SDR Market Study, Task 4:
The US Public Safety Market

Prepared for
The Software Defined Radio Forum

By
Jim Gunn Consultancy
Market and Technology Research
P. O. Box 833157
Richardson, TX 75083-3157 USA
jimgunn@jgunnresearch.com
+1-972-669-9365

May 2007

About the Author

Dr. James (Jim) E. Gunn is a market research and technology consultant specializing in digital wireless communications and multimedia communication systems. He has more than 25 years of industry experience in communication, telecommunication, signal processing, and control. Functionally, Dr. Gunn has contributed as system engineer, software/firmware engineer, technical marketing specialist, and engineering manager. He completed his BSEE and MSEE at Oklahoma State University and his Ph.D. at Southern Methodist University specializing in Electrical Engineering.

He is current developing a series of Software Defined Radio (SDR) market and technology studies for the SDR Forum. The completed reports to date are listed below. He is author of market research reports entitled Wireless Infrastructure: Technology and Markets that have been published by Forward Concepts. He served as principle investigator on a DARPA SUO project to develop advanced software radio architectures for military and commercial waveforms. He is co-author of "Communication Mediums for Intelligent Transportation Systems" (TRB/National Academy Press), which is a multi-media/multi-medium communication system design guide.

Completed SDR Forum Market Study Reports:

1. SDR Market Study, Task 1: Market Segmentation and Sizing, 2005
2. SDR Market Study, Task 2: Cellular Terminals and Infrastructure, 2005
3. SDR Market Study, Task 3: WiFi, WiMAX and Beyond 3G / 4G, 2006
4. SDR Market Study, Task 4: The US Public Safety Market

Table of Contents

TABLE OF CONTENTS ..... **II**

LIST OF FIGURES ..... **III**

LIST OF TABLES ..... **IV**

1 EXECUTIVE SUMMARY AND CONCLUSIONS **1**

1.1. SDR FORUM STUDY SERIES OVERVIEW 3

2 INTRODUCTION **5**

2.1. SDR PUBLIC SAFETY MARKET OPPORTUNITY 6

3 TRENDS, ISSUES AND DRIVERS **9**

3.1. US PUBLIC SAFETY SPECTRUM 17
3.2. PROJECT 25 (P25) OVERVIEW 22
3.3. US PUBLIC SAFETY BROADBAND INITIATIVES 26
3.4. PROJECT 25 TERMINAL AND EQUIPMENT PLAYERS 28
M/A-COM 29
Motorola 31

4 US PUBLIC SAFETY COMMUNICATION OFFICIAL INTERVIEWS **33**

4.1. STATE OF CALIFORNIA 35
4.2. STATE OF COLORADO 44
4.3. STATE OF FLORIDA 48
4.4. STATE OF MISSOURI 52
4.5. STATE OF NEW YORK 56
4.6. STATE OF TEXAS, DEPARTMENT OF PUBLIC SAFETY 59
4.7. CITIES OF PHOENIX AND MESA, AZ 64

5 US PUBLIC SECTOR MARKET **70**

6 ACRONYMS **83**

List of Figures

Figure 1-1 Public Safety Spectrum Allocation Bandwidth and Density of Re-Use 2
Figure 2-1 Diverse Public Safety Stakeholder Community 6
Figure 3-1 Five Interoperability Challenges 9
Figure 3-2 Interoperability Continuum 13
Figure 3-3 Professional Services used in deployment of Private Communication Systems 14
Figure 3-4 FCC Allocated Public Safety Spectrum 17
Figure 3-5 Public Safety Spectrum Allocation Bandwidth and Density of Re-Use 18
Figure 3-6 800 MHz Band Transition Plan (Heartland) 19
Figure 3-7 Public Safety 700 MHz Band Plan 21
Figure 3-8 P25 System Interfaces 23
Figure 3-9 Countries with Project 25-Interoperable Equipment or Networks 26
Figure 3-10 Overview of US Public Safety narrowband, wideband, and broadband Initiatives 27
Figure 4-1 State of Colorado DTR early regional implementation plans 44
Figure 5-1 Public Sector Population Statistics 71
Figure 5-2 Relationships between Site Area and Radius: Hexagon Area 74
Figure 5-3 hexagon - Radius versus Square Miles 74

List of Tables

Table 1-1 US Summary of Public Safety personnel, departments, and agencies 2
Table 1-2 SDRF Market Study Phase and Tasks 3
Table 1-3 SDR Benefits / Value Propositions 4
Table 2-1 US Public Safety SDR Market Opportunity 8
Table 3-1 Public Sector Segments 10
Table 3-2 US Department of Homeland Security Strategic Goals 11
Table 3-3 Key Public Safety Communication Goals 12
Table 3-4 SAFECOM Mission Statement 12
Table 3-5 Key Public Safety Communication Features 15
Table 3-6 US Frequency Re-Use 18
Table 3-7 FCC Part 90.677, 800 MHz Band Reconfiguration 20
Table 3-8 "The State of Interoperability: Perspective on Federal Coordination of Grants, Standards, and Technology" 24
Table 3-9 P25 Terminal and Equipment Suppliers 29
Table 3-10 M/A-COM Network Product Families 30
Table 3-11 Motorola Network Product Families 32
Table 4-1 Law Enforcement Personnel, State of California 35
Table 4-2 Summary State of California Public Safety Agency Communication Challenges and Plans 36
Table 4-3 Analysis Independent Agency Communication System vs. Agency System Sharing 38
Table 4-4 State of California PRISM Shared Public Safety Radio System Cost Estimate 40
Table 4-5 California PSRSPC Summary of Findings and Associated Action Items 41
Table 4-6 California Highway Patrol (CHP) Radio System Cost Estimate 43
Table 4-7 Law Enforcement Personnel, State of Colorado 44
Table 4-8 Law Enforcement Personnel, State of Florida 48
Table 4-9 Select Local Public Safety Communication System Deployment in Florida ... 51
Table 4-10 Law Enforcement Personnel, State of Missouri 52
Table 4-11 Law Enforcement Personnel, State of New York 56
Table 4-12 Law Enforcement Personnel, State of Texas 59
Table 4-13 Estimated State of Texas Combined Agency Communication System 63
Table 4-14 Law Enforcement Personnel, Cities of Phoenix and Mesa, AZ 64
Table 4-15 Phoenix/Mesa System Basic Design Criteria: Coverage 67
Table 4-16 Phoenix/Mesa P25 deployed Portables and Mobiles 68
Table 5-1 US Summary of Public Safety personnel, departments, and agencies 70
Table 5-2 US Law Enforcement Employees and Officers 73
Table 5-3 Reported Number of Sites by States 74
Table 5-4 Representative Public Sector Communication System Costs 77
Table 5-5 Estimated US Public Sector Radio Equipment Replacement Costs 78
Table 5-6 Cellular Comparisons 80
Table 5-7 US Public Sector "What If" Cost Analysis 80
Table 5-8 US Firefighter Population 81
Table 5-9 ITS US DOT Communication Survey 82

1 Executive Summary and Conclusions

A number of recent events, including 9/11 and Hurricane Katrina, have brought considerable attention to the need for enhanced Public Safety (PS) communications. It is a very fragmented market, consisting of a multitude of federal, state, and local agencies, city, county, and regional jurisdictions, and police, fire, and emergency medical functions.

Communications interoperability, the ability for public safety officials of independent organizations to communicate in real-time, has received increased recent attention. The National Task Force on Interoperability[1] identified five issues that are challenges for interoperability of public safety communication systems that are:

1. Incompatible and aging communication equipment
2. Limited and fragmented budget cycles and funding
3. Limited and fragmented planning and coordination
4. Limited and fragmented spectrum
5. Limited equipments standards.

Many public safety stakeholders indicate that they experience operability problems in use of their communication systems even for intended organic organizational uses, due largely to functional inadequacies and these five issues, especially aging equipment.

Sufficient spectrum has been an on-going issue for public safety for many years. Ron Haraseth, APCO International, has provided information on spectrum availability and deployments that is presented in Figure 1-1. The left pie chart depicts total spectrum deployments by band and illustrates that VHF high band is by far the most deployed public safety band in the US. The right pie chart depicts allocated spectrum by band. Historically, the total amount of spectrum for public safety in the US has been 26.1 MHz in the VHF, UHF, and the 800 MHz bands plus a few other little used bands. The 800 MHz band has experienced significant interference problems and is being re-banded to move public safety users from fragmented assignments to frequencies better separated from other users. Sprint Nextel will be paying for the relocation costs. New public safety 700 MHz band allocations (not shown in Figure 1-1) that total 24 MHz will almost double public safety allocations. The 700 MHz frequencies will become available nationwide in February, 2009.

[1] "Why Can't We Talk? Working Together to Bridge the Communications Gap to Save Lives," by National Task Force on Interoperability, February 2003 Final Report

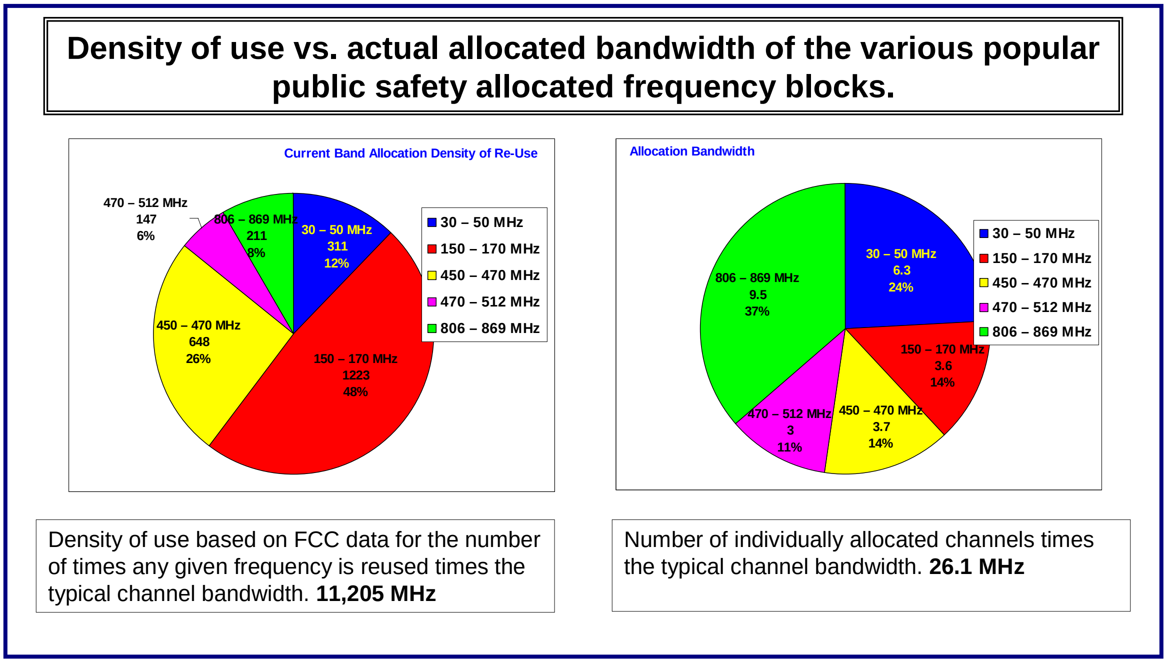


Figure 1-1 Public Safety Spectrum Allocation Bandwidth and Density of Re-Use
(Source: Ron Haraseth, Director, Automated Frequency Coordination, APCO International)

To address the standards problems the first Project 25 (P25) standard was published in 1995 and was the Common Air Interface (CAI). Although other standards have been needed, the CAI has been the only available standard through early 2006. In the 1st half of 2006, announcements have been made that additional needed standards have been ratified that include the Inter-RF Subsystem Interface (ISSI), the Fixed/Base Station System Interface (FSSI), and the Console Subsystem Interface (CSSI). The current P25 standard, referred to as phase 1, provides a FDMA (single channel per carrier) that provides both analog and digital voice in 12.5 kHz, trunking, encryption, Over-The-Air Rekeying (OTAR), and P25 data standards. A key US broadband activity is the Mobility for Emergency and Safety Applications (MESA) initiative, which is an international partnership between the US-lead TIA and the European Telecommunication Standards Institute (ETSI). In the US the targeted spectrum is in the recently allocated 4.9 GHz band.

The key focus of this report has been interviews with US public safety communication officials from various state government agencies. Interviews were accomplished with representatives from the following states:

State of California	State of Missouri	Cities of Phoenix / Mesa, AZ
State of Colorado	State of New York	
State of Florida	State of Texas	

The summary conclusions from these interviews are:

- Many states are planning, or deploying, state-wide shared communication systems. Local or Federal users can use a shared system, typically paying a fee, buying their own terminals, and funding any special infrastructure requirements.
- The slowness of P25 and related standards development has been an issue.
- There have been continuing problems achieving multi-vendor interoperability in public safety communications. P25 is viewed as a positive emerging solution for interoperability as well as re-farming and narrowband requirements, and potentially lower costs due to a more competitive market.
- Funding is a significant problem for most states to upgrade their public safety communication systems. The economic downturn of the early 2000's exacerbated the problem, although the current situation is improving. Many states have completed planning projects, but are unable to fund deployments.
- The FCC mandated transition to 12.5 kHz (and eventually 6.25 kHz) channel width is an issue, with pushed out dates.
- VHF is the most used public safety band in the US, and most of those interviewed would like to continue its use in low density rural population areas where better propagation supports lower cost deployments. 700 MHz and 800 MHz are needed for more densely populated urban areas requiring more capacity and less range and coverage per site.

Due to the fragmented nature of the market, market estimates for the US public safety market have been elusive. Table 1-1 presents a summary estimate of US public safety personnel, department, and agencies.

960,000 Firefighters 830,000 EMS Personnel 710,000 Law Enforcement Officers	28,495 Fire Departments[1] 5,841 EMS Departments[1] 27,496 Law Enforcement Agencies[1]	25,763 Local Agencies [1] 6,396 State Agencies[1] 2,967 Federal Agencies[1]

[1] Source: www.SafetySource.com

Table 1-1 US Summary of Public Safety personnel, departments, and agencies
(Source: 'Interoperability Standards" Presentation, by Dereck Orr (NIST) and Nyla Houser (SAFECOM Support), at Project MESA Meeting, October 25, 2005)

Our market forecast for the US public safety market is based on a top down analysis on a state-by-state basis to estimate the number of sites per state for infrastructure. The FBI's "Crime in United States" report was used to develop estimates by state for personnel counts, and the number of portable and mobile terminals deployed. We developed estimates of loaded costs for a representative state-wide shared public sector communication system developed from information and sources obtained in state public safety communication official interviews. We then applied these results to estimate costs to deploy a public sector communication system intended to serve all Public Safety agencies in each of the 50 states. US totals are:

- $46.5 Billion total, approximately half for terminals and half for infrastructure
- The estimate is total replacement cost that would be adjusted for current or planned usable deployments and would undoubtedly be spread over many years.

State agency only estimates reviewed were skewed with much higher infrastructure costs than terminal costs, which illustrate potential savings with shared infrastructure as opposed to current frequent practice of independent agency deployments.

1.1. SDR Forum Study Series Overview

This report is the fourth of a series of Software Defined Radios (SDR) market studies commissioned by the SDR Forum. The work to create these SDR market reports is divided into two phases and multiple tasks. The first study, entitled SDR Market Study: Market Segmentation and Sizing provides an overview of the most promising market segments with Rough Order of Magnitude (ROM) estimates and general segment discussions. The second study, entitled SDR Market Study: Cellular Terminals and Infrastructure provides a comprehensive look at the cellular industry. The third study entitled SDR Market Study: WiFi, WiMAX, and Beyond 3G / 4G provides a comprehensive look at WLAN and WMAN and anticipated positions within future Fixed Wireless Access (FWA) and 3G evolutions. This fourth study entitled SDR Market Study: US Public Safety Market provides interviews with US public safety communication officials soliciting their input on the opportunities, activities, and issues. Follow-on tasks will provide enhanced segmentation and sizing for each segment and more detailed analyses of requirements, drivers, issues, and business models. An overview of the phases and tasks for these studies is presented in Table 1-2.

Phase 1 Task 1 – Segment and Size – Rough Order of Magnitude (ROM) Task 2 – Cellular – Terminals and Infrastructure
Phase 2 – Follow-on Tasks (Current Work) Task 3 –WLAN, WiMAX, and Beyond 3G Task 4 – Public Safety (Law Enforcement, Fire, Emergency Management, etc.) Task 5 – Cognitive Radios (Recently Added) Task 6 – Military Task 6 – Telematics Task 7 – Avionics Task 8 – Other

Table 1-2 SDRF Market Study Phase and Tasks

For many years, most wireless industry segments have utilized programmable DSP's and/or microprocessors for the less throughput intensive algorithms (i.e., essentially baseband functions) deployed in their terminals and infrastructure. Recent advances in semiconductor technologies including 90 / 65 nanometers and below digital technologies, RF technologies, and data acquisition technologies provide imminent market opportunities for Software Defined Radios (SDR) to extend programmability for more transceiver algorithms and more extensively achieve the long verified software benefits as presented in Table 1-3.

1. Lower development costs. 2. Provide enhanced mass customization flexibility in development, deployment, and fielded products. 3. Provide critical time-to-market enhancements. 4. Facilitate better reuse of Intellectual Property. 5. Support Multi-band and Multi-mode RF operations 6. Enable the SDR vision of field software-enabled waveform, protocol, and application selection and update.

Table 1-3 SDR Benefits / Value Propositions

A fundamental goal of this work is to provide clarity and guidance for the SDR community on "Where are we, where do we need to be, and how do we get there?" based on market opportunities and requirements. However, these are not static conclusions and positions with final end points, but ongoing opportunities that will be enhanced and improved as we progress through these studies, as well as afterwards based on lessons learned and technology advancements.

2 Introduction

This report, entitled "The US Public Safety Market," provides a comprehensive look at a market that has attracted much attention as a result of the 9/11/2001 response in New York and Hurricane Katrina experiences in New Orleans. In both cases, first responders' operational capability was compromised by inadequate interoperable communication resources.

This report is organized as follows:

1. Executive Summary
2. Introduction
3. Trends, Issues, and Drivers
4. US Public Safety Communication Official Interviews
5. US Public Safety Market

As illustrated in Figure 2-1, the Public Safety stakeholder community is very diverse consisting of Federal, State, Local, and other public service organizations, including tribal organizations, Law Enforcement, Fire, and Emergency Management Service (EMS). Historically each of these many diverse organizations has independently procured, operated, and maintained their own communication system. Without consistent and adequate policies, standards, and guidelines regarding public safety communication systems, first responders sometimes lack adequate interoperable communication equipment to coordinate their routine activities. It is much more difficult to communicate effectively in stressful emergency activities.

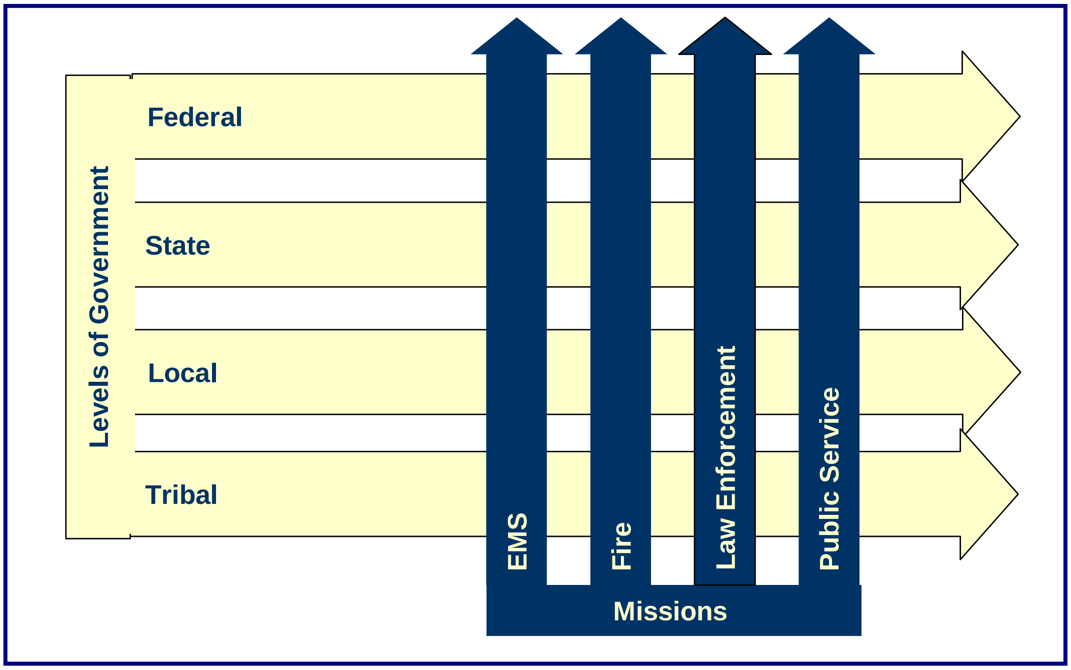


Figure 2-1 Diverse Public Safety Stakeholder Community
(Source: SAFECOM Documents, www.safecom.gov)

The Homeland Security Act of 2002, Section 2(6) [6 U.S.C. 101(6)] provides the following definition: "The term 'emergency response providers' includes Federal, State, and local emergency public safety, law enforcement, emergency response, emergency medical (including hospital emergency facilities), and related personnel, agencies, and authorities." Often the term "first responders" is used to refer to those with immediate response responsibilities.

2.1. SDR Public Safety Market Opportunity

In a meeting of the SDRF Public Safety SIG (Special Interest Group) in March 2005 in Orlando, Florida the proposal that essentially all public safety terminal and network radio products already have significant SDR functionality was advanced, and enthusiastically supported by several participants from the vendor community. Follow-on conversations focused on how to make this functionality more available to better support public safety users objectives as well as supplier goals. A significant percentage of public safety industry products appear to satisfy an emerging definition of SDR that is being considered by the SDR Forum and IEEE 1900 standards initiatives and is paraphrased in the next paragraph. (SDR Forum correspondence)

A radio is considered to be a software defined radio (SDR) if:

1. Some or all of the baseband or RF signal processing is accomplished through the use of digital signal processing software, and
2. This software can be modified post manufacturing.

Introduction

The IEEE P1900 standard initiatives focus on Software Defined Radios (SDR) and Cognitive Radios.

The opportunities for SDR in public safety are immense for the following reasons:

1. SDR concepts and features are already being used in most fielded products today. The SDR benefits are currently benefiting primarily the vendor community with reduced time-to-market (TTM), flexibility for standards inadequacies, misunderstandings, and changes; and incorporating emerging new functionality. Many opportunities exist today to extend these SDR benefits more broadly to include public safety user community goals. Technology advancements will only expand these opportunities.
2. The US public safety spectrum is essentially in a few bands (discussed in section 3.1). The key bands include the VHF (low and high), UHF, 800 MHz, and emerging 700 MHz and 4.9GHz bands. Unlike the military's extreme 2 MHz to 2.5 GHz spectrum flexibility goals for SDR, US public safety has much more achievable spectrum requirements. While these bands will require multiple RF front ends in multi-band radio, the number is reasonable. Additionally, the commercial segment is expending considerable R& D resources on multi-band, multimode radio technologies that should be generally transferable to public safety applications. It appears that flexible baseband multimode functionality is supportable with currently available programmable DSP, emerging application specific standard products (ASSP), FPGAs, ASICs, etc. and can flexibly support public safety baseband requirements.
3. In interviews with public safety communication experts (see section 4), a recurring input has been that a significant public safety interoperability issue has been related to signaling and control functions. Early (1950's vintage) analog FM radios from multiple vendors were highly interoperable. As functions such as control tones, signaling protocols, and vocoders were added to facilitate trunking, digital migration, talk groups, multicast, simulcast, and digital voice, the systems were less able to interoperate. Thus, multi-vendor interoperability has been an increasing issue, with slow progress on completion of P25 standards being a substantial contributing factor. These issues may be addressed with software and SDR features. Lack of interoperability is not a technology problem, but is related to intellectual property rights (IPR), standards, and marketing.
4. Glenn Nash of California (see section 4.1) offered the observation that most public safety requirements for non-standard functionality are at the application level and that most of the underlying communications functionality can be achieved in a standard way. Thus, a need exists to accommodate non-standard functions in a standard way, supplementing a core set of common functions. The current SDRF activities on languages appear well targeted to support this goal. IPR issues and other details must be addressed, but this appears achievable with SDR technologies.

With the above as motivation, essentially all market opportunities presented in section 5 are SDR market opportunities. Table 2-1 presents a summary of this opportunity.

US Population	US Square Miles	Population Density (Pop per square Miles)	Public Safety Agencies	Total Law Enforcement Employees	Total Public Safety Officers
278,433,063	3,537,437	78.71	14,254	970,588	675,734
Total Public Sector Terminals	**% Public Sector Terminals of US Population**	**Total Public Sector Terminal Costs**	**Base Station Sites**	**Total Cost Base Station Equipment**	**Total US Public Sector Cost**
5,289,323	1.90%	$ 22,966,066,921	12,846	$ 22,584,900,000	$ 45,550,966,921

Table 2-1 US Public Safety SDR Market Opportunity
(Source: Table 5-4 and Table 5-5)

3 Trends, Issues and Drivers

The National Task Force on Interoperability identified five issues that are challenges for interoperability of public safety communication systems that are presented in Figure 3-1. These issues have been consistently identified in our interviews with public safety stakeholders. Interestingly, many public safety stakeholders indicated that they experience operability problems in use of their communication systems even for intended organic organizational uses, due largely to functional inadequacies and these five issues.

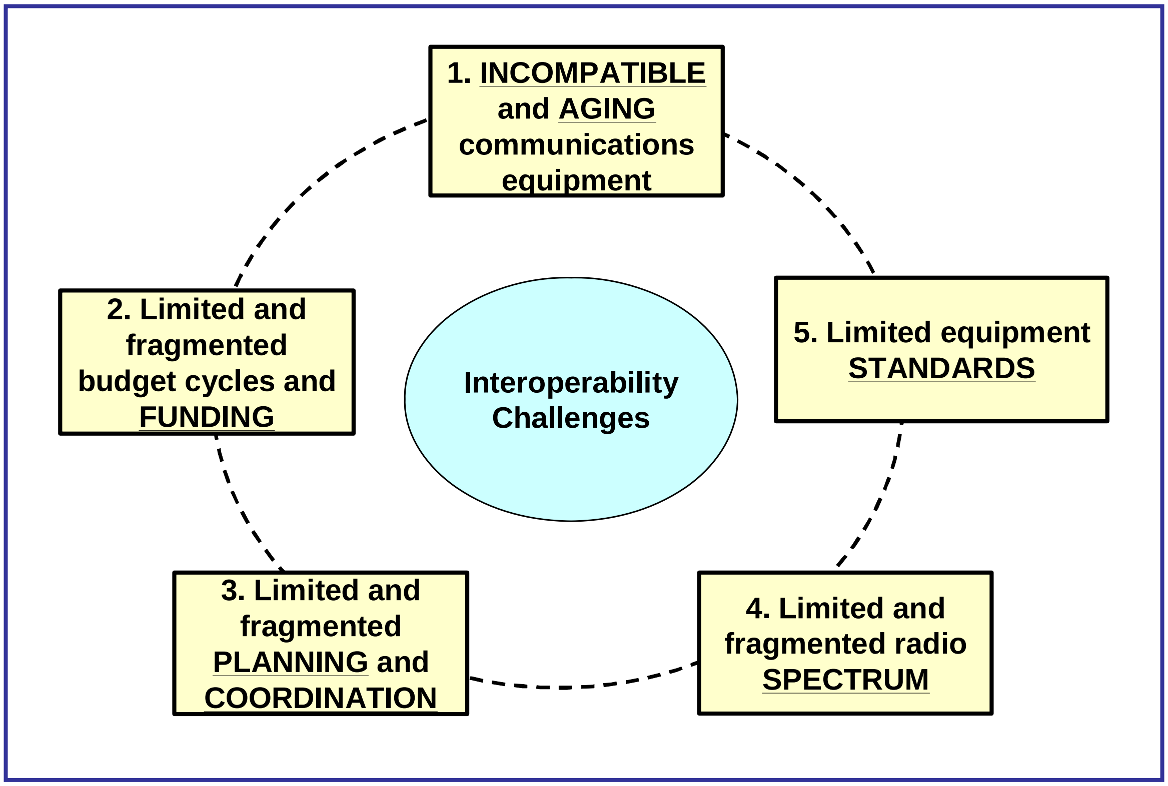


Figure 3-1 Five Interoperability Challenges
(Source: "Why Can't We Talk? Working Together to Bridge the Communications Gap to Save Lives," by National Task Force on Interoperability, February 2003 Final Report)

The Public Safety market is a very fragmented market, consisting of a multitude of federal, state, and local agencies, city, county, and regional jurisdictions, and police, fire, and emergency medical functions. Although each operates from public funds and has operational coordination, public land mobile radio (PLMR) communication system coordination, management, and procurement have historically not usually been a focus for senior public officials with other professional experiences and priorities. PLMR is usually delegated to communication professionals. This appears to have created an environment with generally good local coordination and information, but less than desirable state, national, and international coordination, visibility, and general market information. Of course, 9/11, the 2005 Katrina and other US hurricane experiences have created new Homeland Security priorities.

Although the public safety will be our focus, it is considered by many to be part of a broader segment, often referred to as the Public Sector or even Land Mobile Radio (LMR) as per the US's FCC regulations. Table 3-1 provides an overview of this LMR market. Public Land Mobile Radio (PLMR) is another commonly used term. Included in general LMR are several non-public sector segments that have similar market requirements (e.g., critical infrastructure industries (CII), dispatch, shipping, taxi, etc.) and are usually addressed by common regulatory organizations and suppliers.

Public Sector Segments

Land Mobile Radio (LMR)

• **Public Safety**	Police Emergency Medical Services	Fire
• **Government**	Municipal Services National Ministries	Federal Agencies Education
• **Utilities**	Gas Water	Electric Telephone
• **Transportation**	Airlines Transit	Railroad Courier
• **Manufacturing**	Automotive Industrial	High-Tech Aerospace
• **Other Verticals**	Construction Petrochemical	Retail Corporate

Table 3-1 Public Sector Segments
(Source: Motorola CGISS 4Q 2003 Presentation, CGISS is now part of Motorola's Government and Enterprise Mobility Solutions – (GEM) Organization)

Motivated by 9/11, the United States, as well as the international community, has increased focus on terrorism. The US government has created a single Department of Homeland Security (DHS) to provide a single authority for planning, execution, evaluation, as well as accountability. The general key goals for US homeland security include:

1. First Responder Organization, Staffing, and Planning;
2. Interoperable Communications;
3. Inter-Jurisdictional coordination –Local, State, Federal;
4. Interagency Coordination –Police, Fire, Emergency Medical Services, etc.; and
5. Standards-based Communications that Provides Voice and Data Services.

These strategic goals as articulated at www.DHS.gov are presented in Table 3-2.

US Department of Homeland Security Strategic Goals • Prevention – Detect, deter and mitigate threats to our homeland. • Protection – Safeguard our people and their freedoms, critical infrastructure, property and the economy of our Nation from acts of terrorism, natural disasters, or other emergencies. • Response – Lead, manage and coordinate the national response to acts of terrorism, natural disasters, or other emergencies. • Recovery – Lead national, state, local and private sector efforts to restore services and rebuild communities after acts of terrorism, natural disasters, or other emergencies. • Service – Serve the public effectively by facilitating lawful trade, travel and immigration.

Table 3-2 US Department of Homeland Security Strategic Goals
(Source: www.DHS.gov)

LMR is in slow evolution from legacy analog LMR to comparatively recent emerging digital LMR standards. The primary United States public safety standard for voice communication is Project 25 (or P25). This US public safety standard was originally developed by Miami-headquartered Association of Public-Safety Communications Officials, International (APCO) and was historically referred to as APCO Project 25 The standards are now the responsibility of Telecommunication Industry Association (TIA) and are suite of standards identified as TIA/EIA-102. The specific organization within TIA that is responsible for P25 standards is the TIA TR-8 Committee on Mobile and Personal Private Radio Standards.

TErrestrial Trunked RAdio (TETRA) is an open digital trunked radio standard being developed by the European Telecommunications Standardization Institute (ETSI) that is focused in Europe and much of the rest of the world. It is generally similar is structure to P25.

Increasingly the public sector is using commercial cellular for administrative and routine coordination communication (e.g., Nextel and emerging Push-to-Talk, PTT). Critical command & control, dispatch, etc. communications are still accomplished on dedicated PLMR systems. Some ITS organizations have indicated that they might transition to exclusive commercial PTT services like cellular and decommission their PLMR system. However, we have not observed any exclusive transitions to date.

Commercial cellular service problems and inadequacies in emergency situations have been well documented in post-9/11 reports and other emergencies. Commercial cellular systems are typically not designed for five-9's reliability or increased capacity requirements that emergency situations create. Cellular is particularly vulnerable compared to legacy wireline systems because cellular access is by shared RF links, while wireline has dedicated copper access links. In public safety communications official interviews consistent input has been received that PLMR communication systems are designed for about 10 -30% capacity operation under anticipated routine operations so that sufficient capacity is available in much higher load emergency situations.

Conversely, commercial cellular systems are typically operated at 80 – 90% loading during peak time of day, which creates significant overload and busy or dropped call problems during much higher load emergency situations. Additionally, while the legacy (100 + years) wireline systems have five-9s reliability in their network deployments (perhaps excluding the copper access link), the comparatively young wireless industry has not consistently evolved their networks.

The key technical goals for public safety that have been consistently identified by stakeholders in our engagements are presented in Table 3-3.

Key Public Safety Communication Goals

- Interoperability with supporting agencies in emergency operations (by adding interoperability frequencies, Gateways, Multimode/Multi-band radios, and/or SDR)
- Life Cycle Cost Reductions
- Adequate capacity and reliability for emergency situations
- Data with sufficient speed, coverage, and capacity
- Encryption capabilities and standards
- Continued development of standards for digital voice and data
- Coordinated emergency planning with commercial communication service providers supported by reasonable laws and regulations

Table 3-3 Key Public Safety Communication Goals

A key organization under the DHS after 9/11 is SAFECOM. On its website, the SAFECOM provides a very informative and interesting mission statement that is presented in Table 3-4.

"The tragic events of 9/11 clarified the critical importance of effective first responder communication systems. The lack of public safety interoperability is a long-standing, complex, and costly problem with many impediments to overcome. Interoperability is the ability of public safety agencies to talk to one another via radio communication systems—to exchange voice and/or data with one another on demand, in real time, when needed and when authorized.

While several government programs have made great strides in addressing this issue, much of this work has been disconnected, fragmented, and often conflicting. In an effort to coordinate the various federal initiatives, the SAFECOM program was established by the Office of Management and Budget (OMB) and approved by the President's Management Council (PMC) as a high priority E-Gov initiative. More specifically, SAFECOM is a communications program within the Office for Interoperability and Compatibility (OIC) that provides research, development, testing and evaluation, guidance, tools, and templates for local, tribal, state, and federal public safety agencies working to improve public safety response through more effective and efficient interoperable wireless communications.

SAFECOM is pursuing its mission on a variety of fronts and is consistently guided by the input of local and regional public safety officials."

Table 3-4 SAFECOM Mission Statement
(Source: www.safecomprogram.gov)

SAFECOM has published many interesting papers and presentation on interoperability that is available on its website. One seminal paper is entitled "Interoperable Continuum: A tool for improving public safety communication and interoperability". Figure 3-2 is a recreation of a figure from this paper that very succinctly provides an overview of the elements of interoperability that includes: 1) Governance, 2) Standard Operating Procedures, 3) Technology, 4) Training and Exercises, and 5) Usage. Of particular interest is Technology that classifies approaches to interoperability, from minimal to optimal level, as:

1. Swap radios
2. Gateways (to interconnect radio system, even if on different frequencies)
3. Shared Channels (Mutual Aid and Interoperability channels)
4. Proprietary Shared Systems (probably not interoperable with systems from other manufacturers)
5. Standards-based Shared Systems (with the goal of using equipment and terminals from multiple manufacturers)

The Project 25 standards are key US initiatives for standards-based shared public safety communication systems. Of course, even the optimal Standards-based shared systems must be capable of operating on common frequencies for interoperability.

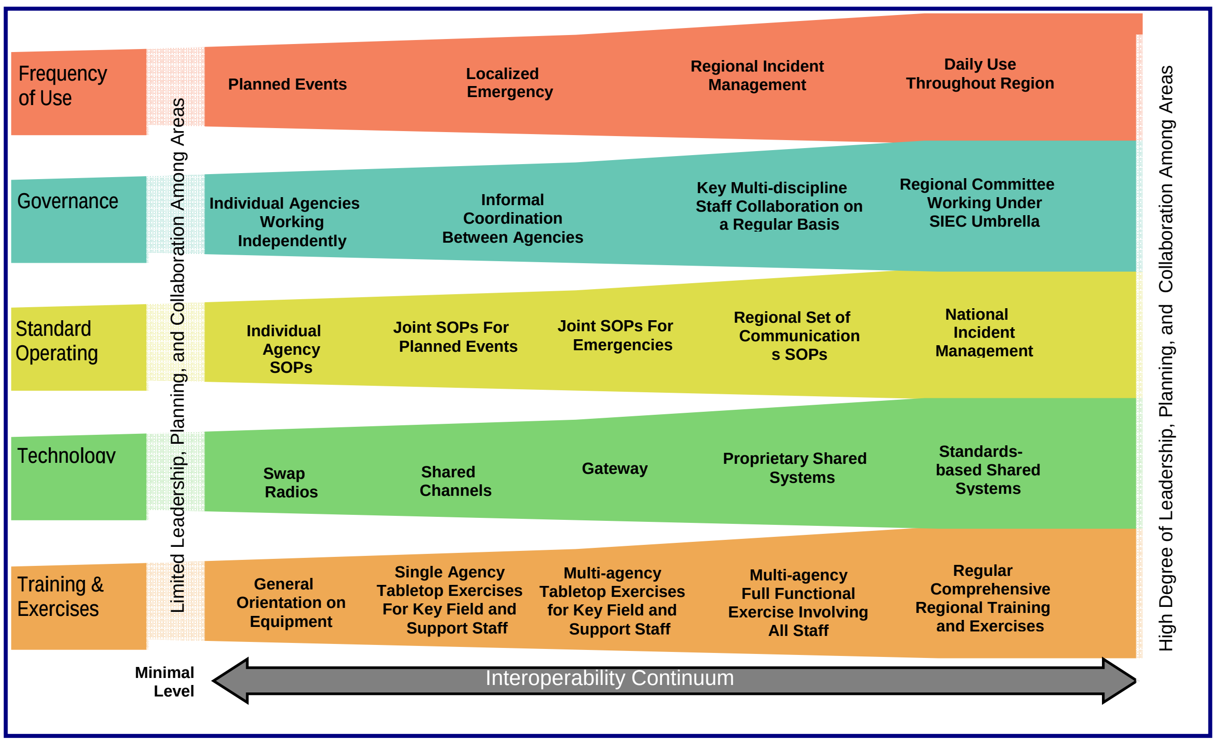


Figure 3-2 Interoperability Continuum
(Source: recreated from paper entitled "Interoperable Continuum: A tool for improving public safety communication and interoperability," www.safecomprogram.gov)

A key SAFECOM strategy is a "System of Systems" approach to deploy interoperable systems. This facilitates agencies to deploy updated systems on phased funding and schedule timelines that are interconnected to provide nation-wide interoperability.

In their yearend 2005 yearly progress report,[2] NTIA/ITS provides interesting discussions on public safety operability and interoperability. "Too often, public safety practitioners' communication systems do not meet their needs for operability (security, service area, performance, and survivability for intra-agency communication) and interoperability (inter-discipline, inter-jurisdiction communication where and when communications are needed)." The public safety community recognizes that five steps are needed to specify and implement interoperable wireless systems:

1. Define user requirements for communication and information exchange (e.g. Statement of requirements or SoR),
2. Specify the architecture framework to support the communication,
3. Develop standards for the systems,
4. Conduct technology performance tests to evaluate proposed solutions for the standards, and
5. Conduct vendor product functional tests to validate that tested equipment supports the standards prior to implementation.

The Software Defined Radio Forum (SDRF) has developed a very good list of public safety communication system key features that is presented in Table 3-5. Figure 3-3 presents an overview of the professional services used in deployment of private communication systems.

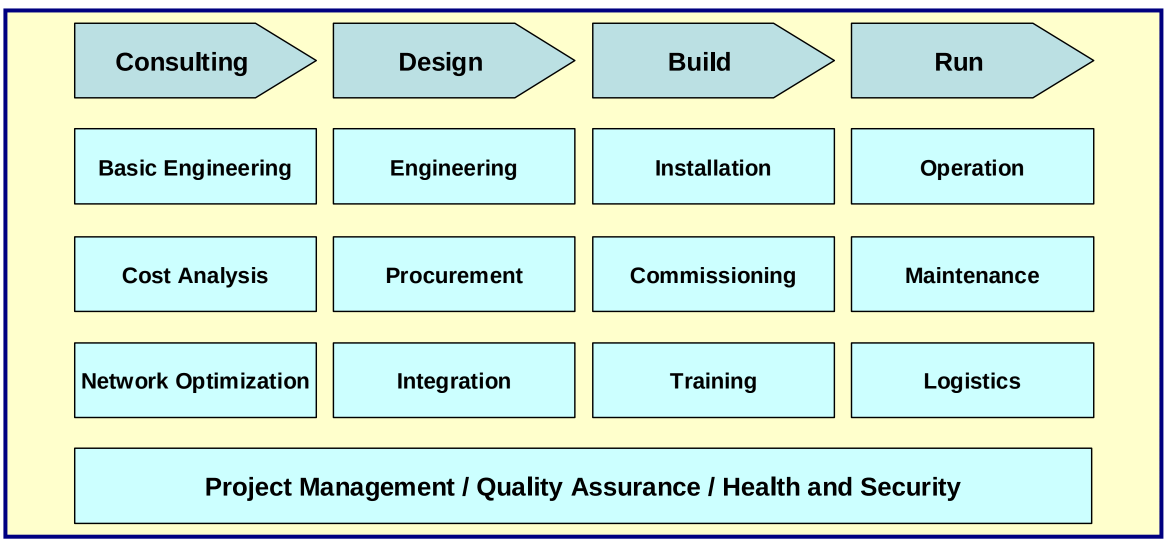


Figure 3-3 Professional Services used in deployment of Private Communication Systems
(Source: "Evolution of Private communications solutions", Alcatel Review, 2004Q3)

2 "Institute for Telecommunication Sciences 2005 Technical Progress Report"; U.S. Department of Commerce, National Telecommunications and Information Administration, Institute for Telecommunication Sciences; January 2006; pp 22-23

1. Key Features

This section provides an abbreviated list of key Critical Communications features with the intent to highlight some of the differences from cellular system features.

- **Addresses Critical Communications segment of overall Land Mobile Radio market**
  - Public Safety—Police, Fire, Highway Maintenance, Local & Federal Gov't, EMS
  - Some Public Works---Utilities and Some Public Transportation
  - Some Business & Industrial—Some Heavy Industry
- **High Performance, Digital Trunked Radio System**
  - Dispatch Focused—One to many communications
  - Rapid Access—Sub-second across network
  - Multiple Level Call Priority
  - Generally Push to Talk Simplex Operation
  - High Availability and Fault Tolerant
- **Multiple Communication Modes**
  - Group Call
  - Individual Call
  - Emergency Call
  - System All Call
  - Data Call
  - Digital Voice Call
  - Encrypted Voice Call
  - Telephone Interconnect
- **Flexible System Architecture**
  - Scaleable Small to Large Area Coverage
  - Wide Area Designs
  - Multisite
  - Simulcast
  - Connectivity
  - PSTN
  - Data/Computer
  - Open System Interfaces
- **Multiple Frequency Bands**
  - 900 (896-901/935-940 MHz)
  - 800 (806-824/851-869 MHz)
  - UHF (380-512 MHz)
  - VHF-H (150-174 MHz)
  - VHF-L (30-50 MHz)
  - New/Emerging (764-776/794-806 MHz)
- **Narrowband Channels & Spacing**
  - Channel width—25 & 12.5 kHz, with evolution to 6.25 kHz
  - Channel spacing—25, 12.5, 15, & 6.25 kHz with evolution to 3.125 kHz
- **Maximum Coverage High Power Sites**
  - Basestation output power—100 W average typical
  - Some tower top amplifiers for site sensitivity at 800 and 900 Mhz
  - Little/no use of site receive diversity
  - Omni and directional antennas both used, depending on coverage design
- **Terminal Products**
  - Rugged with some military specs
  - Mobiles—vehicle mounted
  - Portables—hand held
  - High power terminals
    - Typical 30 W mobile @ 800 MHz; typically up to 100W in lower frequency bands
    - Typical 3 W portable @ 800 MHz; typically up to 5W in lower frequency bands

  Portable battery life—8 hours min with 5% transmit, 5% receive, 90 % standby duty

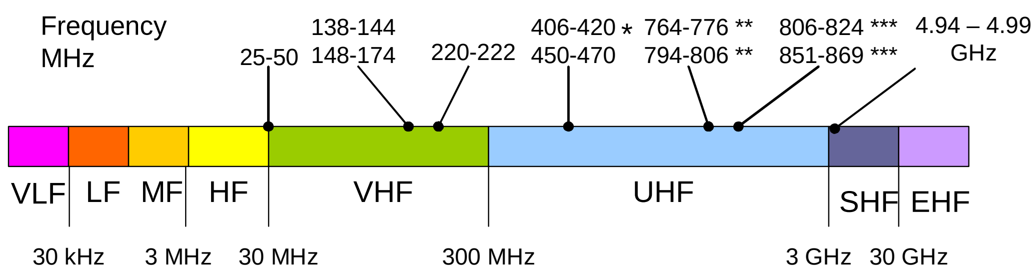
Table 3-5 Key Public Safety Communication Features
(Source: "Critical Communication Features and Descriptive Requirements", by Richard Taylor, Com-Net Ericsson (now M/A-COM), SDRF-01-I-032-V0.00 document, 14 May 2001)

- **High Spec RF Products**
  - Very Low Adjacent Channel Coupled Power—Transmit
  - Very High Desired Channel Selectivity—Discriminate Adjacent Channel Interferer
- **Frequency Allocation/Planning**
  - Frequencies are usually in very short supply, with sometimes as few as 5 frequencies for systems with small numbers of users
  - Stringent allocation to customers typically done by regional frequency coordinators.
    - Customer must justify need based on intended number of users
  - Frequency re-use design less organized than cellular
    - Often FCC inter-system distance offset of 70 mi (based on protecting 40 dBu service contour from undesired station's 22 dBu contour) used for intra-system design
    - For some cases, custom, propagation analysis based contour method used (40/22dBu
    - contours)
- **Radio Coverage**
  - Stringent requirements for public safety à Minimum DAQ 3.01 voice quality (often higher) over at least 95% of the service area
  - Typically design to maximize site coverage (competitive system cost) with required fringe area operation
  - In-building portable coverage usually required
    - Sometimes customer specifies portable operation within selected buildings or a percentage of all buildings with a specified loss (sometimes up to 20-30 dB loss)
- **Grade of Service (GOS) and Traffic Profiles**
  - Public Safety Voice—
    - GOS (Probability of Queue) , 1 to 5%, typically 1% during busy hour for traffic profile
    - Traffic Load Approximately .006 Erlangs per User per Busy Hour
    - Approx 6-7 calls/user/hr, mostly group calls
  - Public Works-Utilities Voice—
    - GOS, 5 to 10 %, typically 5% during busy hour for profile
    - Traffic Load Approximately .003 Erlangs per User Per Busy Hour
      - Approx 2-3 calls/user/hr, mostly group calls
  - Data Traffic Profile—wide range of profiles, treated on custom application basis
    - 5 to 30+ messages/user/hr
    - Wide range of number of bytes per message (10-10,000 bytes)
  - No Call Handoff—with large cells and short calls there is no handoff during call

Table 3-5 (Continued) Key Public Safety Communication Features

3.1. US Public Safety Spectrum

Availability of adequate spectrum is a major issue in public safety. Figure 3-4 presents the frequency bands allocated for public safety. In 2001 the US FCC issued new Part 90 rules to require re-farming in public land mobile radio (PLMR) bands that are under 512 MHz to improve channel spacing and spectral efficiency. Public safety bands under 512 MHz include the VHF low band (20 – 50 MHz), VHF high band (138-144 MHz, 148-174 MHz), and the UHF band (406-420 MHz, 450-470 MHz). These re-farming rules require that certification for new equipment, after specified dates, will only be granted for narrow band capable (12.5 kHz initially and 6.25 kHz at later dates) equipment. Backward compatibility with legacy 25 kHz channel spacing is authorized. Recently there has been much activity and controversy on (re)allocation of 700 and 800MHz bands to better provide for public safety needs.



* FCC re-banding regulations require that Public Land Mobile Radio Equipment operating below 512 MHz eventually be capable of 12.5 KHz and eventually 6.25 kHz, channel spacing from legacy 25 KHz.

** Subject to availability of analog TV channels, 2006 or beyond

*** Initiatives for Re-Banding of 800 MHz band are in progress

Figure 3-4 FCC Allocated Public Safety Spectrum
(Source: FCC Regulations and “Public Safety: Radio Spectrum: A Vital Resource for Saving Lives and Protecting Property”, PSWN Program [now SAFECOM])

At a National Public Safety Telecommunication Council (NPSTC) meeting on March 21, 2006 Ron Haraseth of APCO International presented information on the availability and re-use of public safety Spectrum that is recreated in Table 3-6. The “Unique Channel Re-Use” column indicates the number of times channels in a band are re-used in the US based on the FCC database. In Figure 3-5 two pie charts are presented for (right) allocated bandwidth (~ number of available channels x channel bandwidth) and (left) band allocation density of re-use. The left chart illustrates that, although the available VHF high band spectrum is only 3.6 MHz (14%) of available spectrum, its use is very extensive and popular considering, factoring for total US re-use, that 1,223 MHz spectrum or 48% of deployed public safety spectrum is VHF. Longer term legacy deployments are one reason for VHF high band popularity. Another is the fact that lower frequency VHF propagates better than UHF and the 700 and 800 MHz allocations. Also, the 700 and 800 MHz bands have more recently been made available for public safety use.

Band	Aggregate Frequencies	Unique Channel Re-Use
30 – 50 MHz	6.3 MHz BW	78,456
150 – 170 MHz	3.6 MHz BW	352,280
450 – 470 MHz	3.7 MHz BW	191,909
470 – 512 MHz	Varies by area of US	35,204
806 – 869 MHz	9.5 (6-NPSPAC)	100,063
746 - 806 MHz	24 MHz BW	NEW

Table 3-6 US Frequency Re-Use
(Source: Ron Haraseth, Director, Automated Frequency Coordination, APCO International)

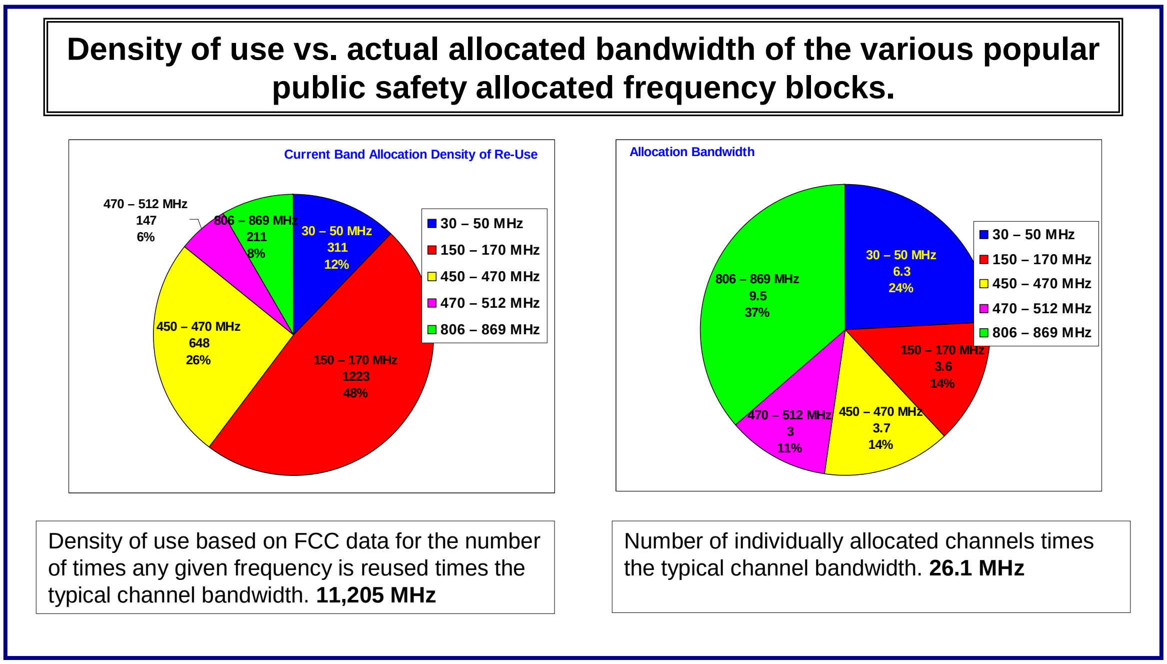


Figure 3-5 Public Safety Spectrum Allocation Bandwidth and Density of Re-Use
(Source: Ron Haraseth, Director, Automated Frequency Coordination, APCO International)

The FCC began receiving reports in 1999 of interference in the 800 MHz band from Commercial Mobile Radio Service (CMRS) providers operating in close proximity to public safety mobile and portable radios. In November 2001[3], Sprint Nextel (then Nextel, prior to merger) filed a white paper with the FCC proposing a restructure of the 800 MHz band to resolve interference problems. The densely deployed and heavily used Nextel SMR spectrum has been very popular and used for cellular-like applications as well as the popular "push-to-talk" services.

Figure 3-6 provides an overview of the latest 800 MHz band plan providing both before and after configurations. Nextel's frequency allocations have been adjacent to the 6 MHz NPSPAC spectrum as well as interspersed in other parts of the band. In March 2002 the

[3] "800 MHz Rebanding Overview and Status", Motorola, May 5, 2006, www.motorla.com

FCC filed a Notice of Proposed Rulemaking (NPRM) indicating an intention to modify the band plan to resolve interference problems. After much industry input and controversy, the text of Report and Order (R&O, under Docket 02-55) was released on August 6, 2004. A supplemental filing was released on December 22, 2004 that provided additional details to the plan, agreements, and transition.

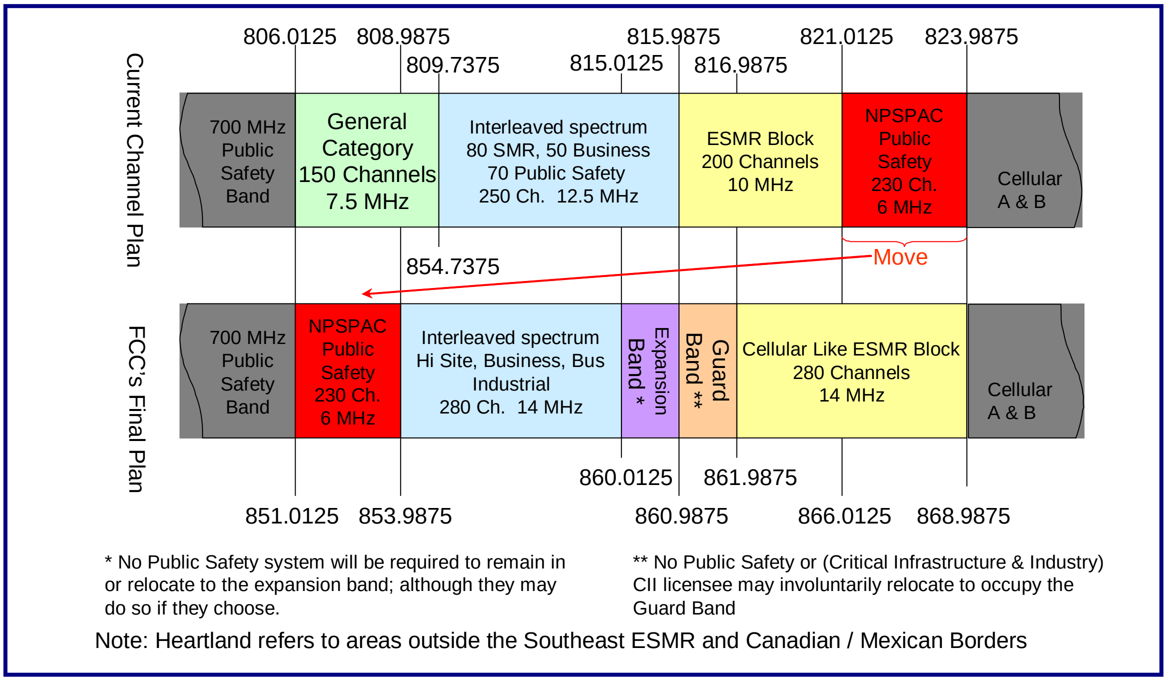


Figure 3-6 800 MHz Band Transition Plan (Heartland)
(Source: "800 MHz Rebanding Overview and Status", Motorola, May 5, 2006, at www.motorola.com,)

As part of the agreement, Nextel agreed to relinquish all of its 800 MHz spectrum holdings below 817 MHz and 862 MHz. To ensure equitable treatment, the FCC awarded Nextel the rights to two 5-MHz blocks in the 1.9 GHz band valued at $4.86 Billion[4]. Nextel will be allowed to offset 1.9 GHz costs by[4] "(1) Nextel's costs to relocate incumbents within the 800 MHz band, including payments Nextel has made for the services of the Transition Administrator; (2) Nextel's own relocation costs; (3) Nextel's costs to clear the 1.9 GHz spectrum; and (4) the net value of the 800 MHz spectrum that Nextel will relinquish for public safety use." Additionally, the R&O states that Nextel is assigned "full responsibility for the full cost of relocation of all 800 MHz band public safety and other 800 MHz band incumbents to their new spectrum assignments with compatible facilities, i.e., systems with comparable technological and operational capability." As depicted in Figure 3-6, the 800 MHz band is to be reconfigured to separate public safety, critical infrastructure industries (CII), and other non-cellular bands, from dense heavily used ESMR systems that create interference problems. The FCC also designated 14 MHz in the upper 800 MHz band for ESMR (Enhanced Specialized Mobile Radio, see Figure 3-6). The R&O also provides for new interference

[4] FCC 800 MHz Report and Order, WT Docket 02-55, Released August 6, 2004

protection rules defining unacceptable interference, interference reporting rules and procedures, and interferences resolution procedures.

The NPSPAC band will be relocated from its current position of 821-824 MHz to 806-809 MHz. As a result, individual NPSPAC licensees will relocate from their current channel assignments to new assignments fifteen megahertz downwards. These relocations will take place on a region-by-region basis on a schedule to be determined by the Transition Administrator. The FCC anticipates that the relocation of NPSPAC systems to the 806-809 MHz band will be one of the last steps in the reconfiguration of each NPSPAC region. The rules for the reconfiguration of the 800 MHz band, defined in FCC Rules Part 90.677, provide a very succinct overview of requirement and procedures for the re-banding and are presented Table 3-7.

"§ 90.677 Reconfiguration of the 806–824/851–869 MHz band in order to separate cellular systems from noncellular systems. In order to facilitate reconfiguration of the 806–824/851–869 MHz band (''800 MHz band'') to separate cellular systems from non-cellular systems, Nextel Communications, Inc. (Nextel) may relocate incumbents within the 800 MHz band by providing 'comparable facilities.'' For the limited purpose of band reconfiguration, the provisions of § 90.157 shall not apply and inter-category sharing will be permitted under all circumstances. Such relocation is subject to the following provisions: (a) Within thirty days of Commission approval of the Transition Administrator, the Transition Administrator described in § 90.676 will provide the Commission with a schedule detailing when band reconfiguration shall commence for each NPSPAC Region. The plan should also detail—by NPSPAC Region—which relocation option each non-Nextel ESMR licensees has chosen. The Chief of the Public Safety and Critical Infrastructure Division of the Wireless Telecommunications Bureau will finalize and approve such a plan. The schedule shall provide for completion of band reconfiguration in no more than thirty-six months following release of a public notice announcing the start date of reconfiguration in the first NPSPAC region. Relocation will commence according to the schedule set by the Transition Administrator but all systems must have commenced reconfiguration within thirty months of release of a public notice announcing the start date of reconfiguration in the first NPSPAC region."

Table 3-7 FCC Part 90.677, 800 MHz Band Reconfiguration
(Source: FCC Rules)

The Balanced Budget Act of 1997 allocated 24 MHz in the 700 MHz band for public safety. The spectrum allocated is the current analog TV channels 63, 64, 68, and 69 that are scheduled to be made available as television broadcasters transition to digital TV (DTV) channels. However, DTV content and uptake as been slower than anticipated and the targeted December 31, 2006 date was not met. In early 2006 Federal budget deficit legislation became law that included requirement for TV broadcasters to surrender this analog spectrum by Feb. 18, 2009. This should permit the redistribution of valuable frequencies to public safety as well as other wireless users.

Figure 3-7 illustrates that the 24 MHz of spectrum in this 700 MHz band will approximately double the 26.1 MHz in the other currently available public safety bands.

The public safety 700 MHz Band rules are defined in Part 90, Subpart R of the FCC rules. The rules provide for general use narrowband channels, narrowband low power channels and wideband general use channels. These channels may be assigned to eligible public safety organizations as defined in the FCC rules. Assignments are subject to Commission approved regional planning committee (RPC) plans. Applications for the 700 MHz public safety General Use channels must be reviewed and approved by the appropriate RPC within the area of proposed operation, prior to submission to a FCC certified public safety frequency coordinator.

The FCC's public safety 700 MHz band plan is presented in Figure 3-7. There are four narrowband segments consisting of 764-767 MHz (Channel 1 – 480), 773-776 MHz (Channel 481-960), 794-797 MHz (Channel 961-1440) and 803-806 MHz (Channel 1441-1920). Each narrowband segment is divided into 480 channels having a channel size of 6.25 kHz. The two wideband segments are 767-773 MHz (Channel 1-120) and 797-803 MHz (channel 121-240). Each wideband segment is divided into 120 channels having a channel size of 50 kHz.

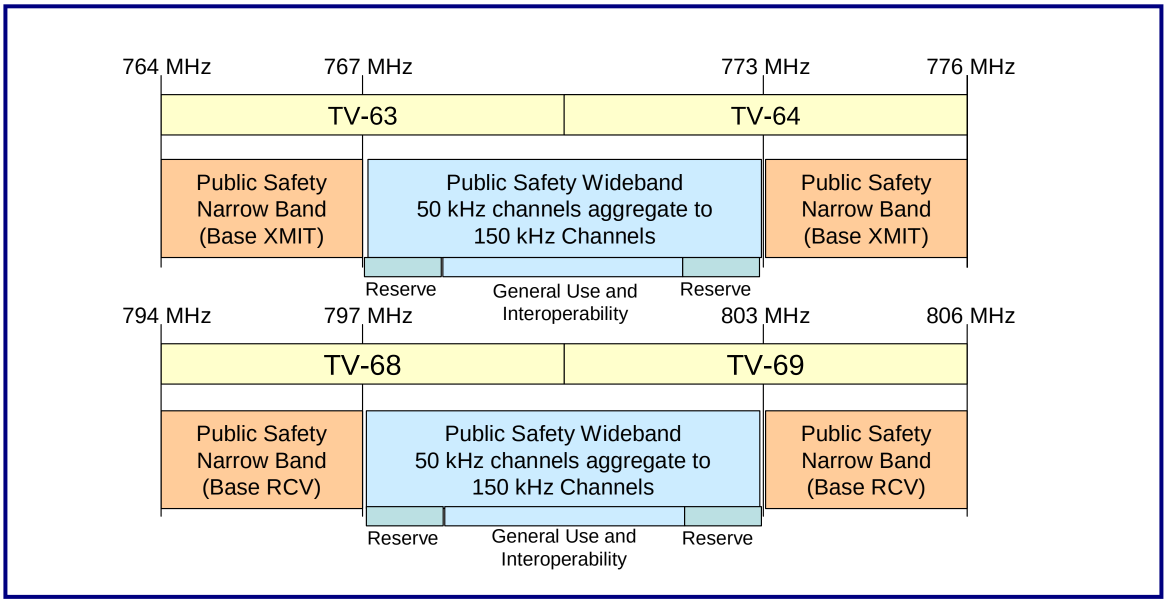


Figure 3-7 Public Safety 700 MHz Band Plan
(Source: FCC web site)

General Use Narrowband Channels are the narrowband channels established in four narrow band segments exclusive of the narrowband interoperability channels, narrowband reserve channels, narrowband low power itinerant channels, and narrowband state channels. Narrowband low power channels are designated for low power use for on-scene incident response purposes using mobiles and portables. Wideband general use channels established in the two wide band segments exclusive of the wideband interoperability channels and wideband reserve channels. Narrowband low power itinerant channels are designated for low power use for on-scene incident response purposes using mobiles and portables. The Narrowband low power itinerant channels are licensed for nationwide itinerant operation and are not subject to regional planning or frequency coordination.

3.2. Project 25 (P25) Overview

According to an interesting narrative on the Project 25 Technology Interest Group[5] (PTIG) website, US public safety community communications standards initiatives trace back to the 1976-1979 timeframe when a functional specification was developed by the Association of Public Safety Communication Officers (APCO) for public safety analog trunked systems known as APCO Project 16 (P16). P16 specified analog voice and radio channel trunking (i.e. system channel assignment) using the newly allocated 800 MHz spectrum. The specification allowed proprietary systems, which reportedly minimized interoperability once a manufacturer was selected in initial procurements. Five mutual aid channels were designated to provide for interoperability. The varying proprietary protocols and differing frequency bands prevented desired interoperability.

In 1988, the US FCC published a Notice of Inquiry (NOI) for public safety digital radio technologies. In 1999 an APCO Project 25 coalition was formed that included APCO as well as other federal, state, etc. public safety stakeholders. Later the Telecommunication Industry Association (TIA) was requested to provide technical advice to Project 25 for its standards. A Memorandum of Understanding (MOU) was executed between TIA and Project 25. A second MOU was among industry participants to ensure proper agreements regarding Intellectual Property Rights (IPR) were achieved. The early major issues were migration including forward and backward compatibility, voice and data security, and protection of system control methods. TIA followed an industry-sanctioned and American National Standards Institute (ANSI) accredited process.

In 1995, the first recommended standard, now generally known as P25, was consummated that specified features and signaling for narrow band digital voice and data, conventional and trunking modes of operation, and configurability for compatibility with older analog mobile and portable radios. The P25 standards are published in the ANSI/TIA/EIA 102 series of documents. The initially published P25 standard was the Common Air Interface (CAI) as identified in Figure 3-8. The current P25 standard suite includes the CAI which is a FDMA (single channel per carrier) that provides both analog and digital voice in 12.5 kHz, trunking, encryption, Over-The-Air Rekeying (OTAR), and P25 data standards.

Figure 3-8 presents a recent version of the P25 architecture and interfaces that include:

1. Common Air Interface (CAI)
2. Subscriber Data Peripheral Interface (SDPI)
3. Fixed/Base Station Subsystem Interface (FSSI)
4. Inter-RF Subsystem Interface (ISSI)
5. Console Subsystem Interface (CSSI)
6. Network Management Interface (NMI)
7. Data Network Interface (DNI)
8. Telephone Interconnect Interface (TII)

[5] www.project25.org

The public safety community has complained for many years that P25 standards are still inadequate and incomplete. In reality, until early 2006 the only completed interface standard was the CAI; systems and equipment supporting multi-vendor interoperability have generally not been available from industry. Many factors contribute to the fact that, in the 10+ years since the 1995 release of the original P25 standard, further completion goals have been elusive. However, Dereck Orr of NIST provided a very succinct, informative, and optimistic overview and status testimony to congress on April 25, 2006 that is presented in Table 3-8. In his testimony, Orr identifies that P25 is a suite of standards that includes the eight interfaces presented in Figure 3-8. He states that three other P25 interface standards have been achieved in early 2006 that include the ISSI, FSSI, and the CSSI; interfaces that have been identified as the most critical by many stakeholders. He provides further statements that NIST, with the support of SAFECOM and the P25 Steering Committee, is developing a P25 Conformity Assessment Program. Commercial cellular system and product vendors have long successfully used similar programs to achieve interoperability for their commercial systems.

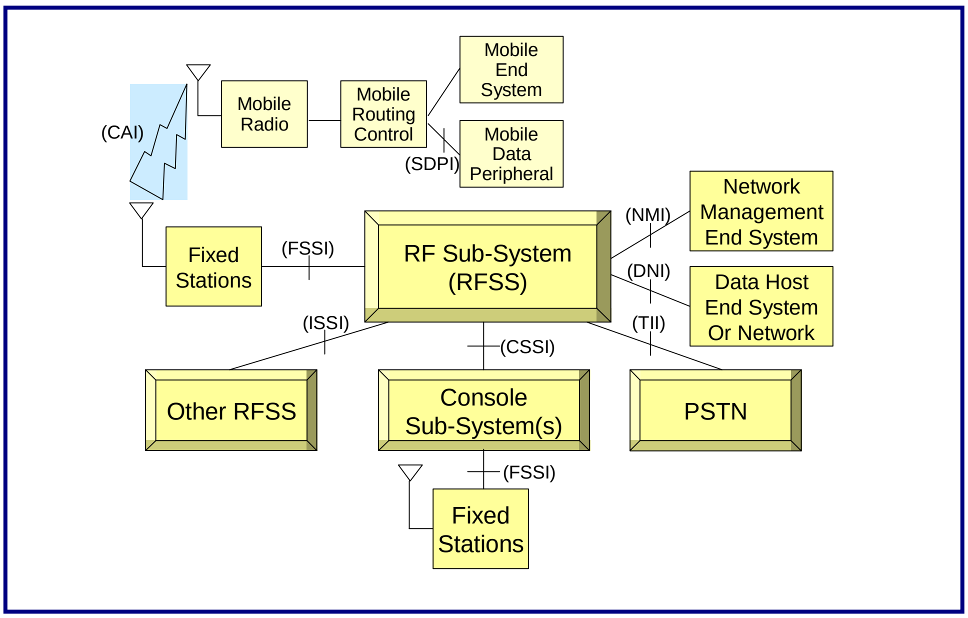


Figure 3-8 P25 System Interfaces
(Source: M/A-COM and "Institute for Telecommunication Sciences 2005 Technical Progress Report"; U.S. Department of Commerce, National Telecommunications and Information Administration, Institute for Telecommunication Sciences; January 2006; pp 22-23

P25, phase 1, has been focused on a Frequency Division Multiple Access (FDMA) air interface that supports one channel per carrier. To enhance spectral efficiency, P25, phase 2, that is ongoing, focuses on a Time Division Multiple Access (TDMA) CAI that provides two channels per 12.5 kHz carrier (or one channel per 6.25 kHz or four channels per 25 kHz). Other P25, phase 2 considerations have included interoperability with legacy equipment, roaming capacity, spectral efficiency and channel reuse, console interfacing, interfacing between repeaters and other subsystems (e.g., trunking system controller), and man-machine interfaces for console operators that would facilitate centralized training, and equipment transitions and personnel movements.

Testimony of Mr. Dereck Orr; Program Manager, Public Safety Communications Systems, National Institute of Standards and Technology, Technology Administration, U.S. Department of Commerce; Before the The Subcommittee on Emergency Preparedness, Science, and Technology, Committee on Homeland Security, U.S. House of Representatives; "The State of Interoperability: Perspectives on Federal Coordination of Grants, Standards, and Technology";
April 25, 2006

Thank you Chairman Reichert and Members of the Committee, I serve as the Program Manager for Public Safety Communications Systems in the Office of Law Enforcement Standards at the National Institute of Standards and Technology (NIST). NIST a non-regulatory agency within the U.S. Commerce Department's Technology Administration serves industry, academia, and other parts of the government by promoting U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life.

NIST's public safety communications program serves as the technical lead for several Administration initiatives focusing on communications, most importantly the SAFECOM Program. NIST is involved in many of the key SAFECOM initiatives, including the Statement of Requirements, Public Safety Architecture Framework, testing and evaluation, and standards development. The strong partnership between SAFECOM and NIST is an excellent example within the Administration of multi-agency coordination and collaboration, and is something for which we at NIST are very proud. In addition, NIST relies heavily on the world-class engineering expertise of the Institute of Telecommunications Sciences within NTIA.

I will focus the remainder of my remarks this morning on the state of standards for public safety communications systems.

Interoperability for public safety communications is defined as "the ability to share information via voice and data signals on demand, in real time, when needed, and as authorized." The public safety community expects that this level of interoperability will be available using equipment from multiple manufacturers, that they are transparent to the user, requiring little or no special knowledge of the system, and that they are not dependent on common frequency assignments. Achieving this definition of interoperability is not possible without the existence of standards that will define how the various components of a public safety communications system will interoperate, regardless of manufacturer. In fact, I would venture to say that in the absence of standards, achieving this level of interoperability would not be possible.

Public safety users have recognized this for some time. Approximately fifteen years ago, representatives from local, state, and federal public safety associations and agencies joined together to address the absence of available standards. They did this for two primary purposes. First was to ensure that interoperability could be achieved, assuming the use of equipment from multiple manufacturers. Second, through standards, the public safety community wanted to be able to take advantage of cost reductions associated with a more competitive land mobile radio market.

Understanding the difficulty in specifying the complex operations of the various components of a land mobile radio system, the public safety community partnered with the Telecommunications Industry Association (TIA) to serve as the standards development organization (SDO) for this effort. Thus Project 25, or P25 as we know it today, was launched. A Memorandum of Understanding formalizing this relationship created a Steering Committee comprised only of public safety and government representatives and invested the committee with the sole authority to designate a P25 standard.

A commonly misunderstood aspect of P25 is that it is comprised of a single standard. Instead, it is a suite of standards that specify the eight interfaces between the various components of a land mobile radio system (hand held to hand held, hand held to mobile unit, mobile unit to repeater, etc.):

- Common air interface: this interface defines the wireless access between mobile and portable radios and between the subscriber (portable and mobile) radios and the fixed or base station radios;
- Subscriber data peripheral interface: this interface characterizes the signaling for data transfer that must take place between the subscriber radios and the data devices that may be connected to the subscriber radio;
- Fixed station interface: this interface describes the signaling and messages between the RFSS and the fixed station by defining the voice and data packets (that are sent from/to the subscriber(s) over the common air interface) and all of the command and control messages used to administer the fixed station as well as the subscribers that are communicating through the fixed station;
- Console interface: this interface is similar to the fixed station interface but it defines all the signaling and messages between the RFSS and the console, the position that a dispatcher or a supervisor would occupy to provide commands and support to the personnel in the field;
- Network management interface: this interface to the RFSS allows administrators to control and monitor network fault management and network performance management.
- Data network interface: this interface describes the RF subsystem's connections to computers, data networks, external data sources, etc.;
- Telephone interconnect interface: this interface between the RFSS and the Public Switched Telephone Network (PSTN) allows field personnel to make connections through the public switched telephone network by using their radios rather than using cellular telephones;
- Inter RF subsystem interface: this interface permits users in one system to communicate with users in a different system, from one jurisdiction to another, from one agency to another, from one city to another, etc.

Until this past January, the last fifteen years had resulted in only one of the above P25 interfaces, the Common Air Interface that deals with the functions of the hand held units (i.e., walky-talky), being advanced to a level where it would help satisfy one or both of the goals of P25. The remainder of the interfaces had either remained undefined, or lacked enough specificity to allow for a common implementation of the interface; in other words each manufacturer's implementation of the interface would be different and proprietary thus resulting in systems that would not meet the "interoperability" requirements as defined by the steering committee.

I would like to emphasize that the Common Air Interface was a major step forward and extremely important. It provides a level of interoperability and competition in the hand-held market that was not available before. But, it alone cannot satisfy the definition of interoperability that the public safety community is calling for.

Table 3-8 “The State of Interoperability: Perspective on Federal Coordination of Grants, Standards, and Technology”
Source: Testimony of Mr. Dereck Orr; Program Manager, Public Safety Communications Systems, National Institute of Standards and Technology, Technology Administration, U.S. Department of Commerce; Before The Subcommittee on Emergency Preparedness, Science, and Technology, Committee on Homeland Security, U.S. House of Representatives; April 25, 2006)

However, over the last year, through the concerted efforts of industry, public safety practitioners, and NIST, with the support of SAFECOM, the technical development of standards for the critical P25 interfaces has been greatly accelerated. Industry representatives, with key involvement by public safety practitioners, have dramatically increased the pace and scope of their standards development activities consistent with priorities set by Congress. As a result, significant progress has been made through the formal P25/Telecommunications Industry Association (TIA) standards development framework established by the P25/TIA partnership in 1993. Specifically, the most critical P25 radio system interfaces have all been addressed. Basic protocol standards that specify the functionality and capability of these interfaces have now been completed and have been, or are on the verge of being published. The adoption of P25 standards is now occurring within a time frame acceptable to public safety users, NIST and its Federal partners, and the manufacturers.

As of the March 2006 P25 meetings the following has been achieved to add to the existing P25 Common Air Interface:

Inter-RF Subsystem Interface (ISSI): A draft ISSI standard was approved on January 11, 2006 for letter balloting as a TIA standard. TIA anticipates that the vote for publication will occur during a formal meeting on May 31, 2006. The public safety community can expect ISSI products to be available in 2007 (within approximately six months after publication of relevant standards in 2006 consistent with deadlines established by the P25 Steering Committee

Fixed/Base Station Subsystem Interface (FSSI): A completed FSSI standard was approved on January 11, 2006 for publication as a TIA standard. The realization of a TIA standard for the FSSI is extremely important because this standard will result in the offering and procurement of interoperable multi-vendor equipment enabling direct control by the console and Radio Frequency Subsystem (RFSS) of fixed/base station equipment. The console functionality provided by the FSSI substantially mitigates the urgency for completion of the CSSI. The public safety community can expect FSSI products to be available in late 2006 (within approximately six months after publication of relevant standards in 2006 consistent with deadlines established by the P25 Steering Committee).

Console Subsystem Interface (CSSI): Completion in January 2006 of a new TIA standard for the FSSI that enables direct basic console control of fixed/base station equipment now serves as the foundation for more comprehensive CSSI standards to be developed in the future. Further development of the CSSI will follow upon continued development of the ISSI and FSSI throughout calendar year 2006. The public safety community can expect CSSI products to be available in 2007 (within approximately six months after publication of relevant standards in 2006 consistent with deadlines established by the P25 Steering Committee).

I can report that State and local public safety agencies are already referencing the above standards in formal requests for proposals (RFPs) to Industry and that manufacturers are in the process of adding these standards to future land mobile radio product lines.

Of course, it is not only important that the various P25 interfaces are completed in a timely manner, but that a mechanism exist to ensure that products built to the standard, meet all of the requirements of the standard. Over the last two years, NIST, with funds from the Department of Homeland Security and the Department of Justice, has tested a number of the hand held P25 radios that claim to meet the available Common Air Interface Standard. Using the test procedures called for in the standard, NIST found that none of the available radios met all aspects of the standard.

As with many other standards developed through the private sector consensus process, the key to correct adoption and implementation by different manufacturers is a strong conformity assessment program. A conformity assessment program will validate P25 standardized systems through a set of agreed upon tests which will validate that the systems can interoperate among themselves, thus ensuring Federal grant dollars are being used appropriately.

NIST, with the support of SAFECOM and the P25 Steering Committee, is developing a P25 Conformity Assessment Program. NIST is preparing and documenting standardized test protocols for the most important spects of the Common Air Interface Standard. The standardized test protocols will then be provided to NIST's National Voluntary Laboratory Accreditation Program (NVLAP), which can accredit laboratories interested in offering these testing capabilities. These test protocols would go a long way in assuring the public safety community that the equipment being purchased meets the P25 standard.

NIST is working closely with the P25 Steering Committee and manufacturers to ensure that the test procedures are correct and that the results are accurate. In addition, not all aspects of the P25 common air interface will be immediately available for testing through this program. To begin with, NIST is focusing on some basic functional tests of the radios, which will allow us to get the Compliance Assessment Program up and running. We will then begin to add interoperability tests, as well as tests for more complex radio functions.

In summation Mr. Chairman, there are positive steps being taken by leaders within the public safety community, key federal programs, the Congress and industry to significantly change the current environment and move the state of standards for public safety forward. The last twelve months have seen significant progress in the development of critical P25 standards and the next twelve months will see even more progress made., In addition, by the end of this year, local, state, and federal agencies procuring P25 equipment will have a mechanism in place to ensure that the products they are purchasing truly do what is called for in the applicable standard. In conjunction with the other efforts mentioned by the other witnesses, I am confident that we are making significant headway in the pursuit of communications interoperability.

NIST looks forward to working with this Committee, Congress, our federal partners, state and local public safety officials, and leaders in industry to make this happen. Again, I am honored to be here before this Committee today, and I will happy to answer any questions that you may have.

Table 3-8 (Continued) “The State of Interoperability: Perspective on Federal Coordination of Grants, Standards, and Technology”

The TIA TR-8 Committee has accelerated the pace of the standards development process in response to public safety and Congressional concerns. Initial demonstrations of multivendor ISSI interoperability early in 2007 indicate demonstrable results of this effort.

P25 is a US and North America led initiative. The Project 25 Technology Interest Group provides a list of countries with Project 25 interoperable equipment or networks that is recreated in Figure 3-9. The figure depicts significant international interests.

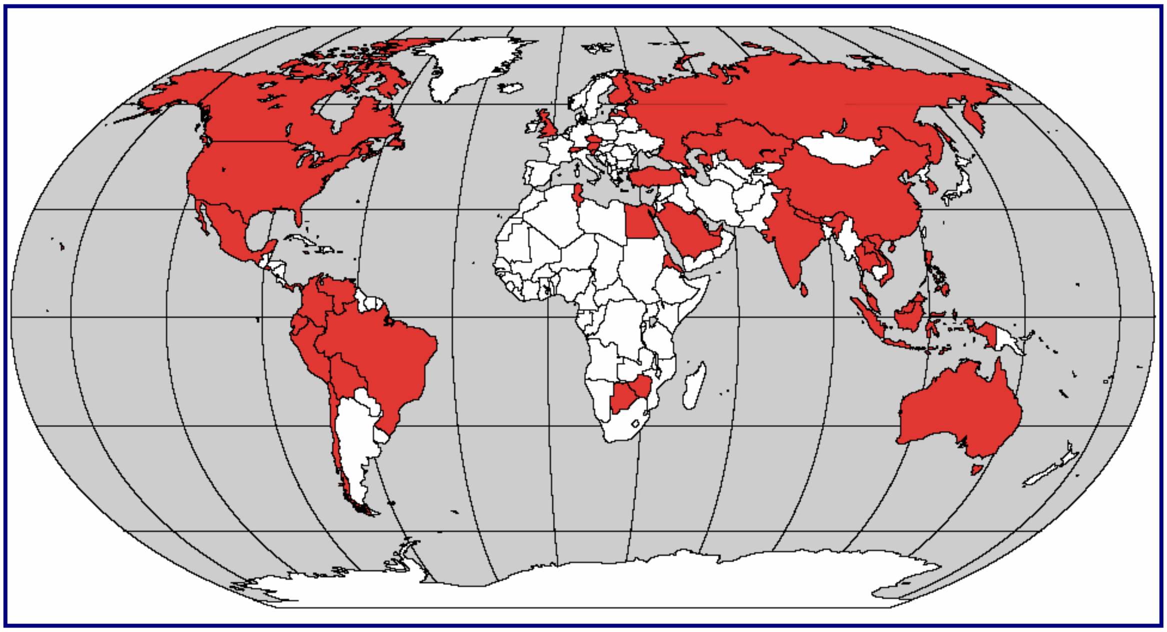


Figure 3-9 Countries with Project 25-Interoperable Equipment or Networks
(Source: recreated from http://www.project25.org/pages/files/P25_map.pdf)

The countries in the figure include:

Australia
Austria
Azerbaijan
Bahrain
Bermuda
Botswana
Brazil
Brunei
Canada
Chile
China
Colombia
Costa Rica
Czech Republic
Ecuador
Egypt
El Salvador
Eritrea
Finland
India
Indonesia
Hong Kong Special Administrative Region, China
Jamaica
Kazakhstan
Korea
Kuwait
Latvia
Laos
Malaysia
Mexico
Nepal
Peru
Philippines
Russia
Saudi Arabia
Singapore
Slovenia
Sri Lanka
Switzerland
Thailand
Trinidad
Tunisia
Turkey
United Kingdom
USA
United Arab Emirates
Venezuela
Vietnam
Zimbabwe

3.3. US Public Safety Broadband Initiatives

Project 25, phase 3, initiatives target public safety broadband communications. Two broadband initiatives have been pursued. The first is the TIA 902 standards initiatives that are generally referred as wideband. The second, the MESA (Mobility for Emergency and Safety Applications) initiative, is an international partnership between the TIA and the European Telecommunication Standards Institute (ETSI). Figure 3-10 presents an overview of US P25 narrowband, wideband, and broadband initiatives.

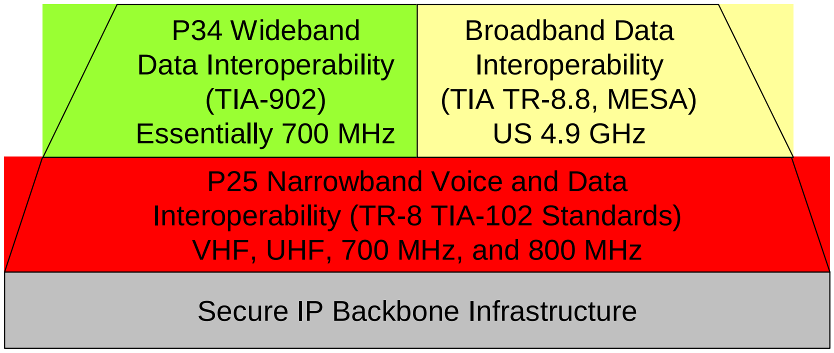


Figure 3-10 Overview of US Public Safety narrowband, wideband, and broadband Initiatives
Source: Adapted from "National Academies Improving Spectrum Management" Presentation, Sharkey, Motorola, March 1, 2006

The TIA 902 suite of standards address public safety interoperable wideband radio systems using high-speed packet data over wideband data channels in the 700 MHz public safety band plan. A key goal is to reuse as much as possible Internet technology to facilitate the convergence with commercial wireline and wireless data networks. TIA/EIA-902 is the responsibility of the TIA TR-8.5 Subcommittee on Signaling and Data Transmission. As presented in Figure 3-7, TIA-902 envisions 50, 100, and 150 kHz channels supporting data rates up to 384 kbs. The term wideband is coined to perhaps denote less than broadband bit rates, but support for wider area coverage. The original TIA standard was published in February 2003 and addresses the 700 MHz band.

The US public safety community has been supporting higher speed broadband initiatives in TIA's TR-8.8 Broadband Data Communications subcommittee. The targeted requirements are to provide higher speed wireless links for emerging data, imaging, and video, multimedia, as well as synergistic voice applications. Requirements exist for mission-critical situations that include best effort as well as more stringent quality of service (QoS) solutions. The US targets new 4.9 GHz spectrum and bit rates to 2 Mbps, perhaps more.

Project MESA[6] was originally known as the Public Safety Partnership Project (PSPP) completing its first partnership agreement in May 2000. In January 2001 a new partnership agreement was ratified in the City of Mesa, Arizona and partnership name became known as "Project MESA." On its web site, Project Mesa initiatives are articulated: "MESA represents the first such international initiative to involve users and organizations from the Public Protection & Disaster Relief (PPDR) and Peacekeeping sectors to join forces with Industry for the production of a truly global standard." The drivers are identified as "A growing demand for mobile broadband services within tele-medicine, fire-fighting, mobile robotics and peacekeeping operations is rapidly emerging."

[6] www.projectmesa.org

Project MESA has planned its work in phases. The first priority has been a common Project MESA Statement of Requirements (SoR) for public safety that will be developed to define harmonized applications and services for very high bit-rate mobile service platforms. This SoR will then drive work to develop the “necessary set of Technical Specifications and Technical Reports for the first phase of a Mobile Broadband System.”

In a TIA brochure on its web site (www.tiaonline.org/standards), the capabilities targeted by Project MESA activities, involving either an ad hoc or day-to-day operational environment, are identified as:

- Wireless mission-critical broadband data
- Secure and interoperable capabilities
- Multiple users with multiple applications
- Self-establishing and -healing network nodes
- IP-based mobile networking
- Robust management and control systems
- Flexible existing infrastructure dependence
- Dynamic and flexible radio configuration
- Real-time digital voice, video and sensing
- Still photos, complex graphics and drawings files
- Enhanced bio-telemetry information
- Maintain integrity/security of national networks

3.4. Project 25 Terminal and Equipment Players

Although the focus of this report is on interviews with public safety government experts and market estimates, as supporting information, Table 3-9 provides overview information on US P25 terminal and equipment suppliers.

In our interviews with stakeholders, Motorola was consistently identified as having a dominant market share of the US public safety market. The mobile and portable terminal markets appears to be more competitive, historically dominated by Motorola, but with other domestic and international suppliers increasingly gaining contracts with agencies desiring lower costs through competition. Motorola seems to often win the critical first terminal opportunities. Subsequently, many agencies encourage competitors to perform terminal interoperability tests on installed P25 networks, and then purchase these terminals, often for applications requiring more modest feature sets and lower cost. Over time, as P25 certification testing becomes more effective and pervasive, it is expected that terminal competition will increase.

The public safety network infrastructure market appears to be dominated by Motorola. M/A-COM appears to be successfully and aggressively gaining market share in both the US infrastructure market and the terminal markets, although it is small compared to Motorola. In our interviews, no infrastructure plans or deployments were identified by vendors other than Motorola and M/A-COM. However, it should be noted that our focus was at state level public safety organizations and it may be that other vendors have successes at Federal and local agencies as well as in non-public safety applications. EF Johnson was the only other network vendor identified in any of our interviews. In the following paragraphs, overviews will be provided for M/A-COM and Motorola's network products and statewide deployments.

Aeroflex, Inc.	Test Equipment
Catalyst Communications Technologies	Dispatch Consoles
Daniels Electronics Ltd.	Infrastructure
Datron World Communications Inc.	Terminals: Portable, Mobile
EADS Telecom	ISSI Equipment
EFJohnson Company	Portables, Mobiles, Infrastructure
Icom America	Mobiles Portables
Kenwood	Mobiles, Portables
M/A-COM	Mobiles, Portables, Infrastructure
Midland Radio Corporation	Mobiles, Portables
Motorola	Mobiles, Portables, Infrastructure
Pantel International Inc.	Console
RELM Wireless Corporation	Mobiles, Portables
Tait Electronics - Radio Communications	Mobiles, Portables, Infrastructure
Technisonic Industries Ltd.	Airborne terminals
Thales Communications Inc.	GPS Software
TMC Radio Pty Ltd	Mobiles, Portables
Vertex Standard, Inc.	Mobiles, Portables
Westel RF Technology Corporation	Infrastructure
Wulfsberg Electronics	Airborne Terminals
Zetron, Inc.	Consoles, Controllers

Table 3-9 P25 Terminal and Equipment Suppliers
(Source: www.project25.org and Company Web Sites)

M/A-COM

M/A-COM appears to be gaining market share in the US public safety market and in recent years has won contracts for statewide public safety communication systems in very high profile states that include:

Florida	New York	Pennsylvania

A key M/A-COM strategy appears to be contracts where they agree to operate and maintain the statewide systems as well as provide turn-key network equipment, and services for installation, commissioning, training, etc. (See discussions for Florida and New York in section 4)

Table 3-10 provides an overview of M/A-COM's public safety radio network product lines. The organization that provides these products is M/A-COM's Wireless Systems

Business Unit that includes the legacy M/A-COM businesses and the Com-Net Ericsson Critical Radio Systems Business Unit that was acquired in July 2001. Com-Net had previously acquired the Ericsson Private Radio business unit in January 2000, and Ericsson had previously acquired GE Mobile

Product Family	Product Origin	Analog/Digital	Standard Compliance	Bands	Channelization	Trunking / Conventional	Comment
EDACS	Initially developed by GE	analog, digital	proprietary	VHF, UHF, 800 MHz, and 900 MHz	12.5 kHz or 25 kHz	Conventional, Trunking, Single Site through Wide Area Multisite, Simulcast	PROVOICE digital voice; supports digital data communication as well
OpenSky	Legacy M/A-COM Product Development	digital	proprietary	700 MHz and 800 MHz	25 kHz	Trunking, Single Site through Wide Area Multisite	2- or 4-slot TDMA; Digital voice and data
P25[IP]	recent M/A-COM Product Development	digital	Designed to P25 Standards	VHF, UHF, 800 MHz	12.5 kHz	Conventional, Trunking, Single Site through Wide Area Multisite, Simulcast	Terminals support Analog-FM, EDACS, OpenSky, and P25[IP]
Analog-FM Conventional	Initially developed by GE as well as M/A-COM	Analog	TIA-603 Compliant	Low-Band, VHF, UHF, 800 MHz	Various	Conventional	Low-band radios are for replacement business

Table 3-10 M/A-COM Network Product Families
(Source; M/A-COM Web Site and Interviews)

Motorola

Motorola has a very high market share in the US public safety market, generally reported to be well over 50%. In interviews, numbers as high as 85% were suggested by some. Government public safety officials were vigorous and consistent in identifying this high market share as being a problem in achieving more cost competitive and lower cost procurements. While some blame Motorola for this situation, we support the position that slow progress by the P25 community in completing the P25 standards is more to blame. Lacking sufficient P25 standards, Motorola has provided solutions that solve customer's problems that are often eventually perceived as proprietary solutions. Going forward, we believe that the public safety community must effectively complete and utilize standards for core requirements. However, as Glenn Nash of California, suggested in interviews (see section 4.1) that the public safety community needs to find ways to provide core functionalities via standards and to provide needed non-standard functionality in standard way.

Motorola has a high market share of states with deployed (or in progress) statewide communication systems that include:

Alabama	Illinois	Minnesota	Virginia
Alaska	Indiana	Ohio	Wyoming
Colorado	Iowa	South Carolina	
Connecticut	Kentucky	South Dakota	
Delaware	Michigan	Utah	

Table 3-11 provides an overview of Motorola's public safety network product lines. The organization that provides these products is Motorola's Network and Enterprise Business. Until early 2006 responsibility for these products rested with the Government and Enterprise Solutions (GEMS) organization, and even earlier in the Commercial, Government, & Industrial Solutions Sector (CGISS). Over the past several years these organizations have been consolidated into the Network and Enterprise Business organization. This organization now includes the commercial infrastructure business of Motorola, suggesting perhaps some future interesting synergies.

Product Family	Analog/Digital	Standard Compliant	Bands	Channelization	Trunking / Conventional	Comment
Smartnet	analog	proprietary	VHF, UHF	25 kHz	Conventional, Smartzone Trunking	Early 1980's
Smartzone	analog	proprietary	VHF, UHF, 800 MHz	25 kHz	Conventional, Smartzone Trunking	Early 1990'a
ASTRO	analog, digital	proprietary, P16, many P25 features	VHF, UHF, 800 MHz	12.5 kHz (25 kHz)	Conventional & Smartzone Trunking, Single and Wide Area	Late 1990's
ASTRO25	analog, digital	P25 compliant, claims to be 1st compliant P25 Infrastructure System	VHF, UHF, 800 MHz, 700 MHz	12.5 kHz (25 kHz)	Conventional & P25 Trunking	2000 Smartzone P25 compliant Trunking, Single and Wide Area Trunked OTAR VoIP

Table 3-11 Motorola Network Product Families
(Source; Motorola Web Site and Interviews)

4 US Public Safety Communication Official Interviews

The Public Safety SIG (Special Interest Group) of the SDR Forum has conducted a survey and study and has issued a report on "SDR for Public Safety"[7]. Thus, we have refocused this market study and report to complement the work of the SIG by focusing on profiles based on interviews with select US state and local public safety communication officials. The profiles address their organization's communication requirements, deployments and anticipated evolution plans. An additional goal was to solicit input on industry issues and drivers; and expert opinions on the status and adequacy of industry standards and available products and service.

The public safety organizations profiled in this section are from the following states/cities:

4.1 State of California
4.2 State of Colorado
4.3 State of Florida
4.4 State of Missouri
4.5 State of New York
4.6 State of Texas
4.7 Cities of Phoenix / Mesa, Arizona

A list of questions was forwarded to each interviewee prior to the interview. The available information and responses to these questions varied from organization to organization. Variability is a consistently identified issue in public safety for interoperability of communication systems and must be addressed for successful solutions. Developing good understandings of organizational requirements addressable by common core solutions and differing unique organizational requirements that should be enabled by flexible SDR technology solutions appears important and synergistic.

The following is a generic version of a list of suggested topics that was forwarded to each interviewee:

1. From FBI Crime in US Report 2004, your state has a population of X and X Law Enforcement Employees (state, county, city, others) including X officers and X civilians working for xxx agencies. The square miles in your state are X. Does this agree with your available numbers? Can we critique this and see if we develop some numbers on deployed portable, mobile (vehicle), and infrastructure sites. Can you also provide information on frequency bands in use in your state?
2. What are types of deployed radio systems in Law Enforcement in general? And deployed currently in your state?
3. Your thoughts on interoperability. What's available today? What is needed?

[7] "Software Defined Radio Technology for Public Safety", SDRF-06-A-0001-V0.00, 14 April 2006

4. Can you help with cost data? Specifically, cost data on portables, mobiles, and infrastructure? Cost data on planning, design costs, and operating costs?
5. Can you provide information on APCO 25, Phase 2?
6. Information and/or contacts on other public sector (e.g. fire, emergency medical, ITS, others) personnel and communication counts, costs, etc in your state?
7. Other topics that should be addressed?

It should be noted that the above generic list of questions was fine tuned as appropriate for each organization. As several interviewees indicated that collecting details for some of the above questions would require more time than they could allocate in a reasonable time frame, we generally asked each interviewee to provide as much information as possible in a 1 hour telephone interview and that prior preparation was less important than a good and timely interview. In many instances, additional information was available on various (usually hard to find) web sites and from other persons and/or organizations. Although some desired information was not available, the interviewees were clearly experts on public safety communication in their jurisdictions as well as the industry, and we were pleased with the information provided. We thank each interviewee for their time.

Not unexpectedly, interviewees and other information sources did not generally have information on total state, county, city, etc public safety personnel as requested in questions 1 and 6. The specific interviewees and organization from each state or city will be identified in the following discussions of each state. Additionally data from the FBI's Crime in the US[8] report on the number of state agencies, total law enforcement personnel, sworn officers, and civilian employees, as well as population and land area (square miles) of each state will be presented.

[8] FBI's Crime in the United States, 2004, Section VI, www.FBI.gov

4.1. State of California

State	Population (M) *	Land Area (sq. mi.) *	Number of Agencies **	Total Law Enforcement Personnel **	Sworn Officers **	Civilian Employees **
California	37.0	155,959	462	113,827	74,174	39,653

Table 4-1 Law Enforcement Personnel, State of California
(Source: * Author Research, ** FBI Crime in US Report)

Glenn Nash, Senior Telecommunications Engineer, Department of General Services (DGS), State of California in a telephone interview, provided the information that provides the basis for our discussions of public safety communications in the state of California. Based on his guidance, we obtained supporting web information and conducted other telephone interviews. Nash has been an active participant in APCO Project 25 since it began in 1989 and served as president in 2002. He has worked on the Public Safety Wireless Advisory Committee (PSWAC), the Technology Committee of the National Public Safety Telecommunications Council (NPSTC), and the National Coordination Committee (NCC), a special advisory committee to the Federal Communications Commission (FCC).

Glenn's DGS organization provides a broad range of engineering, maintenance, and administrative services to California State Agencies. Services include complete system design and augmentation to installation and maintenance. Other services provided are: frequency coordination, procurement, specification development and compliance, vault space management, and microwave service. The organization provides these services for state, federal, and local government agencies involved in the protection of life and property for the citizens of California. Specific non-state agency clients include the Federal Bureau of Investigation, U.S. Coast Guard, and the National Weather Service as well as several California cities and counties.

In its Public Safety Act of 2002, the State of California formally established the Public Safety Radio Strategic Planning Committee (PSRSPC). PSRSPC continued an ad hoc effort that had been underway since 1994 "to develop and implement an integrated statewide public safety communications system that facilitates interoperability among the member state agencies, and fosters shared use and interoperability with local and federal public safety agencies." The state agencies that are members of the PSRSPC are listed in Table 4-2 as well as challenges and plans for their public safety communication requirements. The information in this table was largely extracted from a January 2006 report[9] to the California legislature prepared by PSRSPC.

[9] "2006 Statewide Integrated Public Safety Communication Strategic Plan", by PSRSPC, January 1 2006

California State Agency	Status / Challenges *	Plans
California Highway Patrol (CHP) 10,300 employees and 7,300 sworn officers	Conventional, VHF Low-Band Voice; SMR Data; Low-band VHF system is congested, need wider area communication, officers use Nextel for administrative communication, use private mobile data system	Enhance system in budget process for in 2006, replace all mobile and portable terminal and select infrastructure. VHF will be maintained for coverage but will be able to switch to higher frequencies for operability and interoperability
Department of Justice (DOJ)	Conventional, VHF High-Band Voice; No Data; Current 1970 vintage analog system has 29 radio repeaters and 12 control consoles. ½ of terminals have reached end of useful life and system maintenance costs have escalated.	DOJ has submitted budget proposal to upgrade to Project 25 digital system.
California Department of Transportation (Caltrans) 22,000 employees	Conventional & Trunked, 800 MHz Voice; No Data Has been converting from 47 MHz VHF system to 800 MHz system since 1980. Conversion is complete in 8 districts and underway in 4. Has P25 equipment in Southern California	Complete 800 MHz conversion. Need more capacity in many areas.
Dept. of Corrections and Rehabilitation (CDCR) 50,000 staff	Conventional & Trunked, VHF High-Band & 800 MHz Voice; No Data; Most use is 800 MHz system at facilities. Generally relies on other agencies or public cellphone services elsewhere.	Want effective statewide integrated radio system
Department of Parks and Recreation (CDPR)	Conventional, VHF High-Band & 800 MHz Voice; No Data; Have 124 mobile relays, control stations, etc and 3 dispatch consoles.	Must resolve FCC mandated reallocations to address interference problems. Need interoperability-capable terminals and equipment.
Dept. of Fish and Game (DFG)	VHF High Band	Evaluated systems and funding options
Dept. of Forestry and Fire Protection (CDF)	Conventional, VHF (fm) High-Band and Low-Band Voice; Satellite, Data; System has 250 repeaters, 210 control console stations, 342 base stations, 2,400 mobiles, 3,800 portables, and 147 aircraft radios. 45% of has exceeded life cycle and 90% of infrastructure needs upgrade to comply with FCC narrow band mandate.	Submitted budget request of in 2006 to comply with FCC mandate. Will need additional budget to upgrade to P25 as mandated by California codes.
Department of Water Resources (DWR)	Conventional, VHF High-Band Voice; No Data; Currently replacing 20+year old VHF repeaters statewide with wideband/narrowband digital capable repeaters	Add repeater sites in Northern Calif. Replace all mobiles and portables. Connect infrastructure to seamless integrated state radio system. Interoperability/Mutual Aid. Ongoing training
The Governor's Office of Emergency Services (OES)	Conventional, VHF High-Band Voice; Satellite Data; Owns and operates 4 public safety radio networks for Emergency Management, Fire and Rescue, and Law Enforcement. Majority of fixed infrastructure is 13 to 30 years old and mobile equipment generally is 10 to 20 years old.	Replace or upgrade aging radio networks. Funding has been a major issue.
Emergency Medical Services Authority (EMSA)	Aging communication system. Gaps in coverage. Interoperability problems. Lack of standards to guide EMS communication development. Limited Statewide guidance or direction. Lack of funding to address issues.	Support Statewide integrated voice and data system. Would like navigation and tracking tools.
Department of General Services ~500 people statewide	Have 9-1-1 Emergency Communications Office and Office of Public Safety Radio Service (PSRS)	Would be key organization if integrated state public safety radio network gets authorized and funded
The Governor's Office of Homeland Security (OHS)	Interoperability is focus.	Work with Federal, State, and Local partners to develop coordinated policy and strategies for achieving interoperability and obtaining funding.

Table 4-2 Summary State of California Public Safety Agency Communication Challenges and Plans (Source: Compiled from "2006 Statewide Integrated Public Safety Communication Strategic Plan", "Compendium of Reference to the Report to the California State Legislature", January 1, 2006, http://psrspc.ca.gov/ * and also the Cost Benefit Analysis (CBA), 1999 at the web site)

The Department of Health Services (CDHS) participated in the preparation of the report and legislation is being requested to officially add CDHS to PSRSPC. Each of the agencies is independently budgeted by the State and each of the top 10 agencies (excluding OHS, DGS, and CDHS) has historically independently procured, operated, and maintained their own public safety radio system.

After the early 1994 ad hoc activities, California's ten largest public safety agencies and DGS continued collaborative efforts to develop a statewide strategy for public safety radio communications. Recognizing the potential benefits of partnering, the Public Safety Radio Strategic Planning Committee (PSRSPC) was unofficially established in December 1994. In January 1997 PSRSPC activities resulted in the adoption and publishing of "A Strategic Plan for California's Public Safety Radio Communications."[10] Later in April 1999 a report entitled "Cost Benefit Analysis (CBA) for California's Public Safety Radio Communications Project"[10] was published. In the CBA, three alternatives were evaluated:

1. Baseline Alternative - Continue current piecemeal use and end-of-life replacement of each agencies communication system terminals and infrastructure.
2. Individual System Alternative - Independently upgrade each agencies communication system to meet current needs
3. Shared System – Develop a statewide shared system with optimizations as required to meet individual agency needs.

Alternative 3 was commonly identified under the acronym PRISM for "Public Safety Radio Integrated System Management." The CBA concludes that alternative 1 was not feasible for many reasons including:

1. FCC mandate to evolve to narrowband (e.g. 12.5 KHz, 6.25 kHz)
2. Congestion in existing bands and emerging new 800 MHz bands (and 700 MHz today).
3. Lack of adequate coverage
4. Poor interoperability and often operability
5. Lack of adequate capacity, especially in urban area, requiring upgrades to higher capacity trunking systems
6. Need to migrate to digital for better capacity and security (e.g. encryption)
7. Manufacturers are discontinuing support for many legacy systems and products

Bear in mind the CBA was published in 1999 before 9/11 and current homeland security issues and initiatives.

The CBA developed economic analyzes for alternatives 2 and 3 that is summarized in Table 4-3. Table 4-4 presents the economic analysis for the Agency shared system (alternate 3) to illustrate the methodology and cost elements for the estimates. Interestingly, the shared system potentially saves $509.9 to $795.6 Million over the assumed 15 year analysis period. For comparison purposes, Table 4-6 presents a similar

[10] http://psrspc.ca.gov

analysis from the CBA for an independent California Highway Patrol (CHP) system that provides cost comparisons with shared system presented in Table 4-4.

$ Million	Independent Agency Systems	Agency System Sharing
Capital Investment	$1,931.8 to $2,809.8	$1,526.3 to $2,152.8
Total 15 Year Operating Cost	$1,297.6 to $1,498.8	$1,215.4 to $1,392.8
15 Year Total	$3,251.6 to $4,341.3	$2,741.7 to $3,545.7

Table 4-3 Analysis Independent Agency Communication System vs. Agency System Sharing
(Source: "Cost Benefit Analysis (CBA) for California's Public Safety Radio Communications Project", 1999)

The proposed shared system consists of a voice radio system and data radio system. Additionally the proposed system provides VHF high band coverage throughout the state. 800 MHz overlay coverage is proposed in higher population area requiring higher capacity and greater spectrum. With a hybrid system with 800 MHz / VHF high band coverage the estimated number of sites required is 1,025 sites compared with over 2,500 sites in an 800 MHz only system. The stated coverage goal is 80% geographic area with 95% reliability. Additionally, the shared system proposes separate voice radio and data radio systems (see Table 4-4).

The identified advantages and disadvantages of the shared system from the CBA are presented below:

Advantages
- Improved Interoperability
- Improved access to expensive technology
- Reduced staffing for maintenance
- Reduction in redundant infrastructure

Disadvantages
- Significant upfront capital expenditures
- Detailed, focused planning effort
- New spectrum required

Unfortunately, in the early 2000 time frame, the State of California was in the midst of an unprecedented budget deficit. As a result, the PRISM Program lost its funding support and the program was formally abandoned due to its high price tag (estimated $3.5 Billion over 15 years) and the State's fiscal constraints.

The California Legislative Analyst's office in February 2006 issued an "Analysis of the 2006-07 Budget Bill" that addressed the California Highway Patrol's (CHP) proposal to begin in 2006-07 a five-year $491 Million project to modernize its aging, obsolete, and inadequate radio system. CHP's 2006-07 budget request was $57 Million. The analysis concurred with CHP's needs. It noted that CHP has withdrawn its support for the PRISM project due to delays and its urgent needs. However, it was recommended "that the Director of the Office of Emergency Services, who currently serves as chair of PSRSPC, report at Legislative budget hearings on (1) the extent to which the proposed project supports the state's interoperability goals-without compromising CHP's operational needs, and (2) whether CHP's proposal would hinder or complicate future development of other systems." Other State of California agencies also have continued independent activities to update and modernize their aging and inadequate radio communication resources.

A summary of the California PSRSPC "Findings and Associated Action Items" extracted from their January 2006 report[9] is presented in Table 4-5.

Required Infrastructure Cost Estimates Hybrid Voice/Data Radio Infrastructure (VHF High Band and UHF)					
		Per Unit Cost *		Total Cost	
One Time Costs	Quantity	Low	High	Low	High
Voice Radio System					
Backbone (based on 1025 Total)					
Fixed Site Transceiver Equipment	9,225	$ 25,000	$ 35,000	$ 230,625,000	$ 322,875,000
In-Building Bi-Directional Amp/Antenna System	159	$ 40,000	$ 50,000	$ 6,360,000	$ 7,950,000
Cental System Controllers	50	$ 1,000,000	$ 1,400,000	$ 50,000,000	$ 70,000,000
Simulcast Controllers	13	$ 250,000	$ 300,000	$ 3,250,000	$ 3,900,000
System Controllers	0	$ 150,000	$ 200,000	$ -	$ -
Remote Site Controllers	1,327	$ 50,000	$ 65,000	$ 66,350,000	$ 86,255,000
Voting System	75	$ 15,000	$ 20,000	$ 1,125,000	$ 1,500,000
Console Interface	317	$ 8,000	$ 10,000	$ 2,536,000	$ 3,170,000
Added Microwave Paths (to 29% of new sites w/o backhaul)	225	$ 250,000	$ 350,000	$ 56,250,000	$ 78,750,000
Minor Site Upgrades (to 80% of total sites)	820	$ 60,000	$ 90,000	$ 49,200,000	$ 73,800,000
Major Site Upgrades (to 10% of total Sites)	103	$ 500,000	$ 1,000,000	$ 51,500,000	$ 103,000,000
New Site Acquisition (10% of total Sites)	102	$ 500,000	$ 1,000,000	$ 51,000,000	$ 102,000,000
Design and Configuration (10% of equipment)				$ 41,649,600	$ 57,440,000
Installation/Integration/Training (25% of equipment)				$ 104,124,000	$ 143,600,000
Spare Equipment / Parts (3% of equipment)				$ 12,494,880	$ 17,232,000
Subtotal				**$ 726,464,480**	**$ 1,071,472,000**
User Equipment					
Mobile Radios (High Spec)	15,757	$ 3,100	$ 3,600	$ 48,846,700	$ 56,725,200
Portable Radio (High Spec)	21,980	$ 2,600	$ 3,400	$ 57,148,000	$ 74,732,000
Mobile Radios (Moderate Spec)	16,624	$ 2,400	$ 2,800	$ 39,897,600	$ 46,547,200
Portable Radio (Moderate Spec)	8,467	$ 2,000	$ 2,500	$ 16,934,000	$ 21,167,500
Fixed Stations	932	$ 5,000	$ 7,500	$ 4,660,000	$ 6,990,000
Control Stations / Remote Control Units	1,023	$ 5,000	$ 7,500	$ 5,115,000	$ 7,672,500
Mobile Relays	200	$ 15,000	$ 17,000	$ 3,000,000	$ 3,400,000
Console Upgrades	317	$ 50,000	$ 60,000	$ 15,850,000	$ 19,020,000
Installation / Integration / Training (10% of Equipment)				$ 19,145,130	$ 23,625,440
Spare Equipment / Parts (3% of Equipment)				$ 5,743,539	$ 7,087,632
Subtotal				**$ 216,339,969**	**$ 266,967,472**
Implementation Support (2% of Equipment)				$ 15,324,316	$ 20,578,528
Sales Tax (8% of Equipment)				$ 76,650,301	$ 108,721,440
Contingency (15% of equipment and services)				$ 143,719,315	$ 203,852,700
Total Voice Radio System				**$ 1,178,498,380**	**$ 1,671,592,140**
Data Radio System					
Backbone					
Fixed Site Transceiver Equipment	1,538	$ 25,000	$ 40,000	$ 38,450,000	$ 61,520,000
Network Controllers	20	$ 1,000,000	$ 1,250,000	$ 20,000,000	$ 25,000,000
Message Switching	20	$ 2,000,000	$ 2,500,000	$ 40,000,000	$ 50,000,000
Earth Station Links	32	$ 6,000	$ 8,000	$ 192,000	$ 256,000
Design and Configuration (10% of equipment)				$ 9,864,200.0	$ 13,677,600.0
Intstallation / Integration / Training (25% of equipment)				$ 24,660,500	$ 34,194,000
Spare Equipment (3% of equipment)				$ 2,959,260	$ 4,103,280
Subtotal				**$ 136,125,960**	**$ 188,750,880**
User Equipment					
Mobile Data Devices	19,126	$ 5,000	$ 7,000	$ 95,630,000	$ 133,882,000
Mobile Transceivers / Modems	1,100	$ 1,000	$ 3,500	$ 1,100,000	$ 3,500,000
Transport Costs				$ 3,960,000	$ 5,544,000
Installation / Integration / Training (10% of equipment)				$ 10,069,000	$ 14,292,600
Spare Equipment (3% of equipment)				$ 2,901,900	$ 4,121,460
Subtotal				**$ 113,660,900**	**$ 161,340,060**
Implementation Support (2% of equipment)				$ 3,962,785	$ 5,560,106
Sales Tax (8% of equipment)				$ 20,299,972	$ 28,452,084
Contingency (15% of equipment and services)				$ 38,062,447	$ 53,347,657
Total Data Radio Cost				**$ 312,112,064**	**$ 437,450,786**
Total Voice and Data Radio System Cost				**$ 1,490,610,444**	**$ 2,109,042,926**
Recurring Support Costs					
New lease costs (all new and 25% of existing sites)	742	$ 2,000	$ 2,500	$ 267,120,000	$ 333,900,000
Added telco T-1 circuits (at 71% fo new sites w/o backhaul)	550	$ 500	$ 700	$ 49,500,000	$ 69,300,000
Unit costs				$ 285,645,000	$ 328,500,000
Microwave Services				$ 96,000,000	$ 104,000,000
Engineering				$ 205,000,000	$ 222,000,000
Techniical Services				$ 192,000,000	$ 206,000,000
Miscellaneous Flow Through				$ 120,000,000	$ 129,000,000
Total Recurring Support Costs				**$ 1,215,265,000**	**$ 1,392,700,000**
Total 15 Year Cost				**$ 2,705,875,444**	**$ 3,501,742,926**

* Industry average based on best available estimates, not based on any specific vendor product line. Ranges accommodate variance in competitive pricing features.

Table 4-4 State of California PRISM Shared Public Safety Radio System Cost Estimate
(Source: Adapted from: "Cost Benefit Analysis for California's Public Safety Radio Communication Project", April 1999, available at http://psrspc.ca.gov)

1. **Summary of Findings and Associated Action Items** The PSRSPC has identified immediate stop-gap solutions that can be immediately implemented as well as a work plan for long term solutions. All of these assessments include timelines or implementation steps within this plan. This plan is intended to be the blueprint of activities within the calendar year 2006.
2. Preliminary assessments indicate that the state's backbone systems, including towers, radios, and other communications equipment, need to be assessed and improved upon.
   - The PSRSPC will, within the first Quarter of 2006, initiate a Statement of Requirements (SoR) process. This process will include meetings with industry and one or more Requests for Information (RFI).
   - Based on the results of the SoR/RFI (and other information gathered), the PSRSPC will work to attain a mixture of federal and state funds to finance the solution.
3. There is a need to begin immediate implementation of gateway systems. This will help create incident level communications networks across the state. This technology exists and is readily available.
   - Aggressively continue to explore this relatively low cost solution.
   - Begin a phased implementation over the next two years.
4. The PSRSPC recognizes that a solution for interoperability for the state must include partnerships with local government and federal agencies, and will coordinate its work efforts with CALSIEC.
   - The PSRSPC will assist CALSIEC with creating a governance structure for the use of interoperable communications throughout the state.
   - The PSRSPC formally recognizes the CALSIEC Planning Area structure and will actively pursue solutions within that regional framework.
5. California is a patchwork of existing communication systems, many of which have been heavily invested in.
   - The PSRSPC will work to bridge existing systems and ensure that a "system of systems" solution is implemented.
6. There is a need to follow established communications criteria.
   - PSRSPC will endorse the SAFECOM's Statement of Requirements as the baseline for requirements for state and local agencies to follow.
7. Access to federal spectrum would vastly improve the state's ability to allocate mutual aid radio channels for incidents, allowing more first responders to communicate with each other and providing wireless coverage where necessary.
   - The PSRSPC will work with CALSIEC to advocate the release of federal interoperability spectrum for use by state and local partners.
8. The focus should not just be on interoperability, but ensuring that systems in the state are operable. Many aging systems in the state are in need of immediate upgrades to bring them up to current standards. Funding should be focused on operability as well as interoperability.
   - The PSRSPC calls for the ongoing funding of existing systems, in order to fully use the serviceable life of existing equipment, while new technologies are developed for those agencies to migrate to as their current equipment becomes obsolete.
9. The Incident Command System (ICS) is the fundamental basis for successful interoperable communications. California is actually in a more favorable position than other states due to its institutionalization of the ICS, as well as California's Standardized Emergency Management System (SEMS) and Mutual Aid programs.
   - ICS should be exercised, trained upon, and fully integrated as part of California's comprehensive interoperability landscape.

Table 4-5 California PSRSPC Summary of Findings and Associated Action Items
(Source: "2006 Statewide Integrated Public Safety Communication Strategic Plan," California PSRSPC, January 1, 2006, psrspc.ca.gov)

Nash offered many interesting comments on public safety communication in California and nationally, Project 25 (P25), and related drivers and issues. These comments include:

1. Opinions on key SDR goals for public safety include: 1) must be user friendly; 2) users are not trained to use radios, but for other public safety work; 3) user are often

under stress and react, don't think; and 4) SDR terminals should be quick and simple to switch bands or modes.

2. Conventional analog FM had tremendous interoperability within one year of initial deployments. Analog Trunking (P16) had significant interoperability deficiencies, and agencies typically could only buy from Motorola. P25 adds digital trunking that largely attempted to incorporate analog trunking functionality plus many enhancements and options. P25 interoperability has been a challenge, but seems to be improving.
3. When interoperability is not achieved, agencies often get sweet deals on initial purchases, but lack leverage on follow-on purchases and often pay higher prices, closer to book price. Concerning discounts (to book price), based on unofficial observations, 20% seems easily obtained, 50% seems aggressive and not often achieved.
4. P25 has been slow to achieve significant deployments for many reasons that include:
   a. P25 needs some common modes of operations (standard interoperable features)
   b. Agencies have a wide variety of differing operational requirements. Some are real and others are procedural and personal preferences. P25 has lacked facilities and methodologies to support varying options in a standard way. Some special functions are deemed so important to a procuring agency that they drive the procurement and then create interoperability issues for multi-vendor procurements. Special features/options often dictate single vendor in both initial and subsequent purchases.
   c. The P25 standard does require fair and equitable Intellectual Property Rights (IPR) terms and conditions and pricing by vendors providing their IPR to the standards. However, agencies can and do purchase non-P25 features and supplying vendor is not required to license to others. Vendors often cross-license IPR, creating problems for smaller vendors to effectively participate.
   d. The current Phase 1 P25 12.5 kHz FDMA waveform requires a non-linear power amplifier (PA). The waveform under consideration for P25 Phase 2 for 6.25 kHz TDMA waveforms requires a linear amplifier and thus usually new radios. The trades to most effectively address TDMA waveforms are being carefully and competitively considered by the P25 standards community.
5. Higher populated areas (metropolitan, suburban, freeway corridors, etc.) require Trunked TDMA systems for responsive features and capacity. Less densely populated areas (rural, mountains, deserts, etc.) typically require non-trunked FDMA for lower cost and better range performance. Timing requirements for TDMA can create issues for range and dictate more base station sites, increasing system costs or reducing coverage.

	Quantity	Per Unit Cost Low	Per Unit Cost High	Total Cost Low	Total Cost High
Voice Radio System					
Backbone (based upon 1,025 total sites)					
Fixed Site Transceiver Equipment	4,100	$25,000	$35,000	$102,500,000	$143,500,000
In-Building Bi-Directional Amp/Antenna Systems	60	$40,000	$50,000	$2,400,000	$3,000,000
Central System Controllers	40	$1,000,000	$1,400,000	$40,000,000	$56,000,000
Simulcast Controllers	9	$250,000	$300,000	$2,250,000	$2,700,000
System Controller	0	$150,000	$200,000		
Remote Site Controllers	1,005	$50,000	$65,000	$50,250,000	$65,325,000
Voting System	0	$15,000	$20,000		
Console Interfaces	120	$8,000	$10,000	$960,000	$1,200,000
Added Microwave Paths (to 29% of new sites w/o mwave)	225	$250,000	$350,000	$56,250,000	$78,750,000
Minor Site Upgrades (to 80% of total sites)	820	$60,000	$90,000	$49,200,000	$73,800,000
Major Site Upgrades (to 10% of total sites)	103	$500,000	$1,000,000	$51,500,000	$103,000,000
New Site Acquisition (to 10% of total sites)	102	$500,000	$1,000,000	$51,000,000	$102,000,000
Design and Configuration (10% of equipment)				$25,461,000	$35,047,500
Installation/Integration/Training (25% of equipment)				$63,652,500	$87,618,750
Spare Equipment/Parts (3% of equipment)				$7,638,300	$10,514,250
Subtotal				**$503,061,800**	**$762,455,500**
User Equipment					
Mobile Radios (Hi Spec)	8,080	$3,100	$3,600	$25,048,000	$29,088,000
Portable Radios (Hi Spec)	7,500	$2,600	$3,400	$19,500,000	$25,500,000
Mobile Radios (Moderate Spec)	0	$2,400	$2,800		
Portable Radios (Moderate Spec)	0	$2,000	$2,500		
Fixed Stations	0	$5,000	$7,500		
Control Stations/Remote Control Units	160	$5,000	$7,500	$800,000	$1,200,000
Mobile Relays	0	$15,000	$17,000		
Console Upgrades	120	$50,000	$60,000	$6,000,000	$7,200,000
Installation/Integration/Training (10% of equipment)				$5,134,800	$6,298,800
Spare Equipment/Parts (3% of Eqpmt)				$1,540,440	$1,890,000
Subtotal				**$58,023,240**	**$71,176,800**
Implementation Support (2% of equipment)				$9,337,000	$14,093,000
Sales Tax (8% of equipment)				$38,094,000	$57,501,000
Contingency (15% of equipment and services)				$85,563,000	$127,159,000
Total Voice Radio System Cost				**$694,078,800**	**$1,032,386,000**
Data Radio System					
Backbone					
Fixed Site Transceiver Equipment	1,538	$25,000	$40,000	$38,450,000	$61,520,000
Network Controllers	8	$1,000,000	$1,250,000	$8,000,000	$10,000,000
Message Switching	8	$2,000,000	$2,500,000	$16,000,000	$20,000,000
Earth Station Links	0	$6,000	$8,000		
Design and Configuration (10% of equipment)				$6,243,800	$9,150,000
Installation/Integration/Training (25% of equipment)				$15,609,500	$22,875,000
Spare Equipment (3% of equipment)				$1,873,140	$2,745,000
Subtotal				**$86,176,440**	**$126,290,000**
User Equipment					
Mobile Data Devices	4,540	$5,000	$7,000	$22,700,000	$31,780,000
Mobile Transceivers/Modems	0	$1,000	$3,500		
Transport Costs	0				
Installation/Integration/Training (10% of equipment)				$2,270,000	$3,178,000
Spare Equipment (3% of equipment)				$681,000	$953,400
Subtotal				**$25,651,000**	**$35,911,400**
Implementation Support (2% of equipment)				$1,754,000	$2,540,000
Sales Tax (8% of equipment)				$7,156,000	$10,361,000
Contingency (15% of equipment and services)				$17,035,000	$24,708,000
Total Data Radio Cost				**$137,772,440**	**$199,810,400**
Total Voice and Data Radio Systems Cost				**$831,851,240**	**$1,232,196,400**
New Recurring Support Costs					
New lease costs (all new and 25% of existing sites)	742	$2,000	$2,500	$267,210,000	$334,012,500
Added telco T-1 circuits (at 71% of new sites w/o mwave)	550	$500	$700	$49,500,000	$69,300,000
Adjusted Voice and Data Radio System Cost				**$1,148,561,240**	**$1,635,508,900**

Table 4-6 California Highway Patrol (CHP) Radio System Cost Estimate

(Source: “Cost Benefit Analysis (CBA) For California’s Public Safety Radio Communications Project, April 1999)

4.2. State of Colorado

State	Population (M) *	Land Area (sq. mi.) *	Number of Agencies **	Total Law Enforcement Personnel **	Sworn Officers **	Civilian Employees **
Colorado	4.4	103,717	233	15,489	10,704	4,785

Table 4-7 Law Enforcement Personnel, State of Colorado
(Source: * Author Research, ** FBI Crime in US Report)

Mike Borrego, DTR Project Manager in the Department of Personnel & Administration Division of Information Technologies of the State of Colorado in a telephone interview provided the information that provides the basis for our discussions of public safety communications in the state of Colorado. Additional supporting information was obtained from the State of Colorado and CCNC web sites.[11] Figure 4-1 identifies deployments of the Colorado Digital Trunked Radio System (DTRS) by geography.

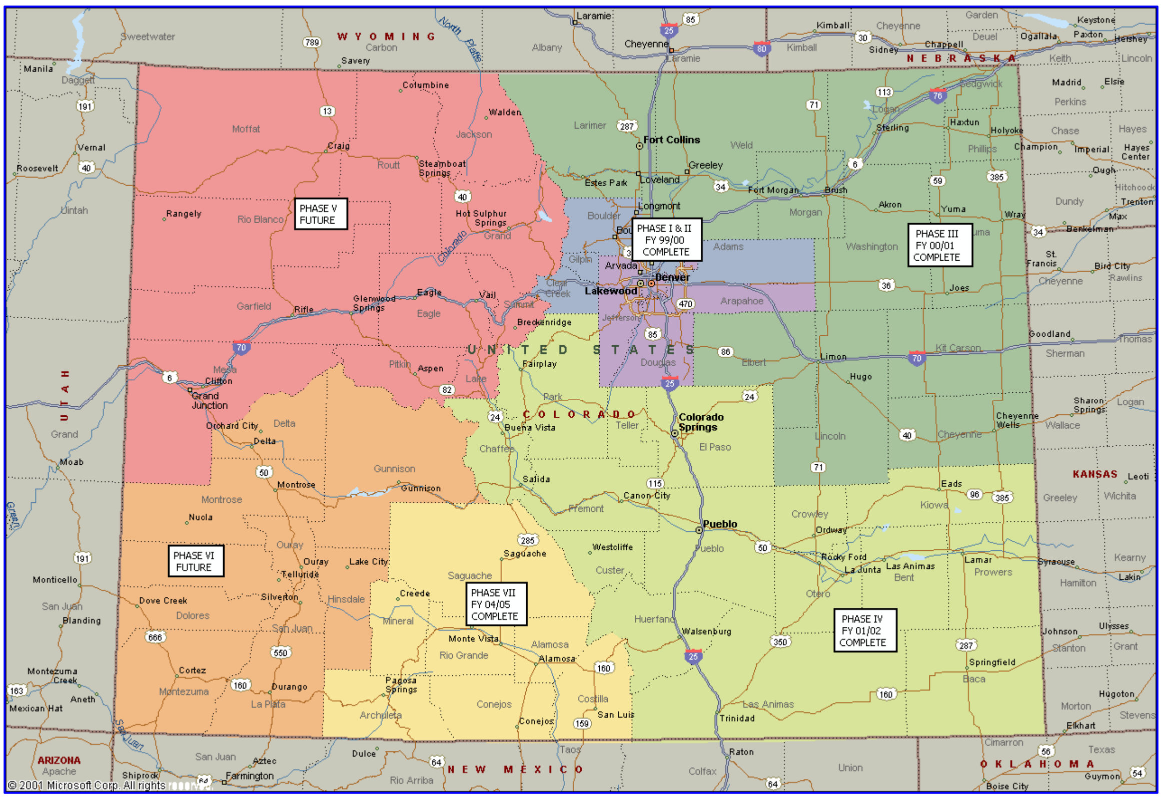


Figure 4-1 State of Colorado DTR early regional implementation plans
(Source: DTR web site[11])

The Digital Trunked Radio System (DTRS) is the adopted name of the system and generally refers to the infrastructure of the system. The organization in Colorado that

[11] Digital Trunked Radio (DTR), http://www.colorado.gov/dtr and Consolidated Communications Network of Colorado (CCNC), www.ccncinc.org

provides public safety communication advocacy and guidance is Consolidated Communications Network of Colorado (CCNC)[12] and was officially formed in 2002 from legacy initiatives. CCNC consists of Federal, State, and Local public safety agencies and organizations.

Information on the DTR web site indicate that the pilot phase 1 was completed in June 1999, phase 2 in June 2000, phase 3 in June 2001, and Phase 4 in June 2002. A high percentage of the states population is on the eastern site of the Rocky Mountains and the early priorities were in the high population areas including Denver, North and Northwest of Denver, and then the southeast portion of the state. Due to the 2002 economic downturn and state general fund problems, phases 5, 6, and 7 generally targeting western part of state deployments were delayed. Phase 7 was completed in 2005. While general funds have not been available, Phases 5 and 6 were funded last year from a State grant program called the Colorado Wireless Interoperability Network (CWIN) and target completion in early 2007.

As background, following organizational meeting and activities originated in 1991, the original Colorado State Plan was completed in 1994 that profiled existing systems, involved users groups and their input, targeted a trunking system, specified consolidation of State Patrol Communication Centers, developed the project schedule, developed system costs and funding plans, and developed plans for system maintenance. After several unsuccessful attempts, House Bill 98-1068 in 1998 provided for a Public Safety Communication Trust Fund and appropriated $3.3M for the pilot phase 1 deployment. An RFP was issued that specified 1) Project 25 Standards, 2) Trunking, 3) 800 MHz, 4) Digital System, 5) fully upgradeable during multiple phases, and 6) compliance with HB 98-1068 provisions. The contract was awarded to Motorola. Ericsson (now M/A-COM) appealed the award, but the appeal was denied and deployment commenced. The deployed system is a Motorola ASTRO P25, trunked radio system.

A March 1, 2006 summary document[13] provides very succinct information on DTR in Colorado is provided and a partial extract in the following two paragraphs.

"DTR is a continuation project envisioned in the early 1990's and begun in 1998 to replace multiple disparate wireless communications systems operated by State and local government agencies. The Division of Information Technologies has finished implementing five of seven phases of the Digital Trunked Radio (DTR) project. DTR is being planned and constructed through partnerships with local governments. It replaces obsolete radio systems operated by state agencies and will be available to all local governments that choose to participate in this new innovative technology.

DTR provides a seamless statewide wireless system that enables direct communications between agencies that absolutely must communicate during times of emergency. DTR supports wireless voice and data communications on a single integrated 800 / 700 MHz system based upon the suite of open standards called Project 25. New 700MHz trunking

[12] www.ccncinc.org
[13] "Digital Trunked Radio (DTR), Project Overview", March 1, 2006, http://www.ccncinc.org/index.php?module=main-docs

equipment located in Metro Denver was recently brought on-line to the DTR system confirming Colorado's DTR as one of the 1st trunking systems in the Country to utilize the newly allocated 700 MHz public safety frequency spectrum. The main deliverables of DTR are the elimination of interoperability issues between public safety agencies and improved statewide wireless communication coverage in support of their mission to protect life and property. DTR has received funding through the "Public Safety Trust Fund "created by HB98-1068 and more recently through Homeland Security and Federal Grants."

In early 2006, the DTR system had 107 sites on the air that provides approximately 75% geographic coverage and 80% population coverage. The project is funded for an additional 64 sites that are estimated to be completed in the fall of 2007. This achieves a total of 171 sites statewide and targets 90% geographic coverage and 95% population coverage. Currently the Colorado DTRS supports over 23,732 subscriber ID's operated by over 430 federal, state and local agencies. Approximately 1/3 of the subscriber IDs are state and 2/3 are local. The current system is partitioned into three zones with 3 controllers with site counts:

Zone 1 - Northeast Colorado - 49 Sites
Zone 2 – Southeast Colorado - 37 Sites
Zone 3 – Western Colorado - 21 Sites

The system has the following Talkgroups implemented: [12]

- 21 General Mutual Aid Talkgroups
- 9 Regional Emergency Medical Coordination Talkgroups
- County Based Emergency Communications Talkgroups
- Regional Emergency Management Coordination Talkgroups
- Various Search And Rescue Related Talkgroups
- Talkgroups Dedicated To Each Trauma Level I-IV Hospital For Medical Coordination
- 5 Direct Comm Center To Comm Center Regional Talkgroups

In 2005 the DTR system experienced over 50 Million calls, 88,000 hours of total talk time, and approximately 4½ Million calls per month.

Mike Borrego offered the following additional comments on the Colorado DTR deployments:

- The State of Colorado DTRS is a partnership of Federal, state, and local agencies. Some of the DTR sites are owned and operated by local agencies. Additional agencies in the State include 83 Federal Agencies and 2 tribal agencies.
- DTR specifications provide for mobile coverage, but they have found portable coverage experience better than expected. Local or other agencies can request portable coverage, but additional costs must be borne by these agencies.

- Local agencies must buy their own mobile and portable terminals. Motorola probably provides 98% of the currently deployed terminals. However, E. F. Johnson, Kenwood, and M/A-COM have compatible terminals deployed and are anticipated to increase share in the future.
- Every tower site has at least 5 repeaters. Omni directional antennas are deployed at 95% of the sites. Directional antennas are typically deployed for purposes such as down canyons and not for sectors. The system has an easy reuse plan. The typical site powers are 100 watts or 220 -203 watt ERP. The typically tower heights are 300 or 400 feet in the relatively flat eastern part of the state and 20 – 30 feet on mountain tops in western part of the state. Typical maximum coverage is 70 – 80 Miles.
- Approximately 95% of backhaul is by state-owned private microwave with the rest largely leased fiber or T1.
- General pricing information includes: ~$20,000 to add a channel, mid tier mobile is ~$3000 and mid tier portable is ~$2,800. ~ $4M for core network controller. $60,000 per console position.
- A greenfield site typically costs approximately $½ Million including building, tower, site works, backup generator, backhaul microwave, and site controller, routers, and switches. Upgrades for existing sites typically cost $¼ Million.
- The old system was a 150 MHz system.
- The state is divided into 5 regions for Mutual Aid Channels (MAC) and has 4 MAC in each region and 1 statewide. Each region has a police, fire, and EMS (Emergency Medical Service) MAC.
- The Cities of Denver, Aurora, Lakewood, Westminster, and Arvada are not on the system and have legacy M/A-COM EDAC systems.
- The state uses the Safecom Governance model.
- The state system is already using 700 MHz spectrum and already has 5 sites operational and 7 more in progress.
- The State has 64 counties and each has a Sheriff.

4.3. State of Florida

State	Population (M) *	Land Area (sq. mi.) *	Number of Agencies **	Total Law Enforcement Personnel **	Sworn Officers **	Civilian Employees **
Florida	17.4	53,927	407	69,762	41,511	28,251

Table 4-8 Law Enforcement Personnel, State of Florida
(Source: * Author Research, ** FBI Crime in US Report)

Bruce Meyers, System Manager, Statewide Law Enforcement Radio System for the State of Florida's Enterprise Information Technology Services (EITS) in a telephone interview, provided the information that provides the basis for our discussions of public safety communications in the state of Florida. Bruce serves as chair of the Project 25 (P25) P25.1 User Needs Subcommittee. Additional information was obtained from Linda Fuchs, Florida DMS EITS Project Management Office and from pertinent web sites**Error! Bookmark not defined.**, [14].

In 1988 the State of Florida started activities to plan and deploy a new state wide public safety system and in the mid-90's awarded a contract to Motorola to procure a statewide public safety system. In 2000, Governor Jeb Bush redirected the activity to compete and procure a statewide contract to built, operate, and maintain a system by the selected company on an agreed monthly fee basis plus some other fees. M/A-COM was the selected company. In 2003 (post 9/11/2001 era) the Florida legislature enacted statutes formally assigning to the Enterprise Information Technology Services (EITS) the specific authority to continue activities "to acquire and implement a statewide radio communication system to serve law enforcement units of state agencies, and to serve local law enforcement agencies through mutual aid channels. The goal of the Statewide Law Enforcement Radio System (SLERS) project is to provide State law enforcement officers with a shared 800 MHz radio system. This digital system serves over 6500 users with 14,000 radios in patrol cars, boats, motorcycles, and aircraft wherever they are in the state." [14] By providing a common communication system for the Joint Task Force agencies the state achieves: 1) effective interagency communications, 2) coordinated communication with local public safety entities, 3) a solution to frequency congestion, and 4) replacement of older agency-specific systems without duplication of effort.[14] The state allows 3rd parties on the SLERS systems provided that they meet the FCC's definition as public safety. 3rd parties as well as state agencies must procure (or make arrangements for) their own terminals, dispatch centers/stations, and other non-standard local equipment and services. 3rd parties may procure communication services from M/A-COM, but must be authorized by the state. Local agencies and certain 3rd party agencies usually must provide their own frequency licenses. In May 2006 the state has 3rd party (local or federal) agencies on the SLERS[14] system that include:

- Baker County Sheriff's Office

[14] www.eits.myflorida.com/slers/index.thm

- Franklin County Sheriff's Office
- Glades County Sheriff's Office
- Gulf County's Sheriff's Office, Emergency Medical Service and Port St. Joe Police Department
- Hillsborough County Sheriff's Office (interoperability)
- Social Security Administration's Office of Investigations in Florida
- Sumter County Sheriff's Office (interoperability)
- U.S. Fish and Wildlife Service
- Wakulla County Sheriff's Office

Florida agencies are included in the 800 MHz system by statutory reference (s. 282.1095, F.S.) or by acceptance into the Governor's Enterprise-wide Sharing of Resources Model. Both categories of members receive equipment and services as provided by the M/A-COM contract. The agencies that are statutorily referenced to comprise the Joint Task Force on State Law Enforcement Communication (JTF) are:

- Department of Business and Professional Regulation / Division of Alcoholic Beverages and Tobacco
- Department of Highway Safety and Motor Vehicles / Division of Florida Highway Patrol
- Department of Law Enforcement / Criminal Investigations and Forensic Science Services
- Fish and Wildlife Conservation Commission
- Department of Environmental Protection / Division of Law Enforcement
- Department of Corrections
- Department of Financial Services / Division of State Fire Marshal
- Department of Transportation / Motor Carrier Compliance Office

Under s. 282.1095(4) (b), F.S., the Joint Task Force may authorize other state agencies to use the 800 MHz system. Other agencies that fall under the umbrella of the Governor's Enterprise-wide Sharing agreement include:

- Department of Law Enforcement / Division of Capitol Police
- Department of Financial Services / Division of Insurance Fraud
- Attorney General / Medicaid Fraud Control Unit
- Department of Agriculture and Consumer Services / Division of Agricultural Law Enforcement
- Department of Juvenile Justice
- Department of Military Affairs / Florida National Guard
- Department of Lottery
- Florida Senate Sergeant at Arms
- Florida House of Representatives Sergeant at Arms
- Florida School for the Deaf and the Blind
- Supreme Court of Florida, Office of the Marshal

State University police departments serve as ex officio members. Currently participating in the existing system are Florida Atlantic University, Florida International University, and the University of Central Florida. There are no local agencies in the Joint Task Force. However, local public sector entities can become third-party subscribers upon reaching mutually-agreeable terms with M/A-COM and subject to final EITS approval.

Also in the 2003 legislation (Statute 282.1095(6)(a)) "The State Technology Office may create and implement an interoperability network to enable interoperability between various radio communications technologies and to serve federal agencies, state agencies, and agencies of political subdivisions of the state for the purpose of public safety and domestic security." Florida interoperability (IO) program has two main goals. The first is a goal to "provide network connections between Florida dispatch centers and install an interoperability tool to connect users on any radio system to any other radio system on the network. This network enables first responders on disparate radio systems and frequencies to communicate with each other as connected talk groups without requiring the replacement of local systems." The second goal is to "Build out nine mutual aid channels throughout the state. Mutual aid channels provide radio service to first responders outside the range of their local system or when they need to communicate with users not on their local system. The mutual aid build-out will substantially increase their geographic coverage, ensuring that wherever they go, Florida's first responders will have radio communication capability. This is in addition to the two 800 MHz channels already provided by the Statewide Law Enforcement Radio System (SLERS)."

The state of Florida has 67 counties. All counties, except Miami, have county sheriffs. Miami has a special consolidated regional sheriff-equivalent authority. There are many major metropolitan area and cities in Florida and many have consolidated their public safety communication initiatives. These include Miami/Dade County, Orlando/Orange County, St Petersburg/Pinellas County and Tallahassee/Leon County. Approximately 80+% of Florida counties and 90% of the population in Florida are covered by 800 MHz public safety communications. Less than 20% of the remaining, generally smaller and less populated, counties are covered by VHF or UHF band systems. Florida is divided into 7 regions. Table 4-9 presents a summary of 2 deployments per region of communications systems by various local jurisdictions in Florida.

Jurisdictions	Region	Vendor, Freq. Band, & System Type
Pensacola PD	1	Motorola 800 MHz Smartzone Analog Trunking
Eglin AFB FD	1	UHF Conventional
Tallahassee PD	2	Motorola 800 MHz Type II Smartnet
Hamilton County Jail	2	VHF Conventional
Jacksonville Fire-Rescue	3	Motorola 800 MHz Type II Smartzone
St Johns Co Fire-Rescue	3	VHF Conventional
Tampa PD	4	UHF Conventional / VHF
US Coast Guard, St. Petersburg	4	Motorola VHF Conventional
Melbourne PD	5	M/A-COM 800 MHz EDACS – Brevard
Orlando PD	5	Motorola Type II Smartzone – Orange
Sarasota County Public Safety Comm. Center	6	Motorola Type II Smartzone
Clewiston Sheriff's Dept	6	VHF Conventional
Miami PD	7	Motorola 800 MHz Type II
N. Miami Beach Public Safety Dept	7	M/A-COM 800 MHz EDACS

Table 4-9 Select Local Public Safety Communication System Deployment in Florida
(Source: Extracted from list provide by Linda Fuchs, State of Florida, EITS)

Bruce Meyers provided the following information about the SLERS:

1. The system is an M/A-COM EDAC system using TDMA with 4 time slots per 25 kHz carrier.
2. The specified general coverage goal is 98% mobile coverage. Some metro and coastal areas have specified portable coverage goals.
3. The state is currently covered by 170 tower sites.
4. The average channels per site are 1 control and 3 working channels. Two specific examples are 1) Tampa metro has 1 control and 7 working channels at some sites and 2) Miami has 1 control and 11 working channels at some sites.
5. Portable range is typically 10 miles and mobile range is typically 15 miles.
6. Hurricanes are a significant concern in Florida. Towers are specified and built to withstand hurricane wind loads. Historically they have held-up during hurricanes, but the antennas often require realignment during high-wind conditions.
7. All sites are equipped with emergency generators (propane or diesel), but at times people must be dispatched to start.
8. Typical queuing load on the system is less than 15% for non-emergency operations. Priority schemes are utilized in emergency situations to ensure priority communication is appropriately serviced.

4.4. State of Missouri

State	Population (M) *	Land Area (sq. mi.) *	Number of Agencies **	Total Law Enforcement Personnel **	Sworn Officers **	Civilian Employees **
Missouri	5.8	68,886	536	18,838	13,202	5,636

Table 4-10 Law Enforcement Personnel, State of Missouri
(Source: * Author Research, ** FBI Crime in US Report)

Steve Devine, Patrol Frequency Coordinator, Communications Division, Missouri State Highway Patrol General Headquarters, in a telephone interview, provided the information that provides the basis for our discussions of public safety communications in the state of Missouri. The agencies in the state of Missouri that have key public safety communication requirements include:

- State Highway Patrol
- Department of Transportation
- Department of Corrections
- State Emergency Management
- State Water Patrol
- State Capital Police
- Department of Conservation
- Department of Natural Resources
- Facilities Management
- National Guard

The State of Missouri has 114 counties which is claimed to be the 3rd highest total in the US. According to the state's web site, Missouri has over 1,400 elected officials. The major metropolitan areas include St. Louis, Kansas City, St. Joseph, and Springfield. The City of St. Louis is not part of a county, due to historical decisions. Kansas City, Missouri is actually part of three counties. All the counties have sheriffs as well as fire districts, emergency management service organizations, etc. The counties in Missouri generally have conventional VHF high band systems deployed.

Missouri's major urban areas generally have local 800 MHz conventional radio systems, while virtually all the other less sparsely populated, generally rural, counties have conventional high band VHF repeater systems, although some are on VHF Low Band.

The Missouri Highway Patrol has a VHF low band (42 MHz) system that covers the state with 17 sites of which approximately half are high power and the rest low power. The system has 14 additional receive sites to relay lower power mobile or portable VHF Low band uplink transmission via UHF band transmissions to the central site.

Steve Devine stated that estimates for a State of Missouri 800 MHz system includes an approximate $300M cost and 250 – 275 sites. An 800 MHz system typically has 3 to 4 times the number of sites for a VHF system. As significant problem in Missouri is that there is little available microwave or fiber in the state. Partnerships could be developed to share costs that would include cities, counties, gas and electric utilities (i.e. critical infrastructure) that could potentially save the state $150 M. However, the state would still have to appropriate or obtain $150 M and the legislature has not appropriated the necessary funds. However, the state has many synergistic activities in place with the hope of developing programs, attracting grants, and other initiatives to develop plans that will eventually successfully achieve needed funding.

Recently, the Missouri legislature initiated HB 1822 entitled "Missouri Uniform Interoperability Communications Act".[15] The bill establishes a "Missouri Interoperability Communication Board to oversee the creation, administration, and maintenance of the Missouri public safety communication network which is to provide public safety communication services and facilities for the benefit and use of public safety agencies." "The board is required to establish guidelines for the lease or purchase of wireless communications products for public safety, review requests by public safety agencies for state or federal funds for wireless communications programs, examine all proposals and requests for funding of wireless communications to identify and evaluate interoperability, and establish other necessary procedures for administering these provisions." "The bill also requires that all purchases of wireless communication products for public safety by the Commissioner of the Office of Administration meet the standards of the Public Safety Communications Committee for Wireless Communications." The bill establishes the member of the board as the designated representatives of:

- Department of Public Safety
- Department of Transportation
- Department of Corrections
- Department of Conservation
- Division of Homeland Security
- Adjutant General
- Missouri Police Chiefs Association
- Missouri Sheriffs' Association
- Missouri Association of Fire Chiefs
- Missouri State Troopers Association

Steve Devine is chairman of Missouri State Interoperability Executive Committee (SIEC). In September 2005 a Memorandum of Understanding (MOU) was issued by the committee to establish "operating parameters for the FCC designated multi discipline interoperability channels set aside by the Federal Communications Commission in the UHF and VHF public safety radio bands. The term 'multi discipline' infers that these channels, as indicated in the attached operational and technical parameters, are to be used

[15] Missouri House of Representatives, 93rd General Assembly, 2nd Regular Session

for all public safety users to communicate to users within their discipline (Police to Police. Fire to Fire, etc) as well as cross discipline communications (Police to Fire, Fire to Local Government) between all public safety users. There are no channels set aside for individual disciplines, as different incidents require varying amounts of participation from public safety First Responders. These channels are most effective when used as a shared resource at the scene of an incident by the Incident Commander. Previously allocated FCC interoperability channels assigned for inter-system sharing (Police Mutual Aid, Fire Mutual aid etc.) within certain disciplines should continue to be used by Missouri's First Responders to facilitate communications within their respective disciplines."

Steve Devine provided a draft version of a 2005 Missouri Public Safety Communication Strategy document. The following two paragraphs are an extract that seems to provide a succinct overview of this document. Note that Missouri, like many other states, indicate intentions to generally follow US Department of Homeland Security Project SAFECOM recommended template for evolving their public safety communications.

> "Certainly, shortcomings exist in the communications capabilities present in the Missouri emergency response arena that require serious attention in the short-term. Many of these particular issues have already been addressed, at least in part, through interoperable channel sharing, readiness exercises, cross-banding equipment, coordinated planning, and cached radio assets assisted by Homeland Security grant funding. While work continues to ensure short-term needs are met, long-term goals and a strategy whereby to achieve those goals are still forthcoming.
>
> It is the intent of this document to illustrate a compliment of common goals for public safety communications in Missouri based on a template developed by the U.S. Department of Homeland Security's project SAFECOM and set strategies for attaining those goals. In a SAFECOM publication referred to as the 'Interoperability Continuum', the template presented guidelines five categories: Governance, Standard Operating Procedures, Technology, Training and Exercises, and Usage. The publication identifies various approaches to achieving interoperability within each category and rates them by the level of interoperability they can achieve noting that some approaches offer only minimal interoperability while others are optimal."

Steve Devine offered the following comments about public safety communication in Missouri and in general:

- In urban areas, trunked systems are advantageous for capacity and enhanced channel utilization. In rural areas conventional systems are typically deployed, being less expensive and generally adequate.
- Many of the public safety issues are not technical problems, but are policy, contractual, partnering, etc (i.e. human) issues.

- The state can no longer get bids from vendors on low band VHF systems and equipment.
- The state bought 12 towers for $1M from Lattice Corp. The towers are designed to withstand 120 mph winds.
- There are Intellectual Property problems in the Project 25 standards process that are largely in the hands of lawyers.

4.5. State of New York

State	Population (M) *	Land Area (sq. mi.) *	Number of Agencies **	Total Law Enforcement Personnel **	Sworn Officers **	Civilian Employees **
New York	16.7	47,214	425	80,990	59,654	21,336

Table 4-11 Law Enforcement Personnel, State of New York
(Source: * Author Research, ** FBI Crime in US Report)

Thomas Cowper, Deputy Director of the Statewide Wireless Network (SWN) for the State of New York's Office of Technology (OFT), in a telephone interview provided information that framed our discussions of public safety communications in the State of New York. The OFT is the lead state agency for SWN and serves as overall project manager. Thomas Cowper is a 23-year veteran of the New York State Police with nine years of patrol experience as a trooper and sergeant, including four years as a member of the State Police Mobile Response (SWAT) Team.

The number of state agency employees that are candidate SWN users is approximately 25,000 and the New York State Police provides approximately 5,000 sworn and non-sworn employee candidates.

On September 22, 2005 the State of New York's OFT[16] announced "that the design and construction of the state's new public safety radio network is set to begin" and "will be the first comprehensive upgrade to many of the state's emergency radio systems in more than 30 years." M/A-COM was awarded the contract at an announced price for the SWN of more than $2 Billion to be financed over a 20 year period. The contract "not to exceed" price includes network design, materials, construction, towers, shelters, fixed assets, network equipment, and finance charges. Additionally, the cost of site leases, operations and maintenance as well as future network upgrades over the 20 year contract period are included. The contract specifies a month-by-month 20 year lease, although the state has a right to purchase the system outright at a later date if deemed advantageous. The MA-COM team includes General Dynamics for project management, site acquisition and other services, and Alcatel for Microwave. The SWN is intended to serve day-to-day as well as emergency needs for real time on-demand connectivity for coordination of police, fire, emergency medical, and necessary public response services.

Although SWN was initiated to replace aging state agency systems, a key additional goal is to foster voluntary partnerships with local governments to address their individual needs. Many local agencies are indicating interest in participating in SWN. Partnerships will facilitate network development of sharing frequencies and infrastructure as well as providing access to end user equipment procurement contacts. The SWN will serve all

[16] September 22, 2005 Press Release "Statewide Emergency Radio Network Project Set To Begin, Contract approved", https://www3.oft.state.ny.us/swn/index.cfm

state agencies and enhance local initiatives by fostering partnerships with local emergency first responders and service providers on a voluntary basis. The initial installation will accommodate up to 65,000 users and 25,000 separate “talk groups” at any give time statewide, and it will support up to 250,000 individual pieces of user equipment (mobiles, portables, MDT’s, etc.). The system will be deployed over a five year period in phases in various regions of the state.

Cowper indicated that the RFP defined requirements as a functional specification with the intent that commercial cellular operators could submit bids. However, no interest or responses were received from the commercial segment.

SWN will eventually replace an 800 MHz M/A-COM system in NYC and a statewide State Police high band VHF system. The NY Department of Transportation has a low band VHF system that will also be retired as will the Department of Environmental Conservation’s VHF system. Various county, metropolitan, city, and other jurisdictions and agencies have a variety of 800 MHz, VHF, and UHF systems deployed across the state that are largely not interoperable. A key SWN goal is to have an effective outreach program to influence local governmental agencies to partner with SWN. The state does currently have a common interoperability channel at 155.370 MHz that local police agencies can use.

The state agencies anticipated to participate on the system include:

1. NY State Police
2. Health Department
3. Department of Correctional Services
4. Department of Transportation
5. Department of Environmental Conservation
6. Office of Fire Prevention and Control
7. Unified Court System
8. Department of Criminal Justice

A key local participant and SWN Governance Board member has been the Metropolitan Transport Authority (MTA) Police Department (MTAPD) for the NYC subway and commuter rail system. Motivated by the Madrid Spain commuter train bombing in March 2001, MTAPD has committed to operate off the current State Police Metro-21 radio system in the near term and then subsume it as part of SWN in the longer term. State Troopers have been assigned to ride MTA trains since the September 11 attacks and require enhanced communication capabilities and interoperability with MTAPD officers.

An overview of the SWN features and parameters include:

1. SWN selected MA-COM’s OpenSky trunked TDMA multisite system supporting 4-slot operations at 19.2 kbps to provide voice and data capabilities.
2. When fully deployed, the network is anticipated to have approximately 1000 transmission sites statewide.

3. The system will operate in the 700 and 800 MHz bands.
4. The coverage requirements include mobile radio coverage across state of New York with 95% area coverage, 97% road coverage, the coverage specification are applied on a county-by-county basis, and the delivered audio quality must conform to DAQ 3.4.[17] New York City requires 97% portable on the hip coverage.
5. The system build out schedule is 58 months from contract approval in September of 2005. The system will be designed and deployed in phases by regions. New York has 12 regions. The first region to be deployed will be in the Erie and Chautauqua counties in the western part of the state with anticipated first operation around mid-year 2007. Subsequent regional build outs will commence then and are scheduled to be completed 3 year later in mid-2010.
6. The Erie and Chautauqua deployment region will be enhanced by the respective counties to provide portable, in-building, coverage above the standard SWN coverage specifications and will pay M/A-COM for needed enhancements.
7. An overlay VHF / IP system with vehicle repeaters will be deployed in mountainous, less densely populated areas of the Adirondack and Catskill Parks.
8. The state will deploy a statewide microwave system to for interconnect and backhaul between system elements.

[17] Delivered Audio Quality, Level 3.4. A quality specification for P25 radios. Level 3.4 indicates speech understandable without repetition, some noise/distortion present. See http://flattop.its.bldrdoc.gov/spectrum/P25/daq_sb/daq_sb.htm

4.6. State of Texas, Department of Public Safety

State	Population (M) *	Land Area (sq. mi.) *	Number of Agencies **	Total Law Enforcement Personnel **	Sworn Officers **	Civilian Employees **
Texas	21.7	261,797	965	77,464	47,710	29,754

Table 4-12 Law Enforcement Personnel, State of Texas
(Source: * Author Research, ** FBI Crime in US Report)

Robert Pletcher, Program Director RF Unit, Texas Department of Public Safety (TDPS), in several telephone interviews, provided the information that provides the basis for our discussions of public safety communications in the state of Texas. Bob serves on Project 25 (P25) committees and serves as chairman of TSIEC (Texas State Interoperability Executive Council). The goals of the TSIEC[18] are to 1) improve interoperability with federal agencies (e.g., Drug Enforcement Agency, Federal Bureau of Investigation, U.S. Customs Service, and U.S. Border Patrol), 2) educate state agencies about systems management and funding opportunities; and 3) provide a methodology for connecting dissimilar systems. The voting members of TSIEC[18] that represent public safety within Texas are:

1. Texas Parks and Wildlife Department
2. Texas Department of Public Safety
3. Texas Department of Transportation
4. Texas Alcoholic Beverage Commission
5. The Chairmen of each of the 6 FCC Regional Planning Committees within Texas
6. Texas Department of Criminal Justice
7. Texas Youth Commission
8. Texas Forrest Service
9. Lower Colorado River Authority

These are considered the key Texas State agencies and representatives for regional and local jurisdictions that utilize public safety land mobile radio (LMR) services.

In Texas approximately 80% of the public safety mobile/portable radios being used are in the 800 MHz band, but about 80% of the public safety radio licenses in Texas are in the VHF band. The reasons for this are that 80% of the population in Texas lives in cities or towns with populations of 50,000 or more. A high percentage lives in metropolitan area (e.g. Houston, Dallas/Fort Worth, San Antonio, Austin, El Paso, etc.). These populated areas have higher budgets, denser population coverage areas, and greater capacity requirements. A high percentage of these areas have deployed 800 MHz systems and require trunked systems for capacity. However, a substantial portion of the land area in Texas is rural areas that have significantly less population densities, have large coverage area that are best served by the better propagating VHF band. These rural areas have

[18] TSIEC web site; http://tsiec.region49.org/

lower capacity requirements. Texas has 3000 towns with populations under 500. The smaller, usually mostly rural, areas can often serve communication needs with a single channel for all agencies/services and often have cost constraints. All 254 counties in Texas have sheriffs and perhaps 90%[19] use VHF spectrum to meet their needs. The DPS has licensed 8 VHF wideband channels and 5 VHF narrowband channels to provide statewide VHS coverage for interoperable operations with and between locals under a MOU agreement. Adequate interoperability in Texas requires appropriate multiband VHF, UHF and 800 MHz capable terminals and infrastructure. Currently, essentially no multi-band VHF/800 MHz or UHF/800 MHz terminals[19] are offered by manufactures, although Motorola indicates it will be offering products in the future.

The Texas public safety population consists of:

- Federal 10-15%
- State 5-10%
- Local 75-85% (Cities, Counties, regional, etc)

The State of Texas has significant Federal participation that includes 6000 Federal agents representing INS (Immigration and Naturalization Service), the Border Patrol, DEA (Drug Enforcement Agency), U.S. Marshall, FBI, and ATF (Alcohol, Tobacco, and Firearms) and others. The 750 mile Mexican Border along the Rio Grande River is a significant focus. A significant consideration is to prevent illegal immigration and at the same time provide humanitarian aid to keep these same immigrants from dying during their illegal entry attempts. There are 5 or 6 port authorities in the state and most are separate from the adjacent cities (e.g. Port of Houston). The Texas City, Port Author and Beaumont refining complexes utilize pipelines to provide approximately 60% of the heating fuel out of the Gulf for the North East United States. The state has major military installations including Fort Hood in Killeen, Fort Bliss in El Paso, Fort Sam Houston in San Antonio, several Naval installations, and a number of Air Force bases. The North American Free Trade Agreement (NAFTA) has created significant border crossings per day at Brownsville and El Paso including 16,000 vehicle crossings per day and 3-5000 railcars at the Laredo entry point.

In the 1970's Texas public safety organizations begin VHF initiatives in the 150 – 160 MHz band that included Fire and EMS (Emergency Medical Services). Three interoperability channels were defined: 1) mobile-to-mobile; 2) mobile-to-base, and 3) base-to-base (county to county). Two significant VHF issues in Texas have been that in some weather and climate conditions, VHF can skip hundreds of miles. Transmitters in Mexico are not well regulated, both creating significant interference problems. In the late 70's and early 80's, UHF was populated by some law enforcement, ambulance and fire departments in metropolitan areas. In 1980 the Dallas deployed UHF for Law Enforcement, Fire, and EMS. Fort Worth deployed 800 MHz in the mid 80's to address skip interference problems.

[19] Joe Peter, Texas Sheriffs Association, early 2006

Pletcher expressed some disappointment in the P25 standards process and evolution, available products, and costs, although he remains optimistic that these same standards will ultimately provide a long term solution. He stated that as of early 2006, the P25, P1 (phase 1) Common Air Interface (CAI) is the only ratified and approved part of the standard suite. The CAI provides a single talk path per carrier. He further indicated that P25, P1 CAI equipment is based on based on FDMA equipment. P25, (Phase 2) equipment will be based on TDMA equipment which presents additional compatibility challenges and is in various stages of specification and ratification. Concern was also expressed that in the past it has generally not been possible to buy interoperable terminals from other than the infrastructure vendor. As of early 2006 there is no independent verification process to certify that any P-25 products actually meet the standard. He indicated that various patents and intellectual property rights have in the past posed challenges within the P25 standards community in their quest to achieve interoperable, multi-vendor, systems and products.

The TxDPS has on-going activities for planning a combined Texas State agencies communication system that can interface and interoperate with regional and local jurisdictions. In our interviews, Bob Pletcher provided some general guidance on generic system elements, rough estimates of anticipated units, and ballpark estimates of historical average costs based on experiences. Using the methodology of the California PRISM system presented in Table 4-4, a similar estimate was developed for Texas that is presented in Table 4-13. The system is a hybrid VHF High band – 700 MHz system. For the infrastructure the analysis generally assumes:

1. Estimate assumes 95% mobile geographic coverage. Portable and in-building coverage would require additional sites and equipment.
2. Texas has 254 counties and each county would require approximately 2-3 sites
3. Specifically, this estimate assumes 90 - VHF sites and 445 - 700 MHz sites
4. Each 700 MHz site assumes an average of 4 trunked transmitter/receivers (TXR) channels, and a minimum of 2 700 MHz I/O (Interoperability channels)
5. VHF High band, assumes 2 channels per site, Conventional
6. In-building coverage not provided
7. Routine traffic for only state agencies (emergency situations excepted)
8. Continued use of at least half of the existing tower sites. Of the remaining sites, 15% require minor upgrades and 35% require major upgrades.

Additional information provided by Bob Pletcher included:

1. Typical cost of 300 foot, self supporting, tower site is ~ $250,000
2. Typical tower cost is ~ $75,000
3. Typical BTS single channel TRX cost: ~$10,000-$12,000 (electronic equipment)
4. Land acquisition; site preparation and construction; legal, zoning is typically 40% of site costs.
5. System design costs can approach 20-25% of total procurement cost
6. Annual maintenance costs are typically 8-10% of purchase price of equipment.
7. Systems must be built for worst case from start, e.g. hurricane, tornados, flooding.

8. Public safety systems plan for typical loading of approximately 10% -15% to allow for significantly higher loading during emergency situations.

Texas DPS has recently been purchasing 500 – 600 VHF portables per year at ~$2000 per unit for a P25 P1 CAI, dual mode, narrowband, wideband units. Conventional, non-P25 VHF portable terminals can be purchased for as cheap as $750 per unit and are suitable for some applications (e.g. campus based, prisons). Many rural fire departments use non-P25 equipment due to funding shortfalls. A seven year depreciation cycle is assumed.

The approximate number of deployed units in TDPS includes 4,500 mobiles and 4,000 portable. A high percentage (~99.5%) of DSP troopers has mobile terminals in their vehicles. Federal funds have historically been available to outfit new DPS officers upon entering service. Only 2% of non-commissioned staff has radio terminals, perhaps 600 radios.

In terms of DPS public safety portable terminal requirements, the following input was offered:

1. Battery life must support an 8 – 12 hour shift
2. 90% of traffic is receive, 10% is talk
3. Fast PPT (push to talk) response is essential; latency should not exceed 250ms for single site operations.

Pacific RIM competitors have been offering VHF radios in the US that has helped achieve some price decreases. Information was not available on the local county, city, etc. public safety population counts and mobile and portable terminal counts. Although exact information is not available, perhaps 98% of county sheriffs and their deputies have radios (mostly mobiles in vehicles).

Estimated Equipment and Infrastructure Budgetary Costs Hybrid VHF-700 MHz Radio Infrastructure					
		Per Unit Cost		Total Cost	
One Time Costs	Quantity	-10%	+25%	-10%	+25%
Voice Radio System					
Fixed Voice Infrastructure (based on 90-VHF & 445-700 MHz sites)					
Fixed Transceivers & antenna systems					
700 MHz 4 channels per site, trunked - 2 I/O)	2,670	$ 24,660	$ 34,250	$ 65,842,200	$ 91,447,500
VHF (2 channels per site, conventional - 90 existing)	90	$ 14,000	$ 19,250	$ 1,260,000	$ 1,732,500
In-Building Bi-Directional Amp/Antenna System	95	$ 40,500	$ 56,250	$ 3,847,500	$ 5,343,750
System Controllers	20	$ 1,125,000	$ 1,562,500	$ 22,500,000	$ 31,250,000
Site Controllers	445	$ 54,000	$ 75,000	$ 24,030,000	$ 33,375,000
Site Electrical and Alarm Systems	565	$ 37,800	$ 44,450	$ 21,357,000	$ 25,114,250
Consoles/Console Interfaces	105	$ 37,000	$ 52,500	$ 3,885,000	$ 5,512,500
Regional Operation Facilities	12	$ 290,000	$ 409,700	$ 3,480,000	$ 4,916,400
Central Operation Facilities	3	$ 475,000	$ 659,722	$ 1,425,000	$ 1,979,166
Microwave Paths (includes equip. and antenna systems)	565	$ 315,000	$ 437,500	$ 177,975,000	$ 247,187,500
Minor Site Upgrades (to 15% of total sites)	85	$ 67,500	$ 93,750	$ 5,720,625	$ 7,945,313
Major Site Upgrades (to 35% of total sites)	198	$ 180,000	$ 250,000	$ 35,595,000	$ 49,437,500
New Sites including acquisition (50% of total Sites)	283	$ 405,000	$ 562,500	$ 114,412,500	$ 158,906,250
Design, Configuration, Project Management (14% of equipment)				45,584,238	$ 62,700,199
Installation/Integration/Training (25% of equipment)				81,400,425	111,964,642
Spare Equipment / Parts (4% of equipment)				13,024,068	17,914,343
Subtotal				**$ 621,338,556**	**$ 856,726,812**
User Equipment					
Mobile Radios (High Tier - avg. VHF-700 MHz)	11,500	$ 3,915	$ 5,438	$ 45,022,500	$ 62,537,000
Portable Radio (High Tier - avg. VHF-700 MHz)	7,750	$ 3,285	$ 4,565	$ 25,458,750	$ 35,378,750
Mobile Radios (Low Tier - avg. VHF-700 MHz)	24,500	$ 2,650	$ 3,680	$ 64,925,000	$ 90,160,000
Portable Radio (Low Tier - avg. VHF-700 MHz)	18,750	$ 2,200	$ 3,055	$ 41,250,000	$ 57,281,250
Control Stations / Remote Control Units	375	$ 5,400	$ 7,500	$ 2,025,000	$ 2,812,500
Console Upgrades	25	$ 49,500	$ 68,750	$ 1,237,500	$ 1,718,750
Installation / Integration / Training (10% of Equipment)			.	17,991,875	24,988,825
Spare Equipment / Parts (3% of Equipment)				5,397,563	7,496,648
Subtotal				**$ 203,308,188**	**$ 282,373,723**
Implementation Support (6% of Equipment & Services)				$ 38,731,751	$ 53,419,560
Contingency (15% of equipment and services)				$ 129,506,774	$ 178,878,014
Total Voice Radio System				**$ 992,885,269**	**$ 1,371,398,108**
Recurring Support Costs					
New lease costs (all new and 25% of existing sites)	354	$ 2,000	$ 2,775	$ 127,440,000	$ 176,823,000
Added telco T-1 circuits (at 65% of new sites w/o backhaul)	184	$ 585	$ 815	$ 19,375,200	$ 26,992,800
Unit costs				$ 39,645,097	$ 55,062,876
Microwave Services				$ 62,055,329	$ 85,712,382
Engineering				$ 99,288,527	$ 137,139,811
Operations/Technical Services				$ 124,110,659	$ 171,424,764
Miscellaneous Flow Through				$ 84,395,248	$ 116,568,839
Total Recurring Support Costs				**$ 556,310,059**	**$ 769,724,471**
Total 15 Year Cost				**$ 1,549,195,328**	**$ 2,141,122,580**

* Costs are based on best available estimates and are not specific to any vendor or product. The cost range specified is based on standard project management guidelines for an unappropriated project. The variance specified will allow for competitive pricing and functionality.

Table 4-13 Estimated State of Texas Combined Agency Communication System
(Source: Author based on adoption of California PRISM System methodology with general interview guidance by Bob Pletcher of the Texas Department of Public Safety)

4.7. Cities of Phoenix and Mesa, AZ

City	Population (M) *	Land Area (sq. mi.) *	Number of Agencies **	Total Law Enforcement Personnel **	Sworn Officers **	Civilian Employees **
Phoenix	1.45	514	N.A.	3,742	2,859	883
Mesa	.45	132.1	N.A.	1,279	795	484

Table 4-14 Law Enforcement Personnel, Cities of Phoenix and Mesa, AZ
(Source: * City Web sites, ** FBI Crime in US Report)

In September 2003, the Cities of Phoenix and Mesa Arizona begin initial system operations on a valley-wide Project 25 (P25) compliant public safety communication system. The spokesperson providing information for this P25 system was Jeff Toye of the Communications Division of the City of Mesa who provided a written response that is the basis of much of these discussions. Information was also obtained from the Cities of Phoenix and Mesa web sites as well as other interviews.

Key system parameters[20] include:

- P25 Phase 1 compliant
- Digital
- Simulcast
- OTAR (Over-the-Air Rekeying of Security/Encryption Keys)

The cities specified the Project 25 standard[20] since they felt that this was the best way to provide and promote interoperability throughout the metropolitan area. The P25 open architecture based standard gives the maximum flexibility for other agencies to connect to the network. Additional infrastructure may be added as separate systems and connected at the network level (when the ISSI standard is completed by TIA and the appropriate hardware/software is available from the manufacturers), or the existing infrastructure can be expanded to meet additional loading.

Some of the P25 features[20] supported by the infrastructure include:

- P25 common air interface
- P25 trunking protocol and standardized messages
- P25 IMBE vocoder
- P25 AES and DES encryption, Type III required and Type I encryption when available
- P25 Unit ID, unit disable
- P25 Emergency Alert

[20] City of Phoenix web site, www.ci.phoenix.az.us/phxprwn.html

The activities leading to this system were originated in the mid 1990's and involved both the fire and police departments as well as the IT/communications departments of both cities. A key motivating factor was the automatic mutual aid agreements of various fire departments in the metropolitan Phoenix area. The procurement was accomplished with separate contracts by each city with the vendor, Motorola, for their portion of the system. Agreements for common system elements where put in place during the design phase and defined funding responsibilities and locations. The Gilbert Fire Department was part of the system because of the in-place automatic aid agreements and the fact they were already being dispatched by Mesa. The Gilbert Police Department expressed an interest in coming onto the system during the detailed design phase of the project and was the first group of users on the system when it went live. The transmitter site in Gilbert was funded by Gilbert. The Apache Junction Fire District, part of the area automatic aid agreement, added two additional sites to the system to provide the same level of portable coverage as require within the Mesa city limits. The Apache Junction Fire District, part of the area automatic aid agreement, added two additional sites to the system to provide the same level of portable coverage as require within the Mesa city limits. The City of Mesa is in the process of adding its municipal services users to the system.

The initial project agreement was based on a hand shake. Since then a basic Intergovernmental Agreement (IGA) between Phoenix and Mesa has since been negotiated. Each City relies on its own Communications organization to maintain and operate their portion of the system. The Cities are now involved in a process to develop a formal Governance agreement as the basic IGA is not sufficient to handle the many requests from other cities to join the system. The cities anticipate that a draft of this agreement will be available by mid-year 2006. Each City has had separate contracts with the vendor to procure their portion of the system and terminals Payment and ownership for common elements has been negotiated between the cities. Each City manages their own portables and mobiles and maintains their own portion of the system. System-wide configuration settings are developed through joint discussions and agreements that are then implemented.

The funding for the system was largely borne by the cities. The State of Arizona has loaned some 700 MHz channels from the State license to be used for demonstrating 700 MHz operation and multi-band trunking (one of Mesa's sites has both 700 and 800 MHz frequencies). There have also been some discussions with the Federal government about possibly doing an interoperability demonstration project. There has been no funding provided by other agencies with the exception of the various fire departments and Gilbert. There are some federal and state agencies that have or will have a small number of radios that are on the system for interoperability purposes. A grant was received from the Department of Justice for a cache of portable radios to be deployed in the event of a major emergency. These radios are programmed with talkgroups on the Phoenix/Mesa system as well as other trunked and conventional systems in the valley. Three different agencies each maintain a portion of this cache at their facility. In addition to these portable radios, DOJ also funded the purchase and installation of control stations at the various PSAPs[21] located in the valley. These control stations provide a mechanism to patch other agencies onto the Phoenix/Mesa system when an interoperability need occurs.

A primary goal for specifying P25 was to take advantage of a competitive procurement environment. Although Phoenix and Mesa were an early adopter of P25 technology (when there wasn't much competition), they now have subscriber equipment from four different manufacturers deployed on the system. In addition, they indicate that two other manufacturers have tested prototype subscriber units on the system which they believe indicate that there will be more options for equipment in the future. Historically, trunked radio systems have been entirely proprietary and locked the owner into one vendor. This is a scenario Mesa wanted to avoid by specifying P25. Mesa has had a long history of participation in the TIA standards setting process for P25. Mesa's former Communications Director has been a member of the P25 Steering Committee for years.

The Phoenix/Mesa system is an 800 MHz trunked system that is a Motorola Smartzone Omni-link infrastructure that includes three zones. Two zones are in the Phoenix area: one for police and public service and one for fire and public service. The third zone is for Mesa. This radio network design goal was to provide in-building coverage throughout the metropolitan Phoenix area from Buckeye to Apache Junction and from Daisy Mountain to Ahwatukee. Mesa and Phoenix plan to implement a public safety and public service radio network of systems that will provide an open architecture, wide-area, radio network serving both cities and their respective client agencies. This network will initially use NPSPAC[22] frequencies in the 821-824/866-869 MHz band. The system goal has been to support voice applications for approximately 15,000 users.

Portable in-building coverage was required. This requirement was described in the RFP as an on-street signal level adjusted by differing db levels corresponding to the type of construction present in particular coverage areas: - 12 db for light residential, 17 db industrial, and 23 db downtown skyscrapers. The intent was to allow a coverage acceptance test to be performed that allowed for on-street data collection to verify signal levels that would be sufficiently robust to provide in-building coverage. Mesa indicates that there aren't any significant coverage issues in Mesa. There are some isolated locations downtown that have some coverage difficulties that appear to be related to multi-path reflections. The City of Phoenix provided a statement of the systems basic design criteria goals concerning coverage that is recreated in Table 4-15.

[21] Public Safety Answering Points (PSAPs)
[22] National Public Safety Planning Advisory Committee

Basic Design Criteria

- Goals
  - 95% coverage with 95% reliability
  - Portable, in-building coverage
    - } Site Location & Signal Strength
  - 2% Grade of Service (GOS)
    - } Capacity, Number of Frequencies

Table 4-15 Phoenix/Mesa System Basic Design Criteria: Coverage
(Source: City of Phoenix Presentation; www.ciphonix.az.us/AGENCY/PHXPRWN)

The Phoenix portion[23] of the system has two zones: one for fire and ½ of Municipal Services and one for Police and the other ½ of Municipal Services. Each zone has a zone controller that provides for a primary Police Department dispatch center and a primary Fire dispatch center, and an EOC (Emergency Operations Center). The Phoenix system has 4 simulcast groupings:

1. Simulcast A for police in the valley consisting of 9 sites and 20 channels
2. Simulcast B for Fire in the valley consisting of 9 sites and 19 channels. B shares sites with A.
3. Simulcast C for South of the Mountainous area
4. Simulcast E consisting of 5 sites and 12 channels for the west valley mostly outside the city of Phoenix.

The system has a total of 649 talkgroups defined system wide, with 329 for Phoenix. Each mobile and portable has site preferences defined. The Phoenix Fire department has a consortium agreement with 17 jurisdictions in the Phoenix area for dispatch. Simulcast E was largely deployed to serve this purpose. Consortium member pay Phoenix Fire for this service. The P25 system has dedicated simplex channels (i.e. terminal to terminal, no infrastructure) for authorized on-scene tactical operations. Simplex supports up to approximately one mile range. The Phoenix also has a 7 channel 700/800 MHz Intelligent Site repeater. The encryption capability has enabled some secure operations that previously could not be handled via the old un-secure voting simplex radio system.

The Mesa Zone includes two sites - simulcast D site consisting of 9 sub-sites and a 10 channel 700/800 MHz Intelligent Site repeater, both under the control of the Zone 3 zone controller. Mesa has three 24/7 dispatch centers: 1) Mesa Police/Fire dispatch, 2) Utility Controls dispatch (for Mesa's utilities/municipal services users), and 3) the Gilbert Police department dispatch center. There is also an offsite EOC (Emergency Operations Center) and a backup dispatch location for Utilities.

The majority of the Mesa terminals are public safety radios with the police department having the largest amount. The numbers are currently changing almost daily since Mesa is in the beginning phases of municipal services deployments. Mesa currently has radios from four different manufacturers on the system. The majority of the frontline public

[23] Interview with Jesse Cooper, Phoenix Police Department

safety radios are Motorola XTS5000. These high tier radios were selected on the basis of several criteria including dual-band (700/800 MHz) capability and encryption support Phoenix and Mesa are currently using encryption on selected talkgroups along with over-the-Air Rekeying (OTAR). EF Johnson radios are used in public safety support applications. And, Kenwood radios are used in the municipal services areas since they are more cost effective in these applications. The City's fixed and rotary-wing aircraft have Technisonic P25 aircraft radios.

The number of portables and mobiles deployed in the cities are presented in

City / Organization	Portables	Mobiles
Phoenix	6220	3675
Mesa	1922	950
Gilbert Fire Department	390	177
AJFD	45	28

Table 4-16 Phoenix/Mesa P25 deployed Portables and Mobiles

The City of Mesa provided interesting input on the success and problems of the P25 standard to enable achievement of their system goals. They indicate that since equipment is built to the relatively new P25 standards, each manufacturer has had issues with software in both subscribers and infrastructure and bug fixes have been needed to achieve proper operation. The city has achieved multi-vendor competition with the subscriber equipment (mobiles, portables), and have four different manufacturers' equipment on the system. At the time of their system procurement there was only one P25 infrastructure provider. The city indicates that other manufacturers are now developing infrastructure as well.

The city further indicates that some of the Some P25 interface standards are not yet complete (Console, ISSI, Fixed Station etc.; early 2006 input). These interfaces would allow the city to tie together separate systems (ISSI) or provide other options for consoles. TIA is being pushed to complete these interfaces particularly by the Federal government. Concerning the adequacy of the P25 standards the city indicates that the standards may leave too much room for interpretation in some instances. There have been cases where one manufacturer interprets a specific standard in one way and another interprets it in a completely different way. The end result is that the two subscriber radios don't behave the same or they don't interoperate correctly. Additionally, terminal vendors other than Motorola have difficulty getting their radios to operate on Motorola's complex trunked infrastructure. Nevertheless, the city indicates that they have seen the advantages of multi-vendor procurements already by multiple manufacturers offering different choices and a general lowering of prices. Motorola has introduced additional models to compete with the units from Kenwood and E F Johnson.

The city indicates that the current high priority task is to complete the new governance framework so that other organizations can join the system. This urgency of this activity is reinforced by inquiries from other cities that wish to become users of the system. Additionally, the city indicates that they are interested in fostering a competitive environment for subscriber and infrastructure equipment and offer the opportunity for manufacturers to test their subscriber equipment on the system.

5 US Public Sector Market

Market estimates and forecasts for public safety and Land Mobile Radio (LMR) have been very elusive. Perhaps the biggest contributor to this has been the fragmentation of the market that consists of a multitude of federal, state, and local agencies with organizations that operate very independently. Thus good inventories of currently deployed federal, state, and local communication systems and equipment do not appear to exist at any level of government; and perhaps even in industry or market research firms. These public organizations are led by professionals with expertise in Law Enforcement, Fire, Emergency Medical Service (EMS), and are often stretched and overloaded when undertaking communication system planning and deployment activities. A bottom up market analysis has been elusive for even well funded government activities. Thus, our approach will be a top down approach based head count estimates and ratios from available reports of representative systems.

In an October 2005 presentation by authors from National Institute of Standards and Technology (NIST) and SAFECOM, US first responder community was identified as consisting of over 44,000 public safety agencies and provided the numbers for personnel, departments, agencies, and local, state, and federal agencies presented in Table 5-1. Interoperability also affects public service organizations, which includes legislative officials, utilities, and chief information officers

960,000 Firefighters 830,000 EMS Personnel 710,000 Law Enforcement Officers	28,495 Fire Departments[1] 5,841 EMS Departments[1] 27,496 Law Enforcement Agencies[1]	25,763 Local Agencies [1] 6,396 State Agencies[1] 2,967 Federal Agencies[1]

[1] Source: www.SafetySource.com

Table 5-1 US Summary of Public Safety personnel, departments, and agencies
(Source: 'Interoperability Standards" Presentation, by Dereck Orr (NIST) and Nyla Houser (SAFECOM Support), at Project MESA Meeting, October 25, 2005)

The relationship between public sector headcount and the general population density is presented in Figure 5-1 for Law Enforcement, Firefighter, and Emergency Medical Service (EMS). The headcount refers to the number of Law, Firefighter, EMS employees and is expressed in percent of the general population (or in per 1000 by multiplying the percentage by 1000). It should be noted that the x-axis is population density and that it is logarithmic (as is the y-axis) and care must be exercised in extrapolating to various sizes of geographic area and to various population densities. This figure as well as Table 5-9 for ITS (Intelligent Transportation Systems) Communications systems provides strong support for consistent input that the US Public Sector head count is approximately five times (5x) the US Law Enforcement headcount.

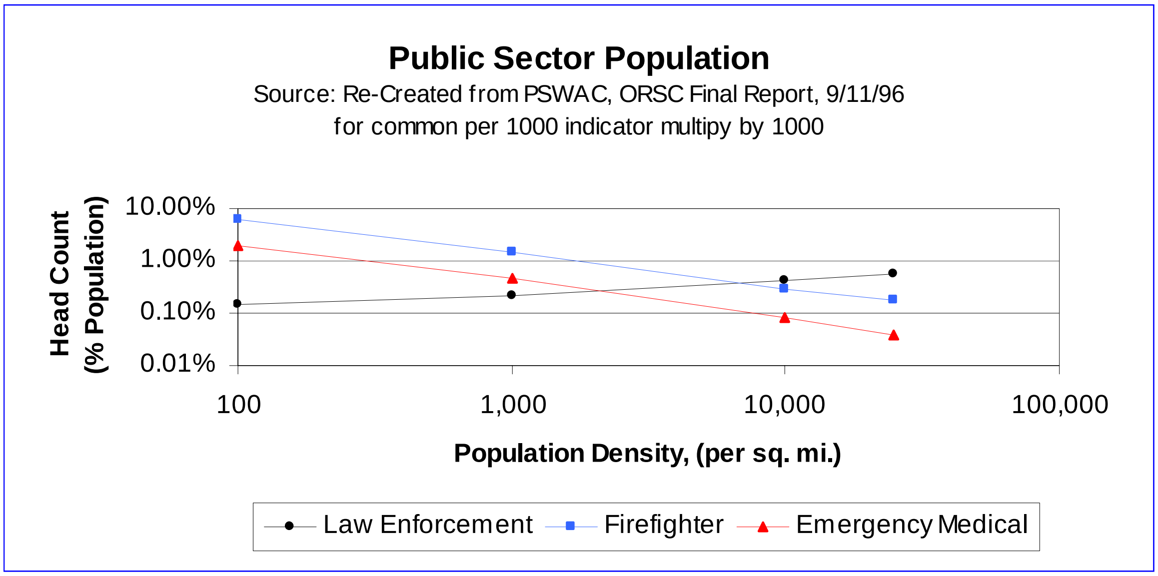


Figure 5-1 Public Sector Population Statistics
(Source: Recreated from PSWAC, ORSC Final Report, 9/11/96)

In engaging public safety stakeholders to collect information and data, we repeatedly found that specific state and local agency communication personnel do have knowledge of specifics of their own organizations and environments, but have very little comprehensive information and data available for other organizations within their state, county, city or even partner organizations. A very succinct input was offered by Chief Harlin R. McEwen, Chairman of the Communication and Technology Committee for the International Association of Chiefs of Police (IACP) who stated that he is not aware of satisfactory market data from government, professional association, or other sources. Further, he indicated that he believes that this has created problems in justifying desired and needed public budgets. He offered a very good suggestion for a methodology for developing market estimates and forecasts using FBI data on US public safety personnel statistics (see Table 5-2). We have used this approach to develop public safety personnel estimates and developed methods for infrastructure estimates.

According to the FBI Crime in United States, 2004, report, the number of total US Law Enforcement Employees per 1000 population was approximately 3.5 and the number of officers was 2.5. Table 5-2 present an extractions of data from this report and lists by state the number of Law Enforcement Agencies, total Law Enforcement employees, total (sworn) officers, and total Law Enforcement civilian employees. We have added population and total area in square miles. The table also presents the percentage of state population of total law enforcement employees (% TLEE), total sworn officers (% T off), and of civilian law enforcement employees (% T Civ). The US totals are presented at the bottom of the table.

Our methodology for estimating the US public safety terminal and infrastructure market cost parameters will be to adapt and simplify the approach employed by the State of California in their PRISM program that is presented in our discussions of California public safety communications presented in Section 4.1. Table 4-4 presents a cost analyst for a shared state (10+ agencies) public safety communication system in California. Using these analyzes for methodology guidance, Bob Pletcher of the Texas Department of public safety provided general guidance via a telephone interview (May 2006) that we used to developed a similar analysis for the State of Texas that is presented in Table 4-13. We will use these analyzes to develop a model to apply to the data in Table 5-2 to develop state by state and total US cost estimates. These estimates will be a total replacement model to estimate the total installed cost (or value) of an upgraded communication system that would address digital migration, FCC mandated narrow banding requirements, interoperability, improved operability, etc. requirements that are badly needed by the public safety community. Of course, these installations and costs would be spread over a number of years and would be altered by appropriate replacement schedules for existing systems, and equipment as well as available yearly budgets. While most electronics would be replaced, some existing system elements such as sites, towers, etc. can be maintained to reduce upgrade costs.

Probably the most significant influence on infrastructure cost is the number of sites that are required to provide coverage in each state. Table 5-3 presents reported number of required sites for select states based on our interviews in Section 4. The California PRISM report provided estimates for a hybrid VHF HB/800 MHz system as well as an 800 MHz system. Similarly, Missouri provided information on its existing VHF Low Band system as well as an 800 MHZ estimate. Both estimates for these states are included in the table. The table also includes the population of each state and area, square miles, and the population density. The table calculates the coverage area of a site in square miles per site by dividing the area of a state by the number of sites. A typical coverage performance specification is 95% geographic area coverage for mobile terminals. We assume for the purpose of our market estimates that this is achieved by the number of required sites reported by various state authorities. The radius of the coverage area is estimated by using the hexagon area formula provided in Figure 5-2. Another influence on infrastructure cost is the number of channels deployed at each site. Shared systems require a higher number of channels per site, but with more cost effective shared site, backhaul, operations, etc. costs compared with independently procured, deployed, operated, maintained, and upgraded communication systems for each agency.

	State	Square Miles	Population	Agencies	Total Law Enforcement Employees	Total Law Enf. Off.	Total Law Enf. Civilians	% TLEE	% T Off
1	Alabama	50,744	4,162,261	307	14,476	9,472	5,004	0.348%	0.228%
2	Alaska	571,951	655,435	41	1,896	1,213	683	0.289%	0.185%
3	Arizona	113,635	5,627,161	99	19,809	11,317	8,492	0.352%	0.201%
4	Arkansas	52,068	2,685,784	242	7,826	5,234	2,592	0.291%	0.195%
5	California	155,959	31,273,858	457	112,584	73,864	38,720	0.360%	0.236%
6	Colorado	103,717	4,443,898	223	15,446	10,528	4,918	0.348%	0.237%
7	Connecticut	4,844	3,503,604	101	9,701	7,898	1,803	0.277%	0.225%
8	Delaware	1,954	830,364	52	3,195	2,263	932	0.385%	0.273%
9	District of Columbia	61	553,523	3	4,876	4,164	712	0.881%	0.752%
10	Florida	53,927	17,395,608	407	72,106	44,037	28,069	0.415%	0.253%
11	Georgia	57,906	8,125,492	466	29,302	21,270	8,032	0.361%	0.262%
12	Hawaii	6,423	1,262,840	4	3,427	2,712	715	0.271%	0.215%
13	Idaho	82,747	1,384,946	118	3,620	2,444	1,176	0.261%	0.176%
14	Illinois	55,584	12,645,893	753	50,174	36,432	13,742	0.397%	0.288%
15	Indiana	35,867	5,991,832	249	17,109	10,769	6,340	0.286%	0.180%
16	Iowa	55,869	2,943,984	231	7,449	4,959	2,490	0.253%	0.168%
17	Kansas	81,815	2,688,942	337	9,966	7,144	2,822	0.371%	0.266%
18	Kentucky	39,728	4,087,276	361	10,164	7,655	2,509	0.249%	0.187%
19	Louisiana	43,562	4,279,321	199	21,439	16,563	4,876	0.501%	0.387%
20	Maine	30,862	1,314,897	131	2,892	2,194	698	0.220%	0.167%
21	Maryland	9,774	5,556,884	147	19,483	14,897	4,586	0.351%	0.268%
22	Massachusetts	7,840	6,340,152	332	19,466	16,124	3,342	0.307%	0.254%
23	Michigan	56,804	10,071,760	631	27,656	20,220	7,436	0.275%	0.201%
24	Minnesota	79,610	4,960,204	303	12,572	8,147	4,425	0.253%	0.164%
25	Mississippi	46,907	2,573,607	191	8,857	5,527	3,330	0.344%	0.215%
26	Missouri	68,886	5,732,783	560	19,073	13,450	5,623	0.333%	0.235%
27	Montana	145,552	926,865	107	2,761	1,626	1,135	0.298%	0.175%
28	Nebraska	76,872	1,714,366	163	4,803	3,443	1,360	0.280%	0.201%
29	Nevada	109,826	2,334,771	36	8,045	4,758	3,287	0.345%	0.204%
30	New Hampshire	8,968	985,947	135	2,644	2,005	639	0.268%	0.203%
31	New Jersey	7,417	8,433,144	533	40,195	31,313	8,882	0.477%	0.371%
32	New Mexico	121,356	1,758,428	94	5,373	3,944	1,429	0.306%	0.224%
33	New York	47,214	18,896,255	465	86,481	63,108	23,373	0.458%	0.334%
34	North Carolina	48,711	8,533,414	509	29,571	20,769	8,802	0.347%	0.243%
35	North Dakota	68,976	630,131	96	1,614	1,182	432	0.256%	0.188%
36	Ohio	40,948	9,782,447	536	28,024	19,589	8,435	0.286%	0.200%
37	Oklahoma	68,667	3,523,553	298	10,446	6,997	3,449	0.296%	0.199%
38	Oregon	95,997	3,107,327	145	6,924	4,920	2,004	0.223%	0.158%
39	Pennsylvania	44,817	8,097,970	715	27,006	22,756	4,250	0.333%	0.281%
40	Rhode Island	1,045	1,074,295	43	3,094	2,473	621	0.288%	0.230%
41	South Carolina	30,109	4,188,882	358	14,592	10,567	4,025	0.348%	0.252%
42	South Dakota	75,885	761,402	151	2,234	1,362	872	0.293%	0.179%
43	Tennessee	41,217	5,898,401	443	24,189	15,585	8,604	0.410%	0.264%
44	Texas	261,797	22,478,824	996	79,415	49,119	30,296	0.353%	0.219%
45	Utah	82,144	2,373,842	123	7,062	4,525	2,537	0.297%	0.191%
46	Vermont	9,250	371,894	64	1,409	1,065	344	0.379%	0.286%
47	Virginia	39,594	7,456,600	276	22,105	17,011	5,094	0.296%	0.228%
48	Washington	66,544	6,197,043	247	14,008	9,825	4,183	0.226%	0.159%
49	West Virginia	24,077	1,805,840	342	4,086	3,177	909	0.226%	0.176%
50	Wisconsin	54,310	5,504,848	367	17,977	12,839	5,138	0.327%	0.233%
51	Wyoming	97,100	504,265	67	1,966	1,279	687	0.390%	0.254%
	US Totals	3,537,437	278,433,063	14,254	970,588	675,734	294,854	0.349%	0.243%

Table 5-2 US Law Enforcement Employees and Officers
(Source: FBI “Crime in United States” Report, 2004, www.fbi.gov, and author research and calculations)

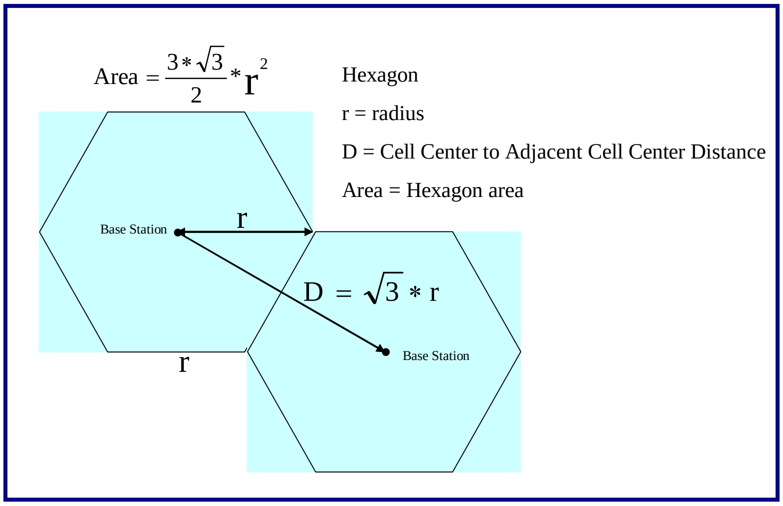


Figure 5-2 Relationships between Site Area and Radius: Hexagon Area
(Source: Author)

State	Population	POP Den	sq. miles	Sites	sq. miles per site	Average radius	Band
California	31,273,858	200.5	155,959	1025	152.16	7.65	VHF HB, 800 MHz Hybrid
California	31,273,858	200.5	155,959	2500	62.38	4.90	800 MHz
Colorado	4,443,898	42.8	103,717	171	606.53	15.28	800 MHz
Florida	17,395,608	322.3	53,972	170	317.48	11.05	800 MHz
Missouri	5,732,783	83.2	68,886	17	4052.12	39.49	VHF Low Band
Missouri	5,732,783	83.2	68,886	250	275.54	10.30	800 MHz
New York	16,900,000	357.9	47,214	1000	47.21	4.26	800 MHz / P25 VHF High Band
Texas	22,478,824	85.9	261,797	700	374.00	12.96	VHF HB

Table 5-3 Reported Number of Sites by States
(Source: Interviews in Section 4 and State of California PRISM CBA Report)

For reference, Figure 5-3 calculates coverage area as per Figure 5-2 in square miles versus radius assuming a hexagon for radii to 30 miles.

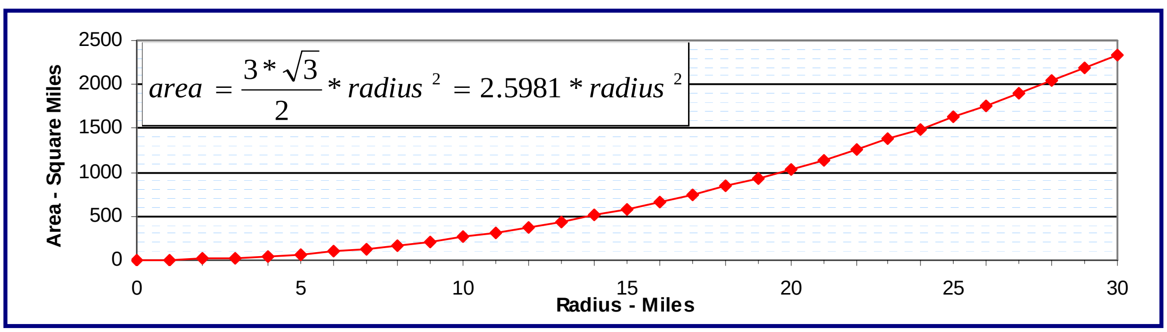


Figure 5-3 hexagon - Radius versus Square Miles
(Source: Author calculation)

In interviews consistent input was received that public safety typically deploys omni directional sites and infrequently uses directional antenna only in special situations such as canyons, valleys, etc. Unlike commercial cellular systems, public safety does not appear to have significant use of sectors. Public safety does make significant use of simulcast (i.e., simultaneously transmit the same signal at multiple sites, requiring timing/synchronization of signals) to make the data available to multiple users (multicast or one to many) over a wide area. Talkgroups are established for users with common organizational and functional affiliations. The California PRISM system presented in Table 4-4 and Table 4-6 provides examples for systems with simulcast specifically delineated.

To develop representative cost data we use the methodology of the California PRISM in Table 4-4, but with the more recent information from the State of Texas estimate in Table 4-13. Texas appears to be a representative state for developing average cost data as Texas is the second most populous state (behind California) and the second largest geographic land area state (behind Alaska). Texas has significant urban population centers (e.g., Houston, Dallas/Fort Worth, Austin, and San Antonio) as well as significant rural areas. Our methodology for this estimate will be as follows:

1. Develop representative (Table 5-4) cost loaded estimates for average cost per site including central equipment, consoles, etc. and related services; and average terminal costs. We will then apply these average costs to all 50 states to develop estimates for the US.
2. The California PRISM and State of Texas example systems are for state agency only systems. The widely verified Erlang methods indicate that more channels allow higher percent utilization at equivalent Grade of Service (GOS). Thus, we assume that 3x the number of channels per site are required for a total public Sector communication system. Specifically, we use 18 channels per 700/800 MHz site and 4 channels per VHF site.
3. Additionally, we assume that shared Federal, State, and local systems require approximately 25% more sites than a State-only system. We received consistent input that State systems are typically designed for mobile coverage and that many urban areas require portable, often in-building, coverage. Additional capacity is also provided with additional sites.
4. We assume that each State's total Public Sector communication terminals count is 5x the Law Enforcement count. Based on analysis and various industry input, we assume as calculated in Table 5-4 that:
    a. Each sworn officer has a mobile terminal and 50% have a portable.
    b. 10% of civilian employees have similar mobile and portable terminal counts.
    c. Approximately, 40% of total terminals are portable and 60% are mobile.
    d. Approximately, 30% of terminals are high tier cost and 70% are low tier cost.
    e. A similar terminal mix applies to the total Public Sector market.
    f. As calculated in the table, we use a 38.3% overhead for terminal purchases based on the user average radio cost figures in the table (e.g., $3,915, $3,285, $2,650, and $2,444).
5. For Infrastructure, we assume as calculated in Table 5-4 that:
    a. The average cost per site is $1.9 Million.
    b. The average cost per console is $55,000. The number of consoles per terminal is .032% (e.g. 125/(70401+46934+164268+109512).

c. The average coverage per site is 300 square miles or 10.7 miles hexagon coverage radius. We will use actual available data in Table 5-3 for the states interviewed.
d. Table 5-5 presents state-by-state and total US cost estimates for an upgraded shared Public Sector Communication Systems based on the methodology discussed above and the parameters extracted from Table 5-4.

State of Texas Statistics	Population	Square Miles	Population Density (POP/Sq. Mi.)	Agencies	Total Employees	Total Officers	Total Civilians	Portable Terminals	Mobile Terminals
Texas State Statistics and Law Enforcement Data	22,478,824	261,797.00	85.86	996	79,415	49,119	30,296	31,289	46,934
Texas Public Sector Employees and Terminal Estimates					397,075	245,595	151,480	156,446	234,669

Site and Channel Estimates	Sites			Channels per site		Total Channels		
	Total	800/700 MHz	VHF	800/700 MHz	VHF	800 MHz	VHF	Total
	700	595	105	18	4	10,710	420	11,130

Estimated Terminal and Infrastructure Budgetary Costs Hybrid VHF-700/800 MHz Radio Infrastructur		**Per Unit Cost**			**Total Cost**			**Category**
One Time Cost	Units	-10%	Average	+25%	-10%	Average	+25%	
Voice Radio System								
Fixed Voice Infrastructure								
Fixed Transceivers & antenna systems (Assume 700 sites, 15% VHF)								
700 or 800 MHz 18 channels per site, trunked, assume 595 Sites)	10,710	$ 24,660	$ 27,400	$ 34,250	$ 264,108,600	$ 293,454,000	$ 366,817,500	Site Equipment
VHF (4 channels per site, conventional - 105 Sites)	420	$ 14,000	$ 15,556	$ 19,250	$ 5,880,000	$ 6,533,333	$ 8,085,000	Site Equipment
In-Building Bi-Directional Amp/Antenna System	95	$ 40,500	$ 45,000	$ 56,250	$ 3,847,500	$ 4,275,000	$ 5,343,750	Site Equipment
System Controllers	23	$ 1,125,000	$ 1,250,000	$ 1,562,500	$ 25,875,000	$ 28,750,000	$ 35,937,500	Site Equipment
Site Controllers	700	$ 54,000	$ 60,000	$ 75,000	$ 37,800,000	$ 42,000,000	$ 52,500,000	Core Network
Site Electrical and Alarm Systems	700	$ 37,800	$ 42,000	$ 44,450	$ 26,460,000	$ 29,400,000	$ 31,115,000	Core Network
Consoles/Console Interfaces	700	$ 37,000	$ 41,111	$ 52,500	$ 25,900,000	$ 28,777,778	$ 36,750,000	Site Equipment
Regional Operation Facilities	12	$ 290,000	$ 322,222	$ 409,700	$ 3,480,000	$ 3,866,667	$ 4,916,400	Backhaul
Central Operation Facilities	3	$ 475,000	$ 527,778	$ 659,722	$ 1,425,000	$ 1,583,333	$ 1,979,166	Backhaul
Microwave Paths (includes equip. and antenna systems)	700	$ 315,000	$ 350,000	$ 437,500	$ 220,500,000	$ 245,000,000	$ 306,250,000	Backhaul
Minor Site Upgrades (to 15% of total sites)	245	$ 67,500	$ 75,000	$ 93,750	$ 16,537,500	$ 18,375,000	$ 22,968,750	Backhaul
Major Site Upgrades (to 35% of total sites)	350	$ 180,000	$ 200,000	$ 250,000	$ 63,000,000	$ 70,000,000	$ 87,500,000	Site Equipment
New Sites including acquisition (50% of total Sites)	105	$ 405,000	$ 450,000	$ 562,500	$ 42,525,000	$ 47,250,000	$ 59,062,500	Site Equipment
Design, Configuration, Project Management (14% of equipment)					$ 86,138,654	$ 95,709,616	$ 118,957,204	Site Equipment
Installation/Integration/Training (25% of equipment)					$ 153,819,025	$ 170,910,028	$ 212,423,579	Site Equipment
Spare Equipment / Parts (4% of equipment)					$ 24,611,044	$ 27,345,604	$ 33,987,773	Site Equipment
Implementation Support (6% of Equipment & Services)					$ 52,790,689	$ 58,656,322	$ 72,903,772	Site Equipment
Contingency (15% of equipment and services)					$ 158,204,702	$ 175,783,002	$ 218,624,684	Site Equipment
Subtotal					**$ 1,212,902,714**	**$ 1,347,669,682**	**$ 1,676,122,578**	
User Equipment								
Mobile Radios (High Tier - avg. VHF-700 MHz) *	70,401	$ 3,915	$ 4,350	$ 5,438	$ 275,618,741	$ 306,243,045	$ 382,839,007	Terminal
Portable Radio (High Tier - avg. VHF-700 MHz) *	46,934	$ 3,285	$ 3,650	$ 4,565	$ 154,177,533	$ 171,308,370	$ 214,252,797	Terminal
Mobile Radios (Low Tier - avg. VHF-700 MHz) *	164,268	$ 2,650	$ 2,944	$ 3,680	$ 435,310,995	$ 483,678,883	$ 604,507,344	Terminal
Portable Radio (Low Tier - avg. VHF-700 MHz) *	109,512	$ 2,200	$ 2,444	$ 3,055	$ 240,926,840	$ 267,696,489	$ 334,559,771	Terminal
Control Stations / Remote Control Units **	1,875	$ 5,400	$ 6,000	$ 7,500	$ 10,125,000	$ 11,250,000	$ 14,062,500	Terminal
Console Upgrades	125	$ 49,500	$ 55,000	$ 68,750	$ 6,187,500	$ 6,875,000	$ 8,593,750	Console
Installation / Integration / Training (10% of Equipment) **				.	$ 112,234,661	$ 124,705,179	$ 155,881,517	Terminal
Spare Equipment / Parts (3% of Equipment) **					$ 33,670,398	$ 37,411,554	$ 46,764,455	Terminal
Implementation Support (6% of Equipment & Services) **					$ 67,340,797	$ 74,823,107	$ 93,528,910	Terminal
Contingency (15% of equipment and services) **					$ 200,338,870	$ 222,598,744	$ 278,248,508	Terminal
Subtotal					**$ 1,535,931,334**	**$ 1,706,590,371**	**$ 2,133,238,558**	
* Direct Terminal costs, ** Indirect Terminal Costs								
Total Voice Radio System					**$ 2,748,834,048**	**$ 3,054,260,053**	**$ 3,809,361,137**	

Infrastructure Cost per Site Data	**Average cost per Site**			**Total Cost**			
	-10%	Average	+25%	-10%	Average	+25%	
Site Infrastructure	$ 1,295,286	$ 1,439,207	$ 1,794,848	$ 906,700,214	$ 1,007,444,682	$ 1,256,393,262	Site Equipment
Backhaul	$ 345,632	$ 384,036	$ 480,163	$ 241,942,500	$ 268,825,000	$ 336,114,316	Backhaul
Core Network	$ 91,800	$ 102,000	$ 119,450	$ 64,260,000	$ 71,400,000	$ 83,615,000	Core Network
Console	$ 8,839	$ 9,821	$ 12,277	$ 6,187,500	$ 6,875,000	$ 8,593,750	Console
Terminal Equipment				$ 1,529,743,834	$ 1,699,715,371	$ 2,124,644,808	Terminal
Total	**$ 1,741,557**	**$ 1,935,064**	**$ 2,406,738**	**$ 2,748,834,048**	**$ 3,054,260,053**	**$ 3,809,361,137**	

Terminal and Console Data	**Average cost per Terminal**			**Total Terminal Cost**		
	-10%	Average	+25%	-10%	Average	+25%
Terminal Equipment direct	$ 2,828	$ 3,142	$ 3,928	$ 1,106,034,109	$ 1,228,926,787	$ 1,536,158,919
Terminal Equipment Indirect	$ 1,083	$ 1,204	$ 1,505	$ 423,709,725	$ 470,788,584	$ 588,485,890
Terminal Equipment Total	$ 3,911	$ 4,346	$ 5,432	**$ 1,529,743,834**	**$ 1,699,715,371**	**$ 2,124,644,808**
Terminal Overhead		**38.3%**				
		Average cost Per Console			**Total Console Cost**	
Console Equipment	**$ 49,500**	**$ 55,000**	**$ 68,750**	**$ 6,187,500**	**$ 6,875,000**	**$ 8,593,750**

Table 5-4 Representative Public Sector Communication System Costs

(Source: Author estimates based on State of Texas example and cost parameters in Table 4-13)

US Public Sector Market

	State	Population	Square Miles	Population Density (POP/Sq. Mi.)	Total Law Enforcement Employees	Total Law Enf. Off.	Total Law Enf. Civilians	Total Public Sector Terminals	Portable Terminals	Mobile Terminals	Average Square Miles per Site	Base Station Sites	Average Cost per Site	Cost Portable Terminals	Cost Mobile Terminals	Cost Base Station Equipment	Total Cost: Terminals & BTS
1	Alabama	4,162,261	50,744	82.02	14,476	9,472	5,004	74,798	29,919	44,879	300	170	$ 1,900,000	$ 116,014,381	$ 208,753,940	$ 323,000,000	$ 647,768,322
2	Alaska	655,435	571,951	1.15	1,896	1,213	683	9,615	3,846	5,769	300	1,908	$ 1,900,000	$ 14,913,310	$ 26,834,709	$ 3,625,200,000	$ 3,666,948,018
3	Arizona	5,627,161	113,635	49.52	19,809	11,317	8,492	91,253	36,501	54,752	300	380	$ 1,900,000	$ 141,536,847	$ 254,678,551	$ 722,000,000	$ 1,118,215,398
4	Arkansas	2,685,784	52,068	51.58	7,826	5,234	2,592	41,205	16,482	24,723	300	175	$ 1,900,000	$ 63,910,860	$ 114,999,915	$ 332,500,000	$ 511,410,775
5	California	31,273,858	155,959	200.53	112,584	73,864	38,720	583,020	233,208	349,812	153	1,025	$ 1,000,000	$ 904,290,979	$ 1,627,162,971	$ 1,025,000,000	$ 3,556,453,950
6	Colorado	4,443,898	103,717	42.85	15,446	10,528	4,918	82,650	33,060	49,590	607	171	$ 1,900,000	$ 128,193,972	$ 230,669,650	$ 324,900,000	$ 683,763,622
7	Connecticut	3,503,604	4,844	723.29	9,701	7,898	1,803	60,593	24,237	36,356	300	17	$ 1,900,000	$ 93,981,769	$ 169,108,903	$ 32,300,000	$ 295,390,672
8	Delaware	830,364	1,954	424.96	3,195	2,263	932	17,678	7,071	10,607	300	8	$ 1,900,000	$ 27,418,620	$ 49,336,512	$ 15,200,000	$ 91,955,132
9	District of	553,523	61	9,074.15	4,876	4,164	712	31,770	12,708	19,062	300	1	$ 1,900,000	$ 49,276,739	$ 88,667,572	$ 1,900,000	$ 139,844,311
10	Florida	17,395,608	53,927	322.58	72,106	44,037	28,069	351,330	140,532	210,798	318	170	$ 1,900,000	$ 544,929,075	$ 980,534,401	$ 323,000,000	$ 1,848,463,477
11	Georgia	8,125,492	57,906	140.32	29,302	21,270	8,032	165,555	66,222	99,333	300	194	$ 1,900,000	$ 256,783,460	$ 462,050,986	$ 368,600,000	$ 1,087,434,446
12	Hawaii	1,262,840	6,423	196.61	3,427	2,712	715	20,880	8,352	12,528	300	22	$ 1,900,000	$ 32,385,845	$ 58,274,438	$ 41,800,000	$ 132,460,283
13	Idaho	1,384,946	82,747	16.74	3,620	2,444	1,176	19,215	7,686	11,529	300	277	$ 1,900,000	$ 29,803,354	$ 53,627,554	$ 526,300,000	$ 609,730,907
14	Illinois	12,645,893	55,584	227.51	50,174	36,432	13,742	283,553	113,421	170,132	300	186	$ 1,900,000	$ 439,803,039	$ 791,372,729	$ 353,400,000	$ 1,584,575,768
15	Indiana	5,991,832	35,867	167.06	17,109	10,769	6,340	85,523	34,209	51,314	300	121	$ 1,900,000	$ 132,649,352	$ 238,686,572	$ 229,900,000	$ 601,235,924
16	Iowa	2,943,984	55,869	52.69	7,449	4,959	2,490	39,060	15,624	23,436	300	187	$ 1,900,000	$ 60,583,866	$ 109,013,388	$ 355,300,000	$ 524,897,254
17	Kansas	2,688,942	81,815	32.87	9,966	7,144	2,822	55,703	22,281	33,422	300	274	$ 1,900,000	$ 86,397,153	$ 155,461,297	$ 520,600,000	$ 762,458,450
18	Kentucky	4,087,276	39,728	102.88	10,164	7,655	2,509	59,295	23,718	35,577	300	133	$ 1,900,000	$ 91,969,287	$ 165,487,682	$ 252,700,000	$ 510,156,969
19	Louisiana	4,279,321	43,562	98.24	21,439	16,563	4,876	127,883	51,153	76,730	300	146	$ 1,900,000	$ 198,351,671	$ 356,910,001	$ 277,400,000	$ 832,661,672
20	Maine	1,314,897	30,862	42.61	2,892	2,194	698	16,980	6,792	10,188	300	104	$ 1,900,000	$ 26,336,765	$ 47,389,845	$ 197,600,000	$ 271,326,610
21	Maryland	5,556,884	9,774	568.54	19,483	14,897	4,586	115,170	46,068	69,102	300	34	$ 1,900,000	$ 178,633,995	$ 321,430,413	$ 64,600,000	$ 564,664,408
22	Massachusetts	6,340,152	7,840	808.69	19,466	16,124	3,342	123,443	49,377	74,066	300	27	$ 1,900,000	$ 191,465,025	$ 344,518,310	$ 51,300,000	$ 587,283,335
23	Michigan	10,071,760	56,804	177.31	27,656	20,220	7,436	157,230	62,892	94,338	300	190	$ 1,900,000	$ 243,871,000	$ 438,816,565	$ 361,000,000	$ 1,043,687,566
24	Minnesota	4,960,204	79,610	62.31	12,572	8,147	4,425	64,425	25,770	38,655	300	266	$ 1,900,000	$ 99,926,154	$ 179,805,109	$ 505,400,000	$ 785,131,263
25	Mississippi	2,573,607	46,907	54.87	8,857	5,527	3,330	43,950	17,580	26,370	300	157	$ 1,900,000	$ 68,168,482	$ 122,660,994	$ 298,300,000	$ 489,129,476
26	Missouri	5,732,783	68,886	83.22	19,073	13,450	5,623	105,098	42,039	63,059	276	250	$ 1,900,000	$ 163,011,082	$ 293,318,858	$ 475,000,000	$ 931,329,940
27	Montana	926,865	145,552	6.37	2,761	1,626	1,135	13,050	5,220	7,830	300	486	$ 1,900,000	$ 20,241,153	$ 36,421,524	$ 923,400,000	$ 980,062,677
28	Nebraska	1,714,366	76,872	22.30	4,803	3,443	1,360	26,843	10,737	16,106	300	257	$ 1,900,000	$ 41,633,959	$ 74,915,307	$ 488,300,000	$ 604,849,265
29	Nevada	2,334,771	109,826	21.26	8,045	4,758	3,287	38,153	15,261	22,892	300	367	$ 1,900,000	$ 59,176,292	$ 106,480,627	$ 697,300,000	$ 862,956,919
30	New Hampshire	985,947	8,968	109.94	2,644	2,005	639	15,518	6,207	9,311	300	31	$ 1,900,000	$ 24,068,360	$ 43,308,122	$ 58,900,000	$ 126,276,482
31	New Jersey	8,433,144	7,417	1,137.00	40,195	31,313	8,882	241,515	96,606	144,909	300	26	$ 1,900,000	$ 374,600,933	$ 674,049,372	$ 49,400,000	$ 1,098,050,305
32	New Mexico	1,758,428	121,356	14.49	5,373	3,944	1,429	30,653	12,261	18,392	300	406	$ 1,900,000	$ 47,543,445	$ 85,548,717	$ 771,400,000	$ 904,492,162
33	New York	18,896,255	47,214	400.23	86,481	63,108	23,373	490,845	196,338	294,507	48	1,000	$ 1,000,000	$ 761,323,292	$ 1,369,909,795	$ 1,000,000,000	$ 3,131,233,087
34	North Carolina	8,533,414	48,711	175.18	29,571	20,769	8,802	162,375	64,950	97,425	300	163	$ 1,900,000	$ 251,851,133	$ 453,175,856	$ 309,700,000	$ 1,014,726,989
35	North Dakota	630,131	68,976	9.14	1,614	1,182	432	9,195	3,678	5,517	300	231	$ 1,900,000	$ 14,261,870	$ 25,662,522	$ 438,900,000	$ 478,824,392
36	Ohio	9,782,447	40,948	238.90	28,024	19,589	8,435	153,248	61,299	91,949	300	137	$ 1,900,000	$ 237,693,959	$ 427,701,721	$ 260,300,000	$ 925,695,680
37	Oklahoma	3,523,553	68,667	51.31	10,446	6,997	3,449	55,065	22,026	33,039	300	230	$ 1,900,000	$ 85,408,361	$ 153,682,085	$ 437,000,000	$ 676,090,446
38	Oregon	3,107,327	95,997	32.37	6,924	4,920	2,004	38,408	15,363	23,045	300	321	$ 1,900,000	$ 59,571,808	$ 107,192,312	$ 609,900,000	$ 776,664,121
39	Pennsylvania	8,097,970	44,817	180.69	27,006	22,756	4,250	173,858	69,543	104,315	300	150	$ 1,900,000	$ 269,661,022	$ 485,222,610	$ 285,000,000	$ 1,039,883,632
40	Rhode Island	1,074,295	1,045	1,028.03	3,094	2,473	621	19,020	7,608	11,412	300	4	$ 1,900,000	$ 29,500,899	$ 53,083,324	$ 7,600,000	$ 90,184,224
41	South Carolina	4,188,882	30,109	139.12	14,592	10,567	4,025	82,275	32,910	49,365	300	101	$ 1,900,000	$ 127,612,329	$ 229,623,055	$ 191,900,000	$ 549,135,384
42	South Dakota	761,402	75,885	10.03	2,234	1,362	872	10,875	4,350	6,525	300	254	$ 1,900,000	$ 16,867,628	$ 30,351,270	$ 482,600,000	$ 529,818,898
43	Tennessee	5,898,401	41,217	143.11	24,189	15,585	8,604	123,345	49,338	74,007	300	138	$ 1,900,000	$ 191,313,798	$ 344,246,195	$ 262,200,000	$ 797,759,994
44	Texas	22,478,824	261,797	85.86	79,415	49,119	30,296	391,118	156,447	234,671	374	700	$ 1,900,000	$ 606,641,328	$ 1,091,578,185	$ 1,330,000,000	$ 3,028,219,513
45	Utah	2,373,842	82,144	28.90	7,062	4,525	2,537	35,843	14,337	21,506	300	275	$ 1,900,000	$ 55,593,375	$ 100,033,599	$ 522,500,000	$ 678,126,974
46	Vermont	371,894	9,250	40.20	1,409	1,065	344	8,250	3,300	4,950	300	32	$ 1,900,000	$ 12,796,131	$ 23,025,101	$ 60,800,000	$ 96,621,233
47	Virginia	7,456,600	39,594	188.33	22,105	17,011	5,094	131,408	52,563	78,845	300	133	$ 1,900,000	$ 203,819,109	$ 366,747,999	$ 252,700,000	$ 823,267,107
48	Washington	6,197,043	66,544	93.13	14,008	9,825	4,183	76,830	30,732	46,098	300	223	$ 1,900,000	$ 119,166,883	$ 214,426,488	$ 423,700,000	$ 757,293,371
49	West Virginia	1,805,840	24,077	75.00	4,086	3,177	909	24,510	9,804	14,706	300	81	$ 1,900,000	$ 38,016,143	$ 68,405,483	$ 153,900,000	$ 260,321,626
50	Wisconsin	5,504,848	54,310	101.36	17,977	12,839	5,138	100,148	40,059	60,089	300	182	$ 1,900,000	$ 155,333,403	$ 279,503,797	$ 345,800,000	$ 780,637,200
51	Wyoming	504,265	97,100	5.19	1,966	1,279	687	10,110	4,044	6,066	300	325	$ 1,900,000	$ 15,681,077	$ 28,216,215	$ 617,500,000	$ 661,397,292
	US Totals	278,433,063	3,537,437	78.71	970,588	675,734	294,854	5,289,323	2,115,729	3,173,594	275.4	12,846	$ 1,758,127	$ 8,203,983,776	$14,762,083,145	$ 22,584,900,000	$ 45,550,966,921

Table 5-5 Estimated US Public Sector Radio Equipment Replacement Costs
(Source: Author based on FBI “Crime in United States” data in Table 5-2 and estimates in Table 5-4, see notes below)

Notes for Table 5-5:

1. The number of sites for the States of California, Colorado, Florida, Missouri, New York, and Texas are based on interview input (PRISM report for California) as opposed to the 300 Square Mile average coverage area estimated for other states (see Table 5-3).
2. The number of sites for the State of New York is 1000 sites for an average coverage area of 48 square miles. As this is significantly different than our averages, the average cost per site for New York is reduced to $1 Million per site.
3. The number of sites for the State of California is 1025 sites for an average coverage area of 7.65 square miles. As this is significantly different than our averages, the average cost per site for California is reduced to $1 Million per site.

Obviously, an estimated $45.6 Billion estimate as per Table 5-5 to upgrade US Public Sector communication systems is a very large number and will be difficult to fund even over a 10 to 15 year time frame. We are sure that interested stakeholders will want to create their own sanity checks on such a large number. To aid in this, we will present our sanity checks and what-ifs. Perhaps the first sanity check should be to re-state the average square miles of coverage and hexagon radius this US estimate. Based on an estimated US 12,846 sites and 3,537,434 square miles the average coverage area per site is 275.4 square miles with an average hexagon site radius of 10.3 miles. Obviously, more populous area (e.g. urban, suburban, etc.) would have sites with less square miles coverage and radius and more than 18 channels per site to provide greater capacity and greater cost. Similarly, many rural areas would have sites with more square miles coverage and radius and fewer channels per site to provide less capacity and with less cost.

Of coarse another significant sanity check is a "what if" analysis with various other average cost per terminal and average cost per site. Table 5-7 presents this analysis for terminal costs varying from an average of $500 to $4,500 per terminal and an average cost per site varying from $0.5 Million to $2.5 Million. At a $500 average terminal cost and an average $1 Million per site cost the total upgrade cost would be $15.5 Billion, whereas if the average per site cost is $0.5 Million the total upgrade cost estimate would be $9.1 Billion. These "what ifs" provide targets for potential cost reductions that probably should focus on Non-Recurring Engineering (NRE) costs for a smaller market compared to cellular.

Another sanity check is available comparisons with commercial cellular systems. Table 5-6 presents data for the two biggest US cellular operators Cingular and Verizon Wireless. Cellular operators typically provide data on population coverage of their networks as this best represents their financial opportunities. Area coverage is typically not provided. Using the total US square miles from Table 5-5, the average square miles per site and average radius are calculated. The smaller cellular site coverage areas and radii are not surprising as mature cellular networks are driven by capacity requirements with typical peak loading of 80-90%. Cingular acquired AT&T Wireless in 2004 and has a higher site count (less than roughly 2X after adjusting for decommissioned sites) than might be otherwise expected.

	Subscriber (M) *	% Penetration *	Cell Sites *	Subscribers per Site **	Square Miles per Site **	Radius per site (Mile) **
Cingular	55.8	20.0%	39,400	1,416.2	89.78	3.65
Verizon Wireless	53.0	19.0%	24,500	2,163.3	144.39	4.62

Table 5-6 Cellular Comparisons
(Source: Company Financial Reports *, year end 2005, and author calculations **)

US Population	US Square Miles	Population Density (Pop per square Miles)	Public Safety Agencies	Total Law Enforcement Employees	Total Public Sector Terminals	% Public Sector Terminals of US Population
278,433,063	3,537,437	78.71	14,254	970,588	5,289,323	1.90%
Avg. Cost per Terminal (loaded)	**Total Public Sector Terminal Costs**	**Average Square Miles per Site**	**Base Station Sites**	**Average Cost per Site**	**Total Cost Base Station Equipment**	**Total US Public Sector Cost**
$ 4,342	$ 22,966,066,921	$ 275	$ 12,846	$ 1,758,127	$ 22,584,900,000	$ 45,550,966,921
				$ 500,000	$ 6,423,000,000	$ 29,389,066,921
				$ 1,000,000	$ 12,846,000,000	$ 35,812,066,921
				$ 1,500,000	$ 19,269,000,000	$ 42,235,066,921
				$ 2,000,000	$ 25,692,000,000	$ 48,658,066,921
				$ 2,500,000	$ 32,115,000,000	$ 55,081,066,921
$ 500	$ 2,644,661,250			$ 1,758,127	$ 22,584,900,000	$ 25,229,561,250
$ 1,000	$ 5,289,322,500					$ 27,874,222,500
$ 1,500	$ 7,933,983,750					$ 30,518,883,750
$ 2,000	$ 10,578,645,000					$ 33,163,545,000
$ 2,500	$ 13,223,306,250					$ 35,808,206,250
$ 3,000	$ 15,867,967,500					$ 38,452,867,500
$ 3,500	$ 18,512,628,750					$ 41,097,528,750
$ 4,000	$ 21,157,290,000					$ 43,742,190,000
$ 4,500	$ 23,801,951,250					$ 46,386,851,250
$ 500	$ 2,644,661,250			$ 1,500,000	$ 19,269,000,000	$ 21,913,661,250
$ 1,000	$ 5,289,322,500					$ 24,558,322,500
$ 1,500	$ 7,933,983,750					$ 27,202,983,750
$ 2,000	$ 10,578,645,000					$ 29,847,645,000
$ 2,500	$ 13,223,306,250					$ 32,492,306,250
$ 3,000	$ 15,867,967,500					$ 35,136,967,500
$ 3,500	$ 18,512,628,750					$ 37,781,628,750
$ 4,000	$ 21,157,290,000					$ 40,426,290,000
$ 4,500	$ 23,801,951,250					$ 43,070,951,250
$ 500	$ 2,644,661,250			$ 1,000,000	$ 12,846,000,000	$ 15,490,661,250
$ 1,000	$ 5,289,322,500					$ 18,135,322,500
$ 1,500	$ 7,933,983,750					$ 20,779,983,750
$ 2,000	$ 10,578,645,000					$ 23,424,645,000
$ 2,500	$ 13,223,306,250					$ 26,069,306,250
$ 3,000	$ 15,867,967,500					$ 28,713,967,500
$ 3,500	$ 18,512,628,750					$ 31,358,628,750
$ 4,000	$ 21,157,290,000					$ 34,003,290,000
$ 4,500	$ 23,801,951,250					$ 36,647,951,250
$ 500	$ 2,644,661,250			$ 500,000	$ 6,423,000,000	$ 9,067,661,250
$ 1,000	$ 5,289,322,500					$ 11,712,322,500
$ 1,500	$ 7,933,983,750					$ 14,356,983,750
$ 2,000	$ 10,578,645,000					$ 17,001,645,000
$ 2,500	$ 13,223,306,250					$ 19,646,306,250
$ 3,000	$ 15,867,967,500					$ 22,290,967,500
$ 3,500	$ 18,512,628,750					$ 24,935,628,750
$ 4,000	$ 21,157,290,000					$ 27,580,290,000
$ 4,500	$ 23,801,951,250					$ 30,224,951,250

Table 5-7 US Public Sector "What If" Cost Analysis
(Source: Author based on estimates in Table 5-5)

In our first report[24] data on US ITS communication systems and on the population counts for the US firefighter force was presented. In Table 5-8 data is presented based on updated data from the US National Fire Protection Association (NFPA). The key take-away from this data is that there is significant volunteer percentage in the US fire fighter community. We contacted several knowledgeable stakeholders in the EMS community but were repeatedly advised that the only available data is fragmented data from individual local government organizations, and no one identified a source of compiled national or even state or local data.

	Fire Departments	Firefighters Career	Volunteer	Total
1998	31,114	278,300	804,200	1,082,500
1999	30,436	279,900	785,250	1,065,150
2000	30,339	286,800	777,350	1,064,150
2001	30,020	293,600	784,700	1,078,300
2002	30,310	291,650	816,600	1,108,250
2004	30,400	305,150	795,600	1,100,750
2004, Per 1000 POPS		0.990	2.773	3.763

Table 5-8 US Firefighter Population
(Source: National Fire Protection Association; Telecoms and web site at www.NFPA.org)

Intelligent Transportation Systems (ITS) have attracted considerable interest in recent years. Significant communication infrastructure has been deployed to integrate traffic control for area-wide traffic light coordination and, more recently, to deploy freeway management systems with video cameras for video surveillance for freeway surveillance and incident management. Most US state Departments of Transportations (DOT) have highway maintenance LMR[25] systems for dispatch and coordination.

Data for US estimates of the ITS communication market was developed based on support by Larry Miller of American Association of State Highway and Transportation Officials (AASHTO). ASSHTO is the FCC’s frequency coordinator for ITS. He forwarded an email survey to state DOT communication officials who have responsibility for DOT LMR radio systems. The compiled results of this survey are presented in Table 5-9.

[24] “SDR Market Study: Market Segmentation and Sizing” by Jim Gunn, January 2005
[25] LMR – Land Mobile Radio

State	Area (Sq. Mi.)	Population	Portables	Mobiles	Infrastructure Cell Sites	Portable per 1000 POP	Mobiles per 1000 POP	Sq. Miles per cell site (95%) Coverage
Arkansas	52,068	2,710,079	1000	1000	151	0.37	0.37	327.58
Colorado	103,717	4,403,008	868	868	165	0.20	0.20	597.16
Connecticut	4,844	3,374,179	275	1675	6	0.08	0.50	766.97
Idaho	82,747	1,311,796	763	1662	102	0.58	1.27	770.68
Illinois	55,584	12,542,030	600	4500	146	0.05	0.36	361.68
Kentucky	39,728	4,068,895	1000	1000	200	0.25	0.25	188.71
Ohio	40,948	10,878,422	1100	5000	140	0.10	0.46	277.86
Tennessee	41,217	5,787,364	1209	1997	129	0.21	0.35	303.54
Texas	261,797	21,670,261	3146	9707	383	0.15	0.45	649.37
Virginia	39,594	7,292,028	1500	5000	342	0.21	0.69	109.98
Washington	66,544	6,064,698	600	3500	125	0.10	0.58	505.73
Total	788,788	80,102,760	12,061	35,909	1,889	0.15	0.45	396.69
							Avg. range	7.67 Miles

Table 5-9 ITS US DOT Communication Survey
(Source: Email Survey of Us State DOT Representatives)

6 Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ANSI	American National Standards Institute
APCO	Association of Public Safety Communication Officers
ASSP	Application Specific Standard Product
BTS	Base Station Transceiver
CAI	Common Air Interface
CII	Critical Infrastructure Industries
CMRS	Commercial Mobile Radio Service
DHS	Department of Homeland Security
DOT	Department of Transportation
EHF	Extremely High Frequency
EIA	Electronic Industry Association
EMS	Emergency Medical Service
ERP	Effective Radiated Power
ESMR	Enhanced Specialized Mobile Radio Services
ETSI	European Telecommunication Standardization Institute
FBI	Federal Bureau of Investigation (US)
FCC	Federal Communication Commission (US)
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
GHz	Giga hertz or 1 Million hertz
GOS	Grade of Service (e.g. erlang)
IACP	International Association of Chiefs of Police
IPR	Intellectual Property Rights
ITS	Intelligent Transportation Systems
ITS	NTIA Institute for Telecommunication Sciences
kHz	kilo hertz or 1,000 hertz
LF	Low Frequency
LMR	Land Mobile Radio
MESA	Mobility for Emergency and Safety Applications
MF	Medium Frequency
MHz	Mega Hertz or 1 Million hertz
NCC	National Coordination Committee
NFPA	National Fire Protection Association
NIST	National Institute of Standards and Technology
NPRM	Notice of Proposed Rule Making (US FCC)
NPSAC	National Public Safety Advisory Council
NPSPAC	National Public Safety Planning Advisory Council
NPSTC	National Public Safety Telecommunication Council
NTIA	National Institute of Standards and Technology (US)
OTAR	Over- the-Air-ReKeying
P25	Project 25, historically referred to as APCO 25
PLMR	Public Land Mobile Radio
PRISM	Public Safety Radio Integrated System Management (California)

PSRSPC	Public Safety Radio Strategic Planning Committee (CA)
PSWAC	Public Safety Wireless Advisory Committee
PTT	Push to Talk
R&D	Research and Development
R&O	Report and Order (FCC)
RF	Radio Frequency
ROM	Rough Order of Magnitude
RPC	Regional Planning Committee
SDR	Software Defined Radio
SDRF	Software Defined Radio Forum
SHF	Super High Frequency
SIEC	State Interoperability Executive Committee
SIG	Special Interest Group
SMR	Specialized Mobile Radio
TDMA	Time Division Multiple Access
Tetra	TErrestrial Trunked RAdio
TIA	Telecommunication Industry Association
TTM	Time to Market
UHF	Ultra High Frequency
VHF	Very High Frequency
VLF	Very Low Frequency