Statewide Needs Assessment and Plan for the Improvement of Public Safety Radio Communications Systems in Wisconsin

Phase II – Technical Requirements

Prepared by:

Federal Engineering, Inc.
10600 Arrowhead Dr.
Fairfax, VA 22030
703 359-8200

Table of Contents

1 Introduction 3
2 Current Wisconsin Radio Communications Systems Overview 6
2.1 State Agencies: 6
2.2 County Agencies: 8
2.3 Local Government Public Safety Agencies: 10
3 Communications System Interoperability Concepts 11
3.1 The SAFECOM Program: 15
4 Overview of FCC Regulations 17
4.1 Federal Government Spectrum Available 20
5 APCO Project 25 Digital Radio Systems 21
6 Public Safety Radio System Solutions 23
6.1 Radio Systems Infrastructure Architecture 23
6.2 Infrastructure Equipment Vendors. 28
6.3 Subscriber Radio Vendors 33
7 Analysis of Cellular System Capabilities 34
8 Computer Controller Interoperability System Approaches 37
8.1 Traditional Console Patch 37
8.2 RF Gateways with Analog Baseband Audio 39
8.3 Gateways with Digital Baseband Audio & Packet Switching 42
9 Emerging Wireless Services and Technologies 44
9.1 Hot-spot 802.11 Wi-Fi Networks 44
9.2 Public Safety 4.9 GHz Band. 47
9.3 Longer Term Technologies 50
10 Summary of Phase II 51

1 Introduction

The first phase of this Report is primarily a user needs assessment activity. The Wisconsin Emergency Management and Federal Engineering surveys, along with individual interviews, were analyzed to determine current best practices and opportunities for improvement in communications interoperability. In this second phase we provide an overview of the technologies available to address interoperability shortfalls and select some alternative approaches for in depth review. We also provide recommendations for the use of several key technologies that are critical to the ability of the State to create and maintain an improved level of interoperability across the agencies and municipalities. Federal Engineering recommends that the State adopt the following technologies and standards:

- A private land mobile radio system should be the foundation of the State's approach. The ownership of the system might be by the State or by a vendor/service provider depending on the financial terms available at the time of procurement. But a shared system, or a system based on commercial services that are also available to the public is not recommended as the primary system.
- The use of public wireless services, either based on public network dialing or on the popular "push-to-talk" capabilities offered by some vendors, should be considered to offload non-essential traffic from the dedicated system. To maximize the overall interoperability of these devices, a limited range (1 or 2) of vendors should be chosen and contracted for on a centralized basis to achieve the best possible pricing.
- The radio system should be based on digital technologies, not analog. It should also be compatible with APCO Project 25 (P25) standards. This will help insure that the next generation of subscriber units, adjuncts, systems, and interfacing capabilities will be compatible with this investment.
- The use of trunking is recommended if a detailed design and further analysis indicates capacity and/or channel limitations. ***FE*** understands that the initial trial generated some degree of confusion and did not garner unanimous support; however, the capabilities that a trunked system offer are worth considering. If selected, special care should be given to the planning and implementation of this capability, especially from the communications and training standpoints.
- The use of non-proprietary technologies is also critical to enabling competitive approaches to design and procurement. But the reality of today's market is that at some level, the systems offered by the primary manufacturers use some degree of proprietary technologies. The State can select a vendor based on functional and non-proprietary technology requirements, although the vendors will utilize proprietary interfaces and specifications as part of their overall system. ***FE*** believes that market

forces are quickly bringing competition to the subscriber unit arena, including for P25 devices.

- There are several emerging technologies that the State should consider:
  - The use of broadband wireless data technologies can provide significant improvements in the performance and availability of some applications. These systems can be done on a trial basis, in selected locations, in order to understand the operational and security implications of this alternative.
  - IP-based solutions are emerging, offered by both radio system vendors and independent firms, and enable a communications path to be established between any two devices including telephones, mobile or fixed-location data computers, public safety mobile radios, PDAs, or wireless telephones. While these systems don't offer a solution to the need for roaming coverage, they do offer the ability to establish communications linkages that were previously only dreamed of. The State should use one of these systems on a trial basis to explore further what the improvements in interoperability would be.
- There are also several computer-controlled radio switching and interconnect systems available. The State should utilize these devices in the short term for providing communications between incompatible radio frequencies at the municipal boundaries as well as for event-driven interoperability needs such as disasters (weather-related or man-made), terrorist situations, or when the coordination of a large number of responders form disparate systems is necessary. The use of these devices must be planned and rehearsed regularly. The systems chosen should be compatible with the P25 standards mentioned earlier.

Further definition of how these recommendations will fit together and be utilized will be discussed in the Phase III report.

More than technology is involved in a statewide plan for radio communications interoperability solutions. The regulatory landscape as well as the activities of standards development organizations (SDOs) must be factored into the decision making process. Longer term FCC initiatives and mandates to develop more channels for public safety use will impact every agency in Wisconsin. The radio system migration from analog to digital modulation, while just emerging in Wisconsin today, will be dominant by the year 2008. SDOs will play a key role in determining which protocols and features can be standardized in the marketplace.

The use of commercial voice and data services by public safety agencies in Wisconsin is continuing to increase. This trend is also occurring nationally. We estimated 10 to 15 percent of the dispatch and unit-to-unit voice calls with a northern Illinois county client are processed over the wireless cellular system. To

what level the cellular system can be utilized in addressing interoperability issues will be factored into our analysis of Phase II and recommendations in Phase III.

The following section, building from the surveys of Phase I, contains a brief technical overview of radio communications systems currently in Wisconsin. This section will set the stage for the review of interoperability concepts and environmental scan to follow.

2 Current Wisconsin Radio Communications Systems Overview

As FE's survey analysis in Phase I of this report noted, public safety agencies in Wisconsin mainly utilize three radio frequency bands (VHF, UHF, 800 MHz). However, the dominant frequency range for State and local agencies is the VHF band. A scan of the FCC license database indicates that all of the 15 KHz VHF public safety frequencies are licensed somewhere in the State. The percentage usage for these bands is indicated in Figure 2.1 below.

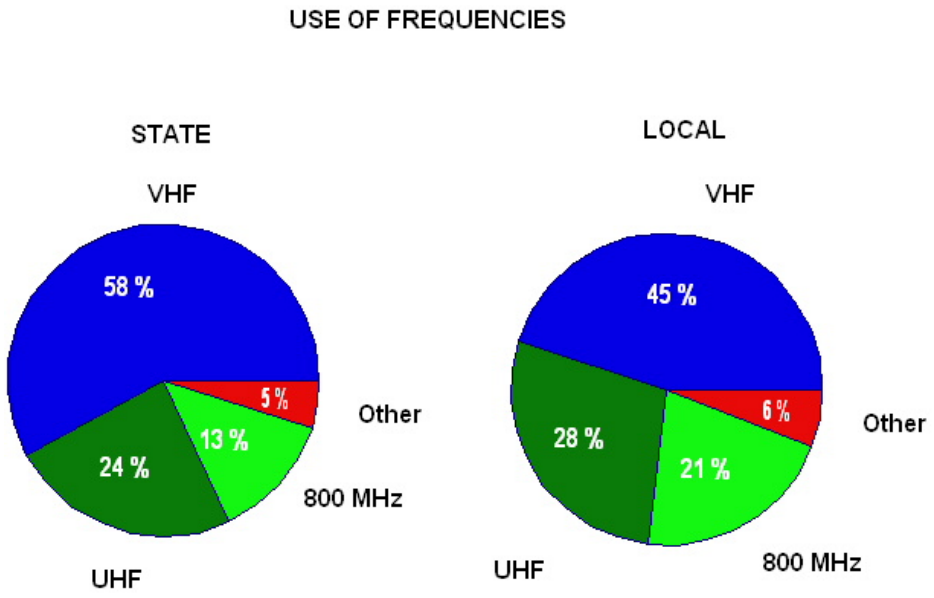

Figure 2.1 – Use of Frequency Bands in Wisconsin

As noted in the Wisconsin Public Safety Communications Survey completed in 2003, public safety agencies also utilize both conventional and trunking technologies for radio communications. However, the majority of systems in use today are analog conventional, with a few Project 25 digital systems. This section is a brief summary of statewide assets on which potential interoperability solutions could be built.

2.1 State Agencies:

The Wisconsin State Patrol (WSP), a division of the Wisconsin Department of Transportation (WDOT), administers and maintains both voice and data statewide communications systems. The voice system is a VHF analog

conventional radio communications network. The data system, known as the mobile data communications network (MDCN), supports remote access to information available from the Department of Justice (DOJ). This system operates in the VHF NTIA licensed military band and uses M/A-COM MASTR III stations at a 4,800 bps data rate. The MDCN is provided as a free service for over 135 local, state, and federal agencies. As of March 2003 there were 1254 Kenwood mobile data units on the MDCN system of which 536 were WSP. The infrastructure for these voice and data networks consists of approximately 80 tower sites that are linked together with a digital microwave backbone, which was completed in early 2003 (Figure 2.2). Technical support for this advanced network comes from the WSP Bureau of Communications, which also provides support for the Wisconsin Department of Natural Resources.

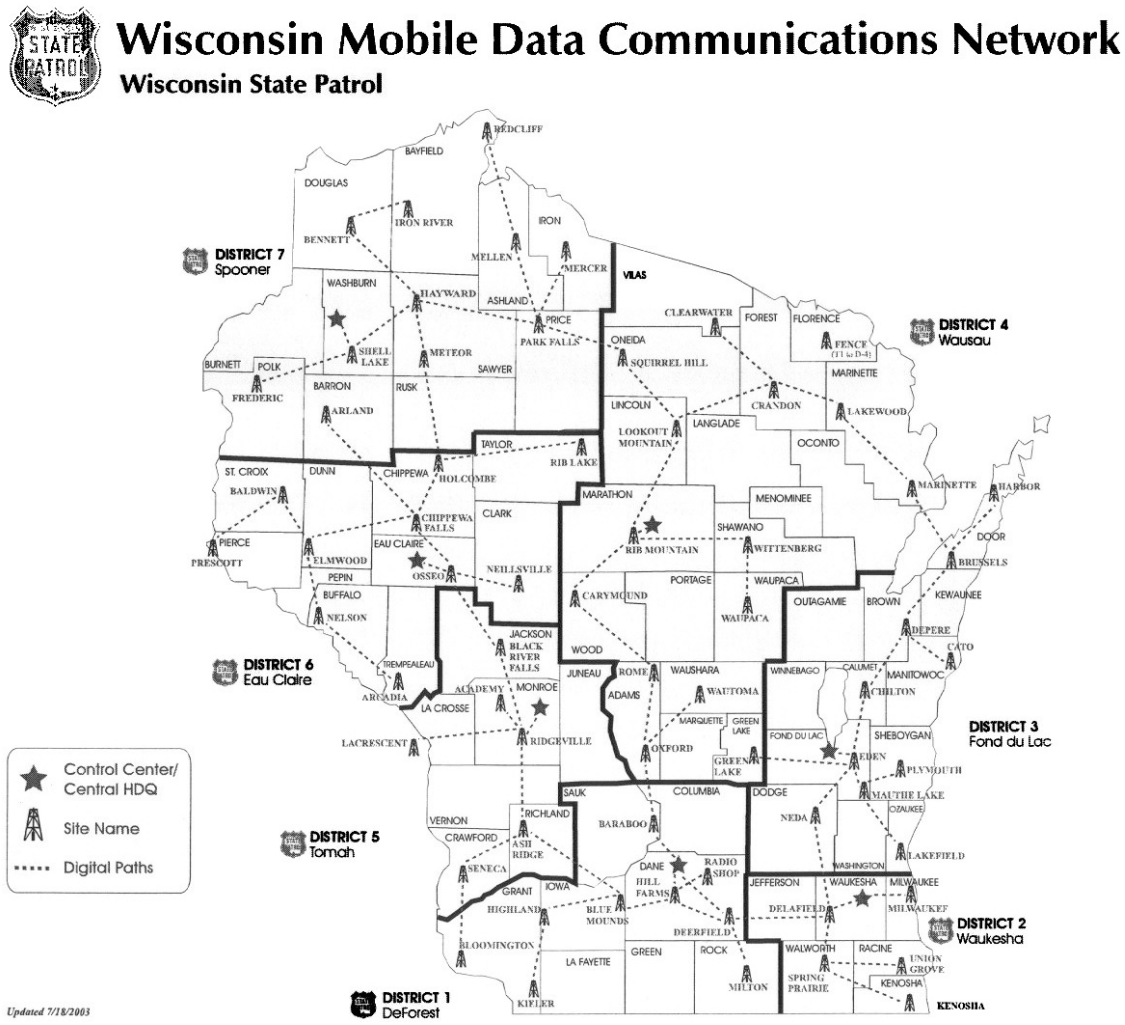

Figure 2.2 – Wisconsin State Patrol Radio Network

The WSP also manages and maintains the VHF digital trunking radio system pilot in western Wisconsin along the I90 – I94 corridor. The impetus to create this pilot came from the Wisconsin Interagency Committee on Radio Tower Sites (WICORTS), which was created in 1990. This ambitious project went on-line in October 1999 to test the operational characteristics of narrowband VHF, Project 25 digital, and trunking technologies. It is a Motorola SmartZone system with four – five channel trunking sites, located in Baraboo, Ridgeville, Black River Falls, and Chippewa Falls. The users have been a cross section of State & Local agencies. The 20 frequency pairs required were obtained from the US Army pool through a waiver with the FCC and NTIA.

The results of this test were mixed. Training and technical issues were encountered during the initial year of use. A key concern for the WSP was the operation of priority channel scan when the radio scan list contained both analog conventional and digital trunking systems. Eventually, the WSP phased out usage of the pilot system while the DNR and DOC continue to utilize it today.

The Wisconsin Emergency Management (WEM) manages seven two-frequency VHF repeaters located throughout the State. These repeaters are not interconnected, are over 20 years old, and are maintained by the WSP. Control for the stand-alone repeaters is from WEM regional offices or WEM Headquarters. Generally, the mobile coverage range from these sites is good, up to 45 miles for some.

WEM also owns a 40-foot Mobile Command Center (MCC), which is equipped with VHF, UHF, and 800 MHz radios for emergency scene communications interoperability. An ACU-1000 Intelligent Interconnect System from JPS Communications was installed last year that allows the WEM on scene commander to cross connect virtually any combination of public safety radios within the incident coverage area.

2.2 County Agencies:

The radio communications systems used by the 72 counties of Wisconsin are primarily single site VHF architecture. However, four counties do operate with 800 MHz multi-site trunking and one utilizes 800 MHz conventional. Additionally, five of the counties using conventional VHF frequencies also use simulcast transmit and receiver voting technologies for enhanced coverage. In addition, five counties also operate at least one digital channel. This information is summarized in Table 2.1 below. Less than half of the counties have WISPERN or MARC mutual aid channel base station capabilities.

Category	Nr. Of Counties	Remarks
Single Site VHF Analog	62	Many of these systems are over 20 years old.
Multi-site VHF Analog	5	Receiver Voting and Simulcast Transmit.
Multi-site 800 MHz Trunking	4	Simulcast Transmit.
Conventional 800 MHz	1	Walworth County
Have at Least One Digital Channel	5	Emerging Project 25 users.

Table 2.1 – County Radio Systems

Some of the counties have joined together to form regional data systems. An example of this is the FoxComm network in Northeastern Wisconsin, which includes the cities in and counties of Brown, Calumet, Outagamie, and Winnebago. When completed this network (Figure 2.3) will link 33 law enforcement agencies, 72 Fire Districts, and 33 EMS Districts together over an 800 MHz MDT system with one common Computer-Aided Dispatch (CAD) system. The various dispatch centers and PSAPs involved are connected together over a T1 WAN.

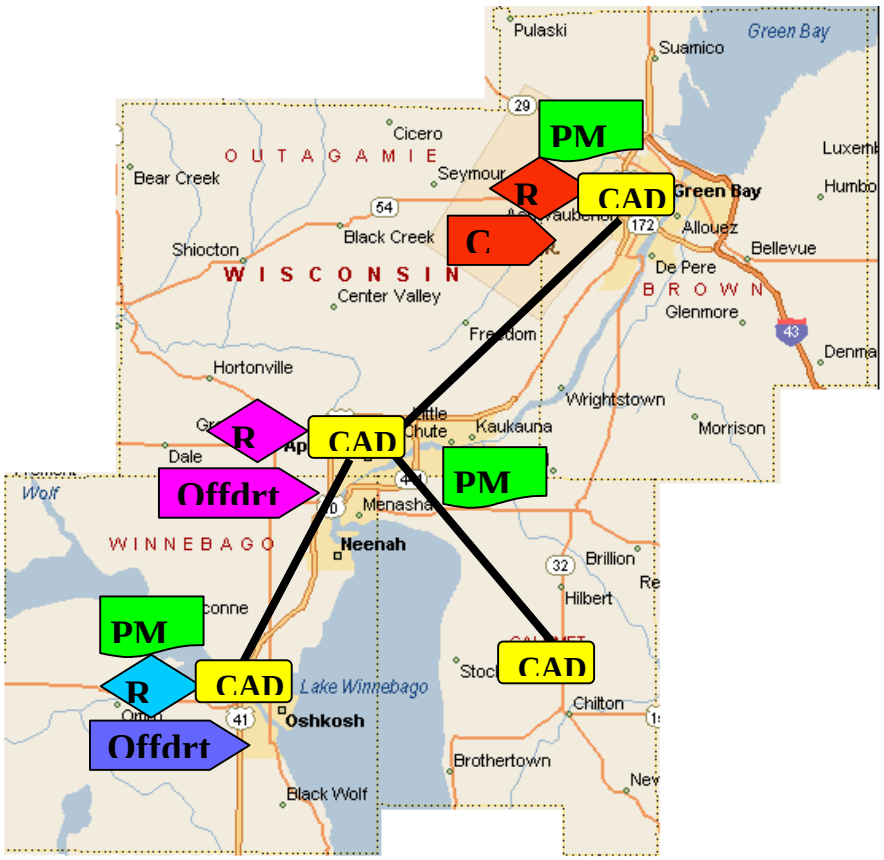

Figure 2.3 – The FoxComm Data network

2.3 Local Government Public Safety Agencies:

The cities and towns of Wisconsin are also primarily VHF frequency users. However, six of the largest cities in the State utilize 800 MHz trunking as the primary means of public safety radio communications. Also, many of the smaller towns in the counties with trunked systems share the system in the 800 MHz band.

3 Communications System Interoperability Concepts

The Federal Communications Commission has defined "interoperability" as "an essential communications link within public safety and public service wireless communications systems which permits units from two or more different entities to interact with one another and to exchange information according to a prescribed method in order to achieve predictable results."

State, county and city agencies in the State of Wisconsin, as well as other public safety entities nationwide, are being challenged with radio system interoperability issues. Over the years separate government entities have deployed radio systems on different bands and technology protocols. During this time, the tendency of government management has been to segment their system coverage to convenient geographic and organizational boundaries. A survey, done by PSWN, of more than 1,500 local and regional public safety agencies found that nearly one-third of these agencies have had difficulty responding to incidents because of a lack of wireless communications interoperability. Similar results were found in the Wisconsin Emergency Management survey (2003) and the interviews conducted by FE earlier this year.

Interoperability is very important to the FCC and it has defined standards for interoperability in the new 700 MHz public safety spectrum. The decisions the FCC has made, endorsed by both APCO and NCC (National Coordination Committee), are well defined in their Fourth Report and Order, WT Docket No. 96-86, released January 17, 2001. This docket describes a plan for the development of operational, technical and spectrum requirements for meeting Federal, State and Local public safety communication requirements through the year 2010.

Much planning has gone into defining proper management and control of the new 700 MHz public safety spectrum. The local planning for this spectrum is taking place within the Regional Planning Commissions (RPCs). In Wisconsin these committees are designated Region 54 and Region 45. This new band is the medium to long-term future. However, the present situation in the State needs to be explored for interoperability between local public safety agencies as the VHF, UHF, and 800 MHz spectrum is utilized today.

Interoperability has been recognized as a key factor in determining the success of any coordinated response. It has been the focus of improvement efforts by, local, state, and federal users since 1989. Meeting the interoperability challenge means not only identifying the appropriate communication technology, but also creating communication channels among organizations to allow for preplanning and coordination activities. PSWN, the Public Safety Wireless Network program,

which was a joint initiative of the U.S. Department of Justice and Treasury, identified three types of interoperability.

- *Day-to-day interoperability* covers routine public safety operations, such as responding to a building fire that requires backup for a neighboring fire department, or a vehicle chase that crosses between villages.

- *Mutual aid interoperability* supports a joint and immediate response to catastrophic accidents, large-scale incidents and natural disasters. It supports tactical communications in response to airplane crashes, bombings, forest fires, earthquakes, hurricanes and similar events that occur without warning.

- *Task force interoperability* supports local, state and federal agencies collaborating for an extended period of time to address a particular problem. For example, a task force might lead extended recovery operations, provide security for major events, or respond to prolonged criminal activity. These are activities that are planned in advance.

The 9-11 terrorist events in New York City and at the Pentagon again emphasized the need to public safety agencies that solutions must be found to address this problem. In these incidents, the local public safety community played a prominent role in the immediate response and throughout the recovery period. The less time responders need to spend solving the “how do I talk to the person next to me” problem during a major incident, the more they can focus on the dangerous, time critical tasks at hand.

The Public Safety Wireless Advisory Committee (PSWAC), in their very thorough final report issued September 11, 1996, found six methods or techniques that can be utilized to achieve radio system interoperability. The technical and operational solutions to improve communications interoperability generally fall into one of these categories, as follows. Many of these solutions have been in use for years, and generally work well for most scenarios. The question is to what degree does the state or the municipalities want to be ready for the catastrophic event – man-made, terrorist, or natural disaster – and be able to handle the stress that it will put on the current systems and methodologies.

1. Swap Radios:
   The simplest and most basic level of interoperability is to physically exchange radios with other agencies involved in an event. This method works well for small-scale incidents. However, it is impractical for every agency to have extra radios and charged batteries on hand for each member of every other possible agency that could appear on-scene, especially for large-scale events.

2. Talk-around:
   Talk-around provides interoperability where multiple radio users talk radio-to-radio during a localized incident on the same transmit and receive frequency, in the conventional mode. In this situation, communications are tightly bound by the air interface: the same frequency band is required and transmissions are digital-to-digital or analog-to-analog, not analog-to-digital.

3. Mutual Aid Channels:
   With mutual aid channels, responding radios talk via designated simplex frequencies similar to talk-around or dedicated repeaters, which extend their communications range and allow connection to a console dispatcher. This method requires agencies to create a channel plan and to program channels into their radios in advance of an event.

4. Gateway/console patch:
   Use of an RF/network gateway or console patch in a dispatch center are methods of connecting disparate systems of different frequency bands. One major drawback for using a gateway or console patch during an unplanned event is that there must be overlapping coverage from the respondent's systems for the gateway to be effective. To get around the requirement for overlapping coverage areas, some gateways are set-up to be transportable. This allows responders from different system types to talk to each other but does have a necessary delay to allow a technician at the scene to set up the relay.

5. System-specific roaming:
   The response of city and county responders at the Pentagon on September 11, 2001 provided an example of the system-specific roaming method of interoperability. One entity's radios are programmed to work on the other's infrastructure within a set of pre-planned channels or talkgroups. The multiple infrastructure networks provide coverage over large areas without any coverage overlap. Since users can roam from one system to the next they may enlist the help of agencies across the entire area at a moment's notice. This method requires pre-planning and system configurations to accommodate the users of the participating systems.

6. Standards-based shared system:
   The ultimate interoperability solution, which is useful for any scale of event from small to massive, is a standards-based, shared system. In this method all radios built to a standard can talk to each other via the infrastructure, or in the case of the Project 25 equipment, conventional mutual aid and talk-around also.

The federal Department of Homeland Security (DHS) has been acutely aware of the need for radio system interoperability improvements since it's creation last

year. Secretary Tom Ridge, speaking to the National Fire and Emergency Services Dinner, April 30, 2003, said the following about interoperability:

> "Helping first responders stay safe and effective and alive is our department's goal. Whether by analyzing the vulnerabilities of our critical infrastructure, enhancing hospitals capacity to treat victims of bioterrorisim, informing communities through our threat advisory system, or encouraging the next generation of homeland security products and technology. One of those is Project SAFECOM. This is our effort to ensure wireless interoperability so firefighters and other emergency responders can communicate with one another in any crisis.
>
> It is imperative that we provide ways for you to communicate across jurisdiction lines. It doesn't necessarily mean that everybody will be able to talk to everybody else at the same time, we don't want that at a time of crisis, but those that need to be connected, particularly back to the command post and to critical centers around the event, need to be part of a system that is progressive and redundant and better than we've ever designed before. With the right structure and strategy in place I think we can focus on providing the right resources."

More recently, Secretary Ridge said the following while speaking to the National Volunteer Fire Council on May 6, 2004.

> "One of the great tragedies of our response at the World Trade Center was that even within New York City, the Police Department radios couldn't transmit to the Fire Department radios. And when engine companies rushed in from nearby neighborhoods, some couplings that fit "hoses to hydrants" weren't compatible.
>
> From these disappointments and wake-up calls emerged a resolve not to let an incompatible radio frequency or a too-small/too-large piece of safety equipment impede the ability of brave men and women to save the lives of citizens -- as well as their own. That's why we're working to develop standards that fit into the National Incident Management System (NIMS) framework and improve your ability to operate effectively across county, city, and even state lines.
>
> Already, Homeland Security has identified technical specifications for a baseline interoperable communications system as the short-term solution to allow first responders to communicate by voice -- no matter what frequency they're on or mode they use.
>
> And recently, we also announced the first standards regarding personal protective equipment, in order to protect first responders against chemical, biological, radiological and nuclear hazards. These standards, which will

> assist state and local procurement officials and manufacturers, are intended to provide emergency personnel with the best available protective gear."

Secretary Ridge and the DHS are emphasizing the need to resolve these interoperability issues with standards based products, whether they are fire hose couplings, protective clothing, or radio communications equipment.

According to a report done by the National Task Force on Interoperability (February 2003), the public safety community has identified the following key issues that hamper public safety wireless communications today:

- Incompatible and aging communications equipment
- Limited and fragmented budget cycles and funding
- Limited and fragmented planning and coordination
- Limited and fragmented radio spectrum
- Limited equipment standards

In short, the Nation is heavily invested in an existing infrastructure that is largely incompatible. The SAFECOM Program, which replaced the PSWN Program in 2002, was established by the Office of Management & Budget and approved by the President's Management Council to address these public safety communications issues.

3.1 The SAFECOM Program:

In fiscal year 2002, as part of the President's Management Agenda, the White House established SAFECOM as the overarching umbrella program within the Federal Government to oversee all communication and interoperability initiatives and projects. The SAFECOM Program is managed within the Department of Homeland Security's Science and Technology Directorate. Through SAFECOM, the Federal Government is attempting to address public safety communications issues in a more coordinated, comprehensive and, therefore, effective way.

The mission of SAFECOM is to serve as the umbrella program within the Federal Government to help local, tribal, state, and federal public safety agencies improve public safety response through more effective and efficient interoperable wireless communications. Communications interoperability from the SAFECOM perspective is "the ability of public safety agencies to talk across disciplines and jurisdictions via radio communications systems, exchanging voice and/or data with one another on demand, in real time, when authorized".

SAFECOM is the first national program designed by public safety for public safety. As a public safety practitioner driven program, SAFECOM is working with existing federal communications initiatives and key public safety stakeholders to address the need to develop better technologies and processes for the cross-

jurisdictional and cross-disciplinary coordination of existing systems and future networks. SAFECOM harnesses diverse federal resources in service of the public safety community. The scope of this community is broad. The customer base includes over 44,000 local and state public safety agencies and organizations. Federal customers include over 100 agencies engaged in public safety disciplines such as law enforcement, firefighting, public health and disaster recovery. And SAFECOM makes it possible for the public safety community to leverage resources by promoting coordination and cooperation across all levels of government.

SAFECOM'S NEAR-TERM INITIATIVES:

- Develop a process to advance standards necessary to improve public safety communications and interoperability.
- Integrate coordinated grant guidance across all agencies providing grants for public safety communications and interoperability.
- Provide training and technical assistance for public safety communications and interoperability.
- Create a one-stop shop for public safety communications and interoperability.
- Research, develop, test, and evaluate existing and emerging technologies for improved public safety communications and interoperability.

SAFECOM'S LONG-TERM GOALS:

- Provide policy recommendations.
- Develop a technical foundation for public safety communications and interoperability.
- Coordinate funding assistance for public safety communications and interoperability.
- Create and implement a national training and technical assistance program.

SAFECOM, with its partners, is attempting to support a safer America through effective public safety communications. On April 26, 2004 The U.S. Department of Homeland Security's Science and Technology Directorate announced the release of the first comprehensive Statement of Requirements (SoR) document outlining future technology requirements for public safety wireless communications and interoperability. The SoR can be found at www.safecomprogram.gov.

The SoR, developed under the SAFECOM Program, marks the first time the 44,000 public safety agencies have a document that defines future requirements for communicating and sharing information -- as authorized, when and where needed, and in a manner that allows for the most effective use of that information.

4 Overview of FCC Regulations

Demand for radio frequency spectrum (radio channels) is increasing. While this valuable resource is, in theory, limitless, practical considerations, such as:

- The distance over which signals in different frequency ranges can be expected to reliably travel, and
- How many signals or channels can be placed in a given amount of spectrum

These factors do, in reality, limit the number of frequency ranges that are suitable for given forms and types of communications.

For public safety agencies in the United States, the Federal Communications Commission (FCC) is chartered with defining the criteria for use of the spectrum, including frequency assignment and technical standards for equipment, all with the benefit to the public in mind.

There are several spectrum related initiatives that impact Public Safety Radio Services and interoperability presently in process at the FCC as follows.

<u>800 MHz</u>

The 800 MHz band has been in use for nearly 25 years, having been originally reallocated from UHF Television Channels 70 through 83. More recently, interference problems have been plaguing Public Safety users of this frequency band in major metro areas, mostly (though not exclusively) attributed to the Nextel network, which uses frequencies interspersed with those assigned to Public Safety Agencies. The “Public Safety Interference Task Force” (PSITF) was created from a FCC meeting in 2000 to develop potential solutions. The FCC is committed to resolving this interference issue, but frequency realignments in the band may be required to accomplish this end. This process could require three years to accomplish and would be funded by NEXTEL. The Bureau should release their plan to resolve this issue by 3Q2004.

<u>700 MHz</u>

Starting in 1997, in association with the implementation of digital technologies for Television Broadcasting to enable High Definition television broadcasts, 10 more Television channels (UHF Channels 60 through 69) are in the process of being made available for Public Safety and Commercial interests. Once the television stations presently holding licenses for those channels can be relocated, 40% of this Spectrum (24 MHz) will be allocated to Public Safety use. Interoperability/mutual aid channels have been included in the band plan. The Regional Planning Commissions (RPCs) must submit their frequency usage plans to the FCC before local agencies can utilize this band.

The earliest that this spectrum is likely to be nationally available for use by Public Safety is December 31, 2006, as that is the date by which UHF Television stations broadcasting in Analog mode on Channels 60 to 69 are required to have completed their transition to broadcast in Digital mode on channels below 60.

VHF/UHF Narrowband Refarming

Better utilization of spectrum can also make more radio channels available. The FCC began a series of proceedings in 1992 to promote more efficient use of the radio spectrum, which has generally come to be known as the "Refarming Plan". The ultimate goal is to achieve voice channel spacing of 6.25 and 7.5 kHz, improving from the 12.5, 15 and 25 kHz spacing in present systems. The initial focus of refarming has been the VHF High Band (nominally 150-174 MHz) and the UHF Bands (nominally 450-512 MHz) but 6.25 kHz (or 7.5 kHz) per voice channel is the ultimate goal of the FCC for all systems in all Land Mobile bands.

The VHF plan will have a significant impact on public safety agencies in Wisconsin because of the predominant use of this band in the State. Referring to Figure 4.1 the "Current Channelization" diagram is typical for Wisconsin as nearly all frequencies separated by 15 KHz are licensed somewhere in the State. Transmitter distance separations are enforced in order to reduce interference.

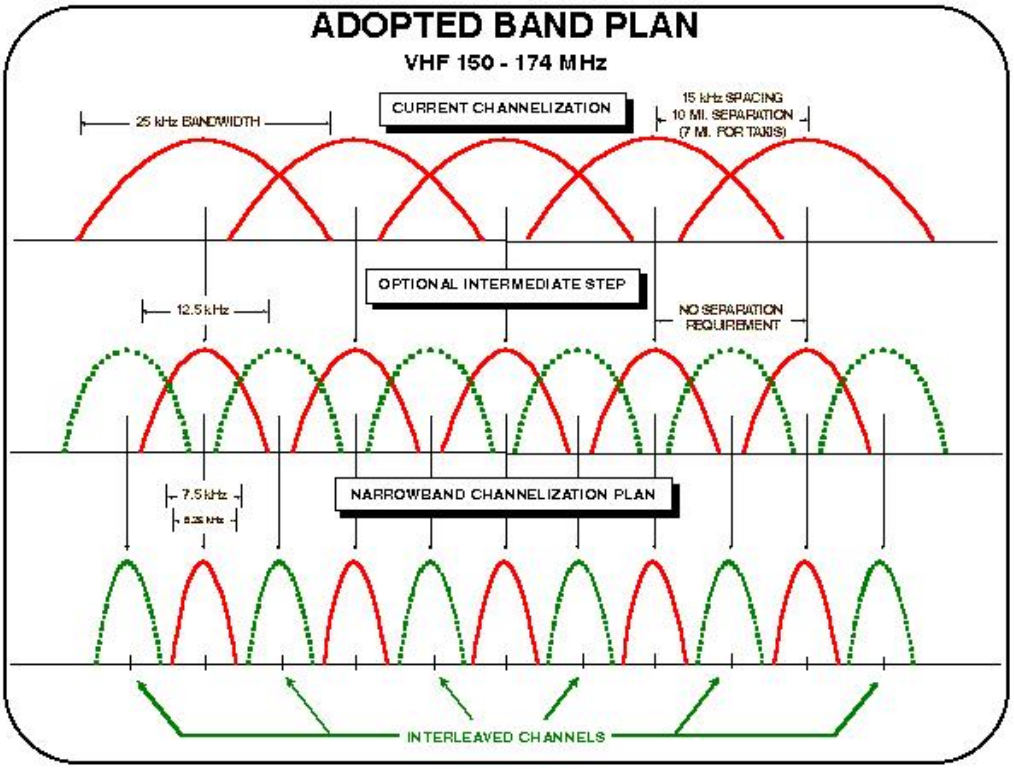

Figure 4.1 – The FCC VHF Band Plan
(Source: http://wireless.fcc.gov/services/plmrs/images/vhfband.jpg)

To meet the FCC mandate of doubling the number of available frequencies (channels) the current license holders must reduce base station and subscriber transmitter deviation by half (optional intermediate plan). This step would also reduce system range and coverage unless the equipment involved is upgraded for narrowband operation.

In December 2003 the FCC issued a "stay" of it's narrowband refarming timeline to analyze the concerns input by the public safety community. While these considerations are important, in our opinion the refarming effort will move forward as planned.

The FCC has also recognized the need for more mutual aid channels and has designated additional frequencies for this application in the traditional public safety bands.

New VHF & UHF Band Interoperability Frequencies

FCC Document 00-348 and FCC Rule CFR47 90.20 © FN 80 pertain to the new VHF & UHF nationwide interoperability channels. For reference these frequencies and current status in Wisconsin are listed in Table 4.1 below.

Freq #	Frequency – MHz	Mutual Aid Title	Status of frequencies in Wisconsin
1	151.1375	VTAC 1	Not licensed in WI
2	154.4525	VTAC 2	Not licensed in WI
3	155.7525	V-CALL	Not licensed in WI
4	158.7375	VTAC 3	Not licensed in WI
5	159.4725	VTAC 4	Licensed by the State of Wisconsin
1	453/458.2125	U-CALL	Licensed by the City of Green Bay
2	453/458.4625	UTAC 1	Not licensed in WI
3	453/458.7125	UTAC 2	Licensed by Portage County
4	453/458.8625	UTAC 3	Not licensed in WI

Table 4.1 – New Mutual Aid Channels Available

After December 7, 2000, any licensing of a new station for purposes other than interoperability only communications would require a waiver of Note 80 to Section 90.20 of the FCC Rules. The note states that the frequencies in question are available "primarily" for interoperability-only communications. In this context, the word "primarily" refers to the fact that stations licensed prior to December 7, 2000 may continue to operate on a "co-primary" basis until January 1, 2005.

An eligible entity must have a license to operate a base or control station on these channels. Public safety licensees who are eligible to hold a Part 90 license, or are currently licensed under Part 90, can operate mobile units on these channels without an individual license.

These channels, which are licensed on 7.5 KHz or 6.25 KHz center frequencies, are allowed to remain on a co-primary basis until January 1, 2005. Subject to the restriction that channels are currently available for interoperability use.

Since mobile units are generally licensed by rule, the problem of adjacent or co-channel interference will generally occur if a user has a base or control station licensed on these channels. Prior to January 1, 2005 interoperability use will be permitted only on a secondary basis to existing users; that is, interoperability transmissions can be made only when the channel is clear and on a non-interference basis. The only drawback until January 1, 2005 is that communications on the VTAC frequencies would be secondary to existing licensees.

It would be necessary for the regional frequency coordinator to work these issues of adjacent or co-channel interference.

4.1 Federal Government Spectrum Available

The National Telecommunications and Information Administration (NTIA) has specified forty (40) Federal Government frequencies that can be used by non-Federal government public safety entities for communications involving coordination and cooperation with Federal Government agencies. These frequencies may not be used to meet the day-to-day communications needs of non-Federal government, public safety entities. Due to previous frequency authorizations to Federal Government agencies, not all channels are available at all locations. The rules governing the use of these frequencies are set forth in Section 4.3.16 of the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management. (See the NTIA web page at: www.ntia.doc.gov/osmhome/redbook.html.)

This does give another complete set of interoperability VHF frequencies for use by the public safety sector during emergency situations.

5 APCO Project 25 Digital Radio Systems

"Project 25" is a very significant undertaking of APCO International, The Association of Public-Safety Communications Officials – International, Inc. It was born as a joint effort between APCO and the National Association of State Telecommunications Directors.

It is an initiative to define standards for interoperability between two-way/land mobile radio systems, primarily for local, state and federal government but there are impacts and advantages for commercial users as well. This is very important in order to avoid the mistakes of the past as radio systems migrate from analog to digital modulation. The goal is to leverage the advances in radio technology, e.g. synthesized versus 'specific channel' transceivers, trunking technologies, and digital modulation for voice and data. Equipment that is compliant with the standards includes additional capability in radio communications (more conversations over the same number of channels, digital modulation with encryption capability for secure voice communications, data communications, radio units belonging to one entity being able to operate on channels of other entities) as the new equipment is deployed but the usefulness of existing, installed equipment is also maintained (so as not to force obsolescence of existing equipment in advance of normal replacement cycles).

The Project 25 (P25) Standard utilizes frequency division multiple access (FDMA) to achieve four main objects, as follows.

1. Improved spectral efficiency using narrow band channels.
2. Interoperability between different agencies and levels of government.
3. Graceful forward and backward system migration.
4. Scalable Trunked and Conventional Capabilities.

Presently, 30+ individual standards documents have been published that define various aspects of the requirements for radio equipment to be able to 'interoperate' according to the "Project 25" Standard. This current set of documents, identified as Project 25 Phase 1, have been developed in an orderly, open Standards Development Process, under the auspices of the Telecommunications Industry Association (TIA). The process was designed to be fair and to encourage wide participation in order to achieve the greatest 'bang for the buck' from the technologies and to exclude technologies dominated or 'owned' by any entity unless the owner agreed to share the technology with competitors. The 'technical areas' of these standards are: common air interfaces (CAI), data interfaces, intersystem interfaces, Trunking services, network and network management interfaces, public-switched telephone network interfaces, host data interfaces, and encryption and key management (including Over the Air Re-keying). The data interface definitions consist of four different documents.

Project 25 has achieved support from both the Public and Private Sectors…the Public Sector being predominantly 'users' of the radio equipment and systems and the Private Sector representing 'users' as well as manufacturers. As mentioned earlier, the FCC has chosen this suite of standards for the new 700 MHz frequency band.

The next generation digital standard called Project 25 Phase II is in process under the direction of the TIA committees. This standard, with it's new suite of documents, is targeted to address the 6.25 KHz channel mandate from the FCC. It will also be backward compatible with the current 12.5 KHz suite of standards.

Many sources of information are available on the World Wide Web and some of these have been used as research for this study. Most notable among these is a web document titled "APCO Project 25 STANDARDS FOR PUBLIC SAFETY DIGITAL RADIO" (http://www.apco911.org/frequency/project25/information.html).

6 Public Safety Radio System Solutions

We know from the summary in Section 2 that public safety agencies in Wisconsin utilize both conventional and trunked radio systems. However, the majority of systems are conventional operating in the VHF radio band. The infrastructure equipment making up these systems was purchased predominantly from two vendors, Motorola, Inc. and M/A-COM Wireless Systems, while the subscriber radios come from numerous vendors. In this section we will initially discuss in some detail the infrastructure architectures, which make up the building blocks for the various radio systems of public safety agencies in Wisconsin. Following this are sub-sections analyzing base station, mobile, and portable equipment available in the public safety market place today with a focus on interoperability features.

6.1 Radio Systems Infrastructure Architecture

Before discussing interoperability issues with various systems and vendors, a common radio systems design reference needs to be established. Typically, land mobile radio (LMR) systems are engineered using one of two radio site architectures: conventional, trunked, or a combination of the two.

A conventional LMR system, in its simplest design, consists of a single base station at a tower site on a single frequency. In this case the base station would be “simplex” because it can’t transmit and receive simultaneously. The mobile or portable user would be able to communicate with a dispatcher but not with other users. If another frequency is authorized for use (licensed) then the base station can operate in what is termed the “duplex” or “repeater” mode, which will repeat the subscriber audio received on frequency F1 simultaneously to a dispatcher and other subscribers that are listening on frequency F2. A typical system diagram can be found in Figure 6.1 below.

The range or coverage area over which the users can communicate with this “single site” conventional system is set by a number of radio engineering design parameters. These design choices include for instance; transmitter power output, height of the tower, frequency band used, mobile radio installation, and portable radio configuration.

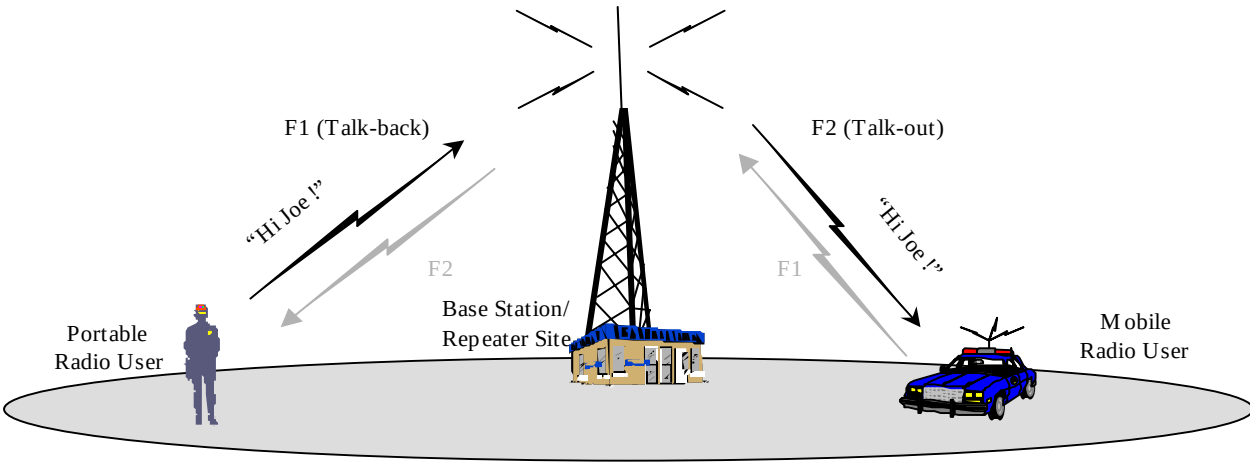

Figure 6.1 – A Single Site Conventional System (Source PSWN).

Depending on the frequency band in use, the base transmitter in a LMR system typically has much more power than mobiles or portable radios. Also, the base antenna is typically at a much higher elevation than mobile or portable radio antennas. For these reasons, dispatcher or repeated two-way communications with mobiles and portables is limited by their talkback capability.

6.1.1 Receiver Voting Sub-systems

In general the mobile user in Figure 6.1 will have a much greater talk-back range than the portable radio user. This results from the higher power output and better antenna efficiencies of the mobile radio installation. A way to improve the talk-back coverage for the portable radio is to add more base station receiver sites on the talk-back frequency at the proper locations throughout the desired coverage area. The recovered audio from these additional "receive-only" sites is brought back to the transmitter location on dedicated links and processed by the signal "comparator" of a "receiver voting" sub-system. The comparator will select (vote) the best signal from among all of the receivers and send that audio to the dispatcher and other system users. The required quantity of these receive-only sites is determined by the system performance desired and is highest if portable in-building coverage is specified. .

For countywide or regional coverage the service area may require multiple transmitter sites for simultaneous coverage of that area. The two major types of such systems are simulcast and multicast transmit.

6.1.2 Simulcast Transmit Systems

Simulcast conventional or trunked systems use several geographically separated base stations/repeaters that transmit on the same frequencies simultaneously. Through this type of a system deployment, a single radio channel can be radiated over a wider region than with a single-site transmitter. These networks require a timing system to synchronize each transmitter on the network to assure that transmissions on the same frequency are in phase thus reducing heterodyne interference. A simulcast system, when keyed, performs a quasi-synchronous transmission, which means that the same message is transmitted at the same time on the same radio channel by two or more transmitters that are phase-locked to the same frequency.

Simulcast transmit systems are used where:

- A large service area must be covered by transmitters of moderate power, in which case there will be a small overlap in the coverage of the transmitters.

- Intensive (high signal-to-noise ratio) coverage is needed throughout the area, for instance if building penetration is required, in which case there will be a substantial overlap in the coverage of the transmitters that are used to provide diversity against shadowing.

- Available spectrum is insufficient to implement a multicast or zone-type system.

6.1.3 Multicast & Zone Systems

Multicast conventional or trunked systems are similar to simulcast systems with exception of the radio channels transmitted (see the diagram in Figure 6.2). While a simulcast system transmits on the same RF channels simultaneously from each base station/repeater, multicast systems use different RF channels at each site. Frequencies can be reused in different cells, but the arrangement ensures the same frequency is never used in adjacent cells. This configuration offers the same coverage advantages of a simulcast system, eliminates the occurrence of co-channel interference from multiple sites, and allows smaller cell configuration which can allow greater RF penetration within the cell. However, multicast systems require multiple frequencies (limited available spectrum) and, for conventional systems, their users need to change mobile channels as they move between cells.