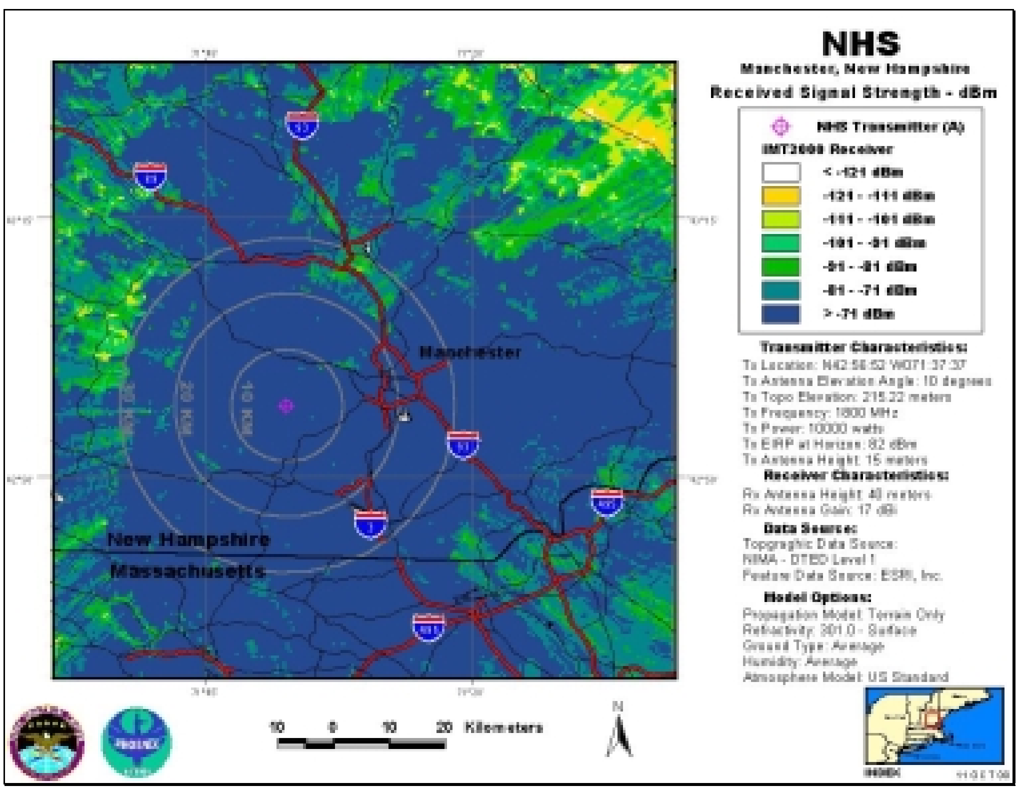

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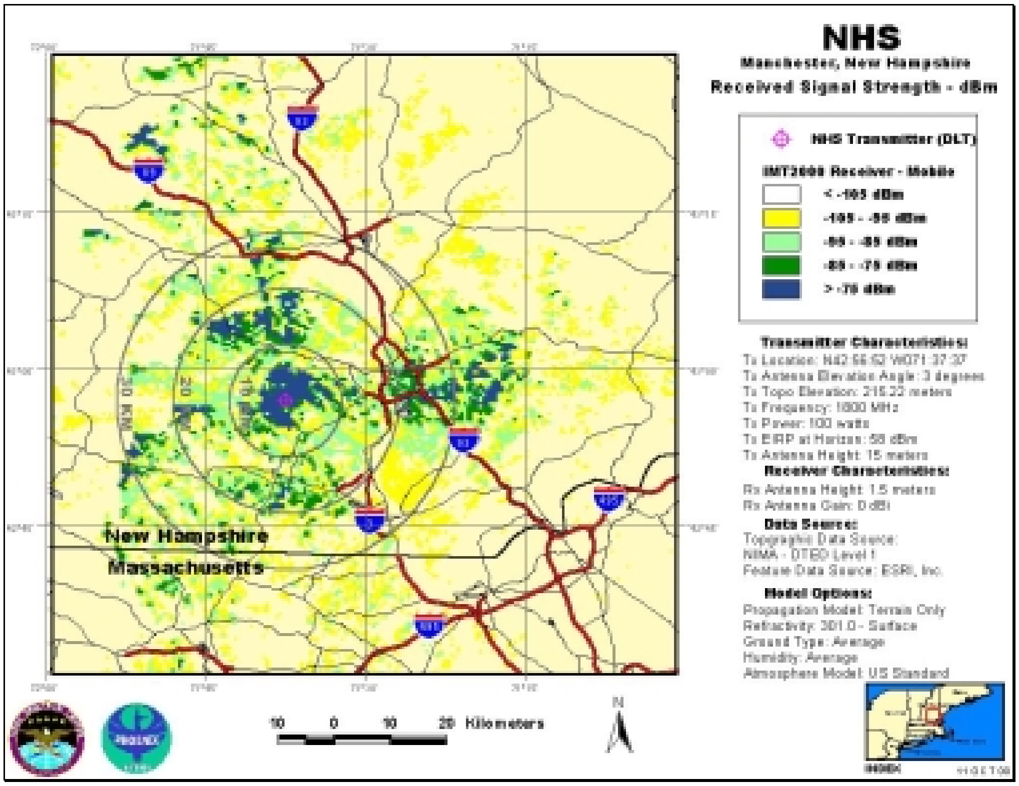

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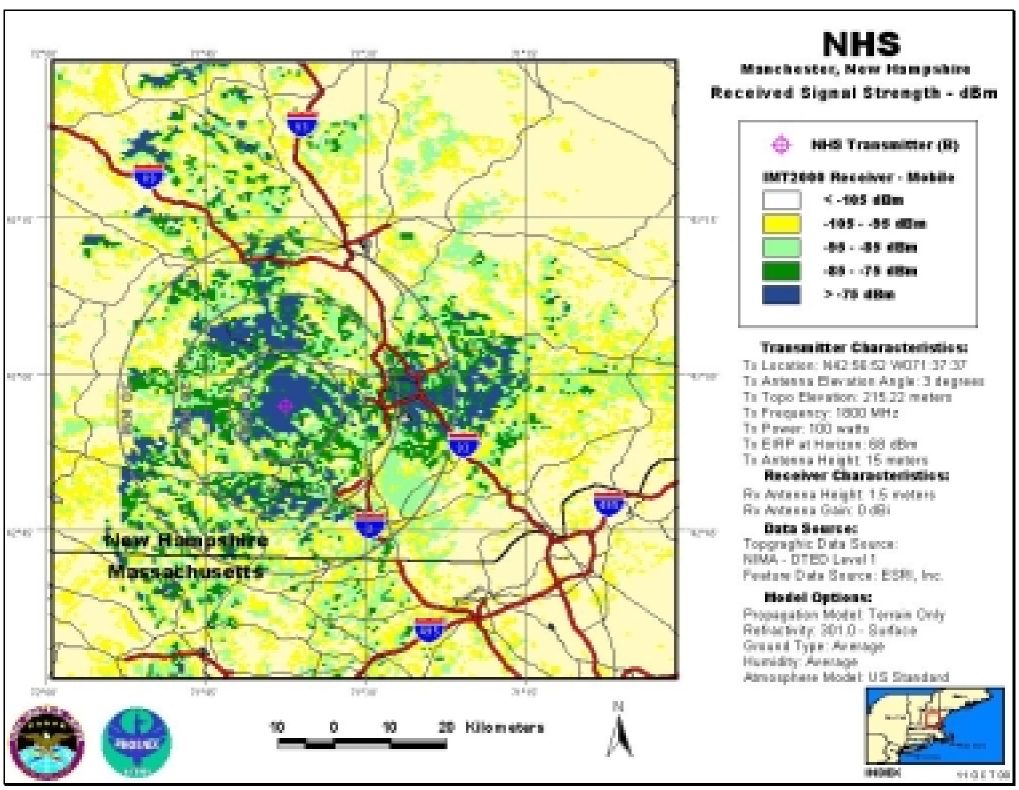

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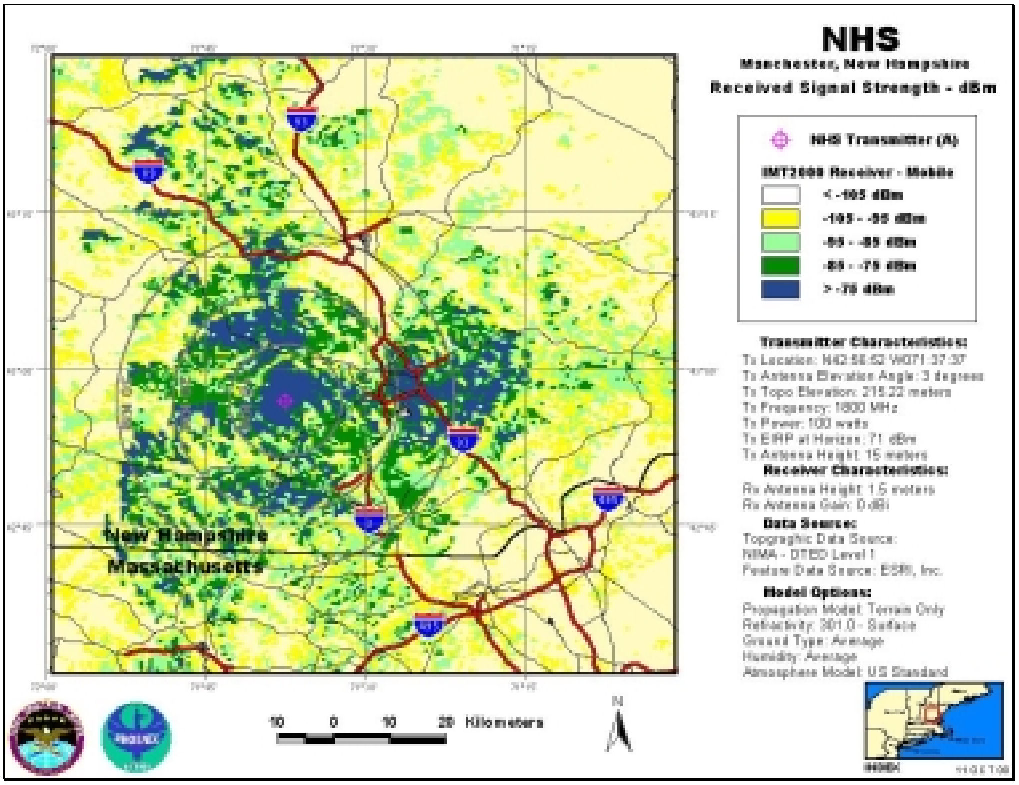

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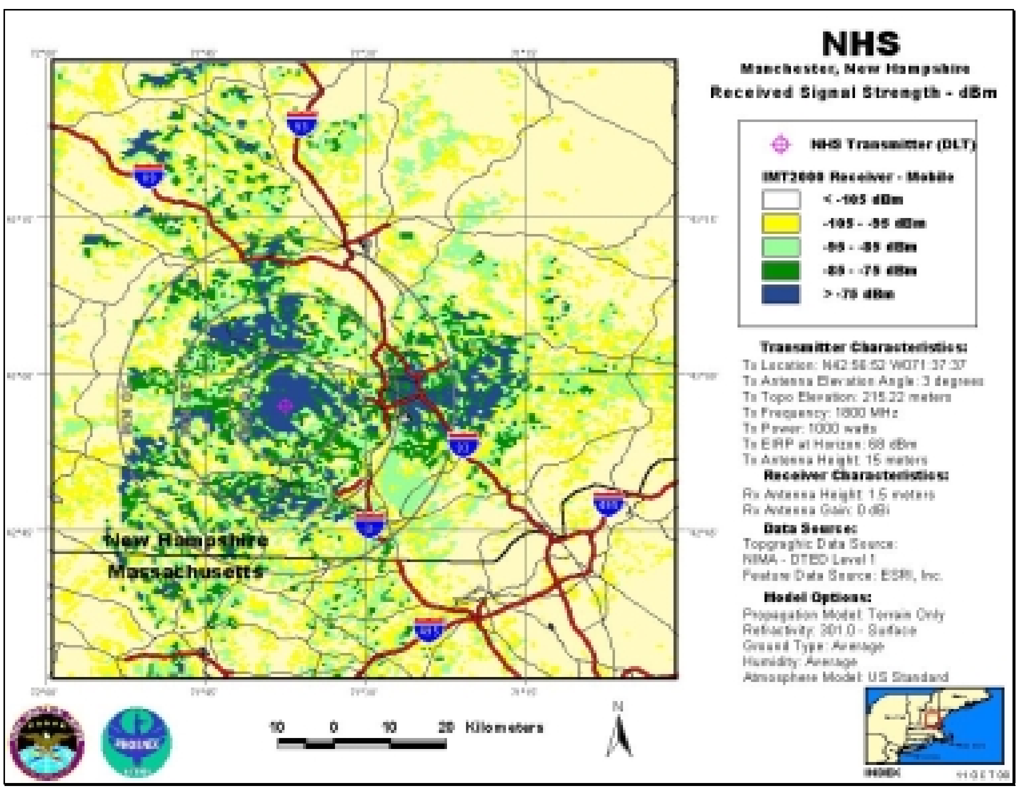

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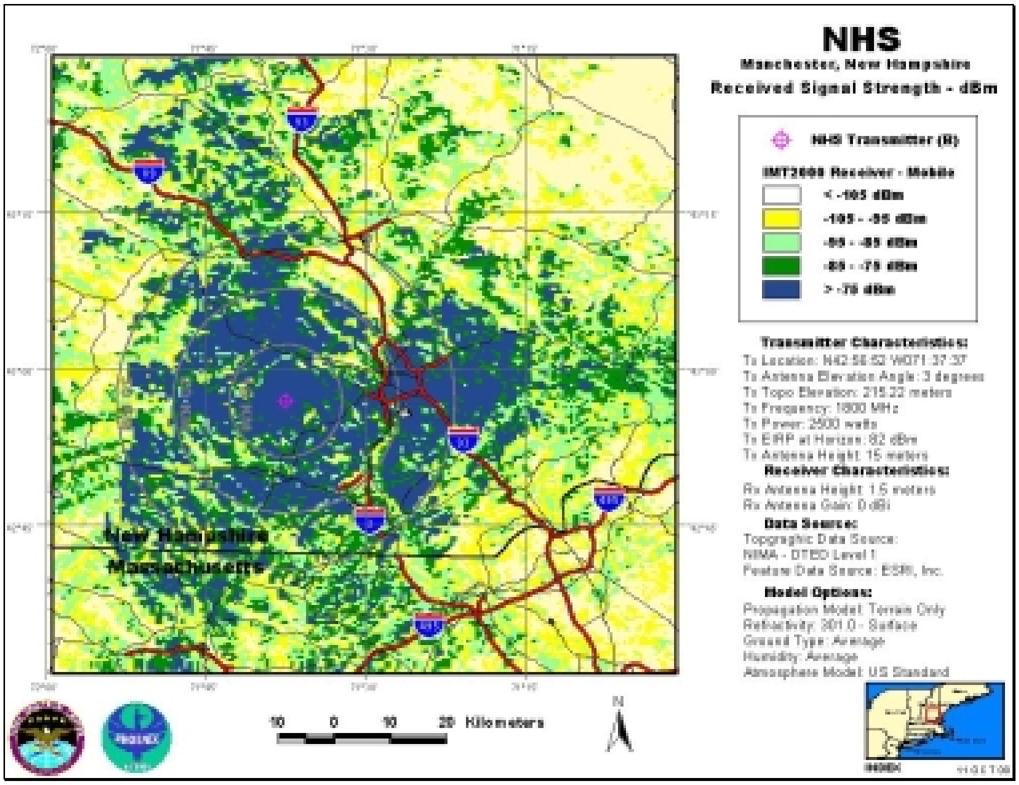

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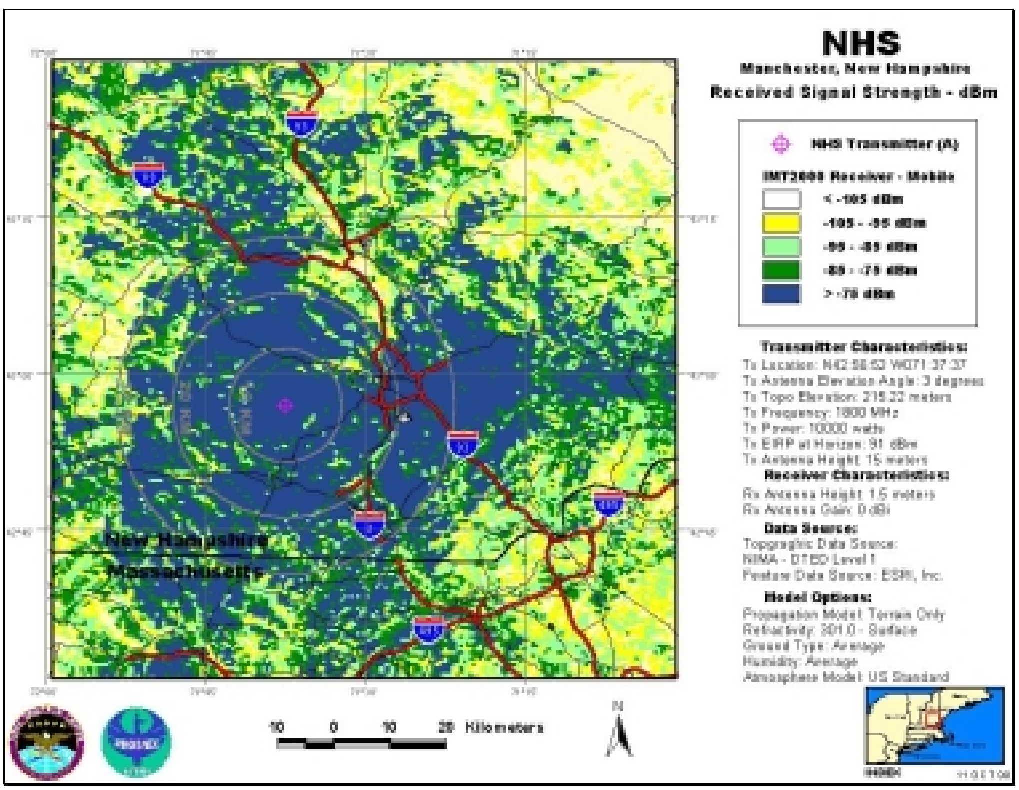

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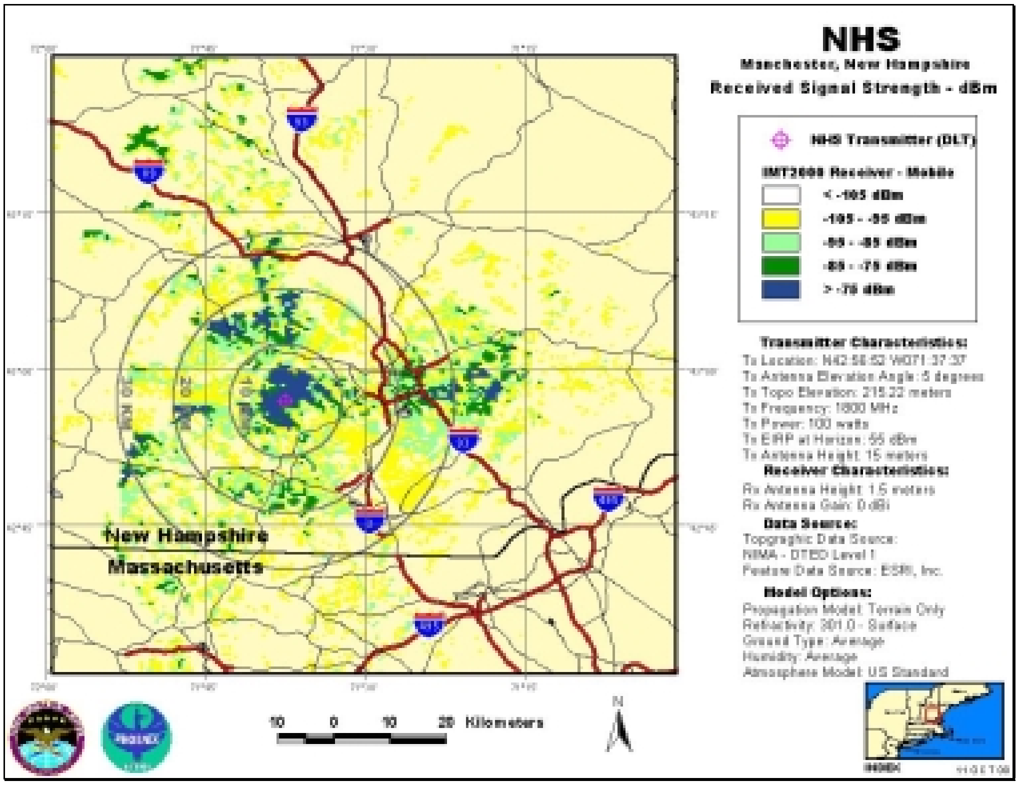

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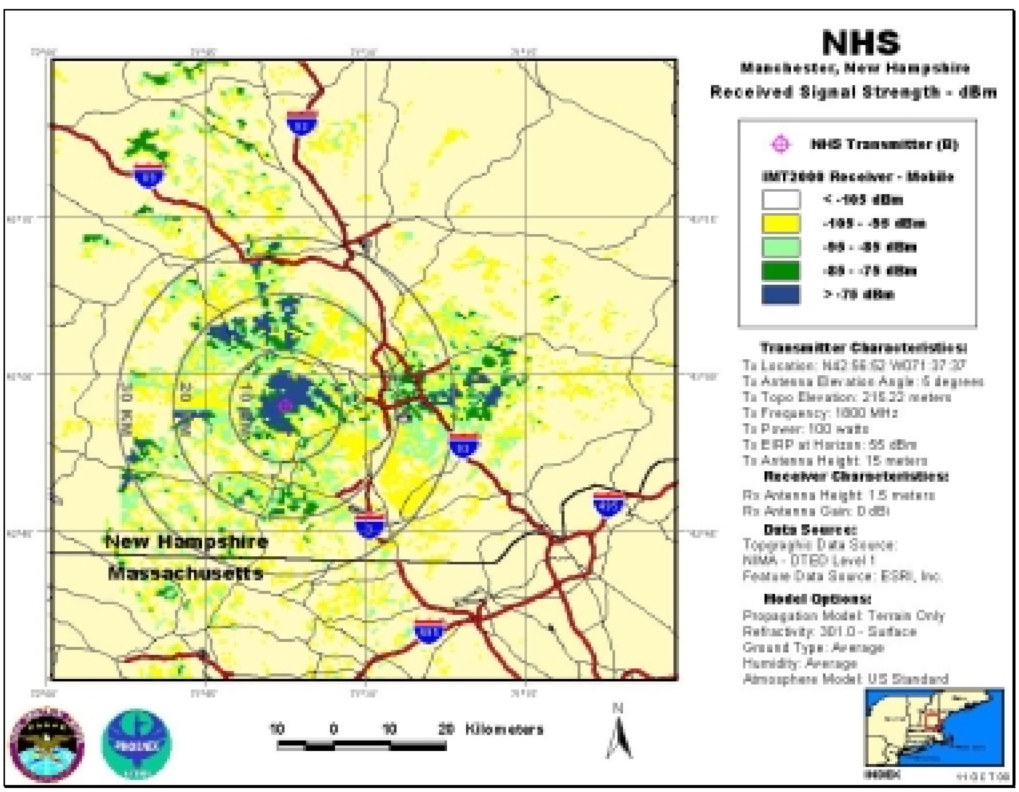

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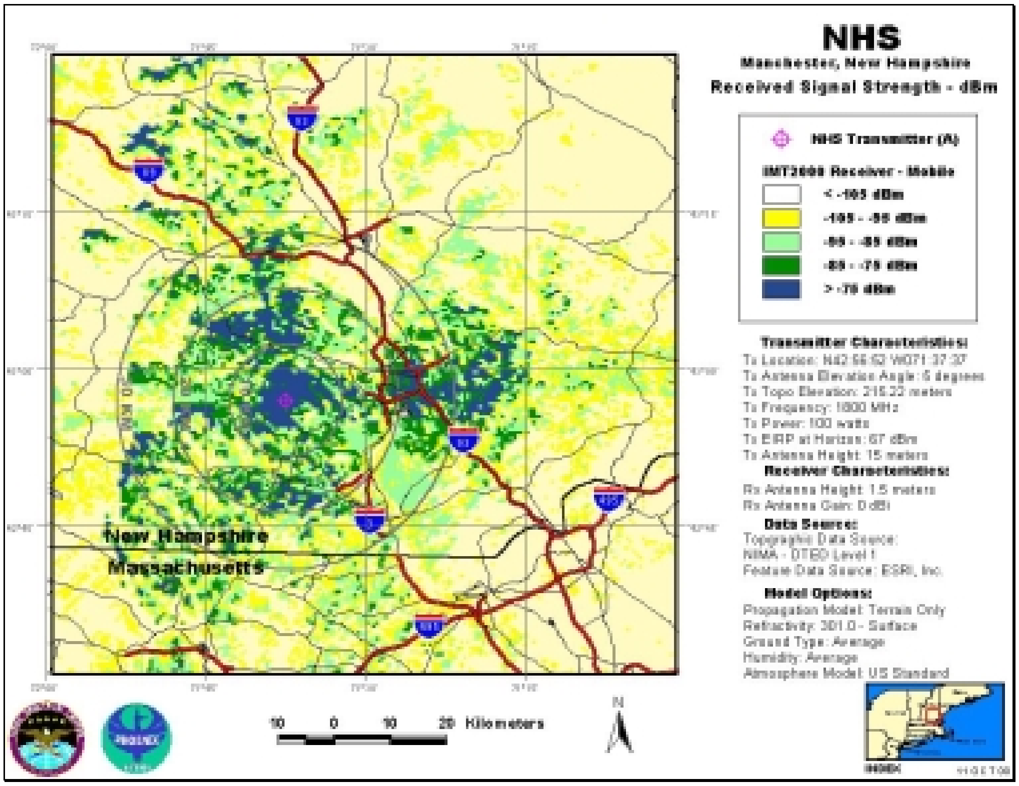

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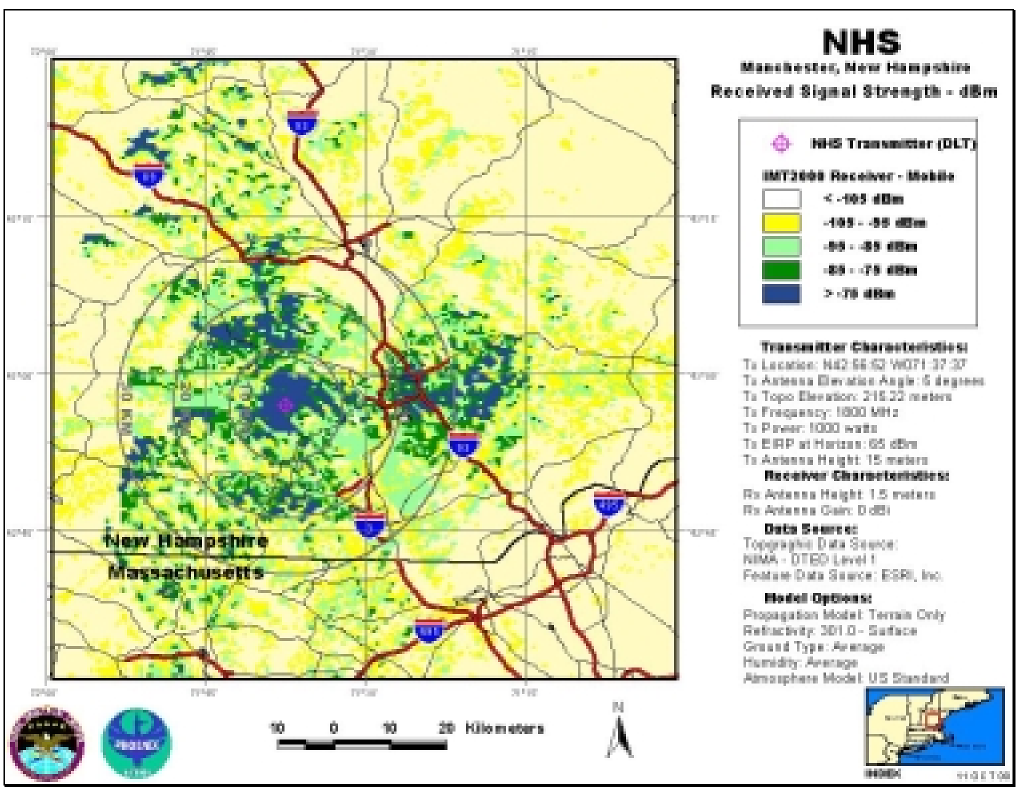

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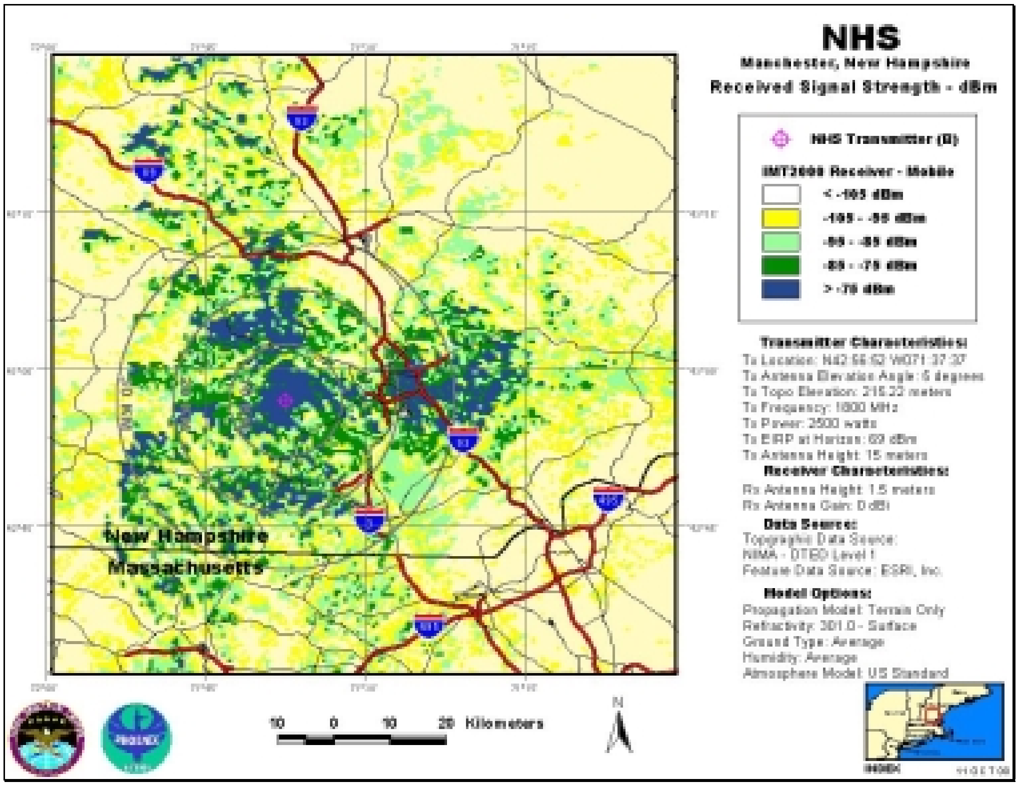

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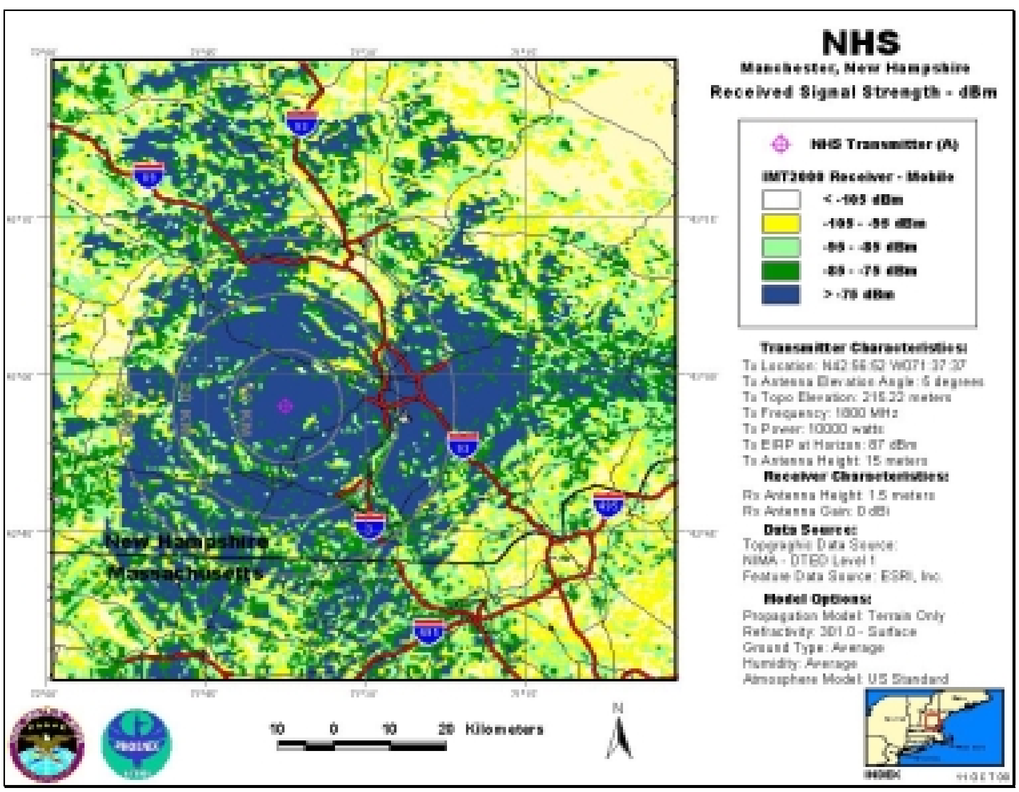

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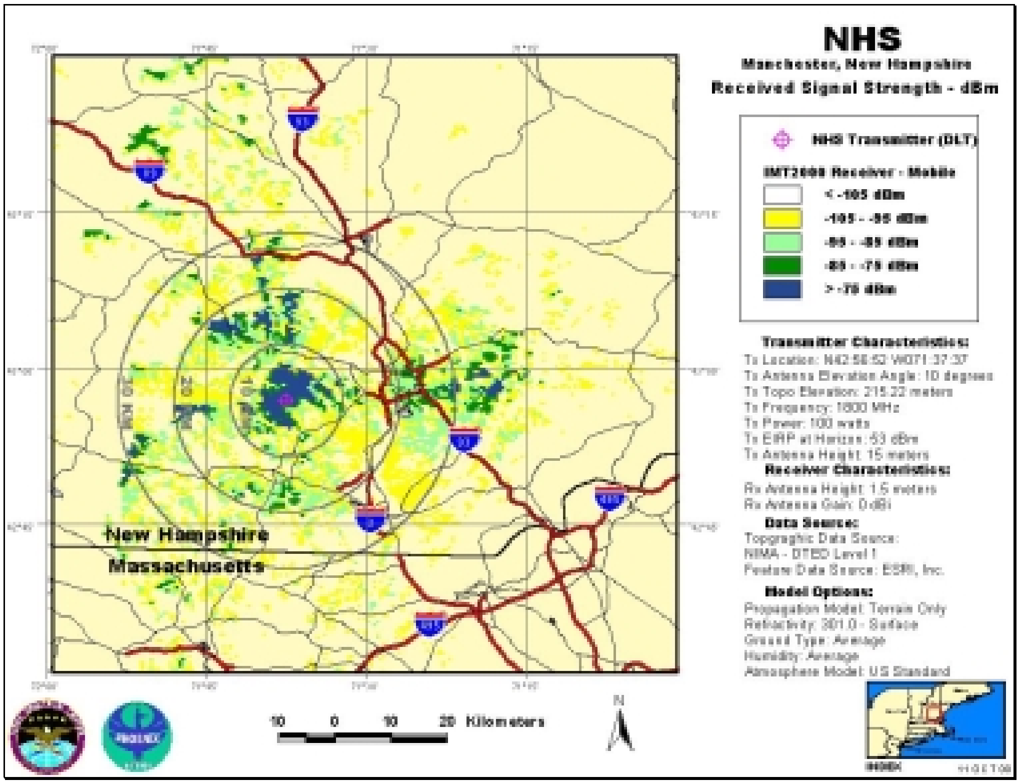

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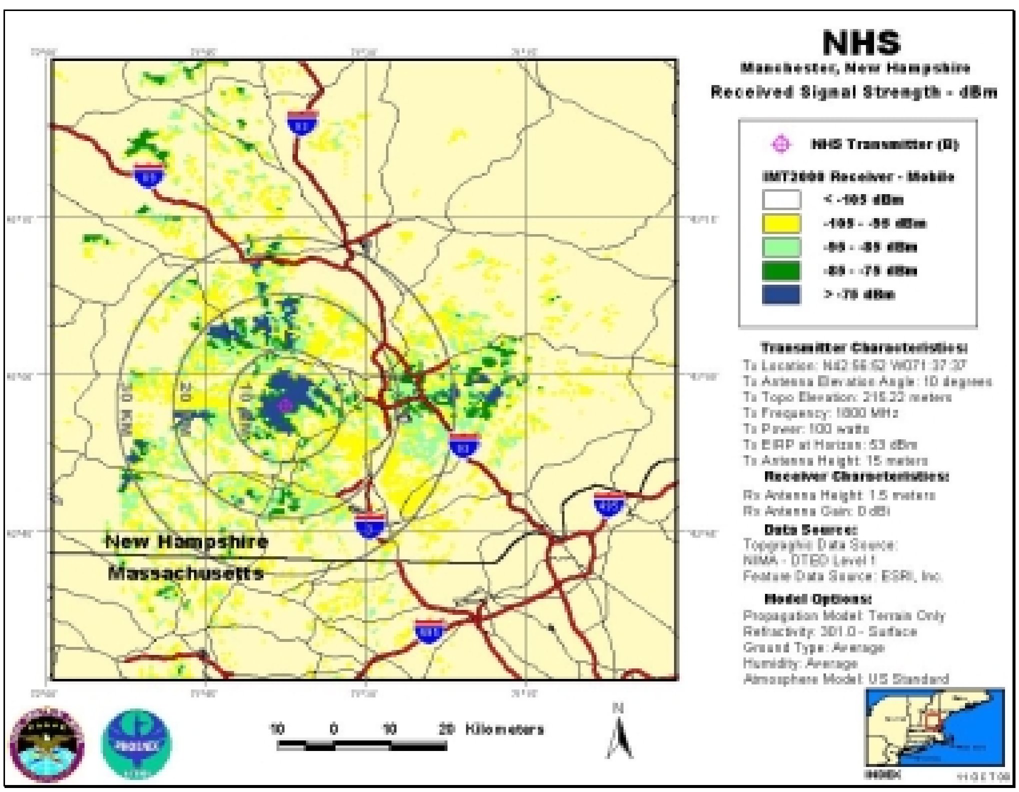

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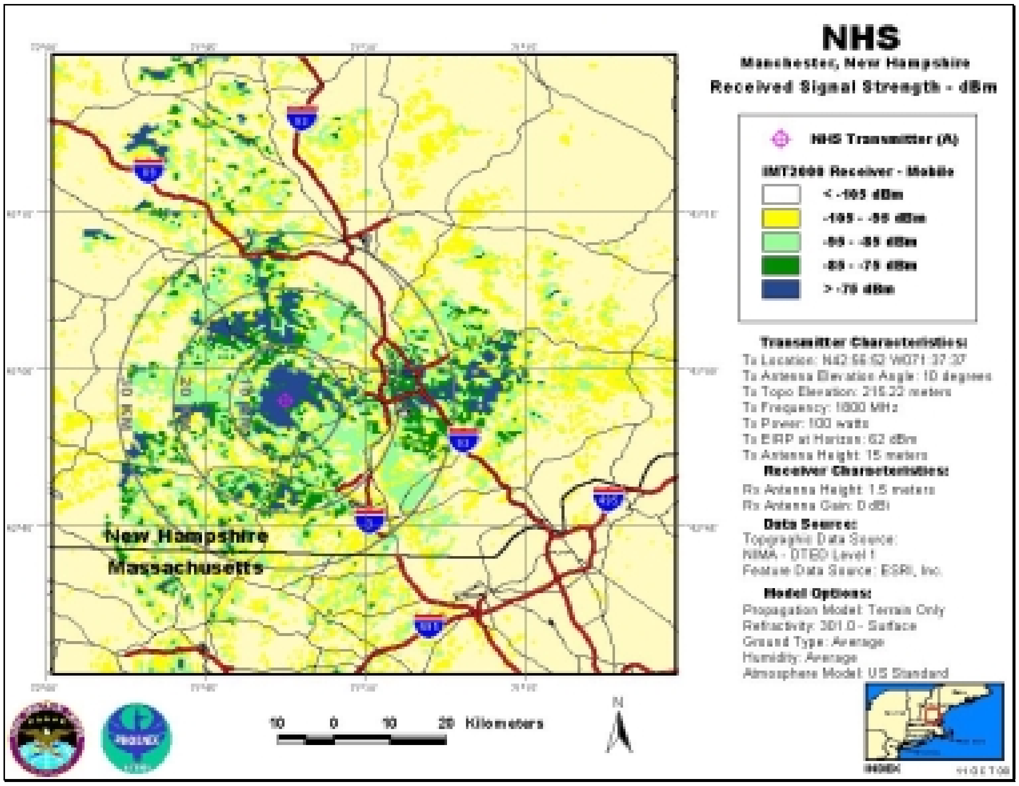

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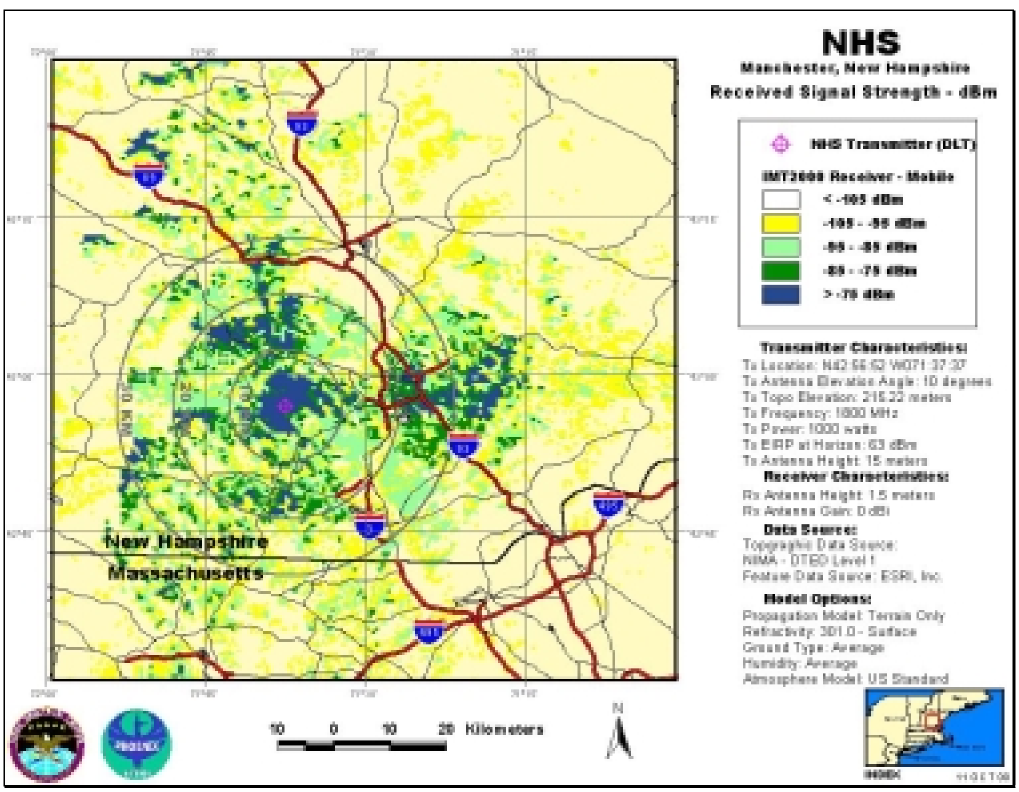
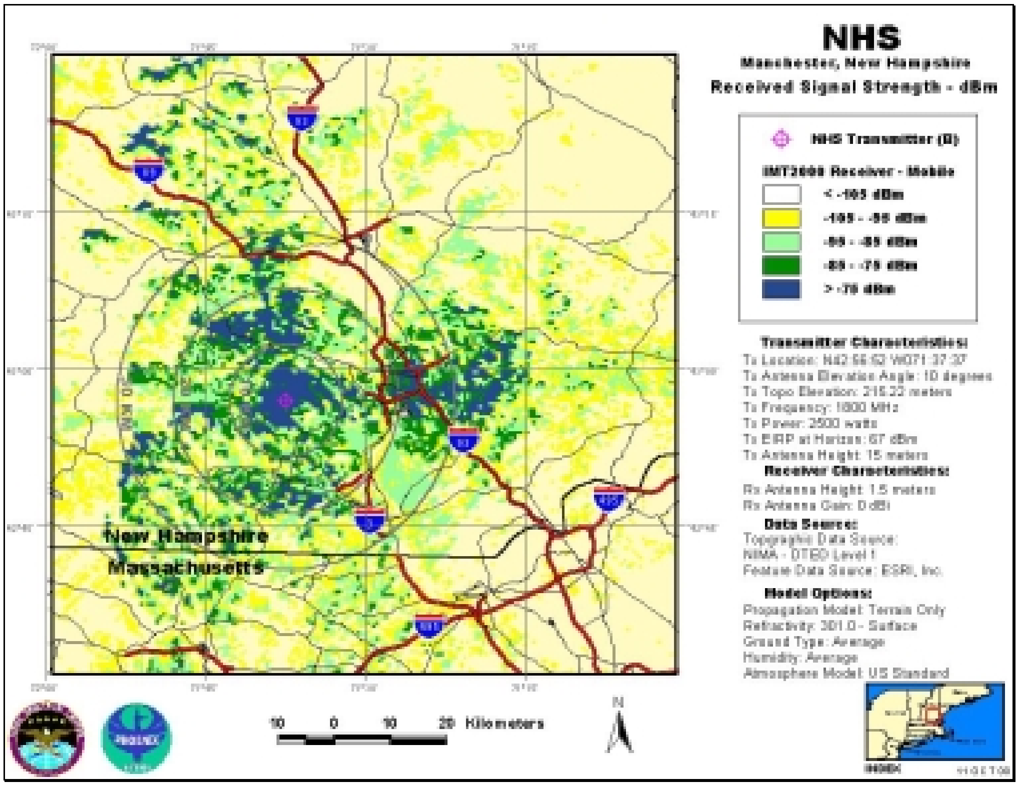
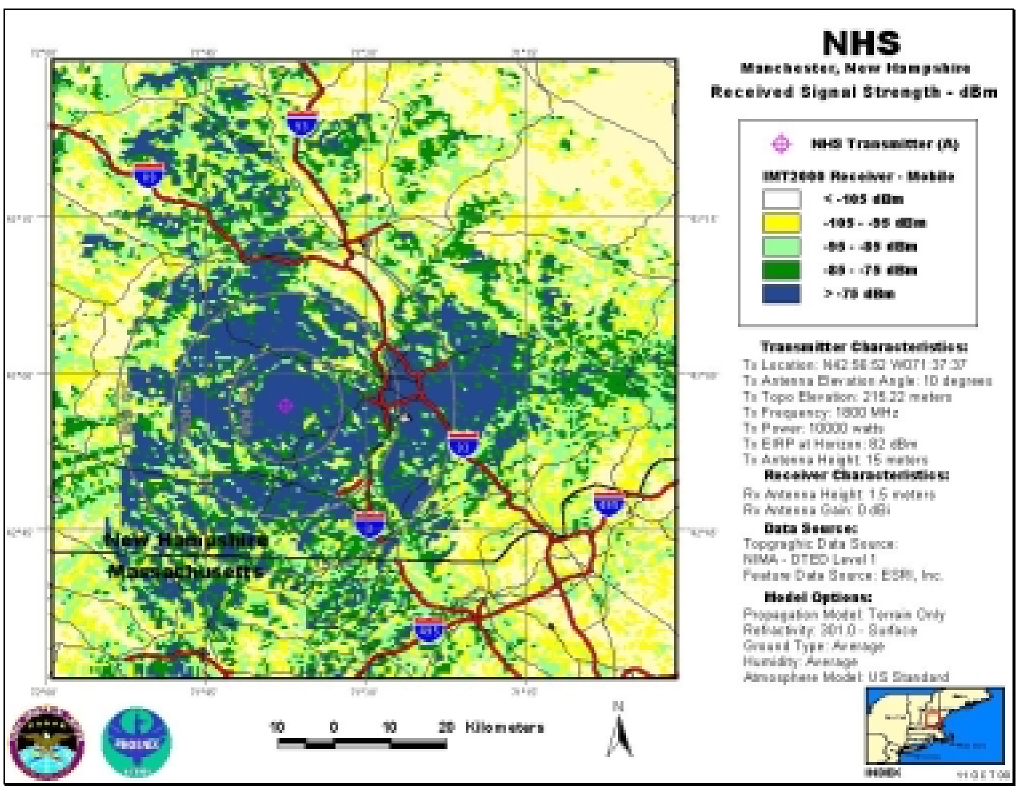


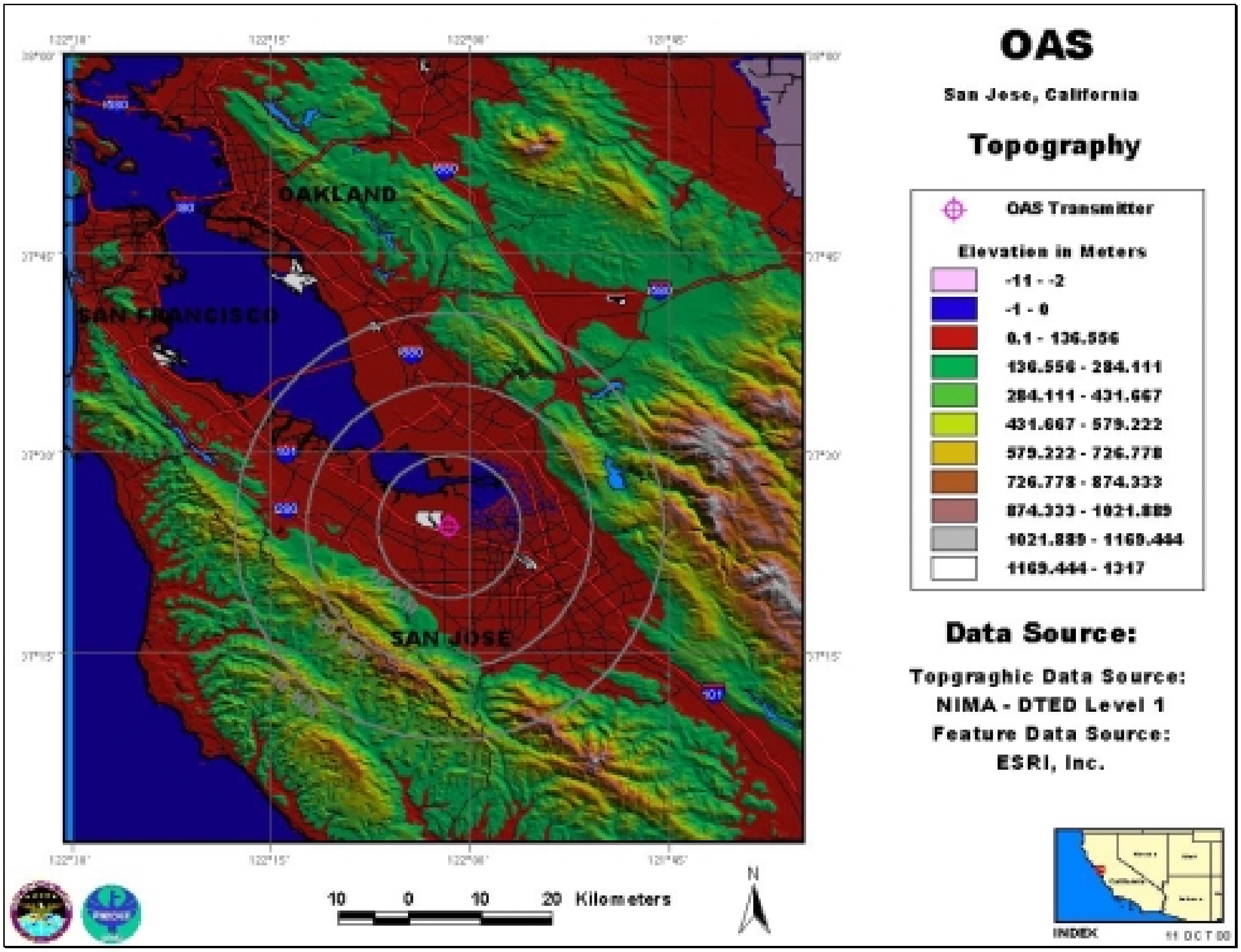
NHS-DLT, Antenna Elevation Angle: 10°, Transmitter Power: 1,000 W, IMT-2000 Mobile Station



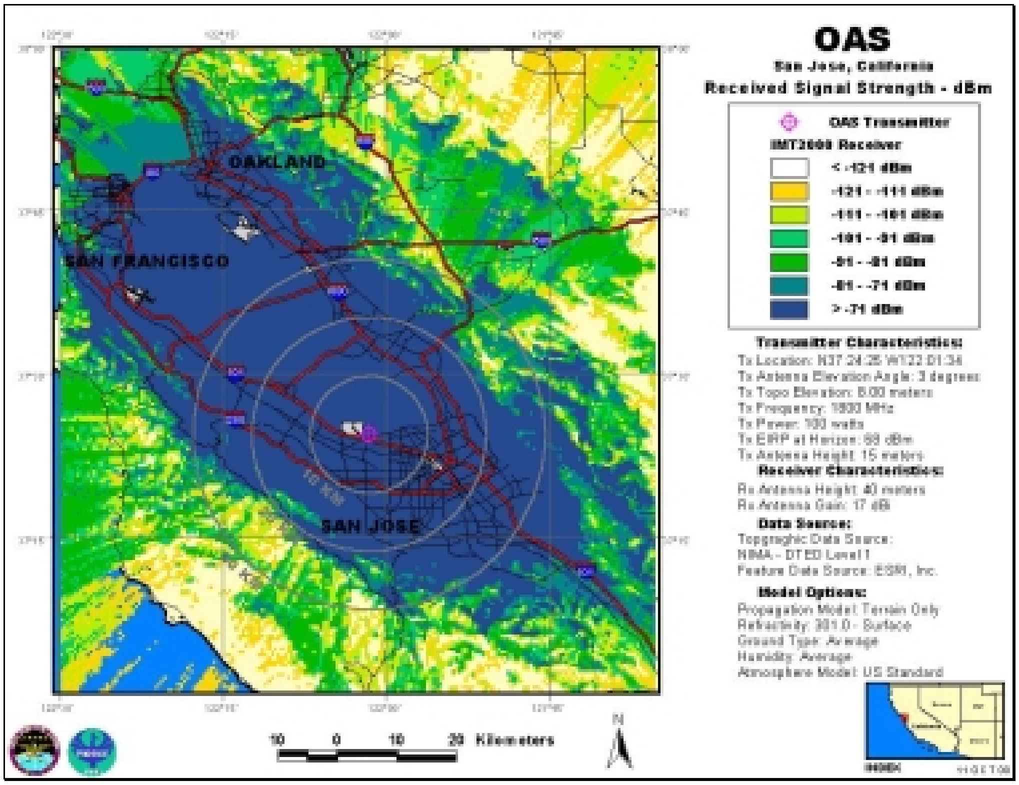
NHS-B, Antenna Elevation Angle: 10°, Transmitter Power: 2,500 W, IMT-2000 Mobile Station



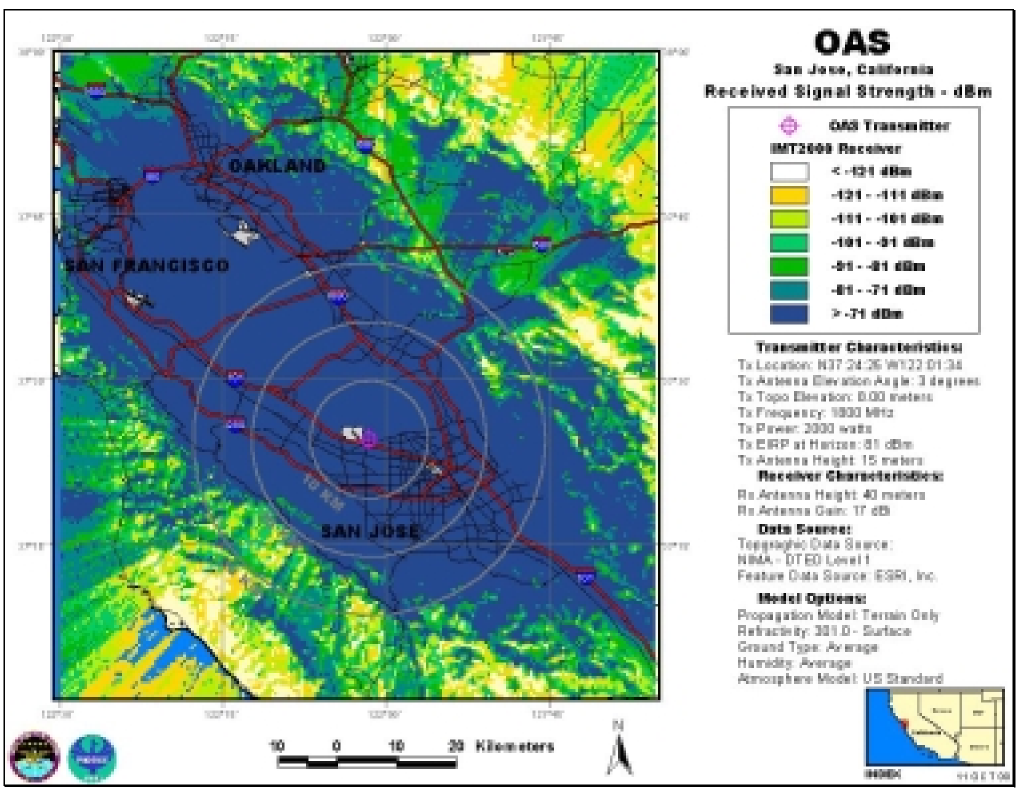
NHS-A, Antenna Elevation Angle: 10°, Transmitter Power: 10,000 W, IMT-2000 Mobile Station



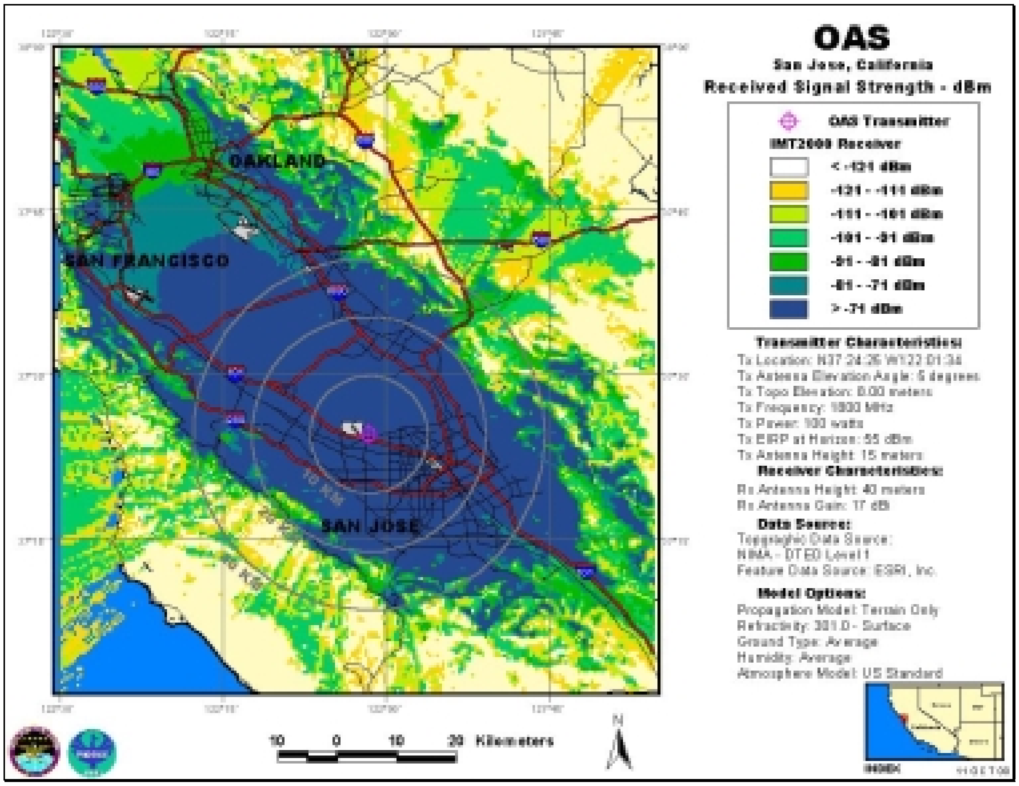
Topography Around OAS, San Jose, California



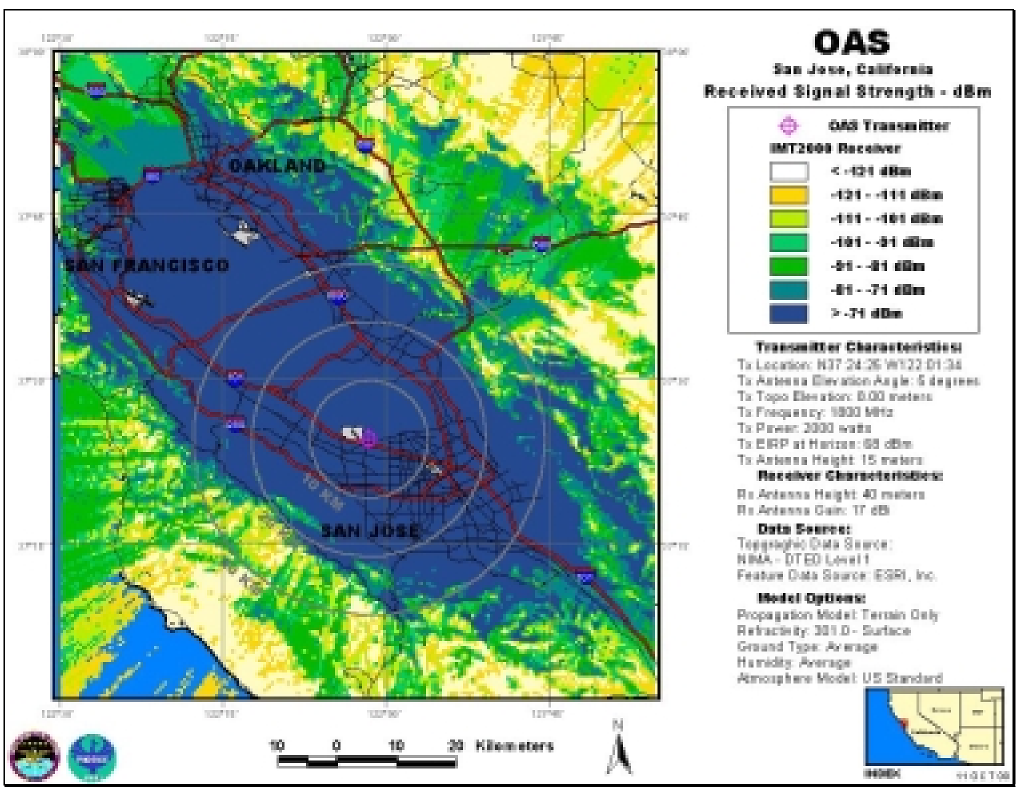
OAS, Antenna Elevation Angle: 3°, Transmitter Power: 100 W, IMT-2000 Base Station



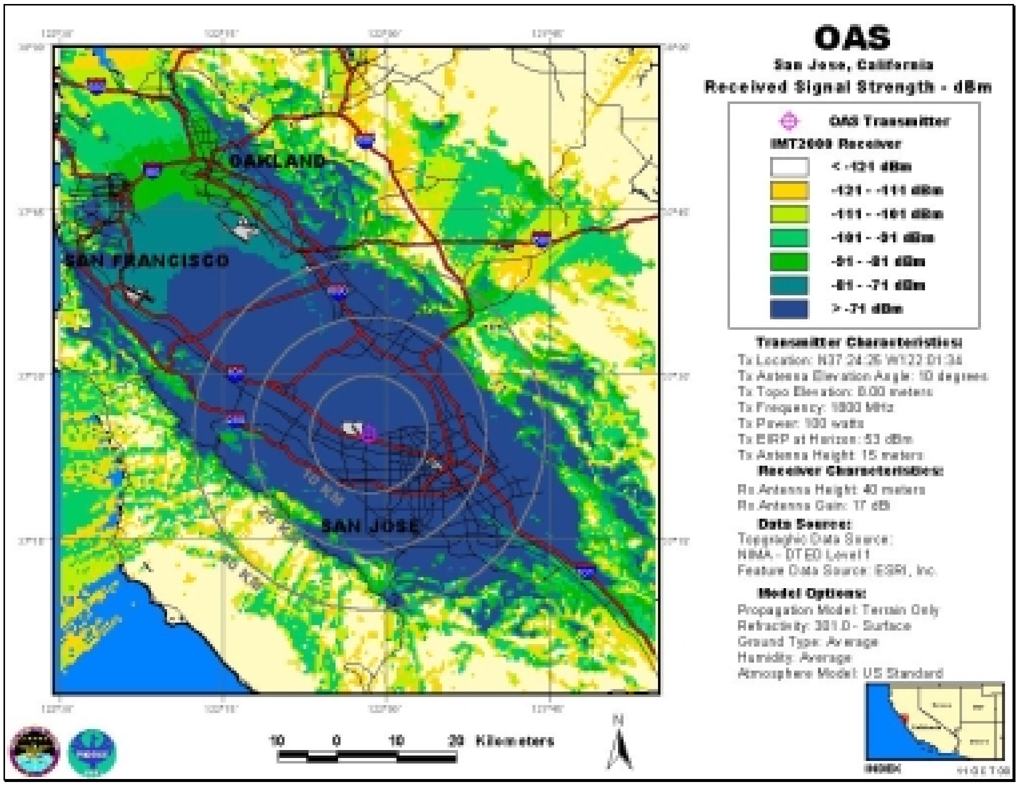
OAS, Antenna Elevation Angle: 3°, Transmitter Power: 2,000 W, IMT-2000 Base Station



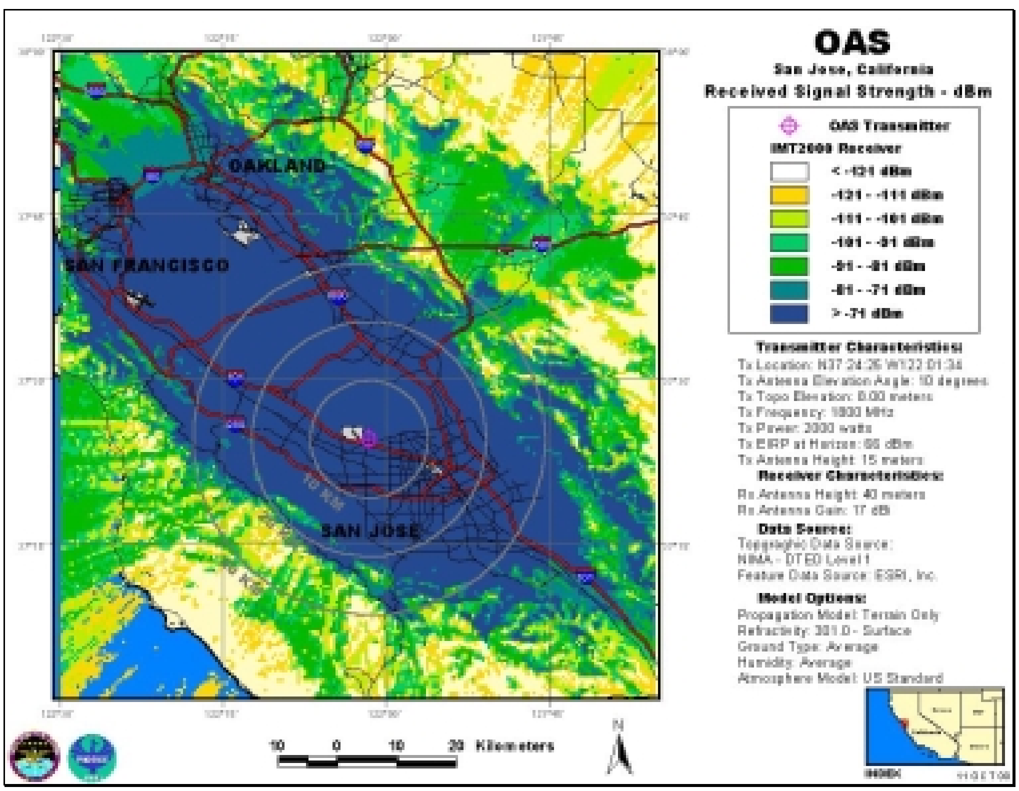
OAS, Antenna Elevation Angle: 5°, Transmitter Power: 100 W, IMT-2000 Base Station



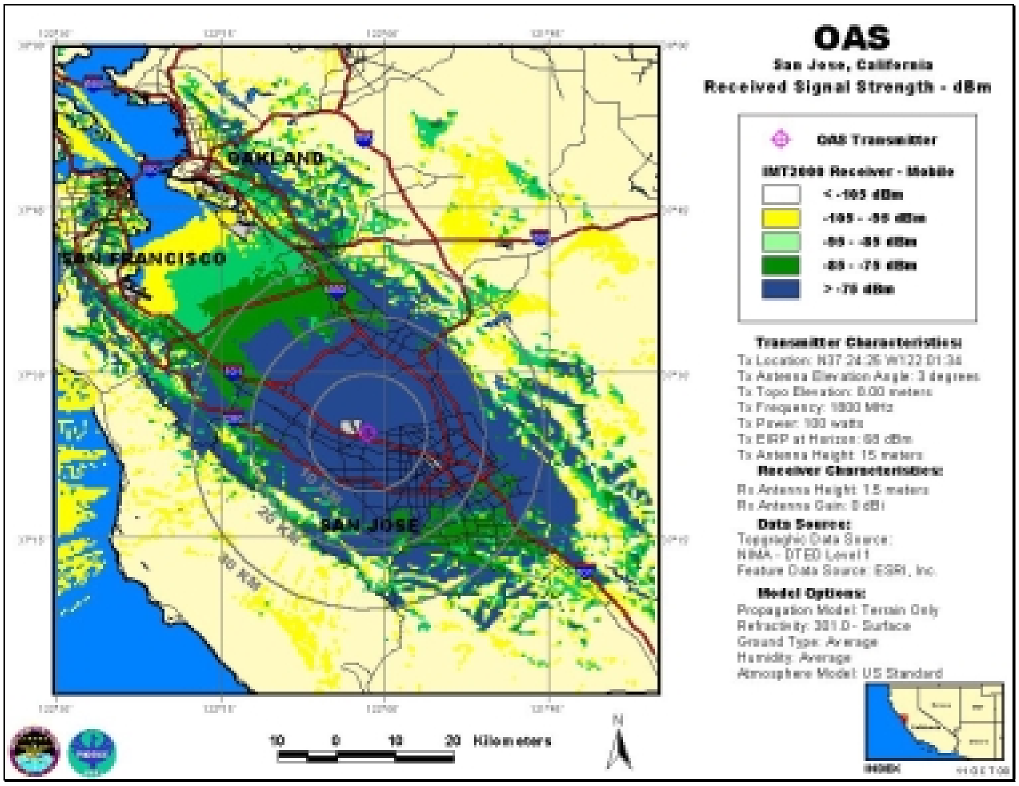
OAS, Antenna Elevation Angle: 5°, Transmitter Power: 2,000 W, IMT-2000 Base Station



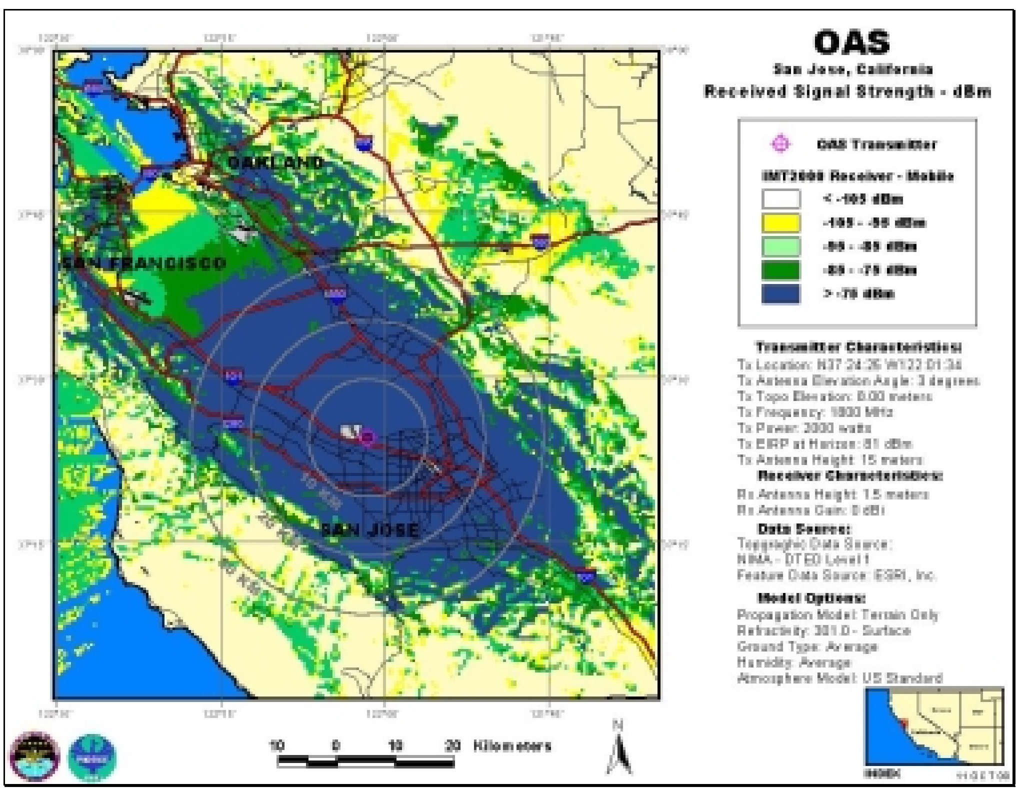
OAS, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Base Station



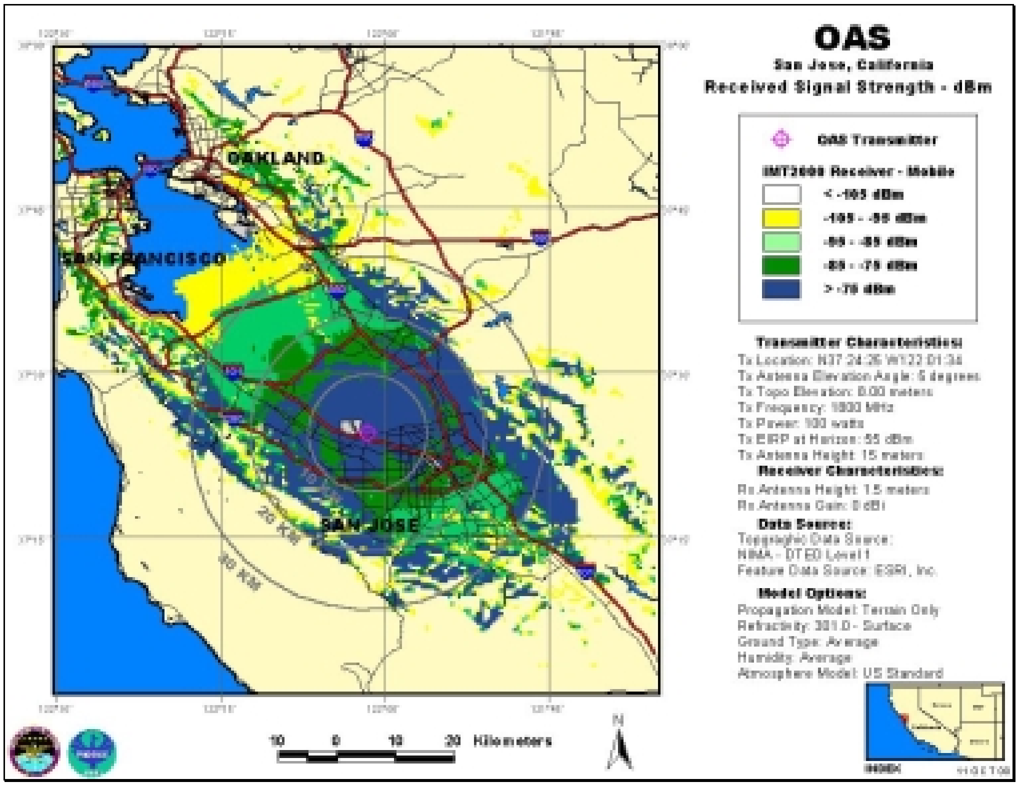
OAS, Antenna Elevation Angle: 10°, Transmitter Power: 2,000 W, IMT-2000 Base Station



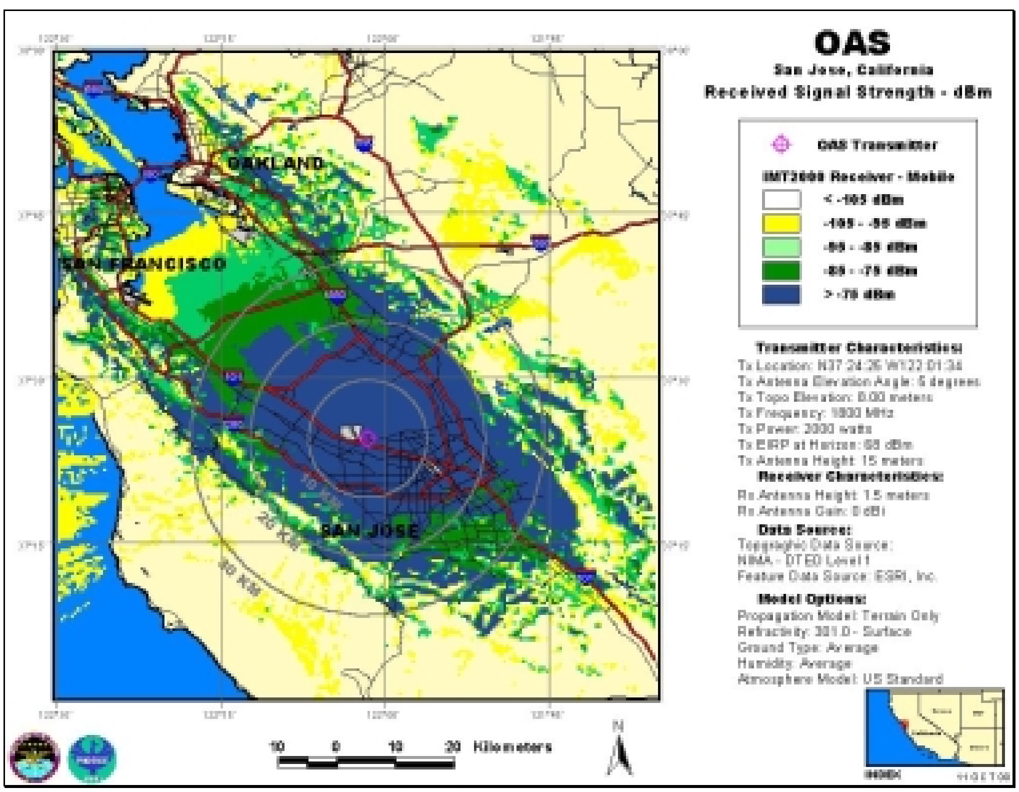
OAS, Antenna Elevation Angle: 3°, Transmitter Power: 100 W, IMT-2000 Mobile Station



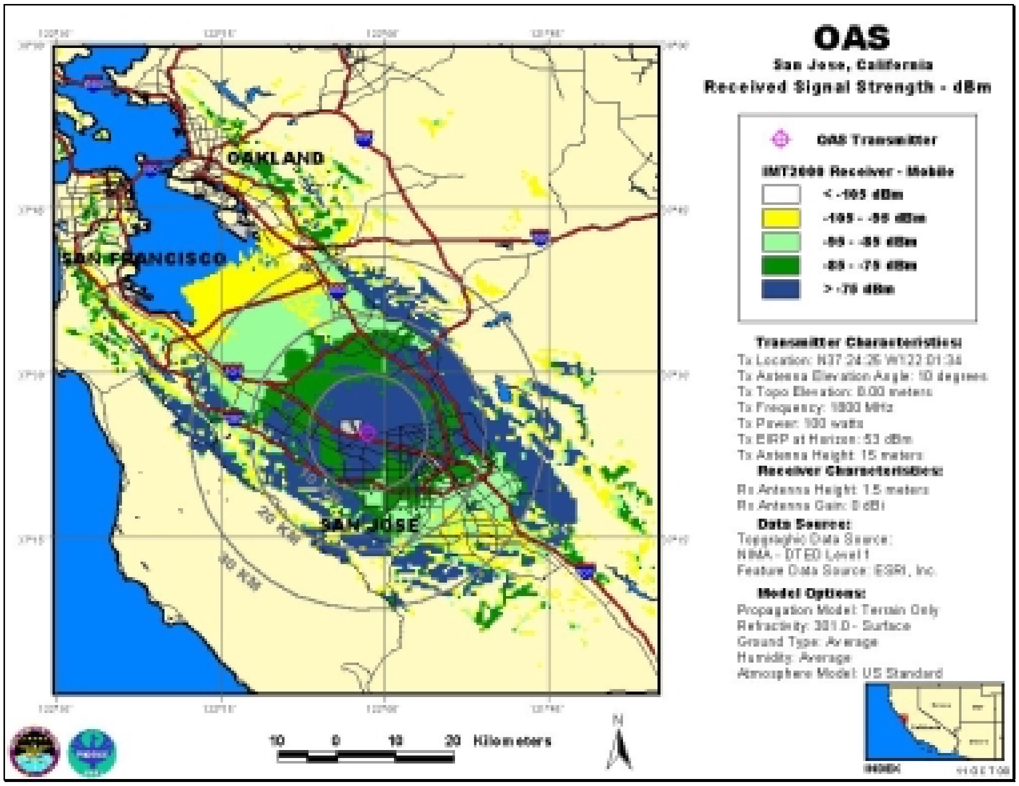
OAS, Antenna Elevation Angle: 3°, Transmitter Power: 2,000 W, IMT-2000 Mobile Station



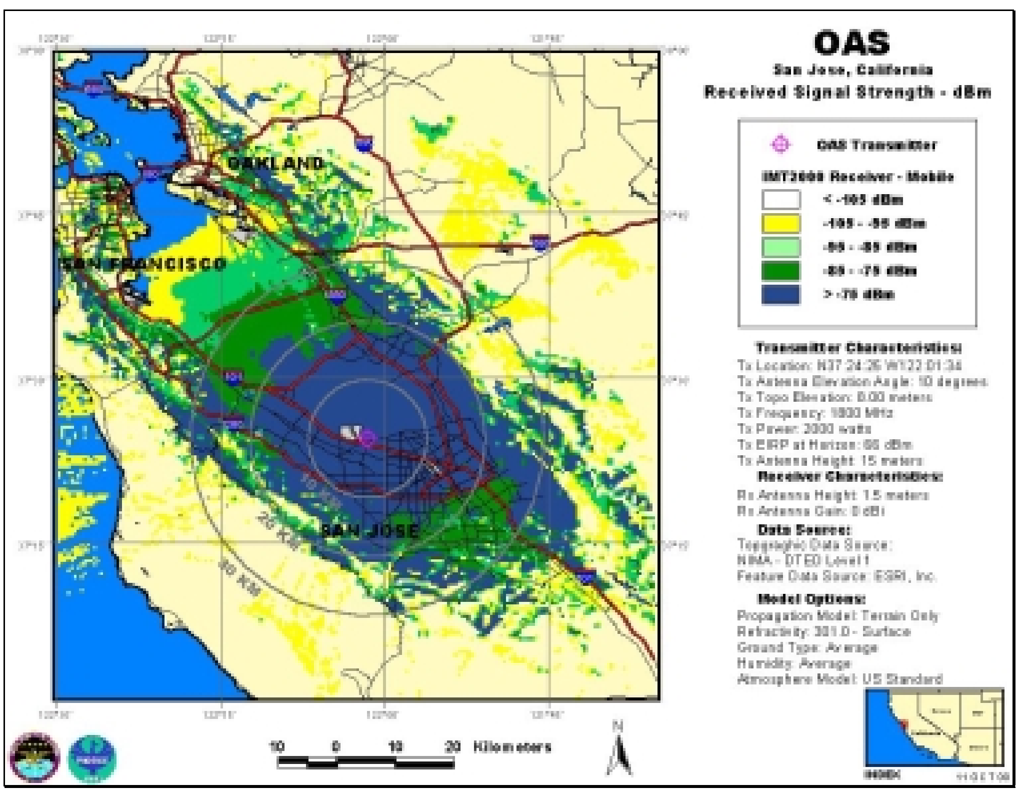
OAS, Antenna Elevation Angle: 5°, Transmitter Power: 100 W, IMT-2000 Mobile Station



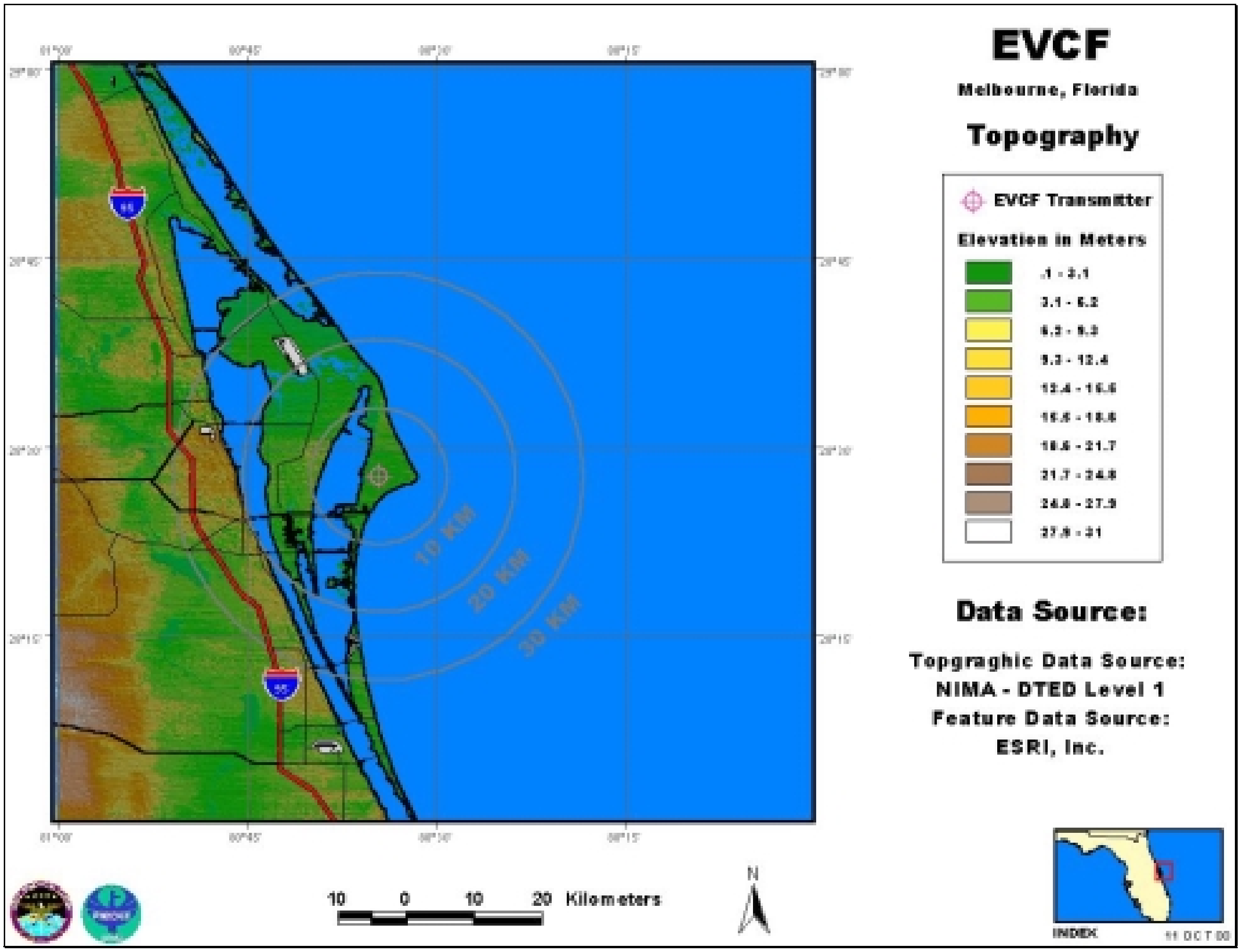
OAS, Antenna Elevation Angle: 5°, Transmitter Power: 2,000 W, IMT-2000 Mobile Station



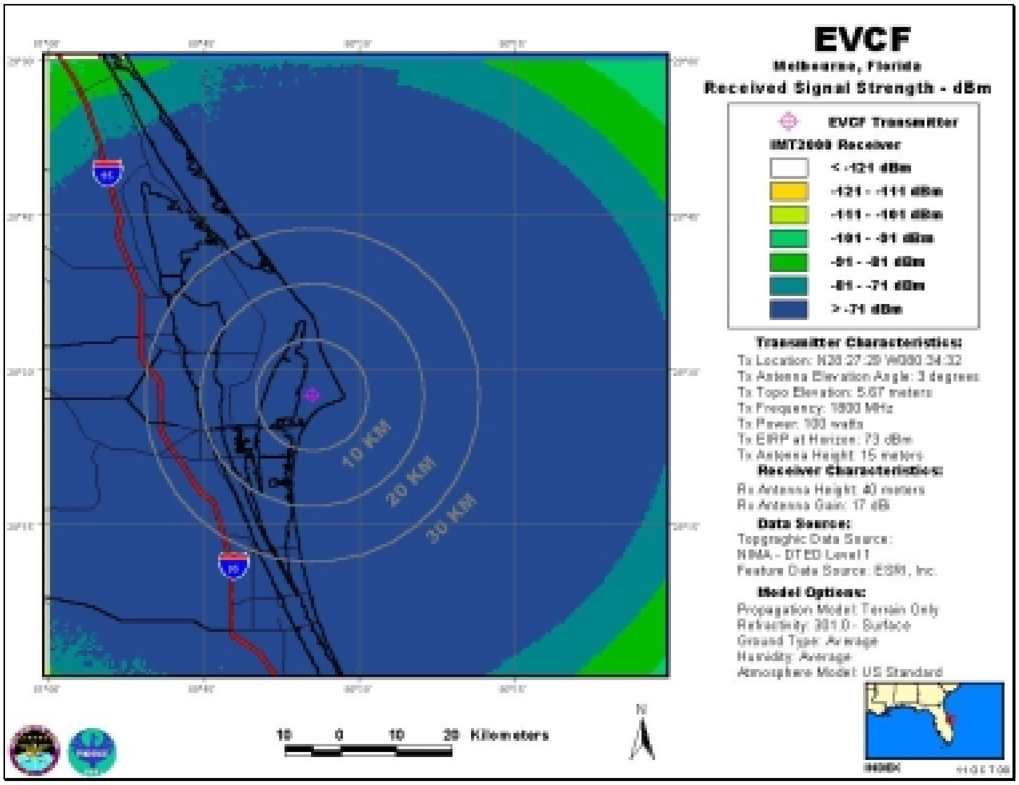
OAS, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Mobile Station



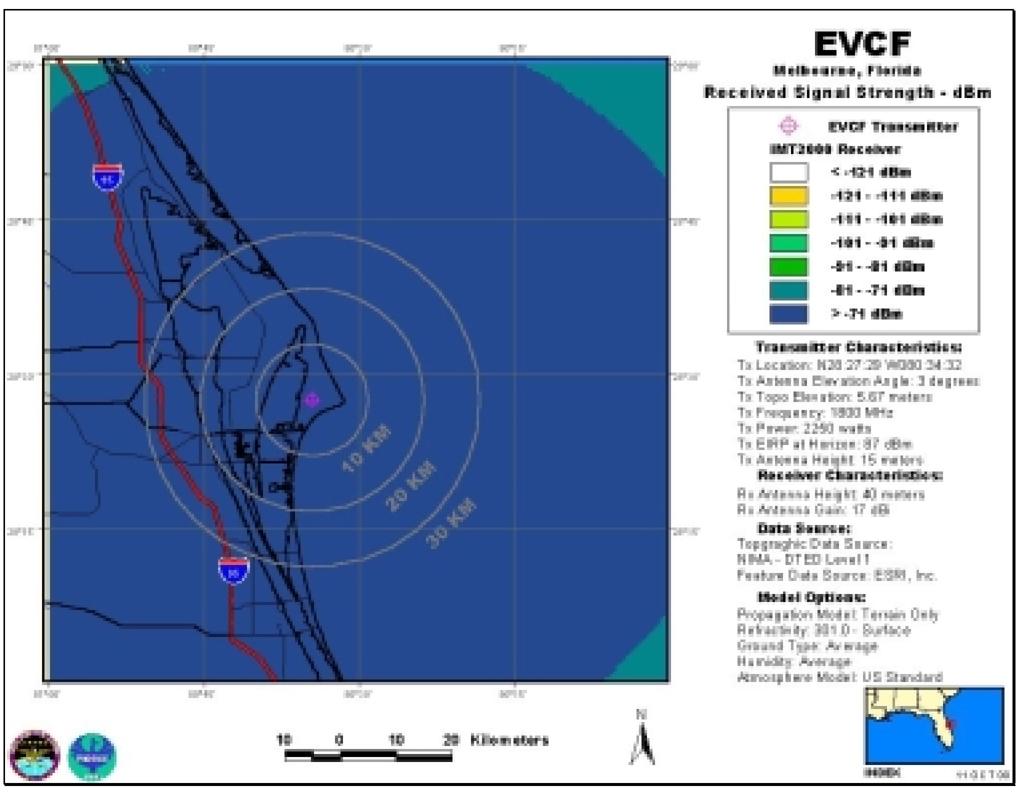
OAS, Antenna Elevation Angle: 10°, Transmitter Power: 2,000 W, IMT-2000 Mobile Station



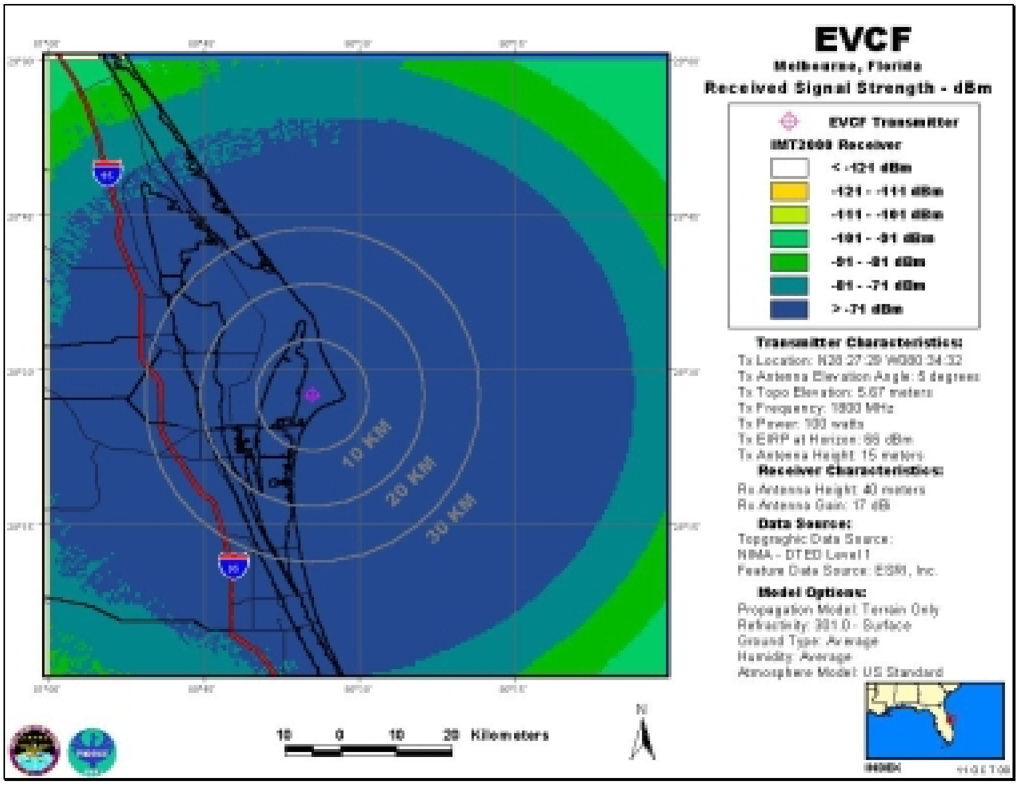
Topography Around EVCF, Melbourne, Florida



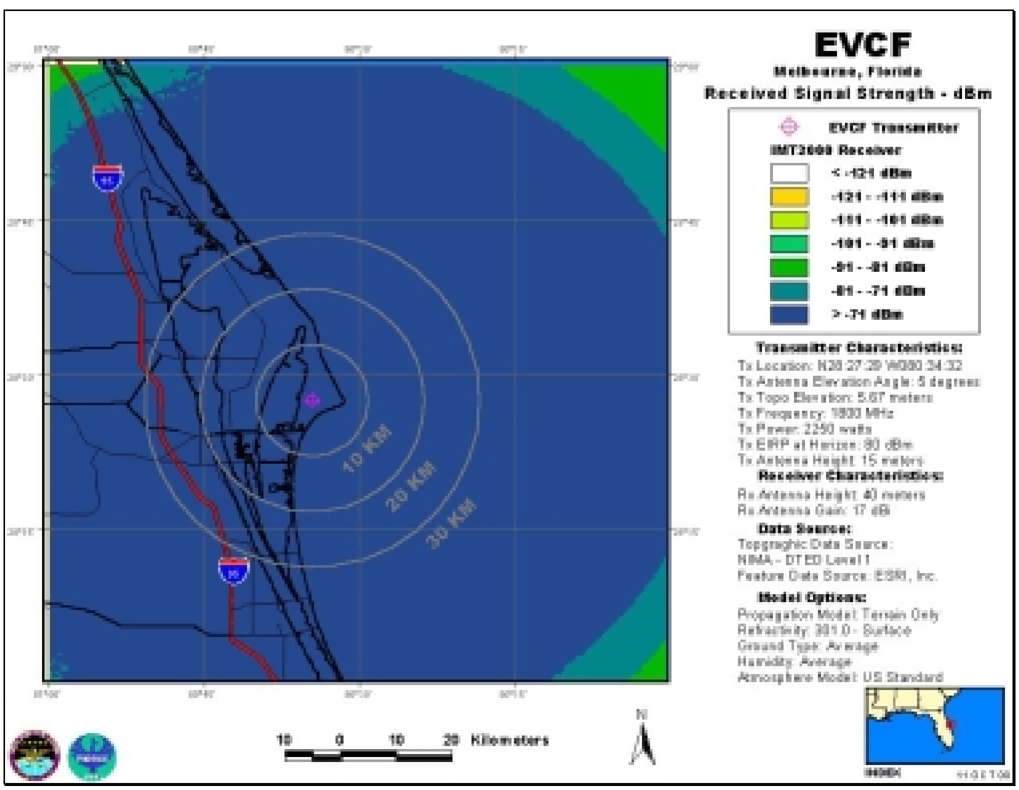
EVCF, Antenna Elevation Angle: 3°, Transmitter Power: 100 W, IMT-2000 Base Station



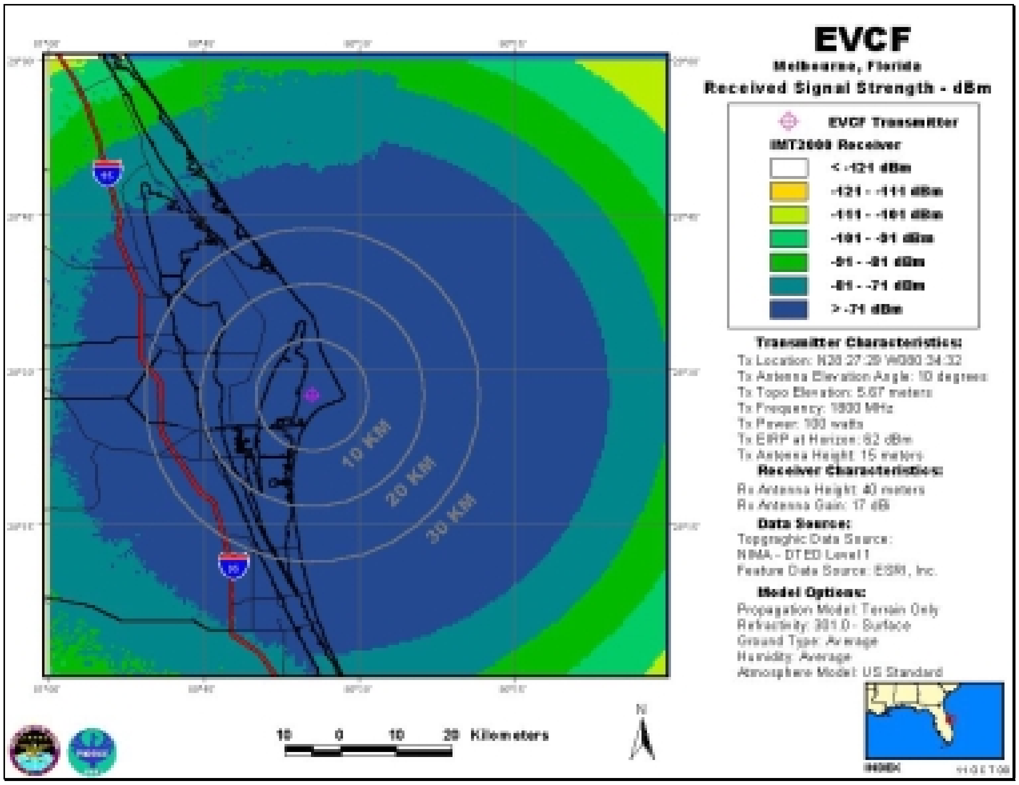
EVCF, Antenna Elevation Angle: 3°, Transmitter Power: 2,250 W, IMT-2000 Base Station



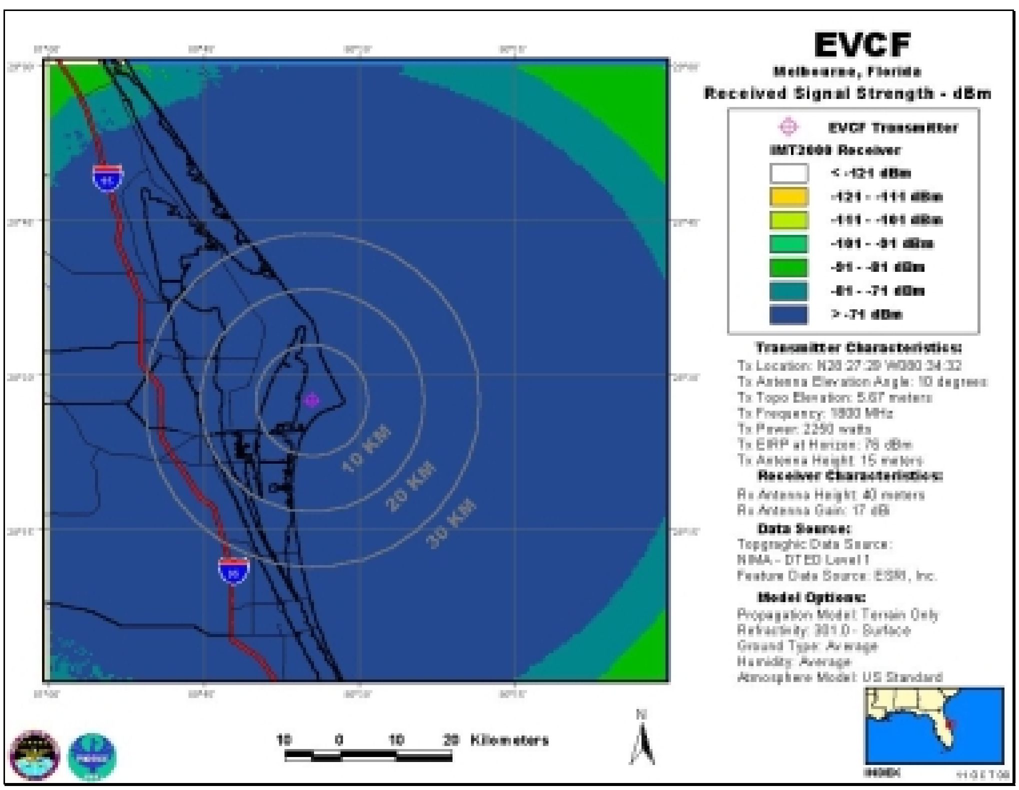
EVCF, Antenna Elevation Angle: 5°, Transmitter Power: 100 W, IMT-2000 Base Station



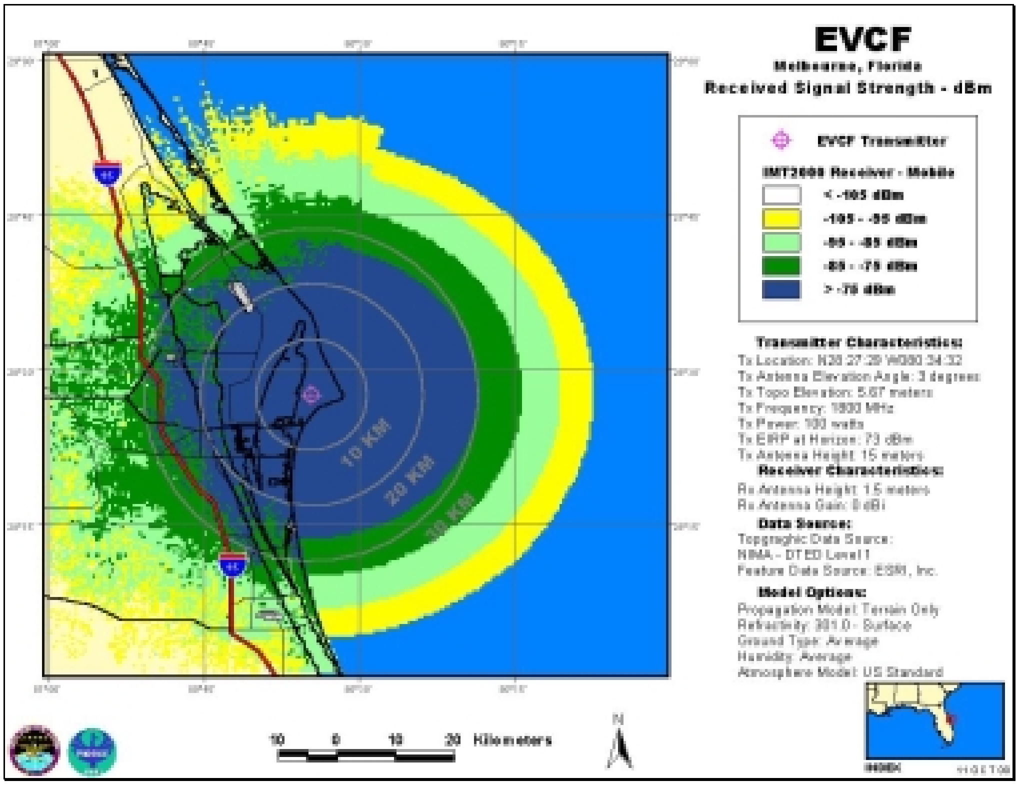
EVCF, Antenna Elevation Angle: 5°, Transmitter Power: 2,250 W, IMT-2000 Base Station



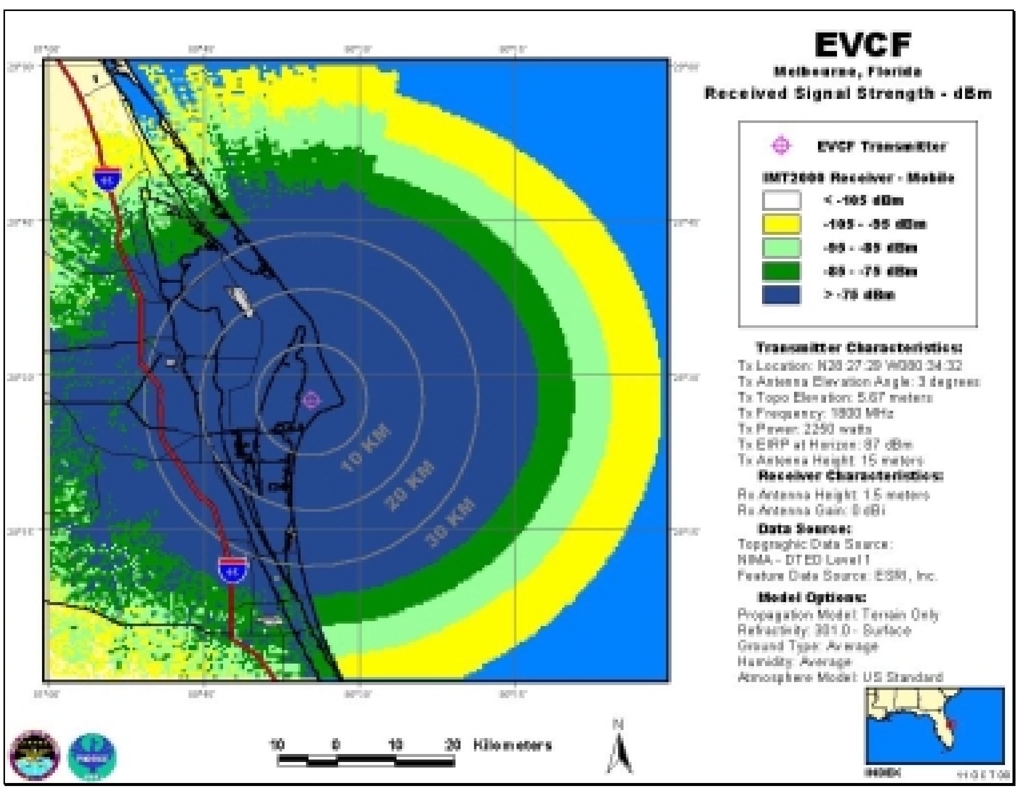
EVCF, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Base Station



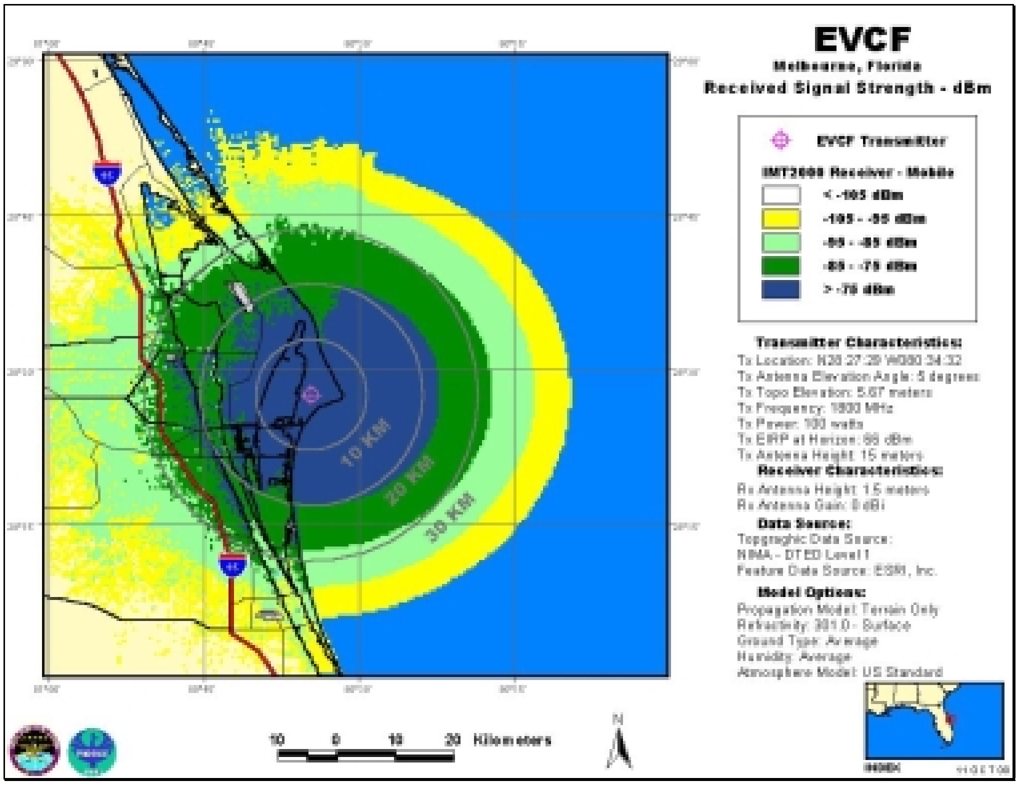
EVCF, Antenna Elevation Angle: 10°, Transmitter Power: 2,250 W, IMT-2000 Base Station



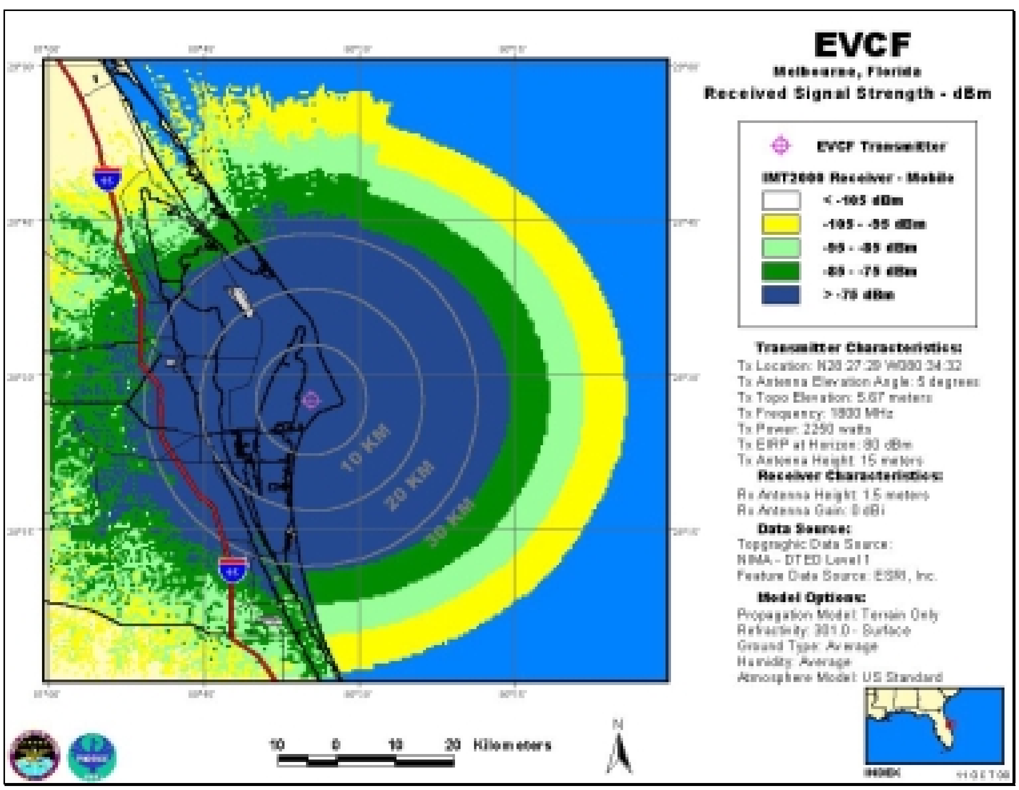
EVCF, Antenna Elevation Angle: 3°, Transmitter Power: 100 W, IMT-2000 Mobile Station



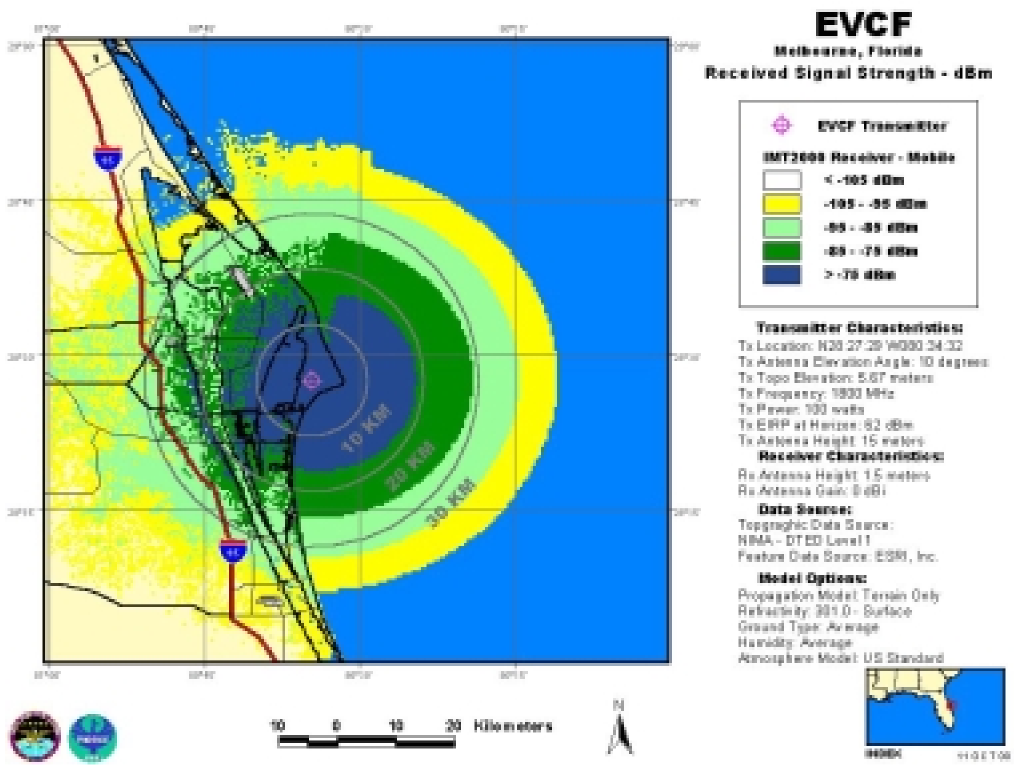
EVCF, Antenna Elevation Angle: 3°, Transmitter Power: 2,250 W, IMT-2000 Mobile Station



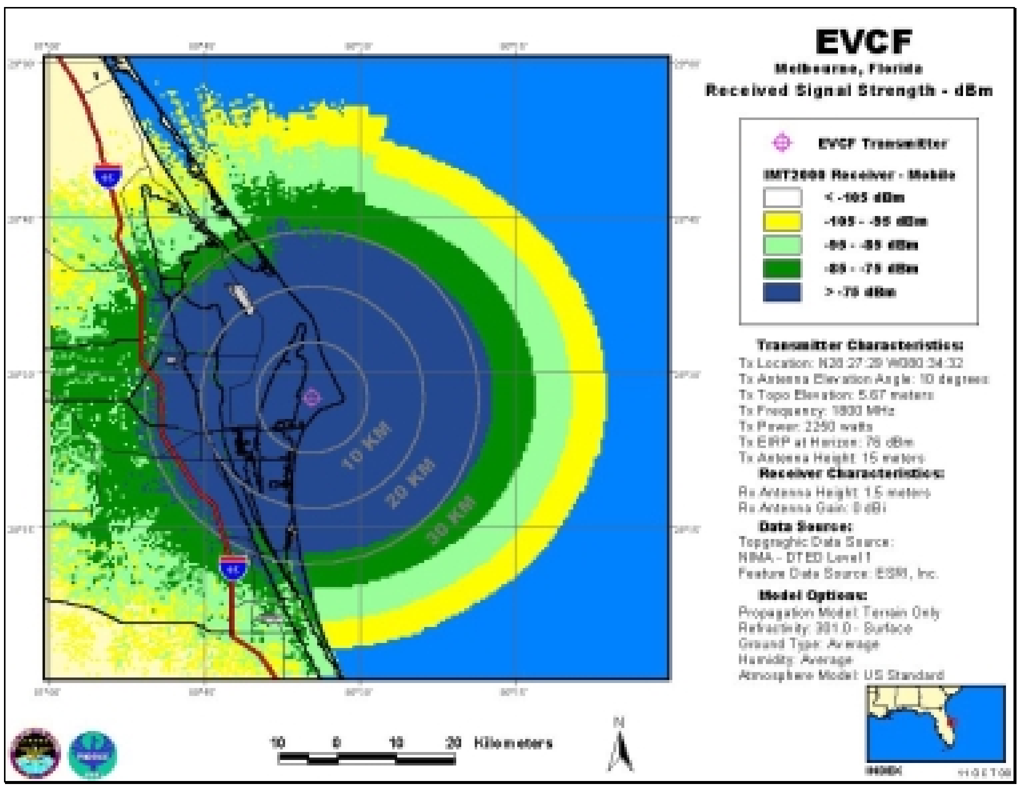
EVCF, Antenna Elevation Angle: 5°, Transmitter Power: 100 W, IMT-2000 Mobile Station



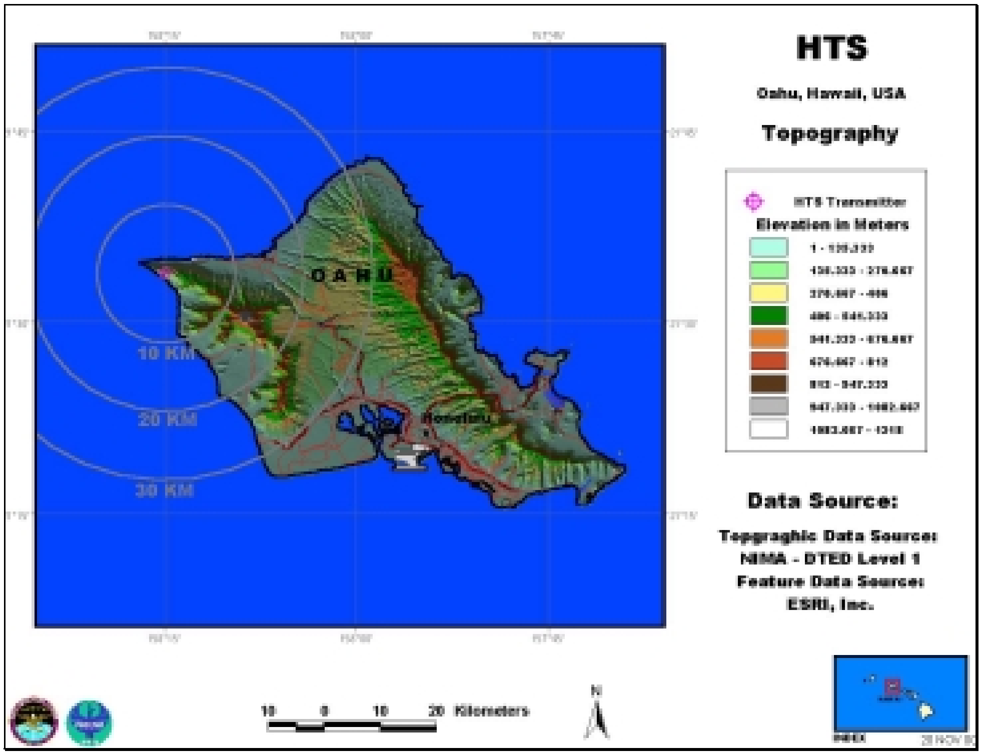
EVCF, Antenna Elevation Angle: 5°, Transmitter Power: 2,250 W, IMT-2000 Mobile Station



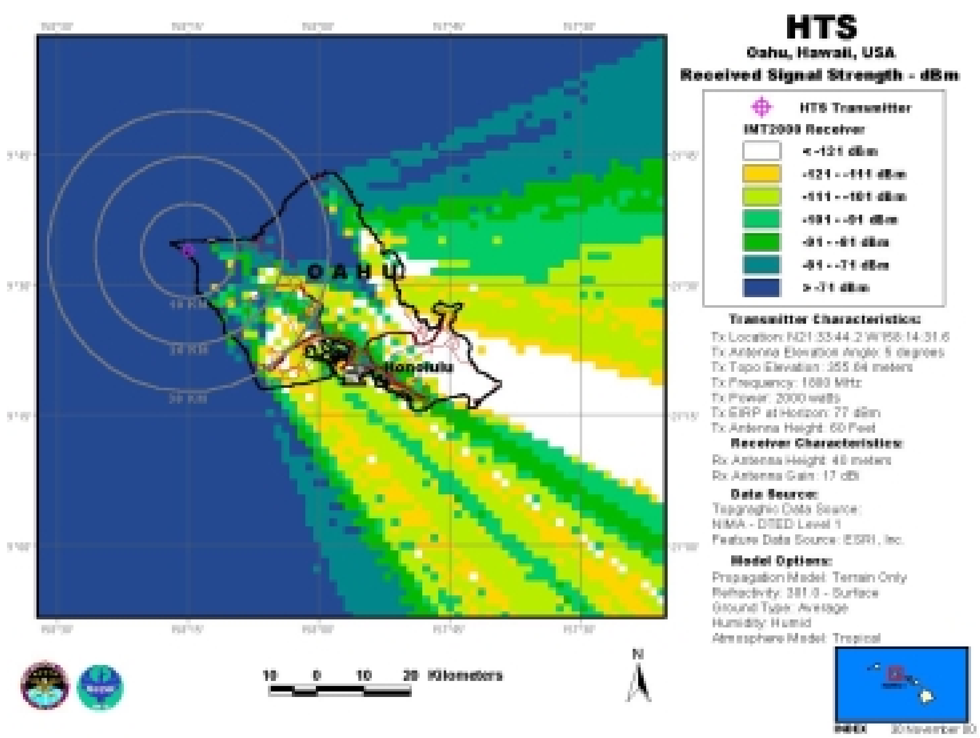
EVCF, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Mobile Station



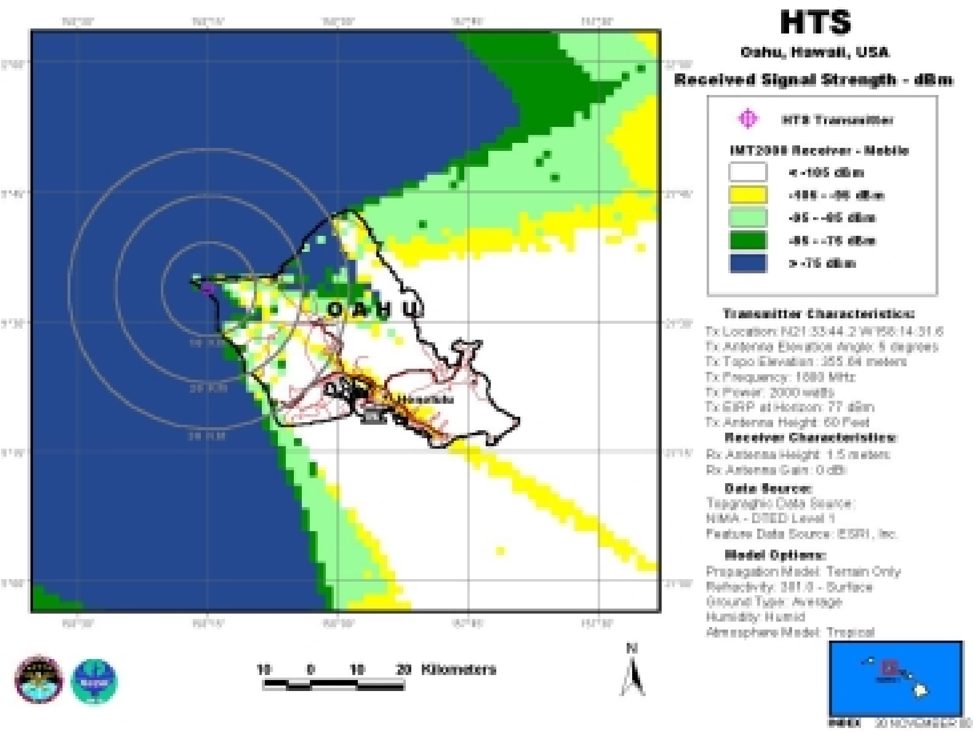
EVCF, Antenna Elevation Angle: 10°, Transmitter Power: 2,250 W, IMT-2000 Mobile Station



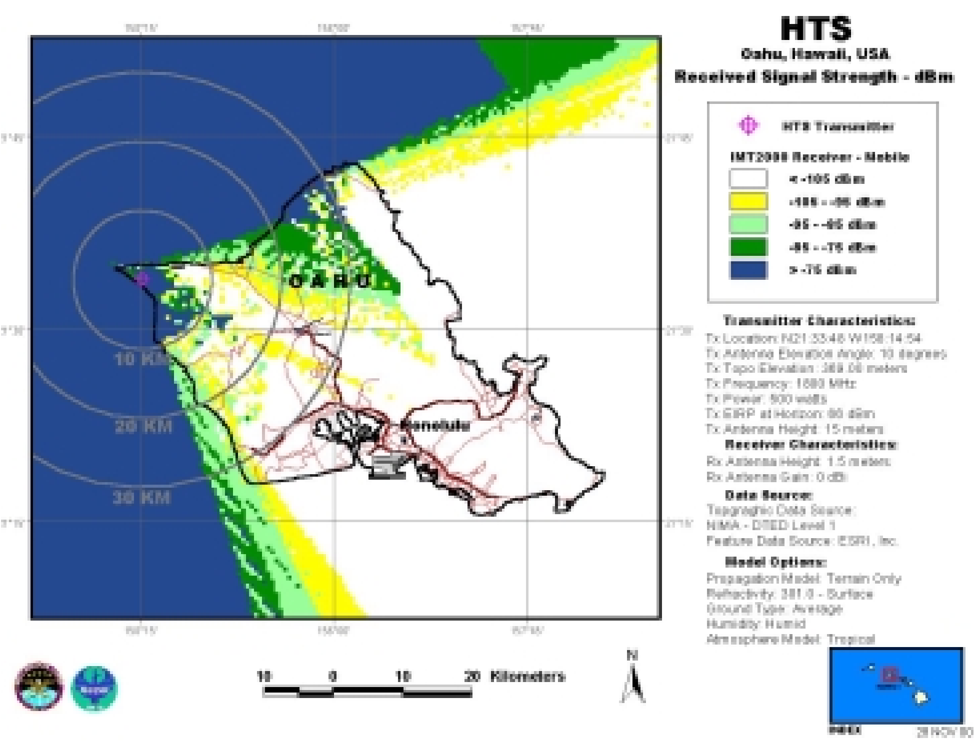
HTS Topography



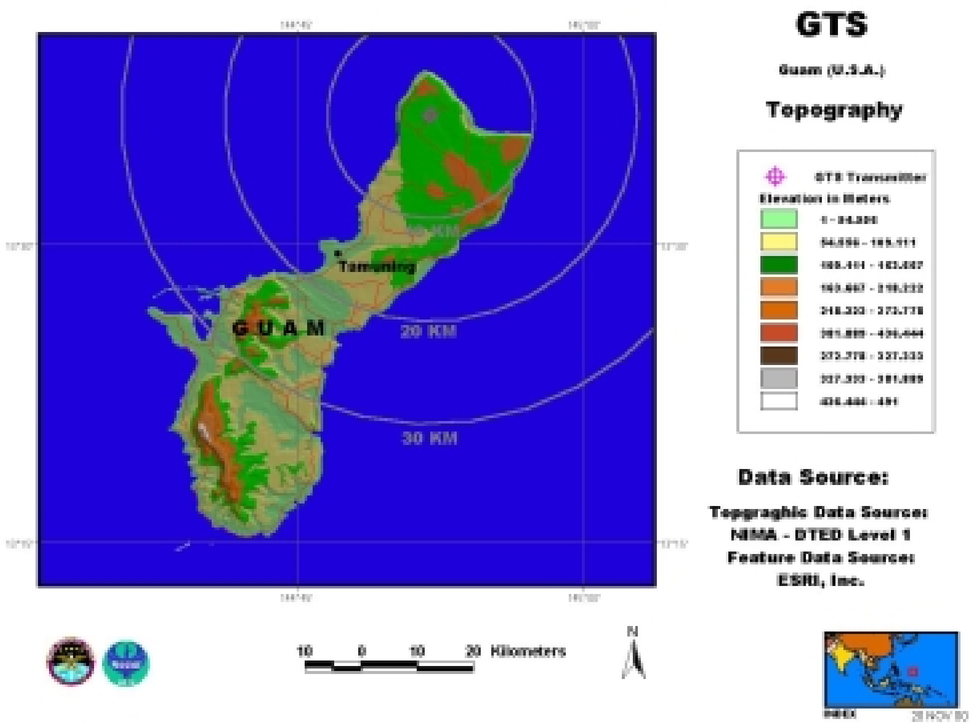
HTS, Antenna Elevation Angle: 5°, Transmitter Power: 2000 W, IMT-2000 Base Station



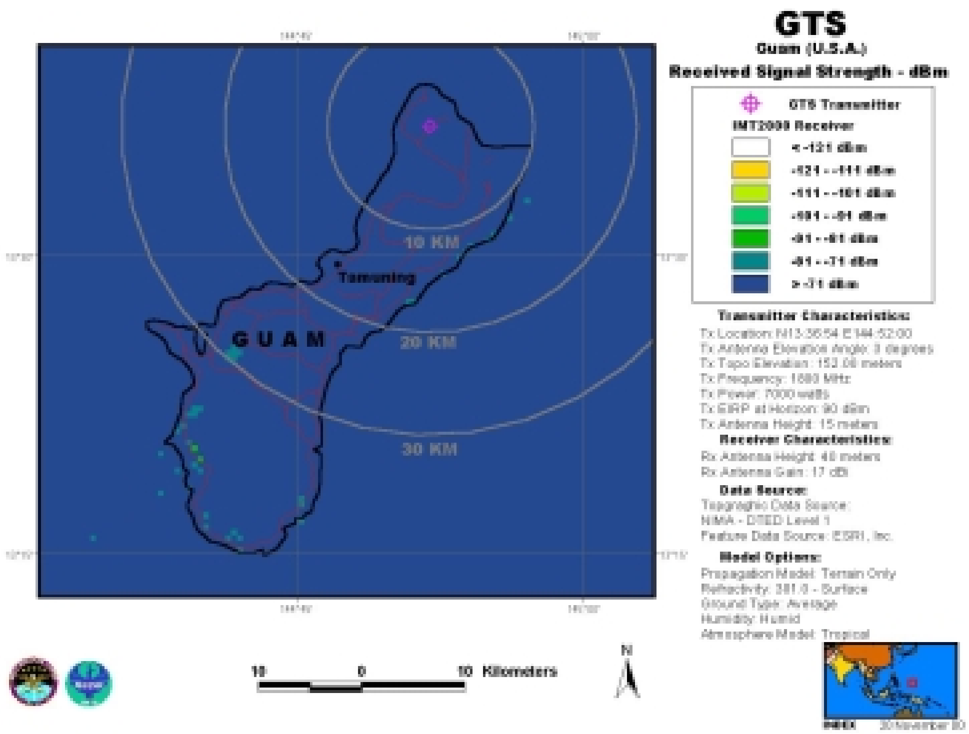
HTS, Antenna Elevation Angle: 5°, Transmitter Power: 2000 W, IMT-2000 Mobile Station



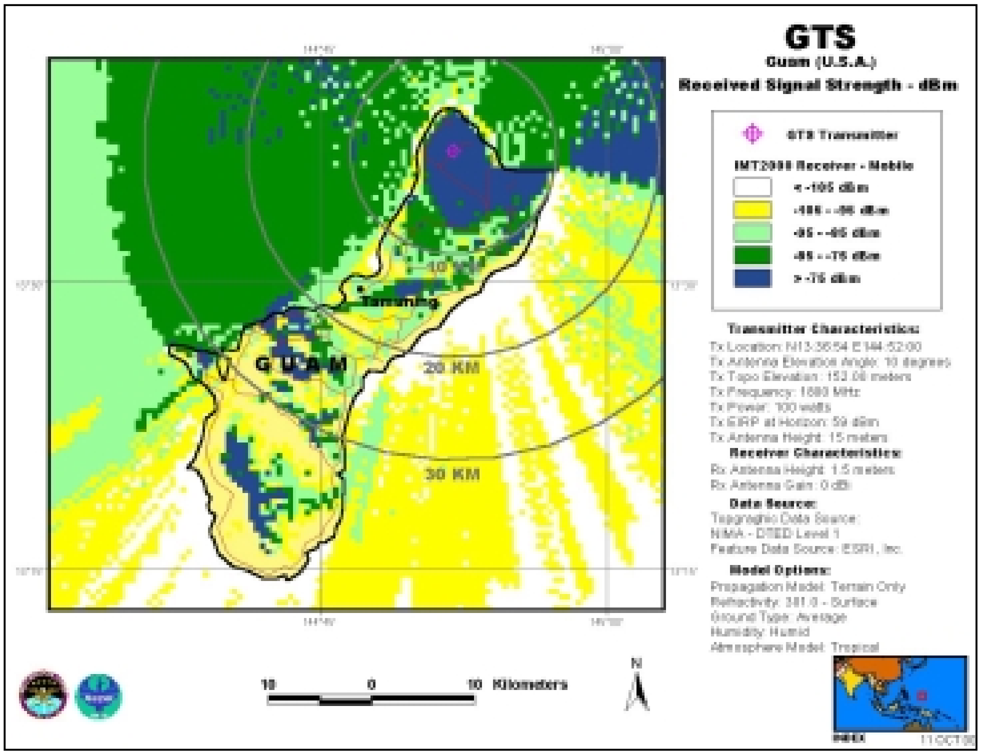
HTS, Antenna Elevation Angle: 10°, Transmitter Power: 500 W, IMT-2000 Mobile Station



Guam Topography



GTS, Antenna Elevation Angle: 3°, Transmitter Power: 7000 W, IMT-2000 Base Station



GTS, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Mobile Station

Department of Defense

United States Army

United States Marines Corps

United States Navy

United States Air Force

Requests for copies of this document shall be referred to Defense Information Systems Agency, Office of Spectrum Analysis and Management.