CTA COMMUNICATIONS, INC

CTA COMMUNICATIONS CONSULTANTS

FINAL

System Alternatives and Recommendations Report

Pima County Wireless Integrated Network (PCWIN)

Arizona

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TABLE OF CONTENTS

1.0 INTRODUCTION 6
1.1 PCWIN Project Goals and Objectives 6
1.2 Business Architecture Planning Overview 9
1.3 System Alternatives and Recommendations 9
2.0 REGULATORY ISSUES 12
2.1 Migration to Digital Technology 12
2.1.1 Digital Communications Techniques 13
2.1.2 Advantages of Digital Technology 13
2.1.2.1 Increased Capacity 13
2.1.2.2 Signal Recovery 14
2.1.2.3 Encryption 14
2.1.2.4 Mobile Data 14
2.1.3 Disadvantages of Digital Technology 15
2.1.3.1 Cost 15
2.1.3.2 Interoperability 15
2.1.4 Project 25 16
2.1.5 TSB-88 17
2.2 Narrowbanding of LMR Spectrum below 512 MHz 19
2.2.1 New Narrowband Channels 19
2.2.2 Narrowband Equipment Requirements 19
2.2.3 Deadline for Wideband Equipment Manufacture 20
2.2.4 Deadline for Migration 20
2.2.5 Deadline for Wideband Applications 20
2.2.6 Trunking in the VHF and UHF Bands 20
2.2.7 Impact of Narrowbanding on Agencies' Communications 21
2.3 The 700-MHz Public Safety Band 21
2.3.1 Congressional Action 21
2.3.2 Objectives 22
2.3.3 State Licenses 23
2.3.4 Regional Planning Committees 23
2.3.5 Availability 24
2.4 The 800-MHz Rebanding Plan 24
2.4.1 The Current Situation 24
2.4.1.1 Existing Frequency Allocations at 800-MHz 24
2.4.1.2 Interference mechanisms 26
2.4.2 The FCC Rebanding Plan 27

2.4.3 Rebanding Management 29
2.4.4 Timetable 29
2.4.5 Regional Timetable 30
2.4.6 Application Freeze 30
2.4.7 Conclusion 31
2.5 Fixed Microwave Services Relocation 32
2.5.1 The Lower 2-GHz Band 32
2.5.2 The Upper 2-GHz Band 32
2.5.2.1 Relocations by AWS Licensees 33
2.5.2.2 Relocations by MSS Licensees 33
2.5.3 Conclusion 33
2.6 The 4.9 GHz Band 34
2.6.1 Band Plan 34
2.6.2 Licensing and Coordination 34
3.0 VOICE RADIO TECHNOLOGIES 35
3.1 Voice Radio System Alternatives 35
3.1.1 Trunked Radio – Project 25 Technology 35
3.1.2 Trunked Radio – Proprietary Technology 40
3.1.3 Conventional Radio – Project 25 Technology 46
3.1.4 Conventional Radio – Analog Technology 48
3.1.5 Commercial Wireless 50
3.1.6 TETRA Professional Mobile Radio 52
3.2 Frequency Band Considerations 52
3.2.1 Frequency Band 52
3.2.1.1 700 MHz Band 53
3.2.1.2 800 MHz Band 54
3.2.1.3 VHF and UHF Bands 54
3.2.1.4 Frequency Coordination with Mexico 55
3.3 Impact Analysis 56
3.4 Impact Results - Voice Radio Systems 58
TABLE 3-1 TRUNKED P25 SERVICES 61
TABLE 3-2 CONVENTIONAL P25 SERVICES 63
TABLE 3-3 IMPACT ANALYSIS RESULTS – VOICE SYSTEM TECHNOLOGIES – COMBINED LAW AND FIRE 64
TABLE 3-4 IMPACT ANALYSIS RESULTS – VOICE SYSTEM TECHNOLOGIES – LAW ENFORCEMENT 65
TABLE 3-5 IMPACT ANALYSIS RESULTS – VOICE SYSTEM TECHNOLOGIES – FIRE DEPARTMENTS 66

FIGURE 3-1 IMPACT BLOCK DIAGRAM 67
4.0 MOBILE DATA SYSTEM TECHNOLOGIES 68
4.1 Mobile Data System Alternatives 68
4.1.1 Stand-Alone Mobile Data Systems 69
4.1.2 Integrated Mobile Data and Voice Systems 71
4.1.3 Commercial Wireless 73
4.2 Impact Analysis 75
4.3 Impact Results – Mobile Data Systems 75
TABLE 4-1 IMPACT ANALYSIS RESULTS – MOBILE DATA TECHNOLOGIES - COMBINED LAW AND FIRE 78
TABLE 4-2 IMPACT ANALYSIS RESULTS – MOBILE DATA TECHNOLOGIES – LAW ENFORCEMENT 79
TABLE 4-3 IMPACT ANALYSIS RESULTS – MOBILE DATA TECHNOLOGIES – FIRE DEPARTMENTS 80
5.0 COMMUNICATIONS CENTER E-9-1-1 PSAP CONSIDERATIONS 81
5.1 Communications Center Location 81
5.2 Communications Center Design 82
5.2.1 Technical Issues 82
5.2.2 Design Issues 83
5.3 Communications Center Development Options (New, Remodel or Adaptive Reuse) 84
5.3.1 New Construction 84
5.3.2 Remodeling of Existing Facilities 85
5.3.3 Addition and Renovation to Existing Facilities 85
5.3.4 Acquisition of an Existing Building 86
5.4 Organizational Considerations 87
5.5 9-1-1 Customer Premises Equipment 93
5.5.1 Convergence of Voice and Data 101
5.5.2 Computer/Telephone Integration 102
5.5.3 Geographic Information Systems 104
5.5.4 Options 106
5.6 Equipment Recommendations 106
5.7 Impact Analysis 107
5.8 Impact Results – Communications Center 109
5.9 Communications Center Dispatch Recommendations 111
TABLE 5-1 IMPACT ANALYSIS RESULTS – COMMUNICATIONS CENTER E9-1-1 PSAP ALTERNATIVES – COMBINED LAW AND FIRE 112

TABLE 5-2 IMPACT ANALYSIS RESULTS – COMMUNICATIONS CENTER E9-1-1 PSAP ALTERNATIVES – LAW ENFORCEMENT 113
TABLE 5-3 IMPACT ANALYSIS RESULTS – COMMUNICATIONS CENTER E9-1-1 PSAP ALTERNATIVES – FIRE DEPARTMENTS 114
6.0 ASSET LOCATION TECHNOLOGIES 115
6.1 Asset Location System Alternatives 115
6.1.1 Non – GPS Based Location Systems 116
6.1.2 GPS Based Location Systems 118
6.2 Impact Analysis 119
6.3 Impact Results – Location Systems 120
TABLE 6-1 IMPACT ANALYSIS RESULTS – LOCATION TECHNOLOGIES – COMBINED LAW AND FIRE 122
TABLE 6-2 IMPACT ANALYSIS RESULTS – LOCATION TECHNOLOGIES – LAW ENFORCEMENT 123
TABLE 6-3 IMPACT ANALYSIS RESULTS – LOCATION TECHNOLOGIES – FIRE DEPARTMENTS 124
7.0 NETWORK TECHNOLOGIES 125
7.1 Network System Alternatives 125
7.1.1 Connectivity Network 125
7.1.1.1 Network Technology Alternatives 126
7.1.1.2 IP Packet Switched Technology for LMR 128
7.1.1.3 Key Design Considerations 129
7.1.1.4 Advantages of Packet Switched Technology 132
7.1.1.5 Link Media Options 134
7.1.2 Interoperability Network 137
7.2 Impact Analysis 140
7.3 Impact Results – Network Systems 140
TABLE 7-1 IMPACT ANALYSIS RESULTS – NETWORK TECHNOLOGIES – COMBINED LAW AND FIRE 143
TABLE 7-2 IMPACT ANALYSIS RESULTS – NETWORK TECHNOLOGIES – LAW ENFORCEMENT 144
TABLE 7-3 IMPACT ANALYSIS RESULTS – NETWORK TECHNOLOGIES – FIRE DEPARTMENTS 145
8.0 RECOMMENDATIONS 146
8.1 Voice Radio System 146
8.2 Mobile Data System 146

8.3 Communications Center 146
8.4 Asset Location 146
8.5 Network System 146

1.0 INTRODUCTION

In December 2003, the Pima County Sheriff's Department joined with thirty-one other public safety entities in a collaborative effort to present a plan for a regional public safety communications system to the Pima County Board of Supervisors. The Board of Supervisors agreed to include the proposal on a bond election ballot. The voters of Pima County approved the bond proposal and authorized the issuance of ninety-two million dollars in bonds for the development, procurement, implementation, and management of a regional radio system. The project is called the Pima County Wireless Integrated Network (PCWIN).

The mission of the PCWIN is to *design, procure, deploy and operate a regional public safety voice and data communications network; improve public safety radio interoperability; and to design, construct and operate a regional communications center*.

1.1 PCWIN Project Goals and Objectives

The PCWIN has adopted the following goals for the project:

- Develop a business plan for the Pima County Wireless Integrated Network that includes a concept of operation, conceptual design, budget analysis, system performance specifications, and an operating and maintenance plan.

- Assess the wireless communications needs of first responders within the County, including the demand to coordinate between agencies and to use satellite-positioning technology to maximize the safety of the public and of first responders.

- Facilitate the execution of intergovernmental or substitute agreements between Pima County and the partner jurisdictions obligating each with specific responsibilities that will further the implementation, operation, support and maintenance of the Pima County Wireless Integrated Network components.

- Recommend to the Pima County Board of Supervisors policy, procedures and expenditures that will further the Pima County Wireless Integrated Network project in a manner benefiting the citizens of Pima County and the public safety community.

- Acquire supplemental federal funding.

- Invite participation in the Pima County Wireless Integrated Network by other self-funded local, county, state and federal agencies.

- Improve communications interoperability between the project partner agencies and other state and federal agencies with whom they must communicate.

- Implement a voice communications network that utilizes modern, state-of-the-art technology to support the voice communications needs of the agencies authorized by Pima County Ordinance No. 2004-18 and to improve communications interoperability between PCWIN public safety agencies.

- Provide a working level of widespread on-street voice radio coverage throughout Pima County and enhanced in-building penetration within the City of Tucson. The proposed systems shall be able to accommodate enhancements to extend coverage outside Pima County for those agencies with service areas outside the County.

- Implement a data communications network, network standards, policies and procedures to provide widespread wireless data on-street coverage to support the computer aided dispatch, mobile incident reporting, and automatic vehicle locator applications deployed by the project partner agencies.

- Design, construct, occupy and operate a regional communications center co-locating the 9-1-1 public safety answering points and dispatch functions of the Pima County Sheriff's Department and the City of Tucson with the Pima County Emergency Operations Center.

- Implement an automatic vehicle location system solution that will provide the user community with the ability to manage field resources based upon their proximity to emergency incidents.

The following are specific project objectives:

- Reuse of existing infrastructure such as antenna, microwave and other communications network resources and facilities to minimize costs and lessen environmental impact.

- Deployment of a "standards" based system that will provide for compatibility with other standards based systems in the State. (It is desirable that a network in Pima County could interface with the system currently being installed by the Cities of Phoenix and Mesa, Tucson Electric Power and the Town of Marana).

- Deployment of a digital 800MHz or 700MHz trunked radio system operated throughout Pima County. Channel resources in the 800MHz band are already licensed to project partner agencies, including the County.

- Provide a high performance data communications network to support mission critical applications.

- Implement an automatic vehicle locating solution that may include integration of existing solutions. GPS capability in mobile radios will send coordinates of vehicles to a mapping application so that agencies can immediately identify, locate and manage vehicle and personnel resources.

- Provide initial subscriber equipment to participating partners.

- Design and construct a building equipped with radio communications and telecommunications infrastructure, furnishings and other equipment necessary to relocate the County Emergency Operations Center, and 9-1-1 and dispatch operations for the City of Tucson and Pima County into one regional facility.

In order to accomplish these project goals and objectives, PCWIN has established five project phases:

- Phase I Business Architecture Planning

- Phase II Conceptual Architecture Planning

- Phase III Procurement Technical Specification
- Phase IV Systems Integrator RFP Solicitation Support
- Phase V Technical and Project Management Oversight

1.2 Business Architecture Planning Overview

The Business Architecture Planning Phase involves the development of five different reports: the User Needs Assessment Report; the Legacy Systems Characterization Report; the Systems Alternatives and Recommendations Report; the Concept of Operations Report, and the Business Plan. This document, the Systems Alternatives and Recommendations Report, is the third of the five reports developed in Phase 1.

1.3 System Alternatives and Recommendations

With this Report, we begin to shift our attention away from existing systems and present problems, and towards future options for the new communications network (PCWIN). Thus far, we have established a good working relationship with Pima County while gaining a thorough understanding of participating agencies and their operations. We have also completed our facility surveys and inventories, affording us a good picture of the assets that will be valuable for future infrastructure. Through direct interviews and research we have also assembled a perspective on future directions being taken by surrounding Counties and the State of Arizona. Using this broad based foundation of local operations, coupled with CTA's knowledge of the technology marketplace, we have identified several system alternatives for PCWIN.

An important task in planning for the system upgrade is to first identify approaches to countywide communications. During this process, we identify the viable technologies that could be applied to the overall communications environment. Alternatives for both voice and mobile data communications along with their interconnecting backbone are considered.

The shared goal of this report is to provide PCWIN participants a clear picture of their options. Each agency should be actively involved by envisioning how the interoperable technology choices will improve their operations. CTA will provide guidance as each agency works through this process. The 32 participating agencies will then be able to make an informed choice on which communication alternatives to move forward with.

Later in the project, once PCWIN has reached consensus on a viable approach, we will embark upon the conceptual design where the selected alternatives begin to take shape specifically for Pima County.

Several alternative approaches are presented for the major subsystems that will constitute the overall PCWIN communications network. Each alternative is described within the framework of Pima County operations. How the technology would be applied in Pima County is described along with the strengths and weaknesses of each approach. This discussion provides the background descriptions needed for agencies to make their evaluations.

We analyzed alternatives in five major areas that will contribute to your overall system design:

1. Voice Radio Systems
2. Mobile Data Systems
3. Communications Center
4. Location Systems
5. Network Systems

Next, we evaluate the fit of each alternative to Pima operations aided by the CTA Impact Analysis process. In this process, each alternative is evaluated in light of the County's ranked system attributes. Each of the 32 PCWIN participants was offered the opportunity to rank the importance (or unimportance) of each attribute to their operation. PCWIN ranking serves as weighting factors during Impact Analysis. A panel of CTA engineers and operations specialists independently assesses each alternative's ability to deliver the attribute set. The resultant numerical impact scores coupled with CTA's judgment on appropriate technologies allow the project team to narrow the alternative choice field.

Cost is another important factor that must be evaluated early in the new system planning process. To help understand relative cost of the various alternatives, CTA provides Rough Order of Magnitude (ROM) cost estimates. At this early stage in the process, we make informed assumptions on some basic information such as dispatch centers, numbers of tower sites and radios, etc. Using our Cost Facility Tool, and cost database, we provide the ROM cost of the most viable alternatives.

CTA is pleased to provide this **Systems Alternatives and Recommendations Report.** We wish to thank Pima County, the City of Tucson and all of the other participating PCWIN agencies for contributing to this study.

2.0 REGULATORY ISSUES

There are several significant regulatory or standards-related issues that will impact the planning of a land mobile radio (LMR) system:

- Migration to Digital Technology
- Narrowbanding of LMR Frequencies below 512 MHz
- The 700-MHz Public Safety Band
- The 800-MHz Rebanding Plan
- Reallocation of the 2-GHz Microwave Bands to Other Services
- The 4.9-GHz Band

Each of these issues will directly affect the technology that will be available to PCWIN.

2.1 Migration to Digital Technology

The migration to digital modulation technology is not, strictly speaking, a regulatory issue. The Federal Communications Commission (FCC) has not mandated the use of digital modulation in any LMR band except for the new 700-MHz public safety band. However, digital modulation has been encouraged by several regulatory proceedings. This migration is driven by several factors:

- rapid growth of wireless communications technologies and services, which has created an increased demand for radio frequency (RF) spectrum;
- the need for improved security of voice communications;
- the need to transfer more varieties of data; and
- the availability of increased computing power for mobile and portable radio equipment.

For decades, LMR systems have utilized analog FM voice technology. The first trunked systems were based on analog modulation. More recently, the major vendors of trunked radio systems have offered dual-mode systems, supporting both analog and digital modulation. In 2004, the largest trunked radio system manufacturer, Motorola, announced it would stop shipping new dual-mode radio systems in favor of its all-digital

product line. Motorola's largest competitor, M/A-COM, still continues to offer dual-mode systems. Most conventional radio systems are still analog, but digital systems are increasing in number.

2.1.1 Digital Communications Techniques

One of the primary advantages of digital communications is the ability to improve spectrum efficiency by increasing the number of communication paths or circuits per RF bandwidth. In LMR systems, there are two main techniques for accomplishing this: frequency-division multiple access (FDMA) and time-division multiple access (TDMA).

In an FDMA system, spectrum efficiency is improved by dividing the existing RF channel into two (or more) narrower channels with one voice channel for each RF channel. In a TDMA system, spectrum efficiency is improved by dividing the channel into two or more time slots with one voice channel per time slot. For example, most existing stations in the VHF and UHF bands operate on 25-kHz channels. Under the FCC's narrowbanding plan, licensees can either convert their systems to operate in 12.5-kHz channels (the FDMA solution) or to use a two-slot TDMA solution in 25-kHz channels. In either case, the spectrum efficiency mandate is achieved by creating two voice channels per 25 kHz of spectrum instead of one.

2.1.2 Advantages of Digital Technology

2.1.2.1 Increased Capacity

As explained above, the main potential advantage of digital technology is the increased capacity generated by improved spectrum efficiency. Creating two or four voice channels per 25 kHz of spectrum doubles or quadruples capacity. In the LMR bands below 800 MHz, the FCC has created rules to allow this efficiency to be achieved by either FDMA or TDMA. In the 800-MHz band, current FCC rules mean that this can only be achieved by the use of TDMA.

2.1.2.2 Signal Recovery

An analog repeater simply retransmits the signal it receives (along with noise and interference), while a digital repeater performs error correction on the received signal and retransmits it, removing noise and interference in the process.

A similar process takes place in the mobile or portable radio. The subscriber unit performs error correction on the received signal, providing better audio quality in weak-signal areas at the fringes of the coverage area.

The drawback to this is that, to the user, there is no sense of signal degradation at the fringes. Audio simply disappears suddenly at the limits of radio coverage. Conversely, analog voice quality experiences a gradual degradation as the user approaches the fringes of the coverage area and thus provides the user some warning that they may soon be out of range.

2.1.2.3 Encryption

Although analog encryption schemes are still available for conventional radio systems, trunked radio system vendors only offer digital encryption. Digital encryption is more secure than analog encryption and does not reduce understandability as older methods did.

Even without encryption, digital systems provide some protection against casual eavesdropping because most scanners cannot decode digital signals. However, because there are digital scanners capable of decoding and tracking trunked digital radio systems, encryption is the only way to ensure security.

2.1.2.4 Mobile Data

Digital modulation schemes offer the potential for improvements in data rates for mobile data applications. Until recently, most LMR vendors offered a data rate of 19.2 kbps per 25-kHz channel. This meets the FCC regulatory requirements for narrowbanding in the VHF and UHF bands and for the new narrowband channels in the 700-MHz public safety band. However, newer technology utilizing scalable adaptive modulation (SAM) offers data rates from 32 to 96 kbps in a 25-kHz channel.

In addition, higher data rates are possible in the wideband channels in the 700-MHz band and the new 4.9-GHz public safety band. The FCC has mandated data rates of 384 kbps per 150-kHz channel in the 700-MHz band. Vendors have developed products capable of around 600 kbps in that bandwidth. The 4.9-GHz band is allocated especially for wideband data transfer at the incident scene. The channel plan is designed for commercial data standards like IEEE 802.11. The major LMR vendors are busy preparing products for these bands.

2.1.3 Disadvantages of Digital Technology

2.1.3.1 Cost

The costs associated with digital technology have been significantly higher than with analog technology. However, digital equipment costs continue to drop. We expect that eventually the difference in cost between analog and digital systems will no longer be an issue. At the present time, digital equipment is more expensive than comparable analog or dual-mode equipment.

2.1.3.2 Interoperability

Interoperability remains a challenge for everyone, but especially for digital radio systems.

Consider the following:

- Analog conventional radio systems offer true over-the-air compatibility—unless the systems are in different frequency bands.

- Trunked radio systems from different vendors do not provide over-the-air compatibility with neighboring systems. In order to provide communications between dissimilar systems, radio vendors must provide patches or other fixes that allow users to talk with each other on an as-needed basis. The alternative is to specify direct over-the-air compatibility with neighboring systems, which typically results in sole-source procurement.

- Trunked radio systems from the same vendor may not be able to communicate with each other. New subscribers may be able to

communicate on older systems, but the older subscriber units may not work on the new systems. This provides "halfway" compatibility.

- Digital radio systems have an inherent latency—the time it takes to translate an analog voice signal into a digital format and then translate it back to analog voice at the receiver. This latency can be minimized within a single radio system, but when two systems are patched together, the analog-to-digital-to-analog conversion is performed twice rather than once, doubling overall latency and causing greater difficulty for field personnel.

These problems continue to make interoperability with adjacent jurisdictions using diverse systems and frequency bands a serious technical and operational challenge.

2.1.4 Project 25

The Association of Public-Safety Communications Officials International (APCO), in conjunction with the Telecommunications Industry Association (TIA) and others, initiated APCO Project 25 (P25) to promote a single non-proprietary set of standards for digital radio communications. The purpose of the standards was twofold:

- to improve interoperability between law enforcement agencies; and
- to provide greater competition and cost savings in the procurement of radio equipment.

The P25 standards are being developed in three phases. Phase I, designated ANSI/TIA/EIA-102, is an FDMA technology based on one voice or data channel per 12.5-kHz RF channel. The Phase I standards are nearly complete. When vendors speak of P25 compatibility, Phase I is usually what they are talking about.

Phase II has several goals. One goal is to define technology standards that will provide one voice channel per 6.25 kHz of spectrum. The P25 committee is currently focusing its efforts on a TDMA standard based on a two-slot 12.5-kHz

channel. Eventually, P25 may include a standard, based on a four-slot 25-kHz channel. The standard requires that any Phase II equipment must be backward-compatible to communicate in Project 25 Phase I mode.

Phase II will also define IP-based interconnection (or "inter-subsystem interface" [ISSI]) standards for infrastructure equipment such as repeaters, controllers and consoles. As it stands now in Phase I, subscriber equipment from a variety of manufacturers can be mixed, but infrastructure equipment, such as repeaters, controllers and consoles, cannot. Once you purchase infrastructure equipment from a single manufacturer, you are locked in to that manufacturer for system upgrades or expansion.

Phase III, also known as Project 25/34, defines the requirements for wideband high-speed data standards. Work on these standards has continued under the auspices of Project MESA, a combined effort of the Project 25 Group and a European group. This effort has produced TIA-902, a wideband data standard which the FCC has proposed for use on the wideband interoperability channels in the 700-MHz band.

Project 25 has made great progress in recent years. Both Motorola and M/A-COM have produced P25 systems, and the push toward interoperability among public safety communicators has heightened the interest in the P25 standards.

2.1.5 TSB-88

Prior to the development of digital modulation technologies, analog radio systems were designed based on a large body of empirical knowledge. Engineers were able to draw upon years of collective experience in the propagation characteristics of analog radio systems, translating acceptable communications to signal level targets. This is not the case with the new digital technologies.

In the case of digital technologies, each modulation technique may have different characteristics, and each vendor's product may have different error correction capabilities. Because of this, very little information has been published on digital propagation outside of information published by vendors on their unique products and coverage philosophies.

In an effort to fill the need for a common reference point in the field of digital radio propagation, the Telecommunications Industry Association/Electronic Industries Alliance (TIA/EIA) released Telecommunications Systems Bulletin 88 (TSB-88), *Wireless Communications Systems - Performance in Noise and Interference-Limited Situations - Recommended Methods for Technology-Independent Modeling, Simulation, and Verification*. Although not a true regulatory (FCC-inspired) action, TSB-88 and its latest revisions have already had an impact on the design of two-way radio systems.

TSB-88 is a beginning step, or basic guideline, for defining and predicting digital/narrowband propagation. It defines many of the elements of radio system coverage in common terms. There are sections devoted to service area, testing methodology, propagation models, reliability, noise and frequency coordination. It is not a standard, but has achieved "quasi-standard" status in that no other document or statement on the subject exists. Once there is more experience in actual field performance of digital systems, these lessons can be applied to the provisions of TSB-88.

The design of any radio system involves a certain degree of risk. As the vendor's engineers approach the project, they must account for this risk factor in the overall system design. A system designed with an overly optimistic propagation model runs the risk of not meeting the coverage requirements of the purchaser. A design that is overly conservative can reduce this risk to negligible levels, but the cost of the system may be exorbitant.

The latest revision of TSB-88, TSB-88-B, takes a very conservative approach to radio propagation and system design. This encourages a design that provides reduced risk for the vendor but possibly higher expense for the customer.

CTA recommends and will assist PCWIN in designing a radio system considering the provisions of TSB-88-B. However, designing the system to meet all of the actual and implied recommendations of TSB-88-B may lead to an over-designed system and excessive costs. Because of its "quasi-standard" status, the issue of TSB-88 "compliance" will be an issue in any liability or conflict situation. We recommend that TSB-88-B be taken into *consideration* during the design of the system, but that provisions of TSB-88-B be applied judiciously to the unique needs of the PCWIN agencies.

2.2 Narrowbanding of LMR Spectrum below 512 MHz

The FCC began in 1992 a proceeding to increase spectrum efficiency in the Private LMR (PLMR) bands below 512 MHz. The "Refarming Proceeding", as it became known, introduced major changes in these bands.

2.2.1 New Narrowband Channels

The FCC created new narrowband channels in the 150-174 (VHF High), 421-430, 450-470 and 470-512 MHz (UHF) bands.

In the VHF high band, where existing 25-kHz (wideband) channels were spaced at 15 kHz, new narrowband channels were created 7.5 kHz from existing channels. The new channels may only be licensed for bandwidths of 12.5 kHz or less.

In the UHF bands, where existing 25-kHz channels were spaced 25 kHz apart, new channels were created at 12.5 kHz and 6.25 kHz from existing channels. The channels 12.5 kHz from existing channels are available for licensing at 12.5-kHz or less bandwidths and those 6.25 kHz from existing channels are available for licensing at 6.25-kHz or less bandwidths.

The new channels are available for licensing now. However, incumbents are still operating at the old 25-kHz bandwidths on adjacent channels, creating the potential for interference to the new channels.

2.2.2 Narrowband Equipment Requirements

All new LMR equipment placed on the market today must be capable of operating at a spectrum efficiency of one voice channel per 12.5 kHz of channel bandwidth. This can be accomplished by using either FDMA technology, transmitting a single voice channel in 12.5-kHz RF channel, or TDMA technology, transmitting two voice channels in a 25-kHz RF channel. (For data transmitting equipment, the efficiency standard is 4800 bps per 6.25-kHz of channel bandwidth.)

The FCC's ultimate goal is one voice channel per 6.25-kHz channel, but the FCC has stayed the deadline for meeting this requirement as it considers the state of technology and narrowband migration. Although new equipment must be capable

of operating in more efficient modes, licensees are still allowed to operate this equipment at the old wideband efficiency standard of one voice channel per 25 kHz of channel bandwidth.

At the time these rules were adopted, the FCC believed that the congested conditions in the refarming bands would provide a "natural inducement" for users to migrate to narrowband equipment. However, since the rules were enacted, very few incumbents have migrated to the narrower bandwidths, so the FCC has reconsidered its decision that the migration be wholly voluntary.

2.2.3 Deadline for Wideband Equipment Manufacture

Recently, the FCC decided to set deadlines for migration to greater spectrum efficiency. As a result, the FCC decided to prohibit manufacture and importation of equipment capable of operating at one voice channel per 25 kHz of bandwidth after January 1, 2011.

2.2.4 Deadline for Migration

The FCC also updated the rules to set a fixed deadline for all users to transition to 12.5 kHz operation. The deadline for conversion to 12.5-kHz efficiency is January 1, 2013 for all licensees. After that date, all licensees in the bands 150-512 MHz must operate at one voice channel per 12.5 kHz of bandwidth. Users may still use 25-kHz channels as long as the spectrum efficiency standard is met.

The FCC has not yet set a deadline for conversion to 6.25-kHz efficiency.

2.2.5 Deadline for Wideband Applications

At the same time, the FCC set January 1, 2011 as the deadline for applications for new wideband licenses and modifications to existing wideband licenses. This allows users flexibility to maintain and expand existing systems until two years before the migration deadline.

2.2.6 Trunking in the VHF and UHF Bands

As part of the Refarming Proceeding, the FCC established rules for trunking in the 150-174 and 450-470 MHz bands. The rules allow trunking as long as concurrence is obtained from affected licensees within 70 miles of the proposed

trunked station. The term "affected licensees" refers to stations with assigned frequencies 15 kHz or less from a proposed trunked station with 25-kHz bandwidth, 7.5 kHz or less from a proposed trunked station with 12.5-kHz bandwidth and 3.75 kHz or less from a proposed trunked station with 6.25-kHz bandwidth. In lieu of concurrence, an applicant may provide an engineering study that demonstrates that the proposed station interference contour does not overlap the affected licensee's service territory. Rules for trunking below 512 MHz require so much coordination with neighboring licensees that they make the implementation of trunking systems in these bands difficult.

2.2.7 Impact of Narrowbanding on Agencies' Communications

With its decision to set deadlines for the transition to 12.5-kHz operation, the FCC has provided much-needed clarity to the narrowbanding issue. PCWIN member agencies may legally continue to operate their existing 25-kHz VHF and UHF systems until 2013, but will eventually face a reduction in bandwidth, which will result in a reduction in coverage. The FCC's decision provides sufficient time to plan for the transition.

If agencies' existing wideband radio systems are adequate, it may make sense to maintain it as is until the transition date is closer. However, major new investments in equipment should be based on more spectrum efficient technologies.

2.3 The 700-MHz Public Safety Band

2.3.1 Congressional Action

The Balanced Budget Act of 1997 mandated that, as part of the conversion from analog to digital television (DTV), television broadcasting be terminated on channels 60 to 69 (746 to 806 MHz) by December 31, 2006. The Act directed the FCC to allocate 24 MHz of the spectrum from these channels to public safety users. However, provisions were added that would allow an incumbent broadcaster to continue broadcasting in this spectrum indefinitely if fewer than 85 percent of households in the station's service area have a digital TV receiver or set-top converter.

These provisions would have delayed significantly the availability of spectrum for public safety users in some areas. Because of the slow pace of the transition, and because of the focus on public safety communications since 9/11, some in Congress recognized the need to expedite the transition and free this spectrum for public safety communications. Therefore, on February 8, 2006, Congress passed the Digital Television Transition and Public Safety Act of 2005 to set a date certain of February 17, 2009 as the deadline for conversion of all TV stations to DTV and cessation of broadcasting in channels 60-69. (In certain areas of the country, because of the limited number of channels available, some DTV stations will continue to operate in channels 60-69 until they can be relocated to vacated channels below 60.)

2.3.2 Objectives

In response to the Balanced Budget Act of 1997, the FCC established a new 700-MHz public safety land mobile radio band. The FCC has adopted rules for the 700-MHz band (764-776/794-806 MHz) with three basic concerns in mind:

A. Efficiency. The FCC seeks to promote spectrum efficiency in the band by requiring an aggressive standard of one voice channel, or one data channel of 4800 bps, per 6.25 kHz of bandwidth.
The FCC has not mandated a specific technology for meeting this requirement, but all systems licensed for this band must use some form of digital modulation. By 2015, all equipment manufactured and marketed for use in the 700-MHz band must meet the 6.25-kHz efficiency mandate, and no new applications for systems operating at 12.5-kHz efficiency will be accepted. By 2017, all systems in the band must operate at 6.25-kHz efficiency.

B. Interoperability. The FCC has set aside a significant portion of the band (2.6 MHz) for interoperability. Although the FCC has refrained from mandating standards for the rest of the band, it has mandated Project 25 Phase I as the standard for use on the narrowband interoperability channels.

C. Flexibility. The FCC has recognized that by mandating the adoption of specific technology standards, it may actually inhibit the acceptance of

more advanced and spectrum-efficient technology. Therefore, it has chosen to allow the market to drive the technology. In that light, it has provided flexibility in the licensing of frequencies in the 700-MHz band. The band is divided into 960 narrowband 6.25-kHz channels and 120 wideband 50-kHz channels.

A licensee may aggregate two or four narrowband channels to create a single 12.5- or 25-kHz channel, as long as the overall spectrum efficiency is one voice channel, or one data channel of 4800 bps, per 6.25 kHz.

A licensee may aggregate two or three wideband channels to create a single 100- or 150-kHz channel with the requirement that the overall spectrum efficiency be at least 384 kbps per 150 kHz.

Recently, the FCC has issued a notice of proposed rule-making (NPRM) on potential changes to the band plan for the wideband data channels. The FCC has received several proposals, some of which involve creating 1.25-MHz channels compatible with commercial cellular code-division multiple access (CDMA) technology. It remains to be seen what will be the end result of this proceeding.

2.3.3 State Licenses

Recognizing the need of states for frequencies across a wide geographic area, the FCC has issued every state (including Arizona) a license for 192 narrowband channels. These licenses are not subject to the regional planning process. The license grants require states to provide "substantial service" to their populations by specific deadlines. If the deadlines are not met, the licenses will be modified accordingly. Frequencies that are unused will revert to the general use spectrum to be administered by regional planning committees.

2.3.4 Regional Planning Committees

The 700-MHz band will be administered by regional planning committees in the same fashion as the 800-MHz NPSPAC band has been. The regions are the same as at 800-MHz with a few exceptions (Michigan and Connecticut). Regional planning committees are in various stages of forming and preparing plans for approval by the FCC. As of the writing of this report, seven regional plans have

been approved. Until the regional plans have been approved, no licenses will be issued to local public safety users.

2.3.5 Availability

The Region 3 (Arizona) Regional Planning Committee submitted its 700-MHz plan to the FCC in May 2006. We expect the approval process to take about six months. After that time, the 700-MHz band will be available to PCWIN. However, there has not yet been a spectrum use agreement negotiated between the U.S. and Mexico regarding use of the band for public safety LMR. Until that agreement is in place, U.S. public safety users must not interfere with and must accept interference from Mexican UHF TV stations.

The major vendors have already produced "dual-band" subscriber units capable of operation in both the 700- and 800-MHz bands. They are also marketing 700-MHz radio systems, although installed systems are few.

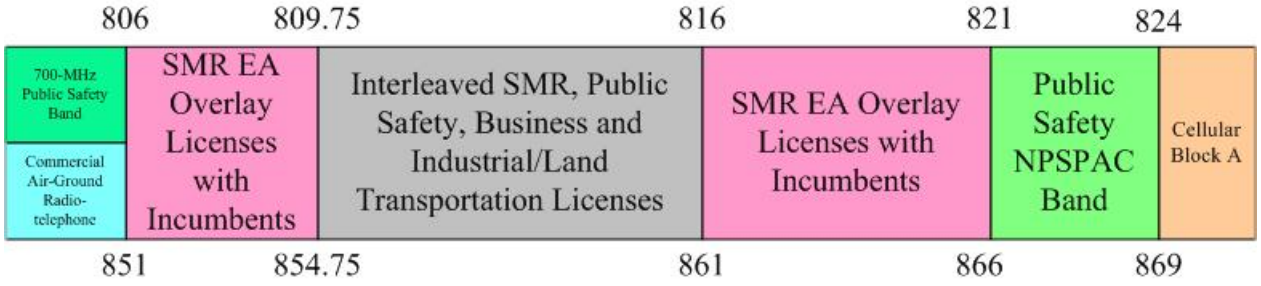
2.4 The 800-MHz Rebanding Plan

In 2001, in response to documented interference issues, Nextel Communications proposed a drastic realignment of the 800-MHz band. After extensive debate and comment, rebanding is finally under way.

2.4.1 The Current Situation

2.4.1.1 Existing Frequency Allocations at 800-MHz

The 800-MHz band has evolved over the years to produce the arrangement we have today, as illustrated below. The segments 806-809.75/851-854.75 and 816-821/861-866 MHz are licensed geographically by Economic Areas (EAs) to the Specialized Mobile Radio (SMR) Service. However, there are still some incumbent public safety and other licensees in these bands who were grandfathered when the EA licenses were auctioned.



The segment 809.75-816/854.75-861 MHz is allocated to four categories of users (SMR, Public Safety, Business, and Industrial/Land Transportation), with the different categories interleaved.

The segment 821-824/866-869 MHz, known as the NPSPAC band, is allocated solely to Public Safety.

The situation in the Mexican border region is similar, with the following changes based on agreements negotiated with the government of Mexico and codified in the FCC rules:

- The 806-809.75/851-854.75 MHz band is allotted to U.S. SMR channels interleaved with channels allotted to Mexico.
- The 809.75-811/854.75-856 MHz band is allotted to Mexico.
- The 816-821/861-866 MHz band is interleaved with U.S. Business, Industrial/Land Transportation, Public Safety and SMR channels alternating with channels allotted to Mexico.
- The NPSPAC band is evenly divided between the U.S. and Mexico, with each nation being allotted alternating blocks of frequencies.

Above 824 and 869 MHz are the cellular blocks A and B. Below 806 MHz is the new 700-MHz Public Safety band and its remaining incumbent TV stations. The band 849-851 MHz is the Commercial Air-Ground Radiotelephone Service.

2.4.1.2 Interference mechanisms

In recent years there have arisen more and more reports of interference to 800-MHz public safety radio systems from Specialized Mobile Radio (SMR), Enhanced SMR (ESMR) and cellular telephone systems (collectively referred to as Commercial Mobile Radio Services [CMRS]) in the 800-MHz bands. The following is a summary of the interference mechanisms involved.

In the early days of the 800-MHz band, SMRs and other radio systems were generally designed to the same parameters. They were designed to cover as much territory with as few sites as possible. This led to systems with sites located at high elevations and operating at high power levels. Coverage for such systems is limited only by the strength of the signal compared to thermal noise of the receiver. Therefore such systems are called "noise-limited" systems.

In order to serve the greatest number of customers possible, modern cellular and ESMR systems are designed to reuse the limited number of channels available as often as possible. An individual cell is designed to cover a smaller territory, so sites are located at lower elevations with lower powers. Coverage areas of cells tend to overlap and receivers are designed to function in an environment in which interference from adjacent cells is common. These kinds of systems are considered "interference-limited" because their range is limited not by signal-to-noise ratio but by interference from adjacent cells.

When noise-limited and interference-limited systems are operated in close proximity (by frequency and geography) the potential for interference increases, especially to the noise-limited systems such as most public safety users operate. The problem is exacerbated by the high duty-cycles of SMR systems.

There are three main categories of interference involved:

A. Intermodulation

Intermodulation is caused by undesired mixing of two or more frequencies. This mixing produces signals at frequencies that are the combination of sums and differences of the frequencies being mixed. Intermodulation can take place in transmitters or receivers or elsewhere

and creates unwanted signals that block desired signals. This is especially a problem when the desired signal is weak as in traditional noise-limited systems.

B. Receiver Desensitization

Receiver desensitization (or "desense") is caused when a nearby strong signal overloads the "front-end" amplifier of a receiver, reducing the gain of the amplifier in the radio, thereby inhibiting the ability to receive the desired signal. The effect to the user is the creation of "holes" in radio system coverage. A mobile or portable operating near an ESMR site will simply not be able to hear calls from its own system.

C. Transmitter Sideband Noise

Transmitter sideband noise is produced by the modulation of the carrier frequency. Modulation produces frequencies above and below the carrier. The FCC sets limits as to how much energy can be transmitted beyond the limits of a channel, but when a transmitter is nearby, sideband noise can override the weaker desired signal.

2.4.2 The FCC Rebanding Plan

This is a summary of the rebanding plan:

(1) All non-Nextel incumbents will be relocated from the 806-809/851-854 MHz General Category band. These licensees will be relocated to former Nextel channels in the 809.75-816/854.75-861 MHz band.

(2) The NPSPAC band will be moved from 821-824/866-869 MHz to the new NPSPAC band at 806-809/851-854 MHz. In most instances, NPSPAC licensees will simply change frequencies by 15 MHz.

(3) Existing Public Safety systems and non-cellular Business, Industrial and Land Transportation (B/ILT) and SMR systems operating on interleaved channels between 809-816/854-861 MHz will continue to operate on those channels.

(4) Nextel will relocate all of its 800-MHz operations to the 817-824/862-869 MHz band, and will vacate all channels it now uses in the 806-817/851-862 MHz band segment. Public safety agencies and later critical infrastructure industries (CII) will have exclusive access to all channels vacated by Nextel in the interleaved portion of the band below 817/862 MHz for a limited period of time.

(5) The FCC has created an Expansion Band at 815-816/860-861 MHz. Incumbent Public Safety licensees will be given the option to relocate from this band to avoid potential interference from the new ESMR band above 817/862 MHz.

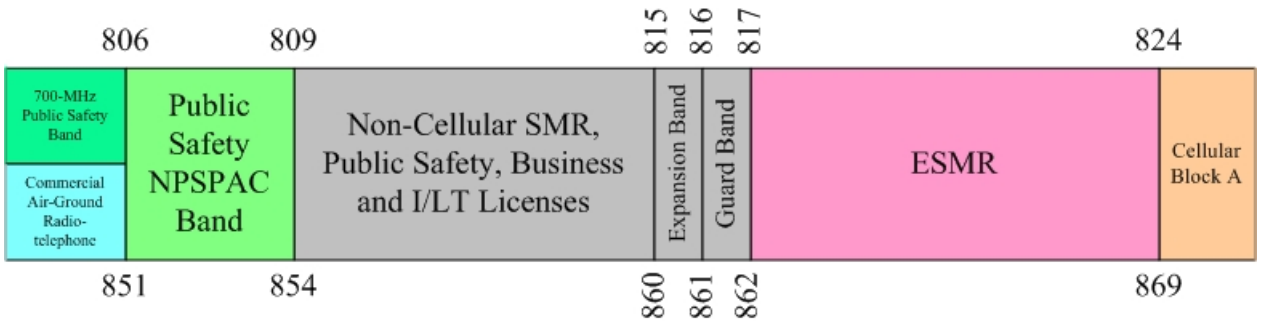
(6) The FCC has also created a Guard Band at 816-817/861-862 MHz. Any 800 MHz licensee may relocate to this spectrum, but will be afforded less protection from interference than licensees in the lower part of the 800-MHz band.

(7) Non-Nextel ESMR operations below 816/861 MHz may stay where they are, but will be subject to a stringent non-interference obligation.

(8) Nextel will receive 10 MHz of spectrum at 1910-1915/1990-1995 MHz.

(9) All costs for all licensees affected by band reconfiguration will be paid up front by Nextel.

Below is an illustration of the 800-MHz band allocations after the transition is completed. In certain parts of the country, most notably border areas and areas served by SouthernLINC, the plan is different.



Since the U.S. has not yet reached an agreement with Mexico on a band-sharing plan along the border, we cannot determine what the final plan will be and its impact on PCWIN. When an agreement is reached, the band will probably resemble the arrangement above; with a similar number of allotments between the U.S. and Mexico as now exist.

2.4.3 Rebanding Management

The FCC ordered the five largest stakeholders in the 800-MHz band to select a Transition Administrator (TA) to oversee the process. The selection team chose BearingPoint, a management consulting firm, and its partners, Squire, Sanders & Dempsey L.L.P., and Baseline Telecom, Inc.

The TA is responsible to oversee the administrative and financial aspects of band reconfiguration, provide accountability for the reconfiguration process, and help facilitate band reconfiguration with minimal disruption to licensees, particularly public safety entities. It will also authorize the disbursement of funds for band reconfiguration and resolve funding disputes through mediation.

2.4.4 Timetable

The TA's reconfiguration schedule is based on four reconfiguration "waves". Pima County is included in Wave 4. Each wave consists of two "stages". Wave 4 began on July 3, 2006 for non-border regions. Each wave begins with the voluntary negotiation period for licensees on channels 1-120 (806-809/851-854 MHz). Voluntary negotiations for NPSPAC licensees are scheduled to begin approximately seven months later. Each licensee must negotiate separate agreements with Sprint Nextel (Sprint purchased Nextel in 2005) for planning funding and for relocation. (The planning funding agreement is optional but highly recommended for any beyond the simplest 800-MHz radio systems.) The TA must review and approve each agreement.

Since Pima County is in the Mexico border zone, the reconfiguration process for licensees in Pima County has been postponed indefinitely until an agreement on band reconfiguration can be reached with the government of Mexico. There is no timetable for such an agreement, so rebanding may not be complete for several years in the border zone.

The schedule is supposed to provide for completion of band reconfiguration within 36 months of the beginning of reconfiguration of the first region. The FCC has mandated that within 18 months, Nextel must have relocated all non-Nextel incumbents in the 806-809/851-854 MHz band and begun negotiations with all NPSPAC licensees in the first 20 regions.

The 36-month deadline is extremely aggressive and experience has already shown that the rebanding process may take significantly longer, especially in regions with complex interoperability arrangements. The process of negotiations, planning and reconfiguration is painstaking. To this point, most of the systems that have completed reconfiguration are smaller, less complex, non-public safety systems. There has been no word yet on when the more complex systems and regions will be completed. In the Mexico border zone, reconfiguration will be delayed indefinitely until an agreement is negotiated with the Mexican government.

2.4.5 Regional Timetable

The FCC will release a public notice 30 days before the official beginning of band reconfiguration for each region. That will initiate a three-month voluntary negotiation period during which Nextel and licensees will seek to come to a retuning agreement, including costs and schedule. If no agreement is reached during that time, there will be a three-month mandatory negotiation period overseen by the TA. If no agreement is reached at that time, the matter will be referred for resolution to the TA and then possibly to the FCC. Licensees must be prepared to act when informed by Nextel or the TA that the negotiation period has begun.

2.4.6 Application Freeze

During the transition period, when the TA announces the beginning of the transition for a particular NPSPAC region, there will be a temporary freeze on new 800-MHz applications within 70 miles of that region. The freeze will begin 30 days before the voluntary negotiations period and end 30 days after the mandatory negotiations period—a total of eight months.

2.4.7 Conclusion

The following PCWIN agencies must remain aware of the constantly changing environment at 800 MHz:

- Pima County
- City of Tucson
- City of Marana
- Tucson Airport Authority
- Pima County Community College
- Tohono O'odham Nation
- University of Arizona
- Pasqua Yaqui Tribe

The TA has announced that rebanding in border regions will begin as soon as border area band plans are finalized. At that time, the TA will issue a Frequency Proposal Report (FPR) to each affected licensee. This report lists licenses and frequencies affected by rebanding and proposed replacement frequencies.

The licensee will have 45 calendar days from the date on the cover letter of the FPR in which to submit a Request for Frequency Planning Funding (RFPF). The RFPF will be reviewed by the TA and forwarded to Sprint Nextel. The licensee and Sprint Nextel will then negotiate a Planning Funding Agreement (PFA). It is extremely important that licensees negotiate the proper amount of funding for planning purposes; although Sprint Nextel is required to pay for all licensee expenses, it will be harder to negotiate adjustments to the agreement after the fact.

When the PFA is completed, planning begins. Existing equipment and systems must be analyzed to determine what needs to be replaced and what can be retuned. The frequencies must be examined for potential interference issues. Cutover to the rebanded system must be planned to avoid system outages.

Once the planning phase is completed, the licensee and Sprint Nextel will negotiate a Frequency Relocation Agreement (FRA). Again, these negotiations are very important because they establish the expected costs for reconfiguration. Cost overruns will be examined intently and may be difficult to justify without careful recordkeeping.

Once the FRA is completed, the actual physical work of rebanding will commence. The work should be completed with no downtime to the licensee's system.

It is safe to assume that all 800-MHz licensees in Pima County will be affected in some way by rebanding. The exact effect on each licensee can only be determined once the band plan is finalized, and the licensee's system and equipment are analyzed.

PCWIN member agencies with 800-MHz systems should be prepared to act when FPRs are received. CTA can help with inventory, assessment, cost estimating, management, negotiations (including legal representation), cutover planning and testing. All costs, including equipment, legal and engineering services, installation, testing and cutover, are to be paid by Sprint Nextel.

2.5 Fixed Microwave Services Relocation

2.5.1 The Lower 2-GHz Band

In 1994, the FCC reallocated the 1850-1990 MHz Fixed Microwave Services (FMS) (Lower 2-GHz) band to Personal Communications Services (PCS). Any microwave licensee remaining in the band after April 4, 2005 has been relegated to secondary status, meaning the system must not cause interference to PCS systems and is no longer subject to interference protection from PCS systems. If a PCS licensee requires use of the spectrum, the FMS licensee will be required to relinquish its license within six months of notification.

2.5.2 The Upper 2-GHz Band

The FCC has reallocated the 2110-2150/2160-2200 MHz FMS band to Emerging Technologies (ET), including the Advanced Wireless Service (AWS) and Mobile-Satellite Service (MSS). The 2110-2150 and 2160-2180 MHz segments have been reallocated to AWS, and the 2180-2200 MHz segment has been reallocated to MSS.

The FCC has decided that relocations in this spectrum will be subject to a mandatory negotiation period during which the ET licensees must negotiate with the FMS incumbents to relocate to comparable facilities. Once the mandatory

negotiations period has ended, an ET licensee may relocate a FMS incumbent involuntarily. The ET licensee must still pay to relocate the incumbent, but there are no negotiations regarding costs.

2.5.2.1 Relocations by AWS Licensees

The auction for AWS spectrum (2110-2150 and 2160-2180 MHz) is scheduled for August 9, 2006. Soon after this date, the winning bidders will begin notifying incumbent microwave licensees to begin negotiations. Each non-public safety microwave licensee will have two years to negotiate, while public safety will have three years. The relocation rules will sunset in approximately ten years, at which time microwave licensees will be secondary to AWS licensees in the band.

2.5.2.2 Relocations by MSS Licensees

The involuntary relocation procedures for 2180-2200 MHz have already begun. MSS licensees may notify licensees in this band to relocate at any time with six months notice. However, the MSS licensees have been slow to implement services, and many MSS licensees have argued that they can peacefully coexist with incumbent microwave licensees.

Relocation procedures will sunset December 9, 2013, after which time microwave licensees will be secondary to MSS in this band.

2.5.3 Conclusion

Any microwave licensee operating in the 1850-1990 MHz band should be making plans to relocate immediately to other spectrum. These licensees are secondary to PCS and may cause or be subject to harmful interference.

Incumbent microwave licensees operating in the 2110-2150/2160-2200 MHz band should continue to operate in the band until approached by an AWS or MSS licensee to negotiate relocation. All relocation costs will be paid by the ET licensee.

CTA can help in the relocation process, providing engineering, cost estimation and negotiation assistance.

2.6 The 4.9 GHz Band

2.6.1 Band Plan

In 2003, the FCC established rules for the 4.9 GHz Public Safety Band. The band is divided into 18 channels with bandwidths of 1 or 5 MHz. The purpose of this band is primarily to provide public safety users with spectrum for broadband communications applications. The spectrum can be used for data, voice, video, wireless local area networks, or any number of high-speed digital technologies. It is intended for mobile use, while temporary fixed use is allowed. The FCC envisions this band's use for the implementation of incident scene networks and wireless "hot spots" for high-speed data transfers of things like maps, building layouts, emergency medical service files, and wanted or missing person images.

Recently, changes were made to the rules for the 4.9 GHz band in order to allow the use of the IEEE 802.11 series of standards. It is hoped that this will make available a wider range of products for use in the band and will leverage the economies of scale to lower equipment costs.

2.6.2 Licensing and Coordination

A license will be issued to any public safety entity, and allow the entity to operate base, mobile or temporary fixed units throughout its legal jurisdictional area of operation. Applications must be made directly to the FCC; there is no frequency coordination necessary and no fees. Permanent, fixed, point-to-point services are allowed on a secondary, non-interfering basis, but require a separate site license.

The spectrum is licensed on a shared basis, i.e., all users are licensed to all channels. Licensees must coordinate with each other to use the band. The FCC gave 700 MHz regional planning committees the option to establish regional plans for the use of the 4.9 GHz spectrum. Since the availability of the band and the development technologies to use it are so recent, the FCC agreed to give the planning committees extended time to prepare plans for the coordinated use of the band.

This band may provide Pima County an opportunity to implement an inexpensive high-speed mobile data network.

3.0 VOICE RADIO TECHNOLOGIES

We maintain our focus on the design objective of developing a common system concept to provide public safety communications for all PCWIN agencies. Key drivers are the agency's requirements (Ranked Attributes); reliability; availability; ease of use, technical feasibility / availability and suitability for future expansion and upgrades.

A major step in the system design process is to identify alternative communication systems that, when combined, would satisfy the majority of PCWIN participant's requirements. Advantages and disadvantages of each are listed and aided in consideration as to suitability of consideration in a detailed analysis. The alternatives were analyzed by CTA as to how well they met each attribute individually. The rankings were further graded by multiplying the PCWIN law enforcement and fire department combined rankings to produce results to determine the alternative that best matches the greatest proportion of requirements and as such achieve the highest total score.

3.1 Voice Radio System Alternatives

Voice system technologies that we evaluated include:

1. Trunked Radio – Project 25 Technology
2. Trunked Radio – Proprietary Technology
3. Conventional Radio – Project 25 Technology
4. Conventional Radio – Analog Technology
5. Commercial Wireless
6. TETRA Technology

3.1.1 Trunked Radio – Project 25 Technology

Project 25 (P25) trunked radio technology is the most recent development in Land Mobile Radio. Based on TIA/EIA 102 standards, the over-the-air protocol, or air interface, is designed for interoperability between different manufacturers. Currently, P25 infrastructure equipment in the configurations appropriate for Pima County is available from E.F. Johnson, M/A-Com, and Motorola. Subscriber equipment is available from these manufacturers and independent radio makers.

We envision the trunked voice radio architecture as containing a mix of simulcast and multiple site technologies in the 700/800 MHz band. Simulcast technology provides seamless wide area radio coverage over the greater Tucson metropolitan area allowing users to work throughout this area without the need to adjust radio settings. Multiple site technology, also full featured trunking, completes coverage throughout the remainder of the County service area. Outside of Tucson users will want their radios affiliated with the nearest tower site. To some degree, switching will operate automatically while allowing the user to switch manually.

All tower sites and dispatch environments are interconnected via the network backbone to form a single integrated radio system sized with capacity to serve all PCWIN agencies.

Advantages

Radio systems based on P25 standards promise improved interoperability through a common air interface. The interoperability we seek is with adjacent jurisdictions and other outside agencies during times of mutual aid assistance. Many neighboring counties indicate intentions of migrating toward P25 technology.

- Yuma County is upgrading from 800 MHz SmartNet trunking technology to P25 technology.
- Santa Cruz County has plans for P25 operated on existing VHF frequencies contributed by participating agencies.
- Pinal County is still in the planning process but is favoring P25.
- Both Tucson Electric Power and Arizona Public Service have settled on P25 in the 800 MHz band
- Phoenix/Mesa is one of earliest and largest P25 users and is expanding the 800 MHz network using 700 MHz channels.

The interoperability we are discussing primarily enables outside responders to bring radios from a neighboring community and use them on the PCWIN system

to communicate with PCWIN agencies. Equally important is for PCWIN agencies to use their radios when offering assistance elsewhere. Such direct radio interoperability is easy to achieve when all parties operate in the same frequency band. Many of the above jurisdictions plan to operate in the 700/800 MHz band. We understand the Arizona Department of Public Safety is also targeting these bands.

The Federal agencies, under the Integrated Wireless Network Project, are committed to P25 technology operating in the Federal portion of VHF band (162-174 MHz). Policy restrictions may prohibit PCWIN agencies from operating on federal frequencies. However, PCWIN agencies have several options for communicating with Federal agencies. The most direct method is for Federal users to own and operate PCWIN radios on the PCWIN system. In areas where both parties have overlapping coverage, dispatch can interconnect agencies using a patch or gateway control.

A common air interface allows radios of one manufacturer to operate on infrastructure of another manufacturer. This leads to an important customer benefit of having a choice during radio procurement. Beside the obvious advantage of receiving competitive marketplace pricing, agencies may also select radios that are best suited to their operations. For example, a fire department may favor a particular vendor because of durability or for compatibility with a specific accessory. Law enforcement may favor a different vendor for some specific features. Both departments' choice of radios can operate on the same infrastructure.

P25 is a digital-only standard, meaning that trunked analog communication is not part of the operation. The main impact of digital-only is that of radio cost: all agencies in the organization must purchase relatively expensive digital radios. The P25 standard also comes with an "enhanced" user function set. However, some owners do not find the enhancements to be a must-have improvement over the previous APCO 16 function set common in other trunked radio systems. Most of the P25 functions have become standard offerings under proprietary non-P25 system architectures.

There is some latitude in the function set that is expected to allow manufacturers to differentiate their products. TABLE 3-1 lists the P25 trunked features as they are defined in the standard.

P25 technology allows users to be organized in "talkgroups" allowing segregated operations so users do not have to listen to extraneous radio traffic. Users share a pool of channels with channels assigned to users automatically. Call queuing and priority resolution is standard. Trunked P25 provides talk group segregation, less than 1 second call setup, dynamic regrouping of subscriber units in emergencies, digital individual voice call, preemptive priority call, AES encryption, and emergency call with priority. Intra-system roaming and inter-system roaming requires little or no user intervention when changing sites or systems and out of system operation is supported by the subscriber units (direct unit-to-unit or talk around).

The Department of Homeland Security advocates radio interoperability and offers P25 as one means of achieving this. When seeking grant funding for interoperable communications, the Department typically looks favorably on P25 equipment.

The common air interface is referred to as Phase 1 of the P25 standard. The main benefit is the ability to use multiple vendor radios. Phase 2 will extend the ability to link adjacent jurisdictions by adding the capability to interconnect infrastructure. The standardized interface is referred to as the Inter Sub-System Interface (ISSI). Phase 2 will improve one's ability to maintain contact with home dispatch while traveling outside jurisdiction during jail transport, for example. Progress on Phase 2 standards has stepped up recently and there is the possibility of including this option within the PCWIN construction.
P25 technology overall is in the early lifecycle stages. PCWIN will possibly benefit from a better return on investment because of a longer support life.

If the County intends to maintain the existing E.F. Johnson system for other County uses, there may be an opportunity for newly purchased radios to work on both new and old systems. E.F. Johnson may offer P25 radios that also operate on the MULTI-NET II systems. This would afford PCWIN users easy communications with users operating on the old system.

Disadvantages

One of the downsides to newer technology is cost. Leading edge technologies usually cost more than mature product lines where the vendor's development costs are fully recouped. However, considering that the P25 platform should be available and supported for at least 20 years, PCWIN should not face premature system replacement, therefore maximizing the investment.

Users of newer technology typically have to endure startup problems. Not that PCWIN would be anywhere near the first installed system for any major vendor; nevertheless, Pima County could from time to time encounter software bugs or product problems. This would most likely happen when trying new vendor's radio products, or migrating to new models. We observe reasonably smooth system launches and a high level of commitment from major vendors, so we don't see product bugs as a major obstacle.

While touching on the topic of technology stability, we need to mention a perturbation that lies down the road assuming this alternative is built using some 700 MHz spectrum. The FCC seeks to improve spectrum efficiency in the 700 MHz band. The goal is to double efficiency from one voice channel per 12.5 kHz bandwidth to one voice per 6.25 kHz bandwidth. Options for achieving this are discussed in more detail in SECTION 2 of this report.

The FCC date for narrow banding 700 MHz spectrum is 2017, within the lifecycle of PCWIN. While this is by no means an obstacle to the PCWIN project, decision makers should be aware of the impact and the options. First, narrow band 700 MHz equipment may utilize TDMA, FDMA, or some other technology. With this fundamental element unknown at this time, it is fairly safe to say that not all equipment initially deployed by PCWIN will be easily programmable to handle the change. This means that PCWIN must endure some capital equipment change-out costs in the 2015 to 2017 timeframe. To help PCWIN understand what is involved, in our specifications and RFP we plan to request direct and detailed information from each proposer on their narrow banding plan including replacements, reprogramming, and costs. We suggest that PCWIN include this known capitol expenditure event in the project business plan. This might involve initiating at system startup a user fee that is escrowed to help pay for the upgrades.

Secondly, some technology options if chosen by the vendors can significantly reduce coverage footprint for each tower site, necessitating additional sites.

From all party's viewpoints, this is not currently a popular approach. In fact, to ward off purchase postponements, vendors are interested in making this transition as painless as possible. We also plan RFP questioning in this area. As the PCWIN project progresses in time, more information will become available. In the meantime, we will certainly be looking for the most feasible and cost effective approach in the vendor proposals.

ROM Cost – Project 25 Trunking Technology

CTA's Rough Order of Magnitude (ROM) cost estimate for the PCWIN Voice System is $60M in a competitive purchasing environment. This is the initial cost for the installed hybrid simulcast/multiple site infrastructure and includes:

- Approximately 7000 initial subscriber radios
- Dispatch consoles for three agencies in a co-located environment
- Site facilities, towers, support equipment
- Interconnecting microwave/fiber links
- Engineering services, spares
- Does not include lifecycle maintenance and replacements

3.1.2 Trunked Radio – Proprietary Technology

Proprietary trunked radio technology provides many of the benefits of standards based technology minus the easy interoperability with others in the Pima County region. Virtually no agencies in the area operate proprietary technology such as the County's current E.F. Johnson MULTI-NET II system. This means that like today, there are few places in southern Arizona that one can take a proprietary radio and expect compatibility. The few existing Motorola SmartNet systems are mostly being upgraded to ASTRO 25, and SmartNet is no longer available as one of PCWIN's proprietary options.

On the other hand, the APCO 16 feature set offers the required communications features and would serve PCWIN's needs. Based on an older TIA/EIA guideline, all of the primary trunking benefits such as group and individual calls are

provided. However, each manufacturer has implemented the guideline using proprietary over-the-air protocols, making each vendor's equipment incompatible with others.

We envision proprietary trunked voice radio technology, like P25, constructed using the 800 MHz band or possibly with a combination of 700 and 800 MHz channels. It should be understood that most of the proprietary product lines are not available in 700 MHz. The greater Tucson metropolitan area needs seamless wide area radio coverage, however with some technologies, simulcast is not available to assist with this.

Multiple site trunking technology, a geographically expanded version of the current PCSD system would be the most appropriate architecture. Modern technologies assist the user with automatic "best tower" radio affiliation. However, as with any technology implemented countywide, users will be involved to some degree adjusting radio settings based on their county location.

All tower sites and dispatch environments are interconnected via the network backbone to form a single integrated radio system sized with capacity to serve all PCWIN agencies.

Currently, proprietary infrastructure equipment in configurations appropriate for Pima County is available from E.F. Johnson in the LTR line and M/A-Com in the EDACS and OpenSky product lines. Compatible subscriber equipment is supplied by the respective manufacturers.

M/A-COM's OpenSky product offering approaches spectrum efficiency and user capacity in a unique way. Time Division Multiple Access (TDMA) technology supports two to four simultaneous voice calls on each channel. It does not use a dedicated control channel, so all channels carry voice traffic. The system works similarly to one of the popular cellular technologies. In fact, because of cellular similarities, OpenSky is unique in land mobile radio in that it supports true "handoff" mid-call from one site to the next while moving.

In practice, since public safety calls last only three to four seconds on average, handoff is of limited value. Again, because of its kinship to cellular, OpenSky supports truly integrated voice and mobile data on the same channel set.

TDMA technology combined with a distributed control channel work together to reduce the number of scarce frequency resources needed. OpenSky is not currently offered with simulcast technology, somewhat negating the improved user density. Limited power at base stations tends to necessitate more tower sites with OpenSky than with other technologies. Higher site density works against frequency conservation. This characteristic combined with OpenSky being completely dissimilar to any radio system in southern Arizona, make it a weak contender from an interoperability standpoint to solve PCWIN's needs.

M/A-Com EDACS technology is no stranger to Pima County. A multiple site version of this product line served PCSD well from the early 1990's until 2000.

EDACS is also available in the simulcast technology, a configuration useful for the Tucson area in our current PCWIN concept.

M/A-Com continues to expand and improve the EDACS line. Since the County's experience, the system management workstation has been revamped with new hardware and software. The internal switching components and networking system have been replaced with IP-based designs, reducing the cost and complexity of the circuits needed for interconnection.

Since M/A-Com uses a common console platform for EDACS as well as P25 systems, consoles have continued to receive updates. Radio products, mobiles and portables, are also common to all lines, so the latest M/A-Com radios are available for EDACS. We have heard of no plans by M/A-COM to adapt EDACS to 700 MHz digital-only narrowband requirements. So EDACS would be limited to only 800 MHz spectrum rather than the larger available space in combined 700/800 MHz. EDACS remains a viable technology option.

E.F. Johnson LTR/Multi-Net II is the radio system currently in use by PCSD. LTR offers analog trunking technology and multiple tower site capabilities. Lack of simulcast capability translates to a higher number of frequencies needed.

Unlike many systems, Johnson technology does not use a dedicated control channel per site, freeing this channel for voice traffic. The downside to this design is somewhat slower call processing, noticeable in radio operation.

Motorola SmartNet and SmartZone. Motorola has made it clear through recent product discussions that their current strategy involves an aggressive phase out of their proprietary analog SmartNet and wideband digital (ASTRO) SmartZone lines in favor of a P25 standards-based, narrowband all-digital product, trademarked ASTRO25. They will continue for the near term to offer expansions and upgrades for installed systems such as additional sites and consoles. However, Motorola has stopped taking orders for new SmartNet and SmartZone systems using their proprietary trunked technology.

Advantages

Trunked radio technology offers two main advantages over the conventional technology currently used by many PCWIN agencies.

1. The possibility of a single regional communications system capable of supporting all agencies.

2. Segregated operations for each user agency on their own talk groups.

Trunked technology replaces the concept of "channels" with "talk groups". A common problem that agencies typically have is a limited number of incident channels licensed to their operation.

During busy times there may be a shortage of incident channels available for assignment by dispatch. This can result in incidents sharing a channel or the incident simply staying on the dispatch channel. In some cases channels must be shared by two organizations creating a cumbersome situation where users wait for airtime or listen to unrelated traffic.

With trunked technology, user groups are segregated into work groups using talk groups. Trunking systems offer a virtually unlimited (at least 16,000) number of talk groups to be divided among participating agencies.

Provision is made for monitoring more than one group and for talking to other agencies on the radio system. Users are segregated by design into work groups, permissions to access other talk groups are granted based on policy, and channels

are pooled for everyone's use reducing shared channel congestion through improved efficiency.

Along with trunked technology come several other useful features including individual radio-to-radio calls, unit identification at the consoles, and an emergency function, among others. Proprietary trunked technology offers a feature set similar to P25 technology.

The above mentioned proprietary technologies have been in production for some time making them mature technologies. Maturity often equates to stability, ease of maintenance, and lower purchase cost for the infrastructure.

Disadvantages

The main shortcoming of proprietary trunked radio is that of protocol incompatibilities in a region where P25 protocol is widely being embraced. As previously discussed, many entities in the southern Arizona area are either committed to or seriously considering standardized protocol as a communications benefit. This is not to say that standard protocol is the complete solution to interoperability.

There are still technical obstacles such as differences in frequency band to overcome. Policies and procedures may still prohibit public safety from freely intercommunicating with Federal agencies. However, with proprietary radio protocols, the obstacles to interoperability are simply greater.

It should be pointed out that the trunked radios purchased for proprietary systems may be equipped for secondary operation on P25 infrastructure. For example, as an extra cost option, both M/A-Com and Motorola radios can be ordered with support for P25 trunking. This could allow PCWIN agencies to roam (with permission) onto other regional P25 radio infrastructure. Proprietary radios can also be optioned with P25 conventional capabilities for more limited interactions with P25 neighbors. This dual protocol configuration would position PCWIN for proprietary operation in Pima County and P25 operation where available.

This approach would be useful in the case where an existing proprietary radio system is being upgraded, not replaced. We see no compelling reason for PCWIN to pursue this expensive approach for a new radio system.

Selection of proprietary trunked technology would commit PCWIN to a long-term relationship with one radio vendor. The main impact would be possibly higher single source pricing for all subscriber equipment, both initial and replacements, for the lifetime of the radio system. Users would forego one of the anticipated major benefits of P25 standardization, competitive radio procurement. Agencies would also forego the ability to tailor radio purchases from different vendors based on product suitability for the job.

Not all proprietary trunked product lines have the flexibility to operate in the combined 700 and 800 MHz frequency bands. We believe that considering the reduction in spectrum in these bands necessitated by coordination with Mexico, the more total channels that PCWIN has available the better. While OpenSky has been adapted for 700 MHz operation, we don't expect proprietary offerings to expand significantly in this direction.

Proprietary systems may not qualify for Federal grants and funding. Even though these systems may feature P25 conventional as a secondary operation, they may not be as attractive for grant funding as primary mode interoperable technology.

ROM Cost – Proprietary Trunking Technology

CTA's Rough Order of Magnitude (ROM) cost estimate for the PCWIN Voice System is $55M in a competitive purchasing environment.

This is the initial cost for the installed wide area site infrastructure and includes:

- Approximately 7000 initial subscriber radios
- Dispatch consoles for three agencies in a co-located environment
- Site facilities, towers, support equipment
- Interconnecting microwave/fiber links
- Engineering services, spares
- Does not include lifecycle maintenance and replacements

The cost is slightly lower than P25 technology due to lower market demand.

3.1.3 Conventional Radio – Project 25 Technology

Conventional radio for PCWIN expands upon the technology currently used by the City of Tucson and many local fire departments. We envision that a conventional design would be constructed in the VHF or UHF (or combined) bands since the FCC generally reserves 700/800 MHz for trunking use. Somewhat lower cost radios are simple to operate but users forego some advanced features and channel efficiency available in more advanced technologies. Under this scenario, additional channels would be established for agencies where a need is indicated by our traffic studies. As with other alternatives, backbone network extensions would be needed to reach new towers used to fill poor coverage areas.

Advantages

Conventional radio offers simple communications that is familiar to many PCWIN participants. Users simply select one of the channels assigned to the agency they wish to communicate with. Achieving regional communications with many agencies complicates the situation somewhat in that not all agencies can fit within 16 channel positions. Several banks of 16 channel groups would be needed for full range communications.

P25 technology offers some improvements to analog conventional radio operation. TABLE 3-2 lists the mandatory and optional features as defined in the P25 standard. Most notable is the concept of talk groups.

Using digital radio and group IDs, users that must share a channel can be segregated into talk groups. While users would still share the channel airtime, they would not have to listen to the conversations of other groups. P25 also enhances digital encryption for privacy, unit ID and status display at consoles and radios, and digital data capabilities such as Automatic Vehicle Location (AVL). Other advantages include:

- Simple operation
- Mature technology
- Lower cost

- Federal funding

Disadvantages

PCWIN regional communications in the VHF and UHF bands would likely be limited in overall channel capacity considering the scarcity of narrowband channel assets in the area. The goal should be to license sufficient new channels to alleviate crowding plus channels for future growth. Without further investigation, narrowband spectrum availability is unknown. To achieve the needed number of channels, a mixed VHF and UHF design may be required, complicating an otherwise simple communications environment and increasing costs with dual equipment. Achieving interference-free spectrum is generally more of a challenge in the VHF and UHF bands because of longer propagation from distant transmitters and because of overlapping wide and narrowband channels during the period between now and 2013.

Operation on the VHF and UHF bands will pose some interoperability challenges as the public safety community in southern Arizona migrates toward more open spectrum in the 700 and 800 MHz bands. Referring to the list of regional entities earlier in this section, only Santa Cruz County has definite plans of remaining in the VHF band.

ROM Cost – Project 25 Conventional Technology

CTA's Rough Order of Magnitude (ROM) cost estimate for the PCWIN Voice System is $51M in a competitive purchasing environment.

This is the initial cost for the installed wide area site infrastructure and includes:

- Approximately 7000 initial subscriber radios (no multi-band duplication of radios)
- Dispatch consoles for three agencies in a co-located environment
- Site facilities, towers, support equipment
- Interconnecting microwave/fiber links
- Engineering services, spares
- Does not include lifecycle maintenance and replacements

This cost reflects the currently higher cost for more sophisticated P25 technology, especially subscriber gear.

3.1.4 Conventional Radio – Analog Technology

Conventional radio for PCWIN expands upon the technology currently used by the City of Tucson and many local fire departments. We envision that a conventional design would be constructed in the VHF or UHF (or combined) bands since the FCC generally reserves 800 MHz for trunking use and 700 MHz requires digital operation. Radios are simple to operate but users forego advanced features and channel efficiency available in more recent technologies. As with other alternatives, backbone network extensions would be needed to reach new towers used to fill poor coverage areas.

Advantages

The main virtue of analog conventional technology is low cost. Many manufacturers fill the marketplace with competitive products in all cost, feature, and quality ranges. PCWIN of course would need to remain with equipment designed for public safety use.

Conventional radio offers simple communications that is familiar to many PCWIN participants. Users simply select one of the channels assigned to the agency they wish to communicate with.

Achieving regional communications with many agencies complicates the situation somewhat in that not all agencies can fit within 16 channel positions. Several banks of 16 channel groups would be needed on the radios for full range communications.

Disadvantages

PCWIN regional communications in the VHF and UHF bands would likely be limited in overall channel capacity considering the scarcity of narrowband channel assets in the area. The goal should be to license sufficient new channels to alleviate crowding plus channels for future growth.

To achieve the needed number of channels, a mixed VHF and UHF design may be required, complicating an otherwise simple communications environment and increasing costs with dual equipment. Achieving interference-free spectrum is generally more of a challenge in the VHF and UHF bands because of longer propagation from distant transmitters and because of overlapping wide and narrowband channels during the period between now and 2013.

Operation in the VHF and UHF bands will pose some interoperability challenges as the public safety community in southern Arizona migrates toward more open spectrum in the 700 and 800 MHz bands. Referring to the list of regional entities earlier in this section, only Santa Cruz County has definite plans for remaining in the VHF band.

Analog radios will not have the advanced features found with digital equipment. Two of the most significant features to PCWIN include digital encryption and digital call features. Eavesdropping becomes a problem without encryption. Users that must share channels do not have the benefit of talk group segregation. Users and dispatchers must do without unit IDs to identify who is calling.

Opting for a basic conventional analog approach may incur higher costs than expected. This is because some existing equipment cannot be reused, but must be replaced under the FCC mandate for narrowband VHF and UHF channels by 2013. This requires replacement of all existing equipment not capable of retuning to 12.5 kHz bandwidth operation.

From our site and equipment surveys, replacements would be needed for some portion of the base stations, and a small portion of the subscriber gear. Narrowband operation tends to result in slightly reduced coverage compared to your current wideband channels.

This means that just to keep the same operable service area you may need to add sites and possibly conventional simulcast gear, a further cost outlay. Please see SECTION 2 for additional discussion on narrowband migration.

ROM Cost – Analog Conventional Technology

CTA's Rough Order of Magnitude (ROM) cost estimate for the PCWIN Voice System is $39M in a competitive purchasing environment.
This is the initial cost for the installed wide area site infrastructure and includes:

- Approximately 7000 initial subscriber radios (no multi-band duplication of radios)
- Dispatch consoles for three agencies in a co-located environment
- Site facilities, towers, support equipment
- Interconnecting microwave/fiber links
- Engineering services, spares
- Does not include lifecycle maintenance and replacements

This lower cost reflects significantly lower subscriber gear costs available in the highly competitive multiple vendor environment.

3.1.5 Commercial Wireless

Under the commercial wireless scenario, PCWIN participating agencies would phase out private mobile radio and adopt commercial services as their primary communications medium. Some of the primary commercial providers in Pima County include Alltel, Nextel, Verizon, and Cingular. The County might negotiate a governmental rate structure for both airtime fees and handset equipment. Agencies could take advantage of the increasing availability of "push-to-talk" service and group calls to organize workgroups.

Public Safety dispatch capabilities over commercial services tend to be very limited. Motorola IDEN, the technology used in the Nextel network, does provide for dispatch capabilities. However, we have not heard of Nextel offering dispatch capabilities to any of its customers.

Devising a means of dispatch service for a large governmental group of users on any the public network would require further investigation.

Advantages

It is sometimes tempting to consider the attractive, small, highly functional handsets of cellular and Nextel services as a viable possibility as an organization's primary radio communications.

The main roadblock for public safety use is lack of guaranteed network availability during emergency conditions. Commercial infrastructure is simply not set up to offer guaranteed access for first responders. As experience has shown us, during emergency situations, commercial systems become congested to the saturation point. The concept of a reserved public safety partition on a public cell system providing priority access has been discussed for some time, but so far we have not seen this come to reality. If the emergency involves severe weather, damage to tower sites can prolong the outage.

Commercial services can reduce the need for upfront capital funding. However, ongoing expense costs must be compared with initial capital outlays. Typically, Public Safety radio system capital costs are amortized over 15 to 20 years. Commercial service costs are affected largely by the number of subscribers, frequency of handset replacements, and negotiated monthly subscription rates. Almost certainly, commercial costs will exceed private ownership costs well before the 20 year mark.

Commercial wireless is ideal for mobile telephone service needed for workgroup management. It is also justified for agencies who must communicate frequently with the general public. Some level of commercial service will continue to augment private public safety radio.

Disadvantages

Commercial service cannot be relied upon for public safety communications during disaster situations, whether they be natural or man made. During these times networks become saturated with traffic. This happens because revenue sensitive carriers design only for traffic loads to support average conditions. During storms, networks can be crippled due to physical damage or extended power outages. Again the networks have weighted their business case and opted not to build in redundancy and large backup power systems. These situations do

not occur often, but a large damaging storm or an incident at the airport could be enough to hamper commercial services. And of course, these are times when emergency communications must be available.

Commercial service coverage is not uniformly available throughout Pima County. Carriers tend to put in coverage in populated areas and along roadways. Improvements to existing coverage can only expected in places with increasing population. Agencies working in remote areas will still need to maintain some form of private radio communications to use in cellular non-coverage areas.

Considering the serious limitations of commercial services such as lack of dispatch and the lack any assurance of service during emergency situations, we cannot recommend this alternative for public safety operations. We eliminate this alternative from further consideration.

3.1.6 TETRA Professional Mobile Radio

TETRA radio technology is a global standard gaining popularity, particularly in Europe where it is endorsed by the European Telecommunications Standards Institute. Functionality, it is similar to the more familiar trunked APCO endorsements, APCO 16 and P25. Like P25, it is called an open standard featuring compatibility among various system and equipment suppliers. TETRA is a TDMA design allowing 4 users per channel and operating in 25 kHz channels in the 800 MHz band (in the Americas).

TETRA is not available in North America and it is not available on U.S. government frequencies and bandwidths.

3.2 Frequency Band Considerations

3.2.1 Frequency Band

Choice of frequency band will have a significant effect of the overall outcome of the project. From a practical standpoint, the choices include the lower bands (VHF and UHF), 800 MHz and 700 MHz. Factors influencing this selection include:

- Spectrum Availability

- Local Interoperability
- Adjacent County Interoperability
- Federal Interoperability
- State Interoperability
- Legacy Interoperability
- Product availability
- Interference

3.2.1.1 700 MHz Band

The 700 MHz band presents an opportunity for open spectrum in Arizona. This may be one of the best options for the shear quantities of radio channels needed for PCWIN. Arizona is one of a few states able to anticipate early deployment of this recently defined Public Safety spectrum. Many areas must wait for relocation of TV broadcast channels 60 – 69, which is not required until 2009. This date is tied to the transition from analog to digital TV signals.

The Regional Plan for region 3 (State of Arizona) was submitted to the FCC on May 15, 2006. While the plan approval date is unknown, several other states have paved the way and we think Pima County should be able to begin licensing by late this year. Pima County has representation on the Regional Committee and can stay abreast of developments. The Regional Plan appears to be coming together in the timeframe needed for implementation of PCWIN.
According to published information from CAPRAD, the Region 3 Plan allocates 40 voice channels to Pima County. These are the 12.5 KHz bandwidth channels used for P25 digital systems. Typically, a Regional Plan also allocates special mobile data channels. While the pending Region 3 Plan does not spell out the mobile data channels, it does contain provision for allocations based on justified need. The mobile data channels are defined as 50 KHz in bandwidth, designed to support greater data speeds than previously available. Three adjacent channels may be used together for 150 kHz bandwidth for even higher transfer speed. We consider these high performance data channels as an important aspect of the 700 MHz band in light of the mobile data requirements for PCWIN.

Phoenix/Mesa has begun expanding their 800 MHz P25 radio system using 700 MHz channels. Lacking the Regional Plan, they are working under a special arrangement where they are borrowing 700 MHz frequencies from the State

allocation. Phoenix's progress and experience bolsters our confidence in the vendor's claims of ability to deliver mixed 800/700 MHz systems.

3.2.1.2 800 MHz Band

The 800 MHz band is familiar territory to both Pima County and the City of Tucson. The County's current trunked radio system occupies 44 channels. The City's new IPMobileNet infrastructure also uses three 800 MHz channel pairs. Quite a number of PCWIN participating agencies are 800 MHz license holders.

PCWIN will require a significant number of total channel pairs for implementation of the regional PCWIN. We will determine the actual needed quantity in the next project phase; conceptual design. The County and City each hold in excess of 40 licensed channels. Combining these approximately eighty channels with the forty 700 MHz channels allows sufficient spectrum for PCWIN.

The 800 Mutual Aid calling channel is already licensed and constructed at the Keystone Peak site in Pima County. If PCWIN shifts a larger percentage of the public safety community into the 800/700 MHz band it may be desirable to increase the build out of 800 MHz mutual aid infrastructure in the county.

3.2.1.3 VHF and UHF Bands

The VHF and UHF frequency bands are viable for some of the voice system alternatives, particularly the conventional designs. Trunked use of these bands involves extra challenges. Since the bands are unstructured, that is, receive frequencies are not automatically paired with transmit frequencies, some reshuffling of existing frequency utilization within the County may be required to achieve satisfactory trunked pairing. Licensees are also required to go through an exercise of coordination with co-channel and adjacent channel licensees within a 70 mile radius. While these challenges can be overcome, they represent an extra level of effort required to use these bands.

Interference can effect operation in these bands in several ways. With the looming narrowbanding deadline, naturally any new construction would use 12.5 kHz channels. Until 2013, there will be overlapping 25 kHz channels in operation that may interfere with PCWIN. Generally high levels of activity in these bands,

both locally and at a distance, in the U.S. and in Mexico, increased the potential for interference.

Local branches of federal law enforcement operate in the federal portion of the VHF spectrum. This presents an opportunity for convenient communications between PCWIN agencies and the federal agencies. Federal conventional radios should be capable of tuning to the VHF public safety band allowing Federal agencies to communicate of PCWIN channels. Public Safety agencies are not permitted to talk on the Federal channels.

3.2.1.4 Frequency Coordination with Mexico

Pima County's border with Mexico presents some potential coordination issues. Spectrum in the 800 MHz band is receiving attention these days in the interest of moving forward with the Nextel rebanding process.

Most of Pima County falls within the Mexico border zone extending 110 km (68.4 mi) from the U.S.-Mexico border. However, the dividing line goes through the northern part of the Tucson area. Mount Lemmon, although it is beyond the 110 km limit, is also governed by the border zone rules.
Within the border zone, frequencies are allotted between Mexico and the U.S, and non-NPSPAC channels are offset by 12.5 kHz. The following licenses are located within Pima County but contain non-border zone 800-MHz channels:

Licensee	Callsign	Sites	Number of Channels	
			Total	Non-Border Zone
City of Tucson	WPQA524	4701 N. Swan Rd.	45	27
City of Marana	WPLV689	10001 N. Silverbell Rd. 13051 N. Tortolita Rd. 5100 W. Ina Rd.	6	6

This simply means that use of these frequencies will be limited to areas beyond the border zone. All other 800-MHz channels licensed within the county are coordinated with Mexico.

The FCC's Nextel rebanding plan will require a new 800-MHz spectrum use agreement between the U.S. and Mexico. Negotiations are under way, but no agreement has yet been reached. Until an agreement is reached, rebanding for border zone licensees is on hold indefinitely. However, other non-border zone licensees in Arizona have already begun the rebanding process.

Intuitively, it would be desirable for PCWIN to be implemented after rebanding to avoid rework. However, Wave 4 rebanding for the Mexico border zone is postponed indefinitely due to border coordination. The rebanding process for each licensee will begin when the licensee receives an FPR from the TA. We recommend that the PCWIN project continue to move forward regardless of progress on 800 MHz rebanding, bearing in mind, Sprint Nextel is required to pay all rebanding costs incurred by PCWIN.

Regarding 700 MHz coordination the pending Regional 3 Plan simply states a willingness of the regional committees to assist the FCC in working out coordination agreements. Lacking agreements, licenses with jurisdictional areas within 120 km (75 M) of Mexico will have to accept interference from UHF television broadcasters in Mexico. Admittedly, this situation is not ideal and we will need to be monitored as the PCWIN project progresses.

3.3 Impact Analysis

Now that several possible voice system alternatives have been developed, we are ready to discuss our Impact Analysis. This process is designed to help evaluate the alternatives in light of all the information learned to date during the Phase 1 Business Architecture Planning process. The results will help us zero in on the alternatives that best fit your needs.

Impact Analysis is an interactive process between PCWIN agencies and CTA. Your inputs include the problems and needs learned during interviews, new system attributes assembled based on your needs, and your attribute importance rankings. FIGURE 3-1 provides a visual picture of the process flow.

- System Attributes – Positive characteristics of a new system that may be emphasized during conceptual design. Attributes were identified by CTA following our interviews. Attributes cover voice, mobile data, and dispatch

operations.

- Attribute Rankings – Attributes importance ratings solicited from each of the 33 PCWIN participating agencies.

The ranking criteria used during this process were as follows:

0 Attribute is NOT IMPORTANT to the user.

1 Attribute is MINIMALLY IMPORTANT to the user.

2 Attribute is NICE TO HAVE, could enhance operations.

3 Attribute is USEFUL, will promote more efficient day to day operation.

4 QUITE IMPORTANT, lack could result in degradation of mission, injury, or loss of property.

5 CRITICAL, lack generally will result in injury, loss of property, or degradation of mission.

Selected attributes were singled out for ranking only by fire departments or law enforcement agencies. This selection was requested by PCWIN during the User Needs Assessment part of the project. Description of the complete attributes list and the ranking results can be found in CTA's PCWIN User Needs Assessment Report.

CTA then evaluated each of the alternatives in light of your inputs to develop our opinion of technical fit.

A panel of CTA engineers and operations people close to the PCWIN project independently assessed how well each design alternative could fulfill the attributes identified for the Pima County. Each panelist considered each design option one attribute at a time and scored the ability of the option to deliver that attribute. Scoring ranges from a value of 0 (nonexistent capability) to 5 (95 % of the function/attribute) based on how well the alternative satisfies the requirement.

The criteria for evaluating and ranking each item were established as follows:

0 Required function (Attribute Does Not Exist)

1 Required function (Available but Totally Insufficient)

2 Generally inadequate (Unacceptable Alternative)

3 Marginally Adequate (Approximately 60% Functionality)

4 Reasonably adequate (A Good Alternative)

5 95% of Function / Attribute Available (Excellent Alternative)

The results were then combined and summed to provide a score for how well the alternatives served the attributes as a whole. The results were used as an input to the Impact analysis process.

Attribute scores were then weighted using the average ranking submitted by PCWIN participants. In this way, characteristics important to you carry more weight and lower importance attributes carry less weight. The final result is a weighted ranking of the system alternatives for overall suitability.

3.4 Impact Results - Voice Radio Systems

TABLE 3-3, Comparison of Voice Radio System Alternatives, contains the results of the impact analysis for alternatives 1 through 4 described in this report section.

At the left side of the table are the attributes established earlier in the project. The reference numbers refer to the attribute definitions provided in the User Needs Assessment Report.

Under “CTA Assessment” are four numerical columns with CTA’s evaluation of fit for each attribute and each alternative. These values can range from a low of 0 to high of 5. In the center of the table is PCWIN’s importance rank for the attribute, an average of the responses returned by all PCWIN agencies.

Under Weighted-Ranked Results are four columns containing the weighted results. Each value is CTA's assessment multiplied times PCWIN's rank used as the weighting factor.

Each of the Weighted-Ranked Results columns are totaled at the bottom arriving at an overall score for each alternative. The totals are summarized below.

Alternative	*Combined Law and Fire Score*
1. Trunked Radio – Project 25 Technology	673
2. Trunked Radio – Proprietary Technology	622
3. Conventional Radio – Project 25 Technology	523
4. Conventional Radio – Analog Technology	480

With about a 100-point spread, clearly the two trunked radio alternatives have the edge over conventional technologies. Among the trunked options, P25 technology stands out, primarily in the areas of:

- Interoperability
- Competitive procurement and multiple sourcing
- Regional connectivity
- Capability for future expansion

We also examined the rankings as in light of the requirements important to law enforcement agencies and fire departments.

TABLE 3-4 repeats the process, but instead of using overall PCWIN Rank, uses average rankings for just the law enforcement agencies.

The alternatives scored as follows.

Alternative	*Law Enforcement Score*
1. Trunked Radio – Project 25 Technology	664
2. Trunked Radio – Proprietary Technology	614
3. Conventional Radio – Project 25 Technology	516
4. Conventional Radio – Analog Technology	473

Comparing these results to those obtained from a combined raking, we see virtually the same outcome.

TABLE 3-5 repeats the process, this time using average rankings for just the fire departments. The alternatives scored as follows.

Alternative	*Fire Departments Score*
1. Trunked Radio – Project 25 Technology	642
2. Trunked Radio – Proprietary Technology	595
3. Conventional Radio – Project 25 Technology	499
4. Conventional Radio – Analog Technology	465

This results indicate a higher suitability for trunked versus conventional and for P25 versus proprietary technology.

We conclude that P25 trunked technology is an appropriate fit for construction of PCWIN.

Table 3-1
Trunked P25 Services

Telecommunications Services	
Bearer Services	**Trunked**
Circuit Switched Unreliable Data	Standard Option
Circuit Switched Reliable Data	Standard Option
Packet Switched Confirmed Delivery Data	Standard Option
Packet Switched Unconfirmed Delivery Data	Standard Option
Teleservices	**Trunked**
Broadcast Voice Call	Mandatory
Unaddressed Voice Call	Not Applicable
Group Voice Call	Mandatory
Individual Voice Call	Mandatory
Circuit Switched Data Network Access	Standard Option
Packet Switched Data Network Access	Standard Option
Pre-programmed Data Messaging	Standard Option
Supplementary Services	**Trunked**
Encryption	Standard Option
Priority Call	Standard Option
Preemptive Priority Call	Standard Option
Call Interrupt	Standard Option
Voice Telephone Interconnect	Standard Option
Discreet Listening (A user can selectively listen in on a any call [individual, group and broadcast])	Standard Option
Silent Emergency (It can be dispatcher initiated – causes radio to key up and allow dispatcher and others to hear activity in vicinity of radio enabled [individual, group and broadcast])	Standard Option
Radio Unit Monitoring (Dispatcher initiated. Supplementary to individual call – causes radio to initiate a call by itself without audible or visible indication to the operator that the radio is initiating the call. Allows dispatcher to hear activity in vicinity of radio enabled)	Standard Option
Talking Party Identification Supplementary to broadcast, group and individual calls. Provides identification of transmitting unit at all receiving points)	Standard Option

Table 3-1
Trunked P25 Services

Telecommunications Services	
Call Alerting (Supplement to Individual calls – call originator can leave his identity to the called unit for subsequent callback (Prompt for callback only)	Standard Option
Bearer Services	**Trunked**
Services to the Subscriber	**Trunked**
Intra-system Roaming	Standard Option
Inter-system Roaming	Standard Option
Call Restriction	Standard Option
Affiliation	Standard Option
Call Routing	Standard Option
Encryption Update	Standard Option

Table 3-2
Conventional P25 Services

Telecommunications Services	
Bearer Services	**Conventional**
Circuit Switched Unreliable Data	Standard Option
Circuit Switched Reliable Data	Standard Option
Packet Switched Confirmed Delivery Data	Standard Option
Packet Switched Unconfirmed Delivery Data	Standard Option
Teleservices	**Conventional**
Broadcast Voice Call	Not Applicable
Unaddressed Voice Call	**Mandatory**
Group Voice Call	Standard Option
Individual Voice Call	Standard Option
Circuit Switched Data Network Access	Standard Option
Packet Switched Data Network Access	Standard Option
Pre-programmed Data Messaging	Standard Option
Supplementary Services	**Conventional**
Encryption	Standard Option
Priority Call	Not Available
Preemptive Priority Call	Not Available
Call Interrupt	Standard Option
Voice Telephone Interconnect	Standard Option
Discreet Listening (A user can selectively listen in on a any call [individual, group and broadcast])	Standard Option
Silent Emergency (It can be dispatcher initiated – causes radio to key up and allow dispatcher and others to hear activity in vicinity of radio enabled [individual, group and broadcast])	Standard Option
Radio Unit Monitoring (Dispatcher initiated. Supplementary to individual call – causes radio to initiate a call by itself without audible or visible indication to the operator that the radio is initiating the call. Allows dispatcher to hear activity in vicinity of radio enabled)	Standard Option
Talking Party Identification Supplementary to broadcast, group and individual calls. Provides identification of transmitting unit at all receiving points)	Standard Option
Call Alerting (Supplement to Individual calls – call originator can leave his identity to the called unit for subsequent callback (Prompt for callback only)	Standard Option
Services to the Subscriber	**Conventional**
Intra-system Roaming	Standard Option
Inter-system Roaming	Standard Option
Call Restriction	Not Available
Affiliation	Not Available
Call Routing	Not Available
Encryption Update	Standard Option

TABLE 3-3
IMPACT Analysis Results - Voice System Technologies
Combined Law and Fire

		CTA Assessment					Weighted - Ranked Results			
		Trunked Radio - Project 25 Technology	Trunked Radio - Proprietary Technology	Conventional Project 25 Radio Technology	Conventional Analog Radio Technology	Combined Law Fire	Trunked Radio - Project 25 Technology	Trunked Radio - Proprietary Technology	Conventional Project 25 Radio Technology	Conventional Analog Radio Technology
Ref.	ATTRIBUTE									
No.		Alt 1	Alt 2	Alt 3	Alt 4	RANK	Alt 1	Alt 2	Alt 3	Alt 4
43	Reliability/Failure Hierarchy	4.6	4.6	3.0	3.0	4.6	21.0	21.0	13.7	13.7
45	Power Backup	4.6	4.6	4.2	4.0	4.5	20.9	20.9	19.0	18.1
42	Survivability	4.4	4.4	3.4	3.4	4.5	19.7	19.7	15.2	15.2
44	Single Points of Failure	4.4	4.6	2.8	2.8	4.3	19.1	19.9	12.1	12.1
4	In-building Coverage	4.4	4.4	3.2	3.0	4.3	18.9	18.9	13.8	12.9
46	Staffing and Training	4.6	4.6	4.4	4.2	4.3	19.8	19.8	18.9	18.1
9	Emergency Alerting	4.6	4.6	2.8	1.6	4.2	19.2	19.2	11.7	6.7
8	Monitored Firegrounds	4.4	4.2	3.6	3.4	4.1	17.9	17.0	14.6	13.8
5	Minimize Local Interference	4.6	4.6	2.8	2.4	4.0	18.4	18.4	11.2	9.6
21	Simplified User Operations	4.0	4.0	3.6	3.8	3.9	15.7	15.7	14.2	14.9
37	Future Expansion	4.6	4.2	3.0	2.6	3.9	18.1	16.5	11.8	10.2
14	Interoperability through Dispatch	4.8	4.4	3.2	3.0	3.9	18.7	17.2	12.5	11.7
20	Recorded Operations	4.8	4.6	3.8	3.8	3.9	18.6	17.8	14.7	14.7
24	Dispatch Coverage	4.4	4.4	3.6	3.4	3.9	17.0	17.0	13.9	13.1
11	Voice Security	5.0	4.2	3.8	1.4	3.8	19.1	16.0	14.5	5.3
7	On-scene Channels	4.6	4.6	4.0	4.0	3.7	16.8	16.8	14.6	14.6
35	Fire Station Alerting	3.2	3.4	2.8	3.0	3.6	11.7	12.4	10.2	10.9
23	Dispatch Capacity	4.8	4.4	3.8	3.6	3.6	17.3	15.8	13.7	13.0
49	Commonality of Equipment	4.4	3.8	4.2	3.8	3.6	15.8	13.7	15.1	13.7
52	Tiered Subscriber Cost	4.6	4.4	3.8	3.8	3.5	16.0	15.3	13.2	13.2
18	Person Location	4.2	3.6	2.2	1.4	3.5	14.6	12.5	7.6	4.9
13	One System Serves All Agencies	5.0	4.0	2.4	2.2	3.4	17.2	13.7	8.2	7.6
19	System Control	4.8	4.4	4.0	3.6	3.4	16.4	15.0	13.7	12.3
6	Increased Channel Capacity	4.8	4.6	2.8	2.4	3.4	16.3	15.6	9.5	8.2
47	Centralized Maintenance	4.2	4.4	4.2	4.0	3.3	14.0	14.7	14.0	13.4
16	Interoperability with State Agencies	4.2	2.6	3.2	2.4	3.3	14.0	8.7	10.7	8.0
10	Workgroup Oriented Operation	5.0	4.8	2.6	2.4	3.3	16.6	15.9	8.6	7.9
15	Interoperability with Adjacent Counties	4.0	3.2	3.0	2.8	3.3	13.1	10.5	9.8	9.1
17	Interoperability with Federal Agencies	3.6	1.8	3.2	2.2	3.3	11.8	5.9	10.5	7.2
48	Competitive Procurement Process	3.6	2.4	4.6	4.4	3.3	11.8	7.8	15.0	14.4
22	Increased Dispatch Channel Capacity	4.8	4.4	2.6	2.4	3.2	15.5	14.2	8.4	7.8
39	Microwave Connectivity	4.8	4.6	4.0	3.8	3.2	15.5	14.9	12.9	12.3
38	Owner-Controlled Backbone	4.6	4.4	4.0	3.8	3.2	14.8	14.1	12.9	12.2
12	Operational Boundary Transparency	4.6	4.4	2.6	2.6	3.2	14.7	14.1	8.3	8.3
41	Regional Connectivity	4.8	4.0	2.4	2.6	3.2	15.2	12.7	7.6	8.2
34	Private Personnel Paging	2.8	3.2	3.2	3.4	3.1	8.6	9.8	9.8	10.4
3	Improved Voice Radio Coverage – Western County	4.8	4.6	4.2	3.8	3.0	14.4	13.8	12.6	11.4
40	Microwave Additional Capacity	4.6	4.4	4.0	3.8	3.0	13.8	13.2	12.0	11.4
51	Phased Implementation	4.0	3.8	4.4	4.4	3.0	11.9	11.3	13.1	13.1
1	Improved Voice Radio Coverage – Eastern County	4.0	3.8	3.2	2.8	2.9	11.7	11.1	9.4	8.2
2	Improved Voice Radio Coverage – Central County	4.8	4.6	4.0	3.6	2.9	14.1	13.5	11.7	10.6
36	Paging over Cellular	2.2	2.2	2.2	2.2	2.9	6.4	6.4	6.4	6.4
50	Multiple Sources	4.0	1.4	4.4	4.2	2.7	10.8	3.8	11.9	11.3
	CTA TOTAL	188	173	147	135					
						WEIGHTED - RANKED TOTAL	673	622	523	480
						OVERALL RANK	1	2	3	4
							Trunked Radio - Project 25 Technology	Trunked Radio - Proprietary Technology	Conventional Project 25 Radio Technology	Conventional Analog Radio Technology

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

TABLE 3-4
IMPACT Analysis Results - Voice System Technologies
Law Enforcement

		CTA Assessment					Weighted - Ranked Results			
		Trunked Radio - Project 25 Technology	Trunked Radio - Proprietary Technology	Conventional Project 25 Radio Technology	Conventional Analog Radio Technology	Law Enforcement	Trunked Radio - Project 25 Technology	Trunked Radio - Proprietary Technology	Conventional Project 25 Radio Technology	Conventional Analog Radio Technology
Ref.	ATTRIBUTE									
No.		Alt 1	Alt 2	Alt 3	Alt 4	RANK	Alt 1	Alt 2	Alt 3	Alt 4
43	Reliability/Failure Hierarchy	4.6	4.6	3.0	3.0	4.8	22.2	22.2	14.5	14.5
42	Survivability	4.4	4.4	3.4	3.4	4.8	21.2	21.2	16.4	16.4
45	Power Backup	4.6	4.6	4.2	4.0	4.7	21.7	21.7	19.9	18.9
44	Single Points of Failure	4.4	4.6	2.8	2.8	4.6	20.4	21.3	13.0	13.0
4	In-building Coverage	4.4	4.4	3.2	3.0	4.6	20.4	20.4	14.8	13.9
46	Staffing and Training	4.6	4.6	4.4	4.2	4.5	20.5	20.5	19.6	18.7
5	Minimize Local Interference	4.6	4.6	2.8	2.4	4.4	20.1	20.1	12.2	10.5
21	Simplified User Operations	4.0	4.0	3.6	3.8	4.3	17.1	17.1	15.4	16.2
37	Future Expansion	4.6	4.2	3.0	2.6	4.2	19.2	17.6	12.5	10.9
20	Recorded Operations	4.8	4.6	3.8	3.8	4.2	20.1	19.2	15.9	15.9
24	Dispatch Coverage	4.4	4.4	3.6	3.4	3.8	16.8	16.8	13.7	13.0
11	Voice Security	5.0	4.2	3.8	1.4	3.8	19.1	16.0	14.5	5.3
9	Emergency Alerting	4.6	4.6	2.8	1.6	3.7	17.1	17.1	10.4	6.0
14	Interoperability through Dispatch	4.8	4.4	3.2	3.0	3.7	17.9	16.4	11.9	11.2
18	Person Location	4.2	3.6	2.2	1.4	3.7	15.7	13.4	8.2	5.2
47	Centralized Maintenance	4.2	4.4	4.2	4.0	3.7	15.5	16.3	15.5	14.8
23	Dispatch Capacity	4.8	4.4	3.8	3.6	3.6	17.5	16.0	13.8	13.1
52	Tiered Subscriber Cost	4.6	4.4	3.8	3.8	3.6	16.7	16.0	13.8	13.8
39	Microwave Connectivity	4.8	4.6	4.0	3.8	3.6	17.5	16.7	14.5	13.8
3	Improved Voice Radio Coverage – Western County	4.8	4.6	4.2	3.8	3.6	17.5	16.7	15.3	13.8
49	Commonality of Equipment	4.4	3.8	4.2	3.8	3.5	15.6	13.5	14.9	13.5
19	System Control	4.8	4.4	4.0	3.6	3.5	17.0	15.6	14.2	12.8
12	Operational Boundary Transparency	4.6	4.4	2.6	2.6	3.5	15.9	15.2	9.0	9.0
1	Improved Voice Radio Coverage – Eastern County	4.0	3.8	3.2	2.8	3.5	13.8	13.1	11.1	9.7
13	One System Serves All Agencies	5.0	4.0	2.4	2.2	3.4	16.8	13.5	8.1	7.4
6	Increased Channel Capacity	4.8	4.6	2.8	2.4	3.4	16.1	15.5	9.4	8.1
22	Increased Dispatch Channel Capacity	4.8	4.4	2.6	2.4	3.4	16.1	14.8	8.7	8.1
38	Owner-Controlled Backbone	4.6	4.4	4.0	3.8	3.4	15.5	14.8	13.5	12.8
51	Phased Implementation	4.0	3.8	4.4	4.4	3.4	13.5	12.8	14.8	14.8
2	Improved Voice Radio Coverage – Central County	4.8	4.6	4.0	3.6	3.4	16.1	15.5	13.5	12.1
48	Competitive Procurement Process	3.6	2.4	4.6	4.4	3.3	11.8	7.9	15.1	14.4
40	Microwave Additional Capacity	4.6	4.4	4.0	3.8	3.3	15.1	14.4	13.1	12.4
10	Workgroup Oriented Operation	5.0	4.8	2.6	2.4	3.2	15.9	15.3	8.3	7.6
17	Interoperability with Federal Agencies	3.6	1.8	3.2	2.2	3.1	11.1	5.6	9.9	6.8
41	Regional Connectivity	4.8	4.0	2.4	2.6	3.1	14.8	12.4	7.4	8.0
34	Private Personnel Paging	2.8	3.2	3.2	3.4	3.1	8.7	9.9	9.9	10.5
16	Interoperability with State Agencies	4.2	2.6	3.2	2.4	3.0	12.6	7.8	9.6	7.2
36	Paging over Cellular	2.2	2.2	2.2	2.2	3.0	6.6	6.6	6.6	6.6
7	On-scene Channels	4.6	4.6	4.0	4.0	2.9	13.4	13.4	11.6	11.6
15	Interoperability with Adjacent Counties	4.0	3.2	3.0	2.8	2.9	11.6	9.3	8.7	8.1
50	Multiple Sources	4.0	1.4	4.4	4.2	2.9	11.6	4.1	12.8	12.2
8	Monitored Firegrounds	4.4	4.2	3.6	3.4	0.0	0.0	0.0	0.0	0.0
35	Fire Station Alerting	3.2	3.4	2.8	3.0	0.0	0.0	0.0	0.0	0.0
	CTA TOTAL	188	173	147	135					
						WEIGHTED - RANKED TOTAL	664	614	516	473
						OVERALL RANK	1	2	3	4
							Trunked Radio - Project 25 Technology	Trunked Radio - Proprietary Technology	Conventional Project 25 Radio Technology	Conventional Analog Radio Technology

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

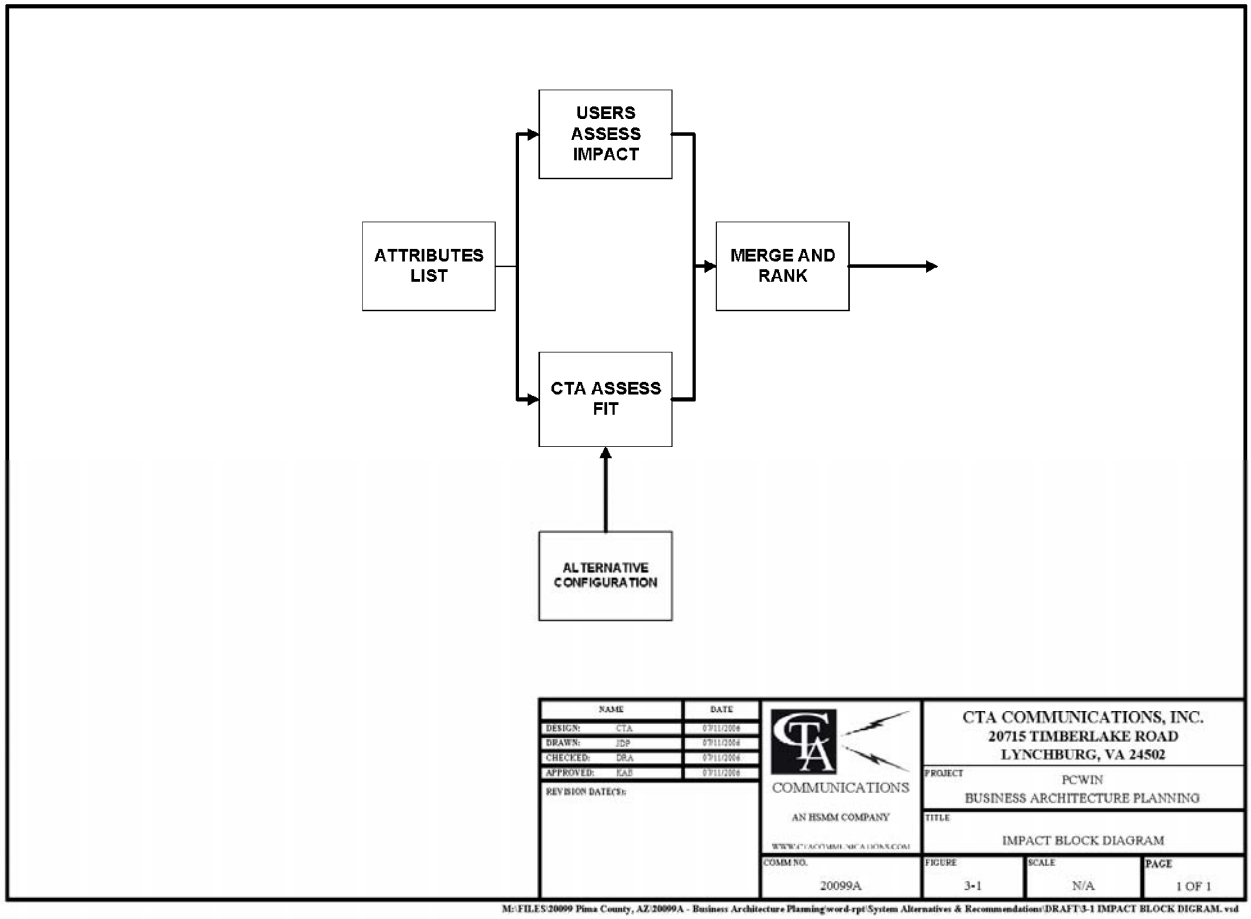
TABLE 3-5
IMPACT Analysis Results - Voice System Technologies
Fire Departments

		CTA Assessment					Weighted - Ranked Results			
		Trunked Radio - Project 25 Technology	Trunked Radio - Proprietary Technology	Conventional Project 25 Radio Technology	Conventional Analog Radio Technology	Fire Departments	Trunked Radio - Project 25 Technology	Trunked Radio - Proprietary Technology	Conventional Project 25 Radio Technology	Conventional Analog Radio Technology
Ref.	ATTRIBUTE									
No.		Alt 1	Alt 2	Alt 3	Alt 4	RANK	Alt 1	Alt 2	Alt 3	Alt 4
43	Reliability/Failure Hierarchy	4.6	4.6	3.0	3.0	4.4	20.3	20.3	13.3	13.3
45	Power Backup	4.6	4.6	4.2	4.0	4.4	20.3	20.3	18.6	17.7
9	Emergency Alerting	4.6	4.6	2.8	1.6	4.4	20.3	20.3	12.4	7.1
42	Survivability	4.4	4.4	3.4	3.4	4.3	18.8	18.8	14.5	14.5
46	Staffing and Training	4.6	4.6	4.4	4.2	4.2	19.4	19.4	18.5	17.7
44	Single Points of Failure	4.4	4.6	2.8	2.8	4.2	18.3	19.1	11.6	11.6
7	On-scene Channels	4.6	4.6	4.0	4.0	4.1	18.9	18.9	16.4	16.4
4	In-building Coverage	4.4	4.4	3.2	3.0	4.1	18.1	18.1	13.1	12.3
8	Monitored Firegrounds	4.4	4.2	3.6	3.4	4.1	17.9	17.0	14.6	13.8
14	Interoperability through Dispatch	4.8	4.4	3.2	3.0	4.0	19.2	17.6	12.8	12.0
24	Dispatch Coverage	4.4	4.4	3.6	3.4	3.9	17.1	17.1	14.0	13.2
5	Minimize Local Interference	4.6	4.6	2.8	2.4	3.8	17.4	17.4	10.6	9.1
37	Future Expansion	4.6	4.2	3.0	2.6	3.8	17.4	15.9	11.4	9.9
21	Simplified User Operations	4.0	4.0	3.6	3.8	3.7	14.9	14.9	13.5	14.2
20	Recorded Operations	4.8	4.6	3.8	3.8	3.7	17.7	16.9	14.0	14.0
35	Fire Station Alerting	3.2	3.4	2.8	3.0	3.6	11.7	12.4	10.2	10.9
49	Commonality of Equipment	4.4	3.8	4.2	3.8	3.6	16.0	13.8	15.3	13.8
23	Dispatch Capacity	4.8	4.4	3.8	3.6	3.6	17.2	15.7	13.6	12.9
16	Interoperability with State Agencies	4.2	2.6	3.2	2.4	3.5	14.8	9.2	11.3	8.5
13	One System Serves All Agencies	5.0	4.0	2.4	2.2	3.5	17.4	13.9	8.3	7.6
15	Interoperability with Adjacent Counties	4.0	3.2	3.0	2.8	3.5	13.9	11.1	10.4	9.7
6	Increased Channel Capacity	4.8	4.6	2.8	2.4	3.4	16.4	15.7	9.6	8.2
52	Tiered Subscriber Cost	4.6	4.4	3.8	3.8	3.4	15.6	14.9	12.9	12.9
10	Workgroup Oriented Operation	5.0	4.8	2.6	2.4	3.4	16.9	16.3	8.8	8.1
17	Interoperability with Federal Agencies	3.6	1.8	3.2	2.2	3.4	12.1	6.1	10.8	7.4
19	System Control	4.8	4.4	4.0	3.6	3.3	16.0	14.7	13.4	12.0
18	Person Location	4.2	3.6	2.2	1.4	3.3	13.9	11.9	7.3	4.6
48	Competitive Procurement Process	3.6	2.4	4.6	4.4	3.3	11.7	7.8	15.0	14.4
41	Regional Connectivity	4.8	4.0	2.4	2.6	3.2	15.4	12.8	7.7	8.3
47	Centralized Maintenance	4.2	4.4	4.2	4.0	3.2	13.3	13.9	13.3	12.6
22	Increased Dispatch Channel Capacity	4.8	4.4	2.6	2.4	3.2	15.2	13.9	8.2	7.6
38	Owner-Controlled Backbone	4.6	4.4	4.0	3.8	3.1	14.3	13.7	12.5	11.8
12	Operational Boundary Transparency	4.6	4.4	2.6	2.6	3.1	14.0	13.4	7.9	7.9
34	Private Personnel Paging	2.8	3.2	3.2	3.4	3.1	8.5	9.8	9.8	10.4
39	Microwave Connectivity	4.8	4.6	4.0	3.8	3.0	14.4	13.8	12.0	11.4
36	Paging over Cellular	2.2	2.2	2.2	2.2	2.9	6.4	6.4	6.4	6.4
40	Microwave Additional Capacity	4.6	4.4	4.0	3.8	2.8	13.1	12.5	11.4	10.8
51	Phased Implementation	4.0	3.8	4.4	4.4	2.8	11.1	10.5	12.2	12.2
2	Improved Voice Radio Coverage – Central County	4.8	4.6	4.0	3.6	2.7	12.9	12.3	10.7	9.7
3	Improved Voice Radio Coverage – Western County	4.8	4.6	4.2	3.8	2.6	12.6	12.1	11.1	10.0
1	Improved Voice Radio Coverage – Eastern County	4.0	3.8	3.2	2.8	2.6	10.5	10.0	8.4	7.4
50	Multiple Sources	4.0	1.4	4.4	4.2	2.6	10.3	3.6	11.3	10.8
11	Voice Security	5.0	4.2	3.8	1.4	0.0	0.0	0.0	0.0	0.0
	CTA TOTAL	188	173	147	135					
						WEIGHTED - RANKED TOTAL	642	595	499	465
						OVERALL RANK	1	2	3	4
							Trunked Radio - Project 25 Technology	Trunked Radio - Proprietary Technology	Conventional Project 25 Radio Technology	Conventional Analog Radio Technology

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

CTA COMMUNICATIONS
Pima County Wireless Integrated Network

FIGURE 3-1 IMPACT BLOCK DIAGRAM



4.0 MOBILE DATA SYSTEM TECHNOLOGIES

4.1 Mobile Data System Alternatives

Data System Technologies that we evaluated include:

1. Stand-Alone Mobile Data
2. Integrated Voice and Data
3. Commercial Wireless Data Service

We envision a hybrid mobile data infrastructure design, including two levels of service, designed to provide mobile access to all needed information sources. The first level of service is the dispatch network that covers the day to day communications between Law and Fire Dispatch operations and the fleet of officers and fire units. This service is provided over medium speed data channels offering wide area county coverage and high user capacity. CAD dispatch, automatic vehicle location (AVL), unit status, records queries, and reasonably sized mugshot-type information access is carried on over this network. Our three mobile data technologies apply to this portion of the network.

The second level of service enables services that require a high capacity network operating at higher speeds. We envision this network constructed using private broadband technology similar to the Wi-Fi hotspot systems that are being installed now by Tucson Fire. Broadband has the ability to support transfers of bulky information to mobile users that would otherwise overload the dispatch network. The variety of applications always expands once a community has the network in place. Initially we envision broadband supporting video surveillance, police video from air support to the ground. Broadband locations at Sheriff substations, police stations, and fire houses can provide access to information residing on agency networks.

An alternative to private broadband that may be more suitable for some users is high speed commercial wireless service. Alltel, Verizon, and others provide this service in the populated areas of Pima County. Two needs tend to drive the need for commercial service over limited-area broadband. One need is extensive out-of-County travel.

Corrections transport operations as an example could maintain mobile data contact while traveling to regional or State facilities. The other need is for downloading bulky information while out in the field. This user might be a Fire Marshal needing a building plan during inspections.

For the purpose of our discussions that follow this second level, whether private broadband or commercial wireless, may be included with any of the primary dispatch network options discussed below.

4.1.1 Stand-Alone Mobile Data Systems

Stand-alone, or along-side mobile data systems as they are sometimes called, allow the greatest flexibility when selecting mobile data technology. When treating the mobile data system as a completely separate procurement and build out from the voice radio system, PCWIN is free to choose from a broad selection of vendors offering competitive and often, more innovative solutions than may be available from the selected voice radio vendor.

Under this scenario, we envision a countywide infrastructure as an array of tower sites, collocated when possible at voice radio sites, with dedicated mobile data transceivers to serve the PCWIN agencies.

Two examples of appropriate stand-alone technologies are the IPMobileNet system being installed by the Tucson, and the popular DataRadio products.

Some data applications such as those listed below would be carried over the voice radio network and not the stand-alone mobile data system. This naturally occurs because each of these functions involves interactions with a voice radio and not the mobile data computer. So logically, these functions would simply be purchased as part of the voice radio system and not as part of the stand-alone mobile data system.

- Unit status messaging from a portable radio
- Transmission of location information from a GPS-enabled portable radio
- Short text messaging between portable radio and dispatch
- Over the air radio personality reprogramming
- Over the air reloading of encryption keys

<u>Advantages</u>

Stand-alone mobile data offers a broadly expanded choice of vendors and suppliers beyond the voice radio system vendor. Some prospective vendors focus

solely on mobile data and offer some innovative solutions. The mobile data system purchase may also be separated from the voice system, improving feature selection and cost competition.

Stand-alone does not mean complete separation from the voice system, and therefore high cost. Mobile data would likely share the voice radio sites using the same physical facilities, towers, power systems, and microwave network. Typically, mobile data technology advances faster than that of voice radio. Decoupled data and voice equipment allows the mobile data system to be expanded or upgraded without impacting the voice system.

Mobile data systems used to be regarded as secondary communications systems meaning as long as the voice radios worked, a public safety organization could function properly. That situation is changing with officers relying on the laptops for plate checks and firemen gaining electronic access to building plans. Increasingly, mobile data systems are being view as part of critical communications. Stand alone mobile data offers some degree of system redundancy allowing two methods of communications between dispatch and field officers.

Stand alone mobile data is built to public safety grade standards and will deliver higher long term availability than commercial services.

One of the primary attractions of the 700 MHz band is provision for higher speed mobile data channels. The band features standard 50 kHz wide channels that run at 128 kbps and 150 kHz wide channels that run at 384 kbps, as compared with less than 40 kbps typically found in other bands. We expect two benefits: noticeably faster mobile data response times, and capacity for more users on the system.

Disadvantages

A separate mobile data system requires a second maintenance contract and maybe a different maintenance organization. This can increase operating cost over a single infrastructure that handles all communications.

ROM Cost – Stand-Alone Mobile Data Technology

CTA's Rough Order of Magnitude (ROM) cost estimate for the PCWIN stand alone mobile data alternative is $22M in a competitive purchasing environment.

Non-Fixed Cost: $14M
Infrastructure Cost: $8M

This is the initial cost for the installed system and includes:

- Infrastructure
- Approximately 1000 new vehicle computer/modem sets (augments existing newer units)
- Site facilities, towers, support equipment
- Interconnecting microwave/fiber links
- Engineering services, spares
- Does not include lifecycle maintenance and replacements

4.1.2 Integrated Mobile Data and Voice Systems

One major LMR vendor is focusing on "integrated voice and data" products. Another vendor believes an integrated backbone network should carry all communications traffic but multiple types of radio links should be used for different mobile data purposes. This alternative is directed at the former completely integrated system approach. One of the main benefits to this approach include the possibility of operating data applications over what were previously thought to be voice-only radios. Integrated voice and data product offerings are generally targeted for construction in the 700 MHz radio band to take advantage of faster channels.

Under this scenario, we also envision countywide infrastructure sharing voice tower sites primarily using the 700 MHz mobile data channels.

We envision the integrated voice and data system providing the same services as Alternative 1. These are the dispatch services that cover the day to day communications between Law and Fire Dispatch operations and the fleet of officers and fire units. This service is provided over medium speed data channels

offering wide area county coverage and high user capacity. CAD dispatch, automatic vehicle location (AVL), unit status, records queries, and reasonably sized mugshot-type information access is carried on over this network.

Advantages

Integrated mobile data systems have the potential for reduced construction costs through shared infrastructure. Voice system tower sites, repeater channels, backhaul network, and management systems are examples of shared elements. In some vendor's offerings even the vehicular radio may serve for both voice and data. Voice and data infrastructure from multiple vendors may not be mixed, possibly limiting PCWIN's choice of mobile data features. The integrated mobile data system is somewhat linked reliability-wise to the voice system. Integrated mobile data is however built to public safety grade standards and will deliver higher long term availability than commercial services.

Integrated voice and data systems offer an opportunity for what is called "voice and data integration". Useful examples include:

- Unit status messaging from a portable radio
- Transmission of location information from a GPS-enabled portable radio
- Short text messaging between portable radio and dispatch
- Over the air radio personality reprogramming
- Over the air reloading of encryption keys

An integrated voice and data system can naturally handle all of these data oriented tasks. This does not rule out a choice by the system operator to direct some of these functions, such as GPS location, over a stand alone mobile data system.

Disadvantages

Technology needs to be refreshed more often on mobile data systems than for voice radio systems. It is difficult to imagine living with the same wireless computer system for 15 to 20 years. Integration of mobile data and voice all tied to the same vendor increase the likelihood that upgrades to the data system will impact operating costs because of upgrade impact to the voice system.

Some vendors offer a solution involving one vehicle radio to perform both voice and mobile data functions. We feel this may lead either to conflicts for the same radio resource or infrastructure resource conflicts between voice and data needs.

While integrated voice and data systems generally use different transceiver channels, site control elements are shared. This means that if a critical element goes down at one site the County may loose use of that site for both voice and data operations.

Because of the single system approach, a single vendor provides both sets of infrastructure. This can limit the County for initial vendor selection and during the entire system lifecycle as upgrades are performed.

ROM Cost – Integrated Voice and Mobile Data Technology

CTA's Rough Order of Magnitude (ROM) cost estimate for the PCWIN integrated voice and mobile data alternative is $18M in a competitive purchasing environment.

Non-Fixed Cost: $12M
Infrastructure Cost: $6M

This is the initial cost for the installed system and includes:

- Infrastructure
- Approximately 1000 new vehicle computer/modem sets (augments existing newer units)
- Site facilities, towers, support equipment
- Interconnecting microwave/fiber links
- Engineering services, spares
- Does not include lifecycle maintenance and replacements

4.1.3 Commercial Wireless

Mobile data using commercial wireless services is essentially an expansion of the same service that has served the Pima County Sheriff's Department since 2000. Additional PCWIN agencies could adopt the service, perhaps reducing

subscription costs through high subscriber volumes. Agencies could procure services from carriers such as Alltel, Nextel, and Verizon.

Advantages

The main advantages to this approach include reduced up-front infrastructure capital, high speed service, region wide service area (in populated areas), and the option for portable handheld user gear.

Commercial wireless does permit one option that private radio options cannot. This is the ability to conduct business over handheld PDA devices. This capability is dependant on handheld software support by the selected CAD vendor.

Commercial wireless costs are structured differently than privately owned options. Up front capital cost is exchanged for long-term airtime expense costs. Over the 20 year period, a large scale rollout of the commercial option will be more expensive than private ownership and maintenance. Keep in mind that a large portion of the maintenance cost is associated with the fleet of mobile equipment as compared with the infrastructure. Commercial services do use lower cost and more easily upgraded radio modems than private systems.

Disadvantages

The main disadvantages are dependence on carrier resources for possibly critical communications, and high recurring subscription expenses. Agencies working in remote areas of the County would not have service (areas where cell phones do not work).
Long term overall cost of operation for commercial services typically exceeds private ownership costs before the 10 year mark, depending on the fleet size.

Coverage service area is determined by the commercial operator to best meet his operating objectives. Governmental users, as important as they can be, have little say in where service is improved. Service is generally installed along roadways, and in populated areas.

As much as the concept has been discussed, we know of no public safety organization that has been able to achieve priority access on public commercial services. So under emergency conditions, when system congestion occurs, grade of service will suffer.

ROM Cost – Commercial Wireless Mobile Data Technology

CTA's Rough Order of Magnitude (ROM) cost estimate for the PCWIN Commercial Wireless Mobile Data System is $44M in a competitive purchasing environment. This estimate is all user equipment and airtime costs since there is no infrastructure cost.

- Approximately 1000 installed vehicle laptop sets (compliments 1000 existing units)
- Approximately 500 handheld devices
- Airtime charges for 2500 units for 20 years at $60/unit/month
- Does not include lifecycle maintenance and replacements

4.2 Impact Analysis

CTA has completed an Impact Analysis evaluation on the three mobile data alternatives described above. The Impact Analysis process is explained in detail in SECTION 3 of this report.

4.3 Impact Results – Mobile Data Systems

TABLE 4-1, Comparison of Mobile Data System Alternatives, contains the results of the impact analysis for alternatives 1 through 3 described in this report section.

At the left side of the table are the attributes established earlier in the project. The reference numbers refer to the attribute definitions provided in the User Needs Assessment Report.

Under "CTA Assessment" are three numerical columns with CTA's evaluation of fit for each attribute and each alternative. These values can range from a low of 0 to high of 5. In the center of the table is PCWIN's importance rank for the attribute, an average of the responses returned by all PCWIN agencies.

Under Weighted-Ranked Results are three columns containing the weighted results. Each value is CTA's assessment multiplied times PCWIN's rank used as the weighting factor.

Each of the Weighted-Ranked Results columns are totaled at the bottom arriving at an overall score for each alternative. The totals are summarized below.

	Alternative	Combined Law and Fire Score
1.	Stand-Alone Mobile Data	264
2.	Integrated Voice and Data	245
3.	Commercial Wireless Data Service	201

Considering PCWIN's weighting to the scores, stand-alone mobile holds a slight edge over the other alternatives. We also examined the rankings in light of the unique requirements important to law enforcement agencies and fire departments.

TABLE 4-2 repeats the process, but instead of using overall PCWIN Rank, uses average rankings for just the law enforcement agencies. The alternatives scored as follows.

	Alternative	Law Enforcement Only Score
1.	Stand-Alone Mobile Data	268
2.	Integrated Voice and Data	249
3.	Commercial Wireless Data Service	200

Comparing these results to those obtained from a combined raking, we see virtually the same outcome.

TABLE 4-3 repeats the process, this time using average rankings for just the fire departments. The alternatives scored as follows.

	Alternative	Fire Departments Only Score
1.	Stand-Alone Mobile Data	253
2.	Integrated Voice and Data	235
3.	Commercial Wireless Data Service	193

These results again indicate a higher suitability for stand-alone mobile data versus the other alternatives. We conclude that stand-alone mobile data technology is an appropriate fit for construction of PCWIN.

TABLE 4-1
IMPACT Analysis Results - Mobile Data System Technologies
Combined Law and Fire

		CTA Assessment				Weighted - Ranked Results		
		Stand-Alone Mobile Data	Integrated Voice and Data	Commercial Wireless Technology	Combined Law Fire	Stand-Alone Mobile Data	Integrated Voice and Data	Commercial Wireless Technology
Ref.	ATTRIBUTE							
No.		Alt 1	Alt 2	Alt 3	RANK	Alt 1	Alt 2	Alt 3
29	EMS Telemetry	3.0	2.8	3.6	3.5	10.6	9.9	12.7
28	Vehicle Location	4.0	3.8	2.6	3.5	14.0	13.3	9.1
27	Mobile Data Criticality	4.0	3.8	2.2	3.5	13.8	13.1	7.6
31	Mobile Applications	4.0	4.0	3.8	3.5	13.8	13.8	13.1
30	High-Speed Broadband Service	4.0	4.0	3.6	3.2	12.8	12.8	11.5
32	Advanced Mobile Applications	3.2	2.8	3.4	3.2	10.1	8.8	10.7
26	Cross CAD Interconnection	3.6	3.2	2.6	3.0	10.8	9.6	7.8
25	One Mobile Data Network Serves All Agencies	3.4	3.2	2.6	2.9	9.8	9.2	7.5
33	Access County Information	3.2	2.8	3.2	2.9	9.2	8.1	9.2
38	Owner- Controlled Backbone	3.8	3.8	0.8	3.2	12.2	12.2	2.6
42	Survivability	3.6	3.4	2.4	4.5	16.1	15.2	10.7
43	Reliability/Failure Hierarchy	3.4	3.6	2.0	4.6	15.5	16.4	9.1
44	Single Points of Failure	3.6	3.6	1.8	4.3	15.6	15.6	7.8
45	Power Backup	3.8	3.8	2.2	4.5	17.2	17.2	10.0
46	Staffing and Training	3.4	3.4	3.0	4.3	14.6	14.6	12.9
47	Centralized Maintenance	3.8	3.8	2.6	3.3	12.7	12.7	8.7
48	Competitive Procurement Process	3.8	2.6	3.2	3.3	12.4	8.5	10.5
49	Commonality of Equipment	3.4	3.0	2.6	4.0	13.6	12.0	10.4
50	Multiple Sources	3.0	2.4	2.8	2.7	8.1	6.5	7.6
51	Phased Implementation	3.2	2.8	3.6	3.0	9.5	8.4	10.7
52	Tiered Subscriber Cost	3.2	2.0	3.2	3.5	11.1	7.0	11.1
	CTA TOTAL	74	69	58				
					WEIGHTED - RANKED TOTAL	264	245	201
					OVERALL RANK	1	2	3
						Stand-Alone Mobile Data	Integrated Voice and Data	Commercial Wireless Technology

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

TABLE 4-2
IMPACT Analysis Results - Mobile Data System Technologies
Law Enforcement

		CTA Assessment				Weighted - Ranked Results		
		Stand-Alone Mobile Data	Integrated Voice and Data	Commercial Wireless Technology	Law Enforcement	Stand-Alone Mobile Data	Integrated Voice and Data	Commercial Wireless Technology
Ref.	ATTRIBUTE							
No.		Alt 1	Alt 2	Alt 3	RANK	Alt 1	Alt 2	Alt 3
42	Survivability	3.6	3.4	2.4	4.8	17.3	16.4	11.6
43	Reliability/Failure Hierarchy	3.4	3.6	2.0	4.8	16.4	17.3	9.6
45	Power Backup	3.8	3.8	2.2	4.7	18.0	18.0	10.4
44	Single Points of Failure	3.6	3.6	1.8	4.6	16.7	16.7	8.3
46	Staffing and Training	3.4	3.4	3.0	4.5	15.1	15.1	13.4
31	Mobile Applications	4.0	4.0	3.8	3.9	15.6	15.6	14.9
47	Centralized Maintenance	3.8	3.8	2.6	3.7	14.1	14.1	9.6
27	Mobile Data Criticality	4.0	3.8	2.2	3.6	14.5	13.8	8.0
52	Tiered Subscriber Cost	3.2	2.0	3.2	3.6	11.6	7.3	11.6
28	Vehicle Location	4.0	3.8	2.6	3.5	14.2	13.5	9.2
30	High-Speed Broadband Service	4.0	4.0	3.6	3.5	14.2	14.2	12.8
49	Commonality of Equipment	3.4	3.0	2.6	3.5	12.1	10.6	9.2
32	Advanced Mobile Applications	3.2	2.8	3.4	3.5	11.1	9.7	11.7
38	Owner- Controlled Backbone	3.8	3.8	0.8	3.4	12.8	12.8	2.7
51	Phased Implementation	3.2	2.8	3.6	3.4	10.8	9.4	12.1
33	Access County Information	3.2	2.8	3.2	3.3	10.5	9.2	10.5
48	Competitive Procurement Process	3.8	2.6	3.2	3.3	12.4	8.5	10.5
26	Cross CAD Interconnection	3.6	3.2	2.6	3.2	11.5	10.2	8.3
25	One Mobile Data Network Serves All Agencies	3.4	3.2	2.6	3.0	10.2	9.6	7.8
50	Multiple Sources	3.0	2.4	2.8	2.9	8.7	7.0	8.1
29	EMS Telemetry	3.0	2.8	3.6	0.0	0.0	0.0	0.0
	CTA TOTAL	74	69	58				
					WEIGHTED - RANKED TOTAL	268	249	200
					OVERALL RANK	1	2	3
						Stand-Alone Mobile Data	Integrated Voice and Data	Commercial Wireless Technology

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

TABLE 4-3
IMPACT Analysis Results - Mobile Data System Technologies
Fire Departments

		CTA Assessment				Weighted - Ranked Results		
		Stand-Alone Mobile Data	Integrated Voice and Data	Commercial Wireless Technology	Fire Departments	Stand-Alone Mobile Data	Integrated Voice and Data	Commercial Wireless Technology
Ref. No.	ATTRIBUTE	Alt 1	Alt 2	Alt 3	RANK	Alt 1	Alt 2	Alt 3
43	Reliability/Failure Hierarchy	3.4	3.6	2.0	4.4	15.0	15.9	8.8
45	Power Backup	3.8	3.8	2.2	4.4	16.8	16.8	9.7
42	Survivability	3.6	3.4	2.4	4.3	15.3	14.5	10.2
46	Staffing and Training	3.4	3.4	3.0	4.2	14.3	14.3	12.6
44	Single Points of Failure	3.6	3.6	1.8	4.2	15.0	15.0	7.5
49	Commonality of Equipment	3.4	3.0	2.6	3.6	12.3	10.9	9.4
29	EMS Telemetry	3.0	2.8	3.6	3.5	10.6	9.9	12.7
28	Vehicle Location	4.0	3.8	2.6	3.5	13.9	13.2	9.0
52	Tiered Subscriber Cost	3.2	2.0	3.2	3.4	10.8	6.8	10.8
27	Mobile Data Criticality	4.0	3.8	2.2	3.3	13.4	12.7	7.4
48	Competitive Procurement Process	3.8	2.6	3.2	3.3	12.4	8.5	10.4
31	Mobile Applications	4.0	4.0	3.8	3.2	12.7	12.7	12.1
47	Centralized Maintenance	3.8	3.8	2.6	3.2	12.0	12.0	8.2
38	Owner- Controlled Backbone	3.8	3.8	0.8	3.1	11.8	11.8	2.5
30	High-Speed Broadband Service	4.0	4.0	3.6	3.0	12.0	12.0	10.8
32	Advanced Mobile Applications	3.2	2.8	3.4	3.0	9.5	8.3	10.1
26	Cross CAD Interconnection	3.6	3.2	2.6	2.9	10.4	9.3	7.5
25	One Mobile Data Network Serves All Agencies	3.4	3.2	2.6	2.8	9.6	9.0	7.3
51	Phased Implementation	3.2	2.8	3.6	2.8	8.8	7.7	9.9
33	Access County Information	3.2	2.8	3.2	2.7	8.5	7.4	8.5
50	Multiple Sources	3.0	2.4	2.8	2.6	7.7	6.2	7.2
	CTA TOTAL	74	69	58				
					WEIGHTED - RANKED TOTAL	253	235	193
					OVERALL RANK	1	2	3
						Stand-Alone Mobile Data	Integrated Voice and Data	Commercial Wireless Technology

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

5.0 COMMUNICATIONS CENTER E-9-1-1 PSAP CONSIDERATIONS

One of the goals of the PCWIN Project is to "Design, construct, occupy and operate a regional communications center co-locating the 9-1-1 public safety answering points and dispatch functions of the Pima County Sheriff's Department and the City of Tucson with the Pima County Emergency Operations Center. A public safety Emergency Communications Center functions as the interface between the public and the public safety agencies of the community and provides coordination and support to those public safety agencies. An important part of that coordination and support is with other agencies and responders. Any situation requiring more than one responder requires coordination. That is true whether the responders are from the same or different agencies. More responders require more efforts. Coordination cannot occur without communication. Bringing the three major communications centers into one facility specifically designed to facilitate communications between the participating agencies will result in significant enhancements to the interagency coordination that is required when more than one agency is responding to an emergency. In addition, both the 9-1-1 network and the radio network structures are on the verge of signification transformation from circuit-based technology to packet-switched technology.

PCWIN participating agencies have identified the following critical success factors for the new center:

- The facility will be contemporary
- A master plan will be completed providing room and direction for growth
- The design will provide for sustainable operations
- Designed for flexibility
- The four agencies harmoniously coexist in a single facility
- Improved Service Delivery
- Pleasant, safe working environment that promotes employee retention
- Employee satisfaction
- Improved efficiency through shared services
- Coordinated Information technology plan

5.1 Communications Center Location

Because of the critical functions performed at public safety communications centers, considerable care is required in the location, design and construction of a center. The

location should be chosen carefully and be as far from known hazards as feasible. For example, the lowest floor in a communications center should be above the 100 year flood elevation. Facilities that use hazardous chemicals should not be close to the center Careful consideration is needed when considering a location near a rail line or major highway that is used to transport hazardous chemicals The Federal Emergency Management Agency recommends that a ten-mile radius around a critical facility be thoroughly investigated. A significant leak of an Extremely Hazardous Substance (EHS), such as chlorine, could necessitate the need for protective actions including evacuation as far as ten miles from the incident. Possible terrorist actions could expand that emergency action zone. A hazard analysis should result in a threat rating – how likely is the facility to face the particular threat(s).

5.2 Communications Center Design

The design of critical communications facilities is a complex field. Public safety communications systems and public safety communications facilities should function under all conditions. The facility should be designed to withstand anticipated hazards. Any effort to enhance the security and survivability of critical communications facilities must consider all of the hazards that the facility may face.

5.2.1 Technical Issues

The impact of technology on emergency communication systems and facilities is becoming increasingly significant. Technological advances have affected the way public safety agencies and corresponding centers operate daily. Technology affects every aspect of doing business – directly and indirectly.

In order to meet future needs over the next 15 to 20 years, a critical communications center should be designed with the following considerations in mind:

- Avoiding fixed objects (walls, furniture, etc.) when practical
- Selecting equipment and peripherals such as displays, keyboards, and computers that can change and move as much as possible
- The infrastructure (data and power cables, etc.) needs to be moveable and reconfigurable

- The space should be as open as possible, and raised flooring and high ceilings should be used
- Adequate equipment room space must be provided
- Extra attention must be focused on electrical grounding

The PSAP must also comply with requirements of the ADA concerning requirements that facilities and equipment be readily accessible and useable by persons with disabilities.

As the equipment in critical communications centers become more integrated, there is a definite trend towards equipping them with more flexible and ergonomic furniture. A number of manufacturers offer adjustable furniture so personnel can raise or lower a chair or work surface to a comfortable position. Many new models allow adjustments from sitting to standing. This amenity is especially helpful when dispatchers and call takers are expected to spend prolonged periods at a workstation.

5.2.2 Design Issues

The consolidation/co-location issue has profound effects on the room design. It will directly impact the number of console positions in the center. In the equipment room, this will dictate the size and quantity of CAD processors, 9-1-1 switching equipment, and recorder processors. These requirements, in turn, will be carried out to determine the floor space, electrical, and HVAC needs.

Redundant utilities systems, including power, sewer, water, etc need to be provided. In many instances it is equally critical to consider additional redundant systems such as dual emergency generators, as an example. Commercial electrical power will, in all probability, be lost during an event. An emergency generator must be capable of providing power for 100 percent of the facility electrical needs. A failure in this “back-up” system can result in the inability of the facility to function, thus the need to consider the provision of dual emergency generators as an additional safeguard. External, pre-wired connectors should also be included so that a mobile generator can be easily connected in the event other systems fail.

The major disasters of the recent past have served as reminders of the need for dispatch centers to be capable of sustained self-contained operations without dependence on outside utilities and other resources for prolonged periods of time. Twenty-four hours may not be long enough for the generators and other system to function without refueling or other attention. A minimum of seven days of self-contained operations should be considered. It is important to design as much flexibility into the facility as possible.

5.3 Communications Center Development Options (New, Remodel or Adaptive Reuse)

Critical communications facilities should be constructed to withstand all anticipated hazards. The type of construction that the project ultimately utilizes will have a significant impact on the overall cost, efficiency, and day-to-day operational issues that are inherent with the development of a new Emergency Communications Center. There are a number of avenues that can be considered. The availability of land and the size of the budget may make the logical choice apparent as the variables are considered.

5.3.1 New Construction

In communities facing rapid growth, such as Pima County and the City of Tucson, the need for new facilities becomes readily apparent often for some time before funding becomes available.

The existing facilities become overcrowded and the size of the existing facility may need to be expanded in order to meet the projected growth.

The new construction option is often the preferred option during the initial thought processes. The option offers the most spatial flexibility without predetermined physical constraints. This offers the potential tenants the opportunity to re-evaluate how they function in regards to the location of various spaces. Adjacencies and the proximity of each function to another, to the public lobby, and within the secured areas of the facility can be reevaluated and relocated in a manner that differs from the existing layouts. Future expansion can be considered at the design stage and mechanical equipment, emergency generated power supply, parking, and so forth can all be sized for the anticipated future.

The new construction option often becomes the most politically challenging of all options, especially when it comes to the location of the facility. Land acquisition costs can add significant expense to the project if it is not located on existing publicly owned land. Construction costs for a new facility, especially if it is hardened, are the highest of the three options. Typical costs for hardened construction are in the $250 to $350 per square foot range.

5.3.2 Remodeling of Existing Facilities

Remodeling of the existing PSAP facilities is not a viable option for either the City of Tucson or Pima County. The City of Tucson's existing center is crowded, especially in the equipment rooms. With the growth of other City departments housed in the same facility, there is insufficient space to meet the long term needs of the City. The Pima County Sheriff's Communications Center is also overcrowded. There is insufficient space for current operations, let alone for future needs. The remainder of the Sheriff's Department is also growing. As a result, expansion in the existing facilities is not feasible

The primary advantage of this option, if it were available, is that there would not be any land acquisition costs. There also could be limited need to upgrade facility services, such as the mechanical, electrical and emergency generator systems. When this is a viable option, this alternative frequently has the lowest construction costs.

Even if this option were available, it would only be a temporary band-aid for the short-term. In addition, it could well be the most disruptive to on-going operations while the renovations are occurring.

5.3.3 Addition and Renovation to Existing Facilities

Adding additional space to an existing facility is often a viable option to meet the needs of any department. A variation of this alternative includes the renovation of the existing structure after the addition is completed. Because of the space constraints discussed above, this option is not a viable option for Pima County or the City of Tucson.

This alternative would work best if the expansion was planned for when the building was originally designed. The option offers the advantage of minimizing

disruption of on-going operations. Costs may be lower than new construction but will generally be higher than remodeling.

The disadvantages of this option include the fact that there will most likely be some disruption of on-going operations. In addition, because of changing technologies, the use of the existing structure may be come less efficient. Additional parking may be required by regulatory codes as well.

5.3.4 Acquisition of an Existing Building

This option has not been widely used because most existing facilities are not appropriately designed or hardened to meet the specialized requirements of an Emergency Communications Center. With this option a building is obtained and converted, or adaptively reused, into an ECC from its previous use.

This can be a successful choice when all of the variables fall into place. A larger, open type of building layout, constructed within no more than fifteen years, with qualified mechanical, electrical, and plumbing systems, and a sound, leak-free roof, can be successfully adapted to meet the needs of an ECC or EOC.

The facility must be thoroughly reviewed for potential issues, known as Unforeseen Conditions, which will impact renovation costs. If none are noted during the inspection, the value of purchasing or utilizing an existing facility can be substantial. The building program, which identifies the interior spaces to be designed into the converted facilities, can be modified to provide the necessary adjacencies and interior security zoning that are needed for this type of facility.

The main issue with adaptively reusing an existing building is that occasionally the space planning of the interior layouts is limited by the existing physical structure. There may be a need to harden the facility. HVAC systems may not be appropriately sized. In most cases a second HVAC system will need to be added in order to comply with the requirements of NFPA 1221.

Generally the renovation costs for adaptive reuse are significantly lower than the costs of new construction. Code compliance, enhanced survivability, and unforeseen building conditions may reduce the savings.

5.4 Organizational Considerations

No two public safety agencies are identical. This is true not just in Pima County, but nationwide and worldwide. While there are many similarities among the PCWIN operations, each agency has evolved specifically to address its own agency and operational situation. There are many factors that have contributed to the current state of each agency. There are four general alternatives to select from for the organization of the communications center.

No Change

Currently the City of Tucson and Pima County operate separate centers. The first alternative to consider is for the two entities to remain separate as they currently are. While this option would minimize any organizational change, it also does not solve the lack of space issues at either center nor does it facilitate any operational improvements.

ROM Cost – No Change

Even if the dispatch centers stay in their current location, there will be costs associated with the land mobile radio system upgrade in a competitive purchasing environment. CTA's rough Order of Magnitude (ROM) cost estimate for the PCWIN "No Change" alternative is $4M. This is the initial cost for the installed system and includes:

- 2 radio console systems
- Upgrade of existing CAD hardware for three systems
- 3 Mobile Data CAD to Radio Network Controllers

Shared Services

The second alternative is for the County and City to share services. Under this alternative, the dispatch centers could remain separate, but the supporting equipment would be centralized. This would permit cost sharing for the common equipment and could result in some efficiency improvements in the technology functions. However, it fails to fully address the lack of space; it does not facilitate any operational improvements, and provides only minimal gains in overall efficiency. While this may not be the most desirable alternative for the City of Tucson and Pima County, it could be advantageous to offer this alternative to some of the smaller dispatch centers in the

Tucson area. Currently, most of the agencies use either the Pima County Spillman CAD/RMS system or the Tucson Police Department's Northrop Grumman system.

Additional options for sharing of services include the centralized electronics for the radio consoles and the 9-1-1 Customer Premises Equipment. Because of the high cost of the centralized electronics and the 9-1-1 CPE, considerable cost savings could accrue to the agencies that are able to share the services. It also will facilitate communications between the centers since, for example by using common console electronics, intercom paths would be provided. It must be noted that both the co-location and consolidation scenarios will also offer the opportunity for shared services.

ROM Cost – Shared Services

CTA's Rough Order of Magnitude cost estimate for the PCWIN shared services alternative is $13M in a competitive purchasing environment. This is the initial cost for the installed system and includes:

- New equipment building (10,000 Square feet)
- 2 Microwave Towers
- 3 Microwave Links
- 1 Single CAD System with position equipment
- 1 Radio Console System with position equipment
- 1 Mobile Data CAD to Radio Network Controller
- 1 9-1-1 System with position equipment

Consolidation/Co-Location

The creation of a shared emergency communications center will result in significant changes in the operations of each of the participating public safety agencies. It is critically important that the process of creating the shared center be focused on making positive improvements to all aspects of the delivery of public safety services to all of the citizens and visitors of Pima County and the City of Tucson.

One of the first issues that must be resolved is the organizational structure of the center. There are two underlying structures for a shared center. The first is a consolidated center, where a single agency provides the dispatch services for all of the participating agencies. The second involves co-location of dispatch centers. Each co-located center operates

independently of the other co-located centers. Facilities are shared, but operations are separate. There are advantages and disadvantages to each form.

A consolidated center offers the following advantages and disadvantages:

Advantages	Disadvantages
Single Agency	Major Organizational Restructuring
Reduced management costs	Loss of Agency Identity
Reduced employment competition	Loss of Agency Control
More flexible use of staff	Multi-agency management
More efficient use of technology	Loss of non-dispatch functions

A co-located center offers the following advantages and disadvantages:

Advantages	Disadvantages
Maintain agency control	Differences in policies/procedures
Improved Operational Awareness	Competition for employees
Least disruptive	Greater facility requirements
Maintain agency identity	No service delivery improvement
	Greater management overhead

There are significant differences in the services provided between the current operations. While both the City of Tucson and Pima County serve as primary 9-1-1 answering points, Pima County only dispatches law enforcement agencies. Fire and medical emergency calls are transferred to a secondary answering point. The City of Tucson dispatches fire, police and ambulance and provides Emergency Medical Dispatch with pre-arrival instructions. In addition, there are significant differences in the way incoming 9-1-1 calls are handled.

The Pima County Sheriff's Office uses a two stage operation. Call-takers normally answer the incoming 9-1-1 and other calls and enter the information into the CAD system. The calls are then dispatched by the appropriate dispatcher. Incoming 9-1-1 calls in the City of Tucson, both wireline and wireless, are answered by the Emergency 9-1-1 Operators. They determine the location and nature of the call, and then transfer the call to either the police or fire call takers or to another agency as appropriate. The call takers then get the necessary information and enter the call into the CAD system. The call is dispatched by the appropriate police, fire or medical dispatcher. The City of Tucson

functionally has three separate, co-located dispatch centers currently (Primary PSAP, Fire/EMS Dispatch, and Police Dispatch).

The City of Tucson Department of General Services currently has a nineteen position dispatch facility. Six of the positions are located in a separate room and function as the primary 9-1-1 answering positions. The thirteen remaining positions provide fire and emergency medical services call taking and dispatch service for the City of Tucson and five other departments. One of the positions is used by the on-duty shift supervisor. Four of the positions are used for emergency medical dispatching for the City of Tucson (two call-taking and two dispatching); four positions are used for fire dispatch for the City of Tucson. A total of three positions are used to provide call taking and dispatch for the departments outside of Tucson that are served by the dispatch center.
The Tucson Police Department currently has a twenty-seven position dispatch facility. Twelve of the twenty-seven positions are used by call-takers. Five of the positions are used by non-emergency call takers. Currently there are six dispatch positions with plans to add two more positions in the near future. There are four supervisor positions.

The Pima County Sheriff's Department Tucson Dispatch has a fourteen position dispatch center. Eight of the positions are call-taking position; five positions are dispatch positions, and one position is used by the shift supervisor.

In addition to the operational differences, there are three separate CAD systems. Each agency has invested significant effort into customizing and updating their CAD system. Trying to consolidate operations and CAD systems while moving into a shared communications center would add significant challenges to an already challenging process.

As discussed in the Legacy Report, all three centers suffer from the lack of space, especially for expansion. With the City of Tucson and Pima County expected to continue to be one of the fastest growing areas in the United States in terms of population, the new communications center must be able to accommodate the anticipated growth. There are a total of sixty positions between the three centers now. Based on the anticipated population growth, which will result in a growth in public safety services, it is not unreasonable that the new center be capable of supporting at least one hundred call-taking and dispatch positions. Based on preliminary information provided at the June 2 Design Workshop, the total number of positions required could approach one hundred and fifty. In addition the center must be sized to accommodate the administrative and

support positions, training spaces as well as provide adequate space for the equipment housed in the equipment rooms.

A further requirement is the need to provide adequate space for equipment change out. It is not unreasonable to assume that all of the equipment in the equipment room will be changed at least once during the anticipated twenty year life of this project. Since the critical nature of the operations does not permit shutting the center down, replacing the equipment, and then reopening, space must be provided to allow the replacement equipment to be installed and made operational before the old equipment is removed. A design goal for the equipment room often is to provide an equal amount of space for change out as is required for existing space.

In addition to the space required for operations, adequate training space is also needed. Training for new public safety dispatch frequently consists of multiple phases. Many training programs include time in a traditional classroom setting as well as "hands-on" training with equipment that is similar to that being used in the dispatch center. Appropriately designed and equipped space is required for each of the phases. Group size and schedule are key space determinants for the training areas. For example, if the three centers contemplate doing joint or regional training, the spaces provided will need to be sized appropriately. Equipment needs and audio visual requirements can also sometimes dictate the size and to some extent the shape of training rooms. Subjects requiring fine detail either dictate more monitors, bigger screens or closer spacing within the room. Certainly as monitor technology has changed different configurations may now be possible. For example, smaller training classrooms may contain only a large screen flat panel monitor rather than a projector and screen which can require more space. It is usually recommended if possible to have an accessible floor in training rooms in order to accommodate this changing technology and various room requirements.

Many centers are now providing separate "live training" rooms where dispatch consoles are set up and configured identically to the actual positions on the operations floor. In addition to being used for training, these spaces can serve multiple purposes. One possible use for the "live" training area is for an incident command center. This space would allow commanders from various agencies to direct operations without actually being in the main dispatch center while getting critical in-field information. For this use it is advisable to have this room immediately adjacent to the main dispatch floor where breaking information can be relayed to the commanders. While the commanders can observe things on the dispatch floor there may be a need to have separate monitors to

display requested information within the room that may not be seen to the whole floor. Secondly, this room may have a moveable wall which is opened up in critical or overflow situations.

This allows the consoles to be activated and be part of the overall critical incident. The moveable wall should be of quality construction so that when it is closed it provides a higher level of acoustic privacy between the rooms than a typical accordion type folding partition. In all cases it is suggested that the technology classroom have an accessible floor so that cabling may be easily run from room to room. Provisions to provide acoustic separation here to are important so that sound isn't transmitted through the accessible floor cavity.

A third use of the "live" training area is as a back-up site for a neighboring jurisdiction. This could provide a reasonable solution to the need to provide a fully functional alternate location that is far enough from the primary facility so that both won't be affected by the same incident for some of the other PSAPs in the Tucson area that do not now have adequate back-ups.

ROM Cost – Co-location

CTA's Rough Order of Magnitude (ROM) cost estimate for the co-location alternative is $32 M in a competitive purchasing environment. This is the initial estimate for the installed system and includes:

- New Communications Center/ECC
- 2 9-1-1 Systems with position equipment
- Move and refresh 3 CAD systems (new hardware)
- 1 Console System with position equipment
- 3 Mobile Data CAD to Radio Network Controllers
- Dispatch Workstation Furniture (123 positions)

ROM Cost – Consolidation

CTA's Rough Order of Magnitude (ROM) cost estimate for full consolidation is $31M in a competitive purchasing environment.

This is the initial estimate for the installed system and includes:

- New Communications Center/ECC
- 1 9-1-1 System with position equipment
- New CAD System with position equipment
- 1 Console System with position equipment.
- 1 Mobile Data CAD to Radio Network Controller
- Dispatch Workstation Furniture (123 positions)

Recommendation

CTA recommends that the communications centers be co-located initially. As described above, there are significant differences in both the services offered and the operational methodology used between the two governmental entities and three agencies that operate the existing emergency communications centers. While the three centers currently use the same 9-1-1 and mapping systems, each agency operates its own computer aided dispatch system. It would be extremely difficult to fully consolidate without migrating to a single, shared computer system. Funding for such a system is not included in the project budget. Additionally, a full consolidation would result in major organizational changes which could cause significant disruptions.

With the continued population growth anticipated in both the City of Tucson and Pima County over the life of this project, it is not unreasonable to expect a number of major changes in the user agencies served by the new center. Co-location provides a higher degree of agency control over the dispatch function than would occur in a consolidated center. While the operations floors will be separate, break areas, locker rooms, electrical and mechanical systems should all be common. We also anticipate that several of the major systems used in the communications center, such as the console system, the 9-1-1 system, and so forth will be shared. The facility should be designed in such a way as to facilitate the eventual full consolidation if, and when, that becomes desirable.

5.5 9-1-1 Customer Premises Equipment

The 9-1-1 System is on the cusp of significant changes both inside the PSAPs and in the network that delivers the request for assistance to the PSAPs. When it was first designed thirty years ago, the then state-of-the-art necessitated that the 9-1-1 network be designed as a single-purpose means of emergency communications distinctly separate from the

public switched telephone network (PSTN).[i] Calls made to 9-1-1 were purposefully segregated from the PSTN and switched instead to a network equipped with dedicated point-to-point circuits from telephone company end offices to the 9-1-1 Tandem Switch or selective router. Those circuits were single function: to transmit a 9-1-1 call (both voice and telephone number) to a specific Public Safety Answering Point (PSAP) associated with the geographic location of the calling party.

The best alternative available at the time was to use the Centralized Automatic Message Accounting (CAMA) system.

Designed originally to record long distance billing information, CAMA technology was co-opted for use in the 9-1-1 network as the only means then available of providing Automatic Number Identification (ANI). CAMA-based 9-1-1 selective routers and trunking are unique to public safety telecommunications networks. They have long since been replaced in modern telecommunications environments. The 9-1-1 functionality that was once an advanced "state-of-the-art" has long since been eclipsed by advanced technology that is now otherwise commonplace in the PSTN. CAMA technology has become a limiting factor in 9-1-1 networks. CAMA based 9-1-1 selective routers were designed to handle only four area codes. In addition to the seven-digit telephone number (987-5800), the design limits the system to only being able to send a number plan digit (NPD) of 0, 1, 2 or 3).

Each of these extra digits corresponds to one of the four area codes served by the selective router. With the increase in demand for telephone numbers, many heavily populated areas quickly outgrew the limits of the system. Either additional selective routers had to be used or some type of patchwork modification had to be able to be made to the system in order for it to meet the demands placed on it. Of course, with the implementation of wireless 9-1-1, the challenge became even greater.

The existing 9-1-1 network relies on in-band multi-frequency (MF) signaling. In-band MF signaling is used to send the telephone number information to the selective routing tandem, which must then digitize the analog signal, determine the proper routing of the call, and convert the digital information back to a MF in-band signal for transmission to the PSAP via CAMA trunks. This inefficiency can have life-threatening consequences when it adversely affects 9-1-1 call set-up times and delivery.

The data portion of a 9-1-1 network also uses antiquated technology. Where private data networks commonly transport commercial data at millions of bits per second, a large portion of public safety data flows between the PSAP and the ALI database at a mere 1200 bits per second. Many Incumbent Local Exchange Carriers have begun replacing the trunks between end offices and the selective router with higher speed digital trunks, but for the most part the trunks between the selective router and the PSAP are still CAMA trunks.

Implementation of more advanced technology is entirely dependant on Incumbent Local Exchange Carriers equipment replacement plans. Since 9-1-1 systems are special use, the process is slowed by the lack of alternative uses and the lack of other forces compelling an aggressive upgrade schedule.

Whereas long distance calls placed over an advanced network are connected almost instantaneously, 9-1-1 calls that rely upon MF signaling may take upwards of 10 to 15 seconds to reach the local PSAP. These delays often lead callers to mistakenly believe their calls are not being connected, and they hang up and redial. Some systems have introduced a false ring so that the caller hears something while the call is being set-up. Unfortunately, the caller may hear 5 or 6 rings, which leads to increased frustration as to why the call wasn't answered sooner.

The explosive growth of Wireless 9-1-1 is well documented. According to current estimates from the Cellular Telephone Industry Association (CTIA)[ii], approximately sixty-nine percent of the population of the United States currently subscribe to wireless service. The impact on the 9-1-1 system has been significant in a number of ways. First is the sheer volume of calls received by a 9-1-1 center. Generally, traditional 9-1-1 wireline call volumes have not decreased. In many areas it is not unusual to receive approximately one wireline 9-1-1 call for every resident. With the advent of Wireless 9-1-1, call volume at 9-1-1 centers has increased significantly. It is not uncommon for a given 9-1-1 center that receives both wireless and wireline 9-1-1 calls to have its volume of incoming calls increase by thirty to fifty percent. In general, the wireless 9-1-1 calls are in addition to the volume of wireline calls previously received.

Implementation of Wireless Enhanced 9-1-1 has required significant upgrades to the equipment in the PSAP. As noted above, the standard 9-1-1 network architecture uses in-band multi-frequency signaling at very slow data rates. In order to implement FCC

mandated Wireless Enhanced 9-1-1 Phase I, which delivers cell site location and call back information to the PSAP, the 9-1-1 system must capable of carrying two ten digit telephone numbers through the system to the PSAP. Wireless carriers may choose between two different approaches for this process (CAS and NCAS).

Call-path associated signaling (CAS) uses the same path to deliver both the voice call and the associated data elements to the PSAP. Call set-up times (the time between when the caller completes dialing 9-1-1 and the time the call appears at the 9-1-1 center) can be significant. Doubling the information to be passed will double the amount of time required for call set-up.

In addition, much of the imbedded equipment, both in the network and at the PSAP, is not capable of handling a twenty-digit data stream. With Non call-path associated signaling (NCAS) data transmission or signaling occurs on a separate channel than that which transmits voice communications. Many 9-1-1 networks use separate data circuits to retrieve wireline Automatic Location Information now. NCAS uses the same circuitry to provide the wireless data stream.

Wireless carriers are free to choose which signaling solution they will implement. Under the FCC rules, there may be up to nine wireless carriers in a given community. Based on filings by the various carriers with the FCC, 9-1-1 centers must be prepared to deal with carriers using both CAS and NCAS.

Wireless Enhanced 9-1-1 Phase II will provide location information as part of the data stream. This data will be in the form of latitude and longitude. The key point in this section is that the CPE at the 9-1-1 center must be capable of handling two ten-digit telephone numbers and the location data.

In the 1970's the telephone companies began converting the Public Switched Telephone Network from analog to digital. It was realized that by converting to digital, the number of concurrent calls that could be carried over an existing circuit could be increased tenfold. As the digitalization expanded, the need for standardization increased. Transmission Control Protocol/Internet Protocol (TCP/IP) is a set of interrelated, standardized protocols that were developed to serve as a means of exchanging data between disparate networks that is independent of host computer technologies, operating

systems, transmission media, and data link technologies. The Internet Protocol (IP) establishes the nature and length of the packets and provides addressing information used by the various switches and routers to direct each individual packet to its intended destination. IP operates in a connectionless datagram mode.

Datagram mode means that, unlike the circuit switched mode, each packet is considered by the network as a separate unit. Connectionless means that there is no predetermined patch through the network established as part of a call setup process. Diagrams of communication using IP use the cloud model rather than showing a connection from Point A to Point B.

Voice over IP makes use of digital signal processors to convert the analog voice signal into a digital format and to compress the signal. The first commercial deployment of IP telephony in the telephone network was in backbone transmission between central offices, which began in earnest in 1998. New telephone services such as frame-relay, ISDN, DSL, and others came into being. VoIP is also emerging as the basis for telephone switching equipment. Voice over Internet Protocol is also starting to be used in PBX's.

There are now initiatives underway to refine the 9-1-1 network in lieu of the move to digital and the new devices that may be used to access 9-1-1 services. A caller using either a wireline or wireless telephone instrument has traditionally initialized 9-1-1 calls. There are a number of non-traditional signaling methods that have been recently introduced or are under development. These signaling methods have the potential to cause a fundamental shift in the model by which public safety agencies receive notification of incidents.

There are two forms of non-traditional signaling – active & passive. Active devices require positive action on the part of the reporting party to initiate the call. Passive signaling may be initiated by a series of events such as air bag deployment or other automated means. The non-traditional signaling may involve data-only transmissions. It also may include data from third party call centers that are relayed along with voice communications. Data only transmissions bring many challenges. First, Arizona, like many states, has a specific legislative prohibition against "An automatic alarm system or other related device shall not be connected in a manner that activates a call to a 9-1-1 service system." These prohibitions came from concerns that malfunctioning automated

devices could clog the 9-1-1 system with inappropriate calls during events such as thunderstorms and so forth.

In addition, most of the devices provide inadequate information as to the nature of the emergency. Many of these non-traditional devices in fact function like an alarm system and could be held to be illegal under the provisions of the statute. As a matter of public policy, many local governments and 9-1-1 systems can be expected to be reluctant to accept direct calls from many of these non-traditional devices. As public reliance on wireless devices increases, more non-traditional devices will be developed an implemented. Assuming that most of these devices will use third party call centers, the challenges associated with dealing with these call centers will continue to increase.

Some specific examples of non-traditional communications include: The Intelligent Transportation System; Third Party Call Centers, including "Concierge Services"; "Mayday" Devices, including "Smart Clothes"; Alternative Non-emergency numbers (311, 211, 511, etc.) and Medical Help Desks.

These are discussed in more detail below:

Intelligent Transportation System

The U.S. Department of Transportation and the Federal Transit Administration are leading the efforts to adapt new information technologies and electronics to the surface transportation network. ITS efforts involve such things as upgrading traffic signals, adding video surveillance of freeways and intersections, deploying sensors to remotely monitor traffic flow, and creating traffic management centers. Another initiative of the ITS is Automatic Crash Notification. The implications of ACN are significant for the 9-1-1 system.

Automatic Crash Notification uses sensors within the vehicle to recognize that a significant event has occurred. ACN systems take the Mayday Systems concept (discussed in further detail below) to the next level. Both systems use sensors from within the vehicle to recognize that a significant event has occurred. Using accelerometers, air bag deployment sensors, and other alerting devices, on-board computers in ACN systems estimate the severity of the crash, number of occupants, and the nature and extent of the injuries sustained. As currently envisioned, this data will be transmitted to a third-party call center, along with the latitude and longitude of the

vehicle. Under the ITS concept, this data would then be sent to the appropriate 9-1-1 center and then to responding units.

While efforts are underway to standardize the data, significant challenges are presented to the 9-1-1 system that must be dealt with if the policy decision is to accept the data. The third party centers are most likely not located in the local jurisdiction. As a result, the 9-1-1 system must have a means of receiving the data and integrating it with existing systems. Assuming that the system may use the 9-1-1 data network for at least part of the transaction, most 9-1-1 system are not currently capable of handling the additional data. Because much of the effort with ACN is still in preliminary development, many of the issues have yet to be defined. Issues with third party call centers and Mayday devices are discussed further below.

Mayday Systems and Devices

Initially developed to provide travel information and related services in vehicles, Mayday systems also provide an emergency notification system. The systems were the generation previous to ACN in vehicle safety systems. Now offered by most vehicle manufacturers as either an option or standard equipment, the systems automatically alert a private call center via an integrated cell phone when either an airbag has deployed or the emergency call button is activated.

The system immediately opens a voice connection between the vehicle and the call center. After conferring with the occupants, the call center can then notify the appropriate PSAP for dispatch of the needed assistance. The call centers have the ability to connect the vehicle with the PSAP. This offers the public safety dispatcher the ability to speak directly to the occupants to gain additional information needed to dispatch the appropriate response. The downside of these systems principally involves the issues of dealing with third party call centers discussed below.

A number of other devices are under development that include emergency alerting capabilities. These range from such things as wearable alert devices, passive tracking devices to be used with lost children or Alzheimer's Disease victims to "Smart Clothing" which has sensors built in to monitor to wearer's overall health. An automated alert could be generated when certain conditions were met. For example, one promotional piece of literature indicates that the notification would be triggered when the wearer's pulse rate exceeds a certain threshold.

Third Party Call Centers

9-1-1 systems deal with a large number of Third Party Call Centers. These include call centers for alarm services and for the in-vehicle communications systems discussed above. "Concierge services" are call centers established to provide traveler information for subscribers of services such as General Motors' OnStar, or AAA's Response. As these services continue to develop, PSAPs can expect to deal with more and more of these third party services. Third party notification of an incident often has the effect of delaying the notification process and, as a result, delaying the appropriate response. Often times, the third party call centers have significant problems in identifying the correct PSAP since they are based in a central location remote from the local jurisdiction and do not have the ability to access specific information concerning emergency service boundaries. They also may suffer from the same limitations in accuracy of their GIS system discussed above. No discussion of third party call centers is complete without mentioning the wide variation in the training and ability of the call center employees. It appears that many call centers use minimum wage employees with little or no training. As a result the accuracy and reliability of the information provided varies significantly.

There are several initiatives underway that deal with various aspects of the third party call center/public safety interface issue. At the present time most of the efforts are focused on interfacing with a public safety agencies computer aided dispatch system rather than the 9-1-1 system. For example, APCO has initiated Project 36, which is focused on creating a standard method for CAD-to-CAD interfaces. The U.S. Department of Transportation, through the Federal Highway Administration, has recently announced that it will be seeking applications for grants to integrate Intelligent Transportation Systems with public safety CAD systems. As envisioned by the FHWA, the projects will involve integration of Advanced Traffic Management Systems and CAD systems with the goal of improving response through the integration of these systems.

The Security Industry Association (SIA) has drafted a standard for the electronic exchange of data between alarm monitoring central stations and public safety answering points. In addition, APCO has joined with the SIA to begin to offer training for central station alarm operators. These initiatives, and others not detailed here, will have a future impact on public safety answering points.

Medical Call Centers

Medical Call Centers are specialized third party call centers established to serve medical insurers. Some insurance carriers have established a policy of encouraging, or even requiring, persons covered by their insurance to contact the call center before they seek assistance from the emergency medical system. These are often termed nurse advice lines. Using established medical protocols; the nurses or other staff, determine if the patients systems warrant immediate attention. Primarily established as a screening mechanism to reduce the high cost of unnecessary emergency room visits, these call centers have the potential of delaying the dispatch of emergency assistance in those cases where it is required. Prompt response is further complicated by the fact that the medical call center does not receive call back number or location information. If the patient looses consciousness and no one else is there to provide location information, it may difficult to dispatch a timely response.

Another issue most closely associated with Medical Call Centers, is the provision of medical history information. There are efforts under various stages of development to provide the capacity to furnish patient/victims medical histories. Some of these efforts involve the concierge services outlined above; other initiatives come from the alarm industry and the medical community. No matter the source, the medical history issue opens a number of concerns for the PSAP such as having the capability to receive the data; determining where and how to use the data, and privacy. The issue is not well developed at this time, but these concerns will have to be dealt with in the future.

5.5.1 Convergence of Voice and Data

Convergence has been defined as the bringing together of two or more technologies. As it applies to 9-1-1 and technology, convergence refers to the unification of voice networks and data networks. The telephone network was originally a voice network. The telephone network relied on a technique called circuit switching. With circuit switching, when a call is made between two parties, the connection is maintained for the duration of the call. That connection forms a circuit. Depending on the location of the caller and the called party, one or more telephone company central offices or wire centers is involved with the call. Analog signaling was the standard.

Sometimes, dedicated (non-switched) circuits were obtained for specific purposes, such as ring down lines to a fire station. As the need developed to send data from one location to another, separate, dedicated circuits were leased from the telephone company. Analog voice circuits are very inefficient. One circuit handles one call.

A data network uses a technique called packet switching. The data to be transmitted is broken down into a series of small packets of information. Each packet also includes the address where the data is to be sent. The sending computer looks for a path for each packet. Depending on conditions on the network, different paths might be used for packets that are part of the same message. The receiving computer reassembles the message. The connection between the two computers is minimized, which reduces the load on the network. This reduces the cost of communications. As technology advances brought about improved quality and reliability, the same techniques were applied to voice and voice and data began using the same network. The need to increase the capacity of the network and, at the same time, to reduce costs has driven the digitalization of the telephone network. As the penetration of digital communications has increased, the transformation of end-to-end digital communications is in full progress.

This convergence of voice and data has impacted the 9-1-1 center in a number of ways as indicated below:

5.5.2 Computer/Telephone Integration

The convergence of voice and data has lead to the integration of the computer and the telephone. Modern 9-1-1 customer premise equipment is computer based and integrates several different applications. Until recently, a 9-1-1 center had separate telephone systems and radio systems. As operations became computerized and applications such as Computer Aided Dispatch (CAD) and access to state and federal databases (ACIC/NCIC) were added, CRT terminals were installed. With the implementation of Enhanced 9-1-1 additional display devices were added.

As technology evolved, personal computers were substituted for "dumb" terminals. As more applications were added to the 9-1-1 center, more terminals were added. Existing workstations were not built to accommodate the proliferation of monitors, keyboards and computers. In addition, moving information from one system to another was a major challenge since many times that meant dealing with multiple vendors and multiple operating systems. As the telephone network evolved and digital technology spread, the 9-1-1 workstations integrated the telephone voice and data display into a computer-based workstation. Voice has become another application on the network.

Intelligent Workstation is the term that has been applied to computer based 9-1-1 answering position equipment that includes computer telephony integration. These workstations help resolve many of the issues facing PSAP's. There are a several integration levels available. Basic integration allows the use of the same keyboard to access multiple computers. A manual switch is used to switch between the computers. A second level of integration allows the use of one computer, serving as a workstation to switch between multiple applications running on multiple host computers. The third and highest level of integration allows for a more complete interface between the various applications.

An example of this is an interface between the 9-1-1 system and a CAD system. Through the use of a programmed interface, caller information is transferred from the 9-1-1 system and reformatted so that it is displayed in the appropriate fields in the calls for service screen in the CAD screen.

While the use of intelligent workstations solves a number of issues, there are also a number of potential concerns with their implementation that must be dealt with. First is the possibility that the applications are incompatible. Even when applications use the same operating systems, problems can occur when similar commands between applications cause undesired results. Often what is called multi-tasking actually refers to the ability to do multiple tasks in rapid succession. This may create problems when applications compete for priority. Even when the operating system of the workstation does permit true multi-tasking, problems may occur when two or more applications try to use the same portion of a computers memory at the same time. Another potential problem involves human factors.

A telecommunicator may need to view multiple applications at the same time. For example, a call-taker may need to see the 9-1-1 display screen, the CAD call-taking screen, and a digitized map. It may become difficult to view all three applications at the same time on one screen. Multiple monitors may be needed. Integration of multiple applications is not only possible; in many cases it is desirable. Because of the potential problems involved, any integration effort must be done with a great deal of care and caution.

In addition to the number of computer monitors, cabling requirements have changed dramatically. Previously, with the older analog technology, several multiple-pair cables were needed between each position and the connection point. New digital communications techniques have dramatically changed that. The new trend is to use computer networking techniques to interconnect the various terminals with the "back-room ". This has greatly reduced the amount of cabling that must be run. However, as more applications become networked, the capacity of the network must expand. To that end, TIA/ANSI/NEMA Category 6 or 7 cabling is recommended for all new installations. These new categories of cabling permit data transfer speeds of up 600 Mb.

5.5.3 Geographic Information Systems

The impact of Wireless 9-1-1 is explained in more detail below. One of the side effects of Wireless 9-1-1 implementation is the trend towards the implementation of Geographical Information Systems (GIS) in the PSAP. Wireline 9-1-1 centers are address driven. That is traditional wireline telephones are installed at fixed locations, which have addresses. Those addresses do not change frequently. With a wireless telephone, the caller is mobile. They are, by definition, not tied to a fixed location. With the current state of technology, the wireless caller is connected to the 9-1-1 center based on the location of the wireless tower site that receives his 9-1-1 call. The tower may or may not be located in the same jurisdiction as the incident being reported. No location information is provided. Because they are mobile, wireless callers may not know their exact location.

Industry press is full of stories about problems incurred because callers were unable to provide accurate location information.

It takes additional questioning by the 9-1-1 call-taker in order to determine the location of the call. Once FCC Phase II is implemented, location information will be supplied to the 9-1-1 center in the form of latitude and longitude. One of the primary needs driving the implementation of GIS in the 9-1-1 centers is the need to quickly convert latitude and longitude to an address that emergency assistance can be dispatched to.

Geographic Information Systems are a collection of hardware, software, procedures and data that bring data together to be displayed on a map. GIS is more than a mapping program. It is a complex mix of databases, display technology, and analysis tools. A well designed GIS system has the ability to combine data and information from a number of different sources into a database. The information is organized into layers. These layers allow for quick and efficient searching to provide the information needed.

The integration of numerous databases into a functioning GIS can be a major challenge. The 9-1-1 system, for example, has the Master Street Address Guide (MSAG). The CAD system has a geo-file. It is a significant challenge just to keep those database synchronized. As more departments are added to the GIS, the challenges increase. Accuracy and reliability are the key factors in public safety communications. As more items are added, the greater the challenge becomes to maintain accuracy and reliability.

The creation and maintenance of an accurate map requires much time and effort, especially if it is to be done economically. It is critically important the 9-1-1 center coordinate its efforts with other public and private efforts in the community. The source of the original map is also critical. Many mapping systems, including those sold commercially; begin by using data available for free from the U. S. Bureau of the Census. That data, from the Topographically Integrated Geographic Encoding and Referencing system (TIGER files) has an accuracy of 1:100,000. That scale means that 1 inch equals approximately 1.5 miles. That level of accuracy is unacceptable for most public safety applications.

In addition to the challenge of creating accurate maps for 9-1-1 purposes, determination of the layers of data, attributes and format must also be resolved.

The City of Tucson and Pima County have taken major steps by implementing a joint GIS program for the 9-1-1 mapping. All of the PSAPs in Pima County are permitted to use the mapping products produced by this program except for the PIMA County Sheriff's Office – AJO Dispatch and Marana. With the continued rapid growth being experienced in PIMA County, keeping the GIS current is a significant challenge. The collaborative approach that has been taken is a positive step to provide the highest quality service to all involved.

5.5.4 Options

Most suppliers of the integrated workstation include "instant recall recorders" and integrated TDD for communications with hearing and speech impaired callers as standardized options. Depending on the option and the vendor, some of the options are included at no additional charge, and some are relatively low cost. By using the replay recorder and TDD included with the telephone, the 9-1-1 center can avoid having to purchase separate, expensive pieces of equipment. In addition with the integration of the functions, operation is significantly easier. The US Department of Justice has interpreted the Americans with Disabilities Act (ADA) legislation to mean that each 9-1-1 position must be equipped with a device capable of communicating with the hearing and speech impaired 9-1-1 caller. The PSAP must also comply with other requirements of the ADA. Concerning requirements that facilities and equipment be readily accessible and useable by persons with disabilities.

As the equipment in the 9-1-1 center becomes more integrated and computer based, there is a definite trend towards equipping the center with more ergonomically correct furniture. A number of manufacturers offer furniture that is adjustable so workers can raise or lower the chair or work surface to a position of comfort. Many new models allow a range of adjustment from sitting to standing. This is especially helpful when workers are expected to spend prolonged periods at a workstation. In addition, the workstations provide additional flexibility as applications are added or upgraded.

5.6 Equipment Recommendations

In 2006 both the City of Tucson and the Pima County Sheriff's Tucson Dispatch Center upgraded their 9-1-1 CPE. The equipment is current "state of the art." An important

element in maintaining a fully functional 9-1-1 system is the system maintenance. Pima County and the City of Tucson have chosen to use 9-1-1 CPE that is supported by QWEST, the 9-1-1 service provider. We believe this is a wise choice since QWEST has end-to-end responsibility for the 9-1-1 system. In addition they have a support staff based in Tucson that is able to respond to outages in a timely manner. In addition to supporting the Plant/CML equipment, the QWEST personnel in Tucson also support at least one PSAP using Positron CPE. Positron is the other major vendor. This gives the County and City the advantage of being able to have a choice from the major vendors of 9-1-1 CPE while maintaining the high level of support that is needed.

We recommend that new 9-1-1 CPE be purchased for the new communications center for three reasons. First, the existing equipment will be several years old at the time the new center is occupied. While it won't be at the end of its service life, it will be approaching that date. In addition, it is extremely difficult to relocate the 9-1-1 CPE while maintaining service. The goal in any 9-1-1 system cutover is to assure that it is completed without any lost calls. Thirdly, industry standards recommend that there be a functional back-up to the primary center. The current 9-1-1 equipment could be installed at the back-up center once cutover to the new center is completed.

5.7 Impact Analysis

Factoring in the design, organizational, and technology considerations presented above, CTA proceeded to perform an Impact Analysis on four communications center alternatives. The Impact Analysis includes only the primary communications center choices. Provisions for back-up to the primary center will be discussed in the Concept of Operations document which will follow this report. Unlike other aspects of the PCWIN system alternatives that involve largely technical decisions, the communications center alternatives involve operational preferences.

The four alternatives evaluated are:

1. Co-Location: The County and City of Tucson dispatch operations are physically located in the same building but remain organizationally separate.

   Advantages:
   - Maintain agency control
   - Improved operational awareness

- Less disruptive than consolidation
- Maintain agency identity

Disadvantages:

- Differences in policies and procedures
- Competition for employees
- "Us versus Them" mentality
- No service delivery improvement
- Greater management overhead

2. Consolidation: The County and City of Tucson dispatch operations are combined into a single organizational entity.

Advantages:

- Single agency
- Reduced management costs, unified command
- Reduced employee competition
- More flexible use of staff

Disadvantages:

- Major organizational restructuring
- Loss of agency identity
- Loss of agency control
- Multi-agency management

3. Shared Services: Common equipment for dispatch and 9-1-1 operations are shared. Equipment sharing would expand upon the current practice of shared CAD/RMS systems. Dispatch centers are not necessarily shared.

Advantages:

- Cost: common equipment
- More efficient use of technology functions

Disadvantages:

- No operational improvements
- Minimal gains in efficiency

4. No Change: The entire dispatch organization and operations remain in their current locations. Equipment and technology is upgraded as needed to meet the requirements of the regional PCWIN radio system.

   Advantages:
   - Minimize Organizational Change

   Disadvantages:
   - No Additional Space
   - No Operational Improvements

   For the communications center Impact Analysis, attributes were selected and included that had a bearing on the outcome of dispatch operations.

5.8 Impact Results – Communications Center

TABLE 5-1, Comparison of Communications Center 9-1-1 PSAP Alternatives, contains the results of the impact analysis for alternatives 1 through 4 described in this report section.

At the left side of the table are the attributes established earlier in the project. The reference numbers refer to the attribute definitions provided in the User Needs Assessment Report.

Under "CTA Assessment" are four numerical columns with CTA's evaluation of fit for each attribute and each alternative. These values can range from a low of 0 to high of 5. In the center of the table is PCWIN's importance rank for the attribute, an average of the responses returned by the four PCWIN operations.

Under Weighted-Ranked Results are four columns containing the weighted results. Each value is CTA's assessment multiplied times PCWIN's rank used as the weighting factor.

Each of the Weighted-Ranked Results columns is totaled at the bottom arriving at an overall score for each alternative.

The totals are summarized below.

	Alternative	Combined Law and Fire Score
1.	Co-Location	401
2.	Consolidation	407
3.	Shared Services	247
4.	No Change	174

Clearly the large difference in score indicates a desire on PCWIN's part for the changes necessary to make significant improvements in dispatch operations.

We also examined the rankings in light of the unique requirements important to law dispatch and fire dispatch.

TABLE 5-2 repeats the process, but instead of using overall PCWIN Rank, uses average rankings for just law dispatch.

The alternatives scored as follows.

	Alternative	Law Dispatch Score
1.	Co-Location	403
2.	Consolidation	412
3.	Shared Services	252
4.	No Change	177

Comparing these results to those obtained from a combined raking, we see virtually the same outcome.

TABLE 5-3 repeats the process, this time using average rankings for just the fire dispatch.

The alternatives scored as follows:

	Alternative	Fire Dispatch Score
1.	Co-Location	488
2.	Consolidation	499
3.	Shared Services	303

4. No Change 213

Comparing these results to those obtained from a combined raking, we see virtually the same outcome.

5.9 Communications Center Dispatch Recommendations

In summary, CTA recommends the following for PCWIN dispatch operations:

- Alternative # 1 Co-Location of the separate dispatch organizations
- New 9-1-1 System
- IP Ready Equipment
- Continued Support by QWEST
- New Computer Based Consoles
- Maintain Three CAD Systems

Future Opportunities:

- Full Consolidation of Dispatch Operations
- Select One CAD System for All Operations

[1] *9-1-1 Networks in the 21st Century, The Case for Competition*. SCC Communications Corp, Boulder, CO, February, 2001.

[1] *Wireless 9-1-1 and Distress Calls*. WOW-Com: Industry Issues and Answers. Cellular Telecommunications and Internet Association. 2001.

TABLE 5-1
IMPACT Analysis Results - Communications Center E911 PSAP Alternatives
Combined Law and Fire

		CTA Assessment					Weighted - Ranked Results			
		Co-Location	Consolidation	Shared Services	As Is - Where Is	Combined Law Fire	Co-Location	Consolidation	Shared Services	As Is - Where Is
Ref.	ATTRIBUTE									
No.		Alt 1	Alt 2	Alt 3	Alt 4	RANK	Alt 1	Alt 2	Alt 3	Alt 4
1	Dispatch Center Size	4.7	5.0	3.0	0.0	3.0	14.0	15.0	9.0	0.0
2	Dispatch Center Staff	3.7	3.7	2.0	2.0	4.0	14.7	14.7	8.0	8.0
3	Technology	4.7	4.7	2.7	2.0	5.0	23.3	23.3	13.3	10.0
4	Light	5.0	4.7	2.7	1.7	4.0	20.0	18.7	10.7	6.7
5	Temperature and Air Control	5.0	4.7	3.0	1.0	5.0	25.0	23.3	15.0	5.0
6	Cleanliness	5.0	4.7	3.0	1.0	4.0	20.0	18.7	12.0	4.0
7	Furniture	5.0	4.7	3.0	1.7	5.0	25.0	23.3	15.0	8.3
8	Technical	4.7	5.0	3.0	2.7	5.0	23.3	25.0	15.0	13.3
9	External Facilities	5.0	4.7	3.0	2.0	4.0	20.0	18.7	12.0	8.0
10	Internal Facilities	5.0	5.0	2.3	1.7	3.0	15.0	15.0	7.0	5.0
11	Radio System	5.0	5.0	2.3	2.0	4.0	20.0	20.0	9.3	8.0
12	Console	4.7	5.0	3.0	1.7	4.0	18.7	20.0	12.0	6.7
13	Computer Aided Dispatch (CAD)	3.7	4.0	2.0	2.7	3.0	11.0	12.0	6.0	8.0
14	Telephone	3.7	4.0	4.0	3.3	4.0	14.7	16.0	16.0	13.3
15	Interoperability with Other Agencies	4.0	4.0	2.0	2.3	4.0	16.0	16.0	8.0	9.3
16	Reliability	4.3	4.7	2.3	1.7	3.0	13.0	14.0	7.0	5.0
17	Maintenance	4.3	4.7	4.0	2.0	3.0	13.0	14.0	12.0	6.0
18	Back-Up	4.0	4.3	3.3	1.0	3.0	12.0	13.0	10.0	3.0
8	Monitored Firegrounds	3.0	3.3	2.0	3.0	3.0	9.0	10.0	6.0	9.0
14	Interoperability through Dispatch	3.7	4.0	2.0	2.7	3.0	11.0	12.0	6.0	8.0
20	Recorded Operations	3.0	3.0	2.0	3.3	3.0	9.0	9.0	6.0	10.0
22	Increased Dispatch Channel Capacity	3.0	3.3	2.0	0.0	3.0	9.0	10.0	6.0	0.0
23	Dispatch Capacity	3.0	3.3	2.0	1.0	3.0	9.0	10.0	6.0	3.0
24	Dispatch Coverage	3.0	3.3	2.0	2.3	4.0	12.0	13.3	8.0	9.3
26	Cross CAD Interconnection	4.0	4.0	2.0	0.0	3.0	12.0	12.0	6.0	0.0
46	Staffing and Training	3.7	3.3	2.0	2.3	3.0	11.0	10.0	6.0	7.0
	CTA TOTAL	108	110	67	47					
						WEIGHTED - RANKED TOTAL	401	407	247	174
						OVERALL RANK	2	1	3	4
							Co-Location	Consolidation	Shared Services	As Is - Where Is

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

TABLE 5-2
IMPACT Analysis Results - Communications Center E911 PSAP Alternatives
Law Enforcement

		CTA Assessment					Weighted - Ranked Results			
		Co-Location	Consolidation	Shared Services	As Is - Where Is	Combined Law/Fire	Co-Location	Consolidation	Shared Services	As Is - Where Is
Ref.	ATTRIBUTE									
No.		Alt 1	Alt 2	Alt 3	Alt 4	RANK	Alt 1	Alt 2	Alt 3	Alt 4
1	Dispatch Center Size	4.7	5.0	3.0	0.0	3.7	17.1	18.3	11.0	0.0
2	Dispatch Center Staff	3.7	3.7	2.0	2.0	5.0	18.3	18.3	10.0	10.0
3	Technology	4.7	4.7	2.7	2.0	4.3	20.2	20.2	11.6	8.7
4	Light	5.0	4.7	2.7	1.7	3.3	16.7	15.6	8.9	5.6
5	Temperature and Air Control	5.0	4.7	3.0	1.0	3.0	15.0	14.0	9.0	3.0
6	Cleanliness	5.0	4.7	3.0	1.0	3.3	16.7	15.6	10.0	3.3
7	Furniture	5.0	4.7	3.0	1.7	3.3	16.7	15.6	10.0	5.6
8	Technical	4.7	5.0	3.0	2.7	4.0	18.7	20.0	12.0	10.7
9	External Facilities	5.0	4.7	3.0	2.0	3.0	15.0	14.0	9.0	6.0
10	Internal Facilities	5.0	5.0	2.3	1.7	3.3	16.7	16.7	7.8	5.6
11	Radio System	5.0	5.0	2.3	2.0	4.0	20.0	20.0	9.3	8.0
12	Console	4.7	5.0	3.0	1.7	3.7	17.1	18.3	11.0	6.1
13	Computer Aided Dispatch (CAD)	3.7	4.0	2.0	2.7	4.7	17.1	18.7	9.3	12.4
14	Telephone	3.7	4.0	4.0	3.3	4.7	17.1	18.7	18.7	15.6
15	Interoperability with Other Agencies	4.0	4.0	2.0	2.3	3.7	14.7	14.7	7.3	8.6
16	Reliability	4.3	4.7	2.3	1.7	4.7	20.2	21.8	10.9	7.8
17	Maintenance	4.3	4.7	4.0	2.0	4.7	20.2	21.8	18.7	9.3
18	Back-Up	4.0	4.3	3.3	1.0	4.3	17.3	18.8	14.4	4.3
8	Monitored Firegrounds	3.0	3.3	2.0	3.0	0.0	0.0	0.0	0.0	0.0
14	Interoperability through Dispatch	3.7	4.0	2.0	2.7	3.7	13.7	14.9	7.5	9.9
20	Recorded Operations	3.0	3.0	2.0	3.3	4.2	12.5	12.5	8.4	13.9
22	Increased Dispatch Channel Capacity	3.0	3.3	2.0	0.0	3.4	10.1	11.2	6.7	0.0
23	Dispatch Capacity	3.0	3.3	2.0	1.0	3.6	10.9	12.1	7.3	3.6
24	Dispatch Coverage	3.0	3.3	2.0	2.3	3.8	11.5	12.7	7.6	8.9
26	Cross CAD Interconnection	4.0	4.0	2.0	0.0	3.2	12.8	12.8	6.4	0.0
46	Staffing and Training	3.7	3.3	2.0	2.3	4.5	16.3	14.8	8.9	10.4
	CTA TOTAL	108	110	67	47					
						WEIGHTED - RANKED TOTAL	403	412	252	177
						OVERALL RANK	2	1	3	4
							Co-Location	Consolidation	Shared Services	As Is - Where Is

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

TABLE 5-3
IMPACT Analysis Results - Communications Center E911 PSAP Alternatives
Fire Departments

		CTA Assessment					Weighted - Ranked Results			
		Co-Location	Consolidation	Shared Services	As Is - Where Is	Combined Law Fire	Co-Location	Consolidation	Shared Services	As Is - Where Is
Ref.	ATTRIBUTE									
No.		Alt 1	Alt 2	Alt 3	Alt 4	RANK	Alt 1	Alt 2	Alt 3	Alt 4
1	Dispatch Center Size	4.7	5.0	3.0	0.0	5.0	23.3	25.0	15.0	0.0
2	Dispatch Center Staff	3.7	3.7	2.0	2.0	5.0	18.3	18.3	10.0	10.0
3	Technology	4.7	4.7	2.7	2.0	5.0	23.3	23.3	13.3	10.0
4	Light	5.0	4.7	2.7	1.7	5.0	25.0	23.3	13.3	8.3
5	Temperature and Air Control	5.0	4.7	3.0	1.0	5.0	25.0	23.3	15.0	5.0
6	Cleanliness	5.0	4.7	3.0	1.0	5.0	25.0	23.3	15.0	5.0
7	Furniture	5.0	4.7	3.0	1.7	5.0	25.0	23.3	15.0	8.3
8	Technical	4.7	5.0	3.0	2.7	5.0	23.3	25.0	15.0	13.3
9	External Facilities	5.0	4.7	3.0	2.0	2.0	10.0	9.3	6.0	4.0
10	Internal Facilities	5.0	5.0	2.3	1.7	5.0	25.0	25.0	11.7	8.3
11	Radio System	5.0	5.0	2.3	2.0	5.0	25.0	25.0	11.7	10.0
12	Console	4.7	5.0	3.0	1.7	5.0	23.3	25.0	15.0	8.3
13	Computer Aided Dispatch (CAD)	3.7	4.0	2.0	2.7	5.0	18.3	20.0	10.0	13.3
14	Telephone	3.7	4.0	4.0	3.3	5.0	18.3	20.0	20.0	16.7
15	Interoperability with Other Agencies	4.0	4.0	2.0	2.3	5.0	20.0	20.0	10.0	11.7
16	Reliability	4.3	4.7	2.3	1.7	5.0	21.7	23.3	11.7	8.3
17	Maintenance	4.3	4.7	4.0	2.0	5.0	21.7	23.3	20.0	10.0
18	Back-Up	4.0	4.3	3.3	1.0	5.0	20.0	21.7	16.7	5.0
8	Monitored Firegrounds	3.0	3.3	2.0	3.0	4.1	12.2	13.5	8.1	12.2
14	Interoperability through Dispatch	3.7	4.0	2.0	2.7	4.0	14.7	16.0	8.0	10.7
20	Recorded Operations	3.0	3.0	2.0	3.3	3.7	11.1	11.1	7.4	12.3
22	Increased Dispatch Channel Capacity	3.0	3.3	2.0	0.0	3.2	9.5	10.5	6.3	0.0
23	Dispatch Capacity	3.0	3.3	2.0	1.0	3.6	10.7	11.9	7.2	3.6
24	Dispatch Coverage	3.0	3.3	2.0	2.3	3.9	11.7	13.0	7.8	9.1
26	Cross CAD Interconnection	4.0	4.0	2.0	0.0	2.9	11.6	11.6	5.8	0.0
46	Staffing and Training	3.7	3.3	2.0	2.3	4.2	15.4	14.0	8.4	9.8
	CTA TOTAL	108	110	67	47					
						WEIGHTED - RANKED TOTAL	488	499	303	213
						OVERALL RANK	2	1	3	4
							Co-Location	Consolidation	Shared Services	As Is - Where Is

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

6.0 ASSET LOCATION TECHNOLOGIES

6.1 Asset Location System Alternatives

Asset Location Technologies that we evaluated include:

1. Non – GPS Based Location Systems
2. GPS Based Location Systems

During our interviews with PCWIN participants, most agencies strongly indicated requirements for unit location. Agencies generally referred to this capability as Automatic Vehicle Location (AVL) implying the need to locate assets down to the vehicle level. Some agencies expressed a desire to locate people, implying the capability of locating users away from vehicles carrying portable radios. In either case, the requirement is for location capabilities over the countywide service area.

Location information is important for personnel management and safety purposes. The information is fed to CAD systems, which in turn make automatic unit recommendations for fire and law operations. Dispatchers benefit from maps views of officer and asset location. Field supervisors better manage assigned resources with the capability of viewing unit locations on vehicle laptops. Responding officers benefit by locating their backup support moving in behind them. These are some of the operational features possible using AVL systems.

Location technologies provide the means of automatically locating assets within a service area. Maintaining an inventory of asset locations is a mandatory task within the world of public safety dispatch. Technology is increasingly being employed to automate this task. CAD systems process the location data and assist dispatchers with mapping and unit recommendations. We examine two technologies available in the marketplace for achieving automatic asset location.

The first alternative is referred to as non-GPS based technology because it does not require each tracked asset to be equipped with GPS receiver hardware. Position information is inferred from characteristics of the signaling that occurs as part of routine radio calls. The advantage of this system is that any type of radio, portable or mobile, without special GPS equipment may be located.

The second alternative involves direct measurement of unit location using a GPS receiver. Latitude and longitude (lat/long) location, measured at the field user, is periodically transferred up to dispatch over the radio traffic channels. This type system tends to be more accurate than non-GPS, but only works outdoors.

6.1.1 Non – GPS Based Location Systems

The system tracks trunked radios by monitoring the control signaling that occurs with each voice radio call. Software using a triangulation method calculates radio location. Signals from monitoring towers are routed to a central processor that correlates the data with specific radios and users before presenting the information in the dispatch center. The system uses overlay equipment, typically involving receivers at the radio tower sites, plus possibly additional receivers (and backhaul links). The location system must maintain a three-receiver view of radios in the desired service area. Information in a standard format is presented to the CAD system for processing and display on the CAD vendor's mapping module.

<u>Advantages</u>

Non- GPS technology advances location technology from tracking vehicles (mobile radios) to locating people (portable radios). This can improve officer safety when working on foot away from the vehicle. Radios must be trunked radios with control channel signaling. The system will not work with analog or digital conventional radios (or trunked radios operated in conventional mode by groups such as SWAT teams).

The system provides location in places where GPS based technology does not work. This includes indoors, in parking garages, under dense foliage, and other situations where the sky view is impaired. Locations are updated each time the user keys the radio. Radios can also be polled for on-demand updates.

The non-intrusive system does not impact traffic loading on the radio infrastructure. Owners do not incur the cost of extra channel capacity to support AVL operations.

The technology may also be added after the fact to existing trunked radio systems. If, for example, the County were to maintain operation of the E.F. Johnson County system after installation of PCWIN, the AVL system could be set up to locate users on old and new radio systems. The same multiple system feature applies to other co-existing systems such the new Marana 800 MHz system.

Disadvantages

Location accuracy is considerably lower than for GPS-based location systems. The minimum accuracy is described as within 300 meters 95% of the time and within 100 meters 67% of the time. Although billed as an indoor system, it may not accurately locate a person to the correct building or the correct floor in a building.

Providing countywide coverage (construction of a countywide overlay) is almost impractical due to the large County size. Placing location receivers on a countywide basis such that each user is always within range of three receivers is simply impractical in terms of cost and the number of backhauls needed. It would be reasonable to consider deployment over a limited area such as the Tucson Valley. To add the capability of locating people with portable radios in a defined area such as Tucson, a limited non-GPS deployment might be considered in addition to a countywide GPS based system.

Systems such as this, with limited service area, are not able to locate out-of-County travelers such as Corrections transport vehicles.

ROM Cost – Non – GPS Based Location Systems

CTA's Rough Order of Magnitude (ROM) cost estimate for a non-GPS location overlay applied over the Tucson metropolitan area is $2M. This is the initial cost for the installed AVL or "location" system infrastructure and includes:

- Location receiver equipment in the Tucson area
- Sufficient user licenses for 3500 portable radios
- Dispatch equipment and software licenses for Pima County and Tucson Police/Fire consoles

6.1.2 GPS Based Location Systems

GPS based location systems are offered by a number of vendors, and as part of mobile data systems by most providers. Using this technology, each unit to be located must be equipped with a GPS receiver. Radio vendors are sensitive to the user request for locating portables (people) as well as mobiles (vehicles). In response, they are starting to offer GPS accessories, typically built into the lapel-worn speaker microphone.

System designs vary, but two basic architectures are available in the marketplace. The first shares the voice or mobile data channels to relay user position up to dispatch. Location information either tags along with other traffic or is sent in response to polling or scheduling. Under this design, AVL coverage matches the voice or data system coverage on which it is transported. Airtime capacity for AVL traffic is included in the system design, but is a small overhead factor.

The second architecture uses dedicated AVL channels overlaid on the service area (typically matching voice or data service area). Under this design, the central AVL system in the dispatch center issues scheduled polling requests to the fleet of mobile users. Information is then updated on the dispatch mapping screens. Use of dedicated AVL channels eliminates the need for extra AVL capacity in the voice or data system. It also requires dedicated AVL radios. This design is suitable for an operation that needs AVL but does not plan universal mobile data deployment.

<u>Advantages</u>

AVL infrastructure shares with the voice and data towers resulting in countywide AVL coverage.

Location accuracy for GPS based technology is typically about 3 meters, significantly better than triangulation technologies.

GPS based systems have the ability to locate out of County travelers such as Corrections transport vehicles. Such vehicles should be equipped with commercial wireless mobile data service for routing locations back to dispatch.

Disadvantages

GPS-based location systems most commonly locate vehicles over mobile data systems, not people with portables over LMR voice systems. This situation is changing with the advent of GPS enabled portables and integrated voice and data using P25 radio systems. P25 includes the ability to convey data information over portable radios, traditionally thought of as voice devices. The disadvantage for portable radios is cost. The GPS option for portables is expensive and requires an expensive "integrated voice and data" system infrastructure addition.

GPS based technology does not work without a view of the sky. Users going indoors, into parking garages, under parking sun sheds, etc will continue to show up on the map, but at their last detected location.

ROM Cost – GPS Based Location Systems

CTA's Rough Order of Magnitude (ROM) cost estimate for a GPS location system installed as part of the countywide mobile data system is $2M in a competitive purchasing environment.

This is the initial installed cost including:

- Vehicular GPS receivers for approximately 3500 mobile users attached to the voice mobile or the mobile data radio
- Does not include any GPS accessories for portable radios
- AVL software option for the 3500 mobiles
- Does not include the dispatch center AVL module or mapping module for the three CAD systems. This cost is included under the dispatch center

6.2 Impact Analysis

CTA has completed an Impact Analysis evaluation on the two location system alternatives described above. The Impact Analysis process is explained in detail in SECTION 3 of this report.

6.3 Impact Results – Location Systems

TABLE 6-1, Comparison of Location System Technologies, contains the results of the impact analysis for alternatives 1 and 2 described in this report section.

At the left side of the table are the attributes established earlier in the project. The reference numbers refer to the attribute definitions provided in the User Needs Assessment Report.

Under "CTA Assessment" are three numerical columns with CTA's evaluation of fit for each attribute and each alternative. These values can range from a low of 0 to high of 5. In the center of the table is PCWIN's importance rank for the attribute, an average of the responses returned by all PCWIN agencies.

Under Weighted-Ranked Results are three columns containing the weighted results. Each value is CTA's assessment multiplied times PCWIN's rank used as the weighting factor. Each of the Weighted-Ranked Results columns is totaled at the bottom arriving at an overall score for each alternative.

The totals are summarized below:

	Alternative	**Combined Law and Fire Score**
1.	Non – GPS Based Location Systems	127
2.	GPS Based Location Systems	138

The main PCWIN requirement, countywide location of assets, would be best fulfilled using GPS based technology.

We also examined the rankings in light of the unique requirements individually important to law enforcement agencies and fire agencies.

In TABLE 6-2, we consider the attributes in light of average rankings for just the law enforcement agencies. The alternatives scored as follows.

	Alternative	**Law Enforcement Only Score**
1.	Non – GPS Based Location Systems	136
2.	GPS Based Location Systems	146

Comparing these results to those obtained from a combined raking, we see virtually the same outcome.

In TABLE 6-3, we consider the attributes in light of average rankings for just the fire departments. The alternatives scored as follows.

	Alternative	Fire Department Only Score
1.	Non – GPS Based Location Systems	123
2.	GPS Based Location Systems	134

Again, the results are similar to those obtained in the combined analysis.

While each technology has its strengths and weaknesses, we conclude that GPS based technology is an appropriate fit for construction of PCWIN.

TABLE 6-1
IMPACT Analysis Results - Location System Technologies
Combined Law and Fire

		CTA Assessment			Weighted - Ranked Results	
		Non GPS-Based Location Technology	GPS-Based Location Technology	Combined Law Fire	Non GPS-Based Location Technology	GPS-Based Location Technology
Ref.	ATTRIBUTE					
No.		Alt 1	Alt 2	RANK	Alt 1	Alt 2
13	Computer Aided Dispatch (CAD)	4.0	4.5	4.8	19.0	21.4
4	In-building Coverage	3.8	1.3	4.3	16.1	5.4
37	Future Expansion	4.0	4.8	3.9	15.7	18.7
28	Vehicle Location	4.3	4.5	3.5	14.9	15.8
18	Person Location	4.3	1.5	3.5	14.7	5.2
3	Improved Voice Radio Coverage – Western County	2.8	4.3	3.0	8.3	12.8
1	Improved Voice Radio Coverage – Eastern County	4.0	4.5	2.9	11.7	13.2
2	Improved Voice Radio Coverage – Central County	2.8	4.0	2.9	8.1	11.7
New	Location Accuracy	3.8	4.5	2.5	9.4	11.3
New	Countywide Service	3.0	4.5	2.5	7.5	11.3
New	Out of County Service	0.8	4.5	2.5	1.9	11.3
	CTA TOTAL	37	43			
				WEIGHTED - RANKED TOTAL	127	138
				OVERALL RANK	2	1
					Non GPS-Based Location Technology	GPS-Based Location Technology

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

TABLE 6-2
IMPACT Analysis Results - Location System Technologies
Law Enforcement

		CTA Assessment			Weighted - Ranked Results	
		Non GPS-Based Location Technology	GPS-Based Location Technology	Law Enforcement	Non GPS-Based Location Technology	GPS-Based Location Technology
Ref.	ATTRIBUTE					
No.		Alt 1	Alt 2	RANK	Alt 1	Alt 2
13	Computer Aided Dispatch (CAD)	4.0	4.5	4.7	18.7	21.0
4	In-building Coverage	3.8	1.3	4.6	17.4	5.8
37	Future Expansion	4.0	4.8	4.2	16.7	19.9
18	Person Location	4.3	1.5	3.7	15.8	5.6
3	Improved Voice Radio Coverage – Western County	2.8	4.3	3.6	10.0	15.5
28	Vehicle Location	4.3	4.5	3.5	15.1	16.0
1	Improved Voice Radio Coverage – Eastern County	4.0	4.5	3.5	13.8	15.5
2	Improved Voice Radio Coverage – Central County	2.8	4.0	3.4	9.3	13.5
New	Location Accuracy	3.8	4.5	2.5	9.4	11.3
New	Countywide Service	3.0	4.5	2.5	7.5	11.3
New	Out of County Service	0.8	4.5	2.5	1.9	11.3
	CTA TOTAL	37	43			
				WEIGHTED - RANKED TOTAL	136	146
				OVERALL RANK	2	1
					Non GPS-Based Location Technology	GPS-Based Location Technology

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

TABLE 6-3
IMPACT Analysis Results - Location System Technologies
Fire Departments

		CTA Assessment			Weighted - Ranked Results	
		Non GPS-Based Location Technology	GPS-Based Location Technology	Fire Departments	Non GPS-Based Location Technology	GPS-Based Location Technology
Ref. No.	ATTRIBUTE	Alt 1	Alt 2	RANK	Alt 1	Alt 2
13	Computer Aided Dispatch (CAD)	4.0	4.5	5.0	20.0	22.5
4	In-building Coverage	3.8	1.3	4.1	15.4	5.1
37	Future Expansion	4.0	4.8	3.8	15.2	18.0
28	Vehicle Location	4.3	4.5	3.5	14.8	15.6
18	Person Location	4.3	1.5	3.3	14.1	5.0
2	Improved Voice Radio Coverage – Central County	2.8	4.0	2.7	7.4	10.7
3	Improved Voice Radio Coverage – Western County	2.8	4.3	2.6	7.2	11.2
1	Improved Voice Radio Coverage – Eastern County	4.0	4.5	2.6	10.5	11.8
New	Location Accuracy	3.8	4.5	2.5	9.4	11.3
New	Countywide Service	3.0	4.5	2.5	7.5	11.3
New	Out of County Service	0.8	4.5	2.5	1.9	11.3
	CTA TOTAL	37	43			
				WEIGHTED - RANKED TOTAL	123	134
				OVERALL RANK	2	1
					Non GPS-Based Location Technology	GPS-Based Location Technology

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

7.0 NETWORK TECHNOLOGIES

The PCWIN countywide communications system will contain a network backbone that interconnects the facilities at all the physical locations. This section discusses the high level alternatives for construction of such a network backbone. We will refer to this interconnection system as the "backbone network" or simply the "network".

7.1 Network System Alternatives

We examined network alternatives constructed using microwave radio, fiber optic connections, and leased wire line technologies. Network alternatives that we evaluated include:

- Connectivity Network
- Interoperability Network

The Connectivity Network Alternatives involve appropriate connectivity of each node or location in the entire voice, mobile data, and dispatch network. Suitable media, whether it is microwave, fiber, or leased lines, is used to interconnect locations for routing voice, data, control, and maintenance information to any needed location in the County.

The Interoperability Network Alternative is identical to the Connectivity Alternative but adds an important layer of functionality; the ability to communicate outside the PCWIN radio system. This is accomplished using a layer of software and gateway devices placed at strategic locations to facilitate the interface between PCWIN and adjacent regions. This is essentially building in the mechanisms in advance for the eventual need for convenient communications with neighboring counties and adjacent regions.

7.1.1 Connectivity Network

The connectivity network is conceptually designed during the radio coverage design process.

During examination of potential tower sites for coverage performance, existing and potential connectivity options are also considered. Other considerations being equal, sites with better connectivity options are more likely to be selected.

Two basic technologies are available for construction of the needed connectivity network. One technology is traditional circuit switching. The other technology is the adaptation of Voice over Internet Protocol (VoIP) technology, using packet switched networking, to land mobile radio systems. The case can be made for why an IP packet switched network offers some strong advantages in a network used for both voice and data services.

7.1.1.1 Network Technology Alternatives

This section contrasts the two major types of switching technology used in communications: circuit switching and packet switching. A brief overview of the Internet Protocol (IP) and VoIP protocols is provided. Discussion continues on considerations when applying VoIP in the LMR environment.

Two fundamental technologies exist for design of the network. The first follows a traditional approach of using individual circuits to interconnect all elements. The model followed is that of the telephone system, called circuit-switched technology that provides a dedicated circuit from one connection point to another. This architecture is implemented in traditional ways for LMR and includes circuits of varying density, carried on all types of media such as copper, fiber and radio links. Switching systems are located, as needed serving the various resources. It is assumed that the reader is familiar with the circuit switched architecture.

An alternative technology known as packet-switching is emerging in both LMR and the telephone systems. The LMR industry is migrating to a new generation of control architecture based on packet-switching technology. This technology migration is resulting in a fundamental shift from the existing circuit-switched architecture to a packet-based architecture using the mature Internet Protocol (IP). Until recently, packet networks were not suitable for handling real-time data such as voice.

However, as network speed and capacity have increased and new protocols have been developed, it is now practical to discuss the transmission of voice over packet networks using IP. As LMR systems continue to migrate from analog to standards-based digital networks and system planners envision larger networks, the concept of using packet switched networks with IP addressing has superseded the idea of replacing circuit-switched control of wide-area LMR repeater, base

station, and control console networks. The ultimate solution is to use Voice over Internet Protocol (VoIP) in a packet switched network, replacing the complex time division multiplex (TDM) audio switches and circuit-based connections now used. Packet networking using IP has the potential to enable enhancements such as full-featured LMR data services, as well as true, end-to-end encryption.

Circuit switching is simply tying two communication lines together temporarily to complete a call. Key to this technology is the need for a complete dedicated call path from end to end for duration of the call. Sufficient numbers of single-call paths also must match or exceed the number of concurrent calls desired in the system to avoid blocked calls. Typically, the number of circuits and switching system capacity limits the number of simultaneous calls.

Packet switching can be thought of as an efficient method for time-sharing a line by multiple users. In packet networks, data can be made to share simple networks—because the networks are very fast, the entire bandwidth of the network can be chopped into time slots and divided among its users. Each user is assigned a unique time slot, effectively putting multiple users on one path and the network functions more efficiently among a larger number of users.

Because packets can be sent as independent data messages, with their own addressing and routing information, physical circuits are not required, and users with no packets to send or receive will not be using bandwidth. This means that the entire bandwidth is always available to carry traffic. The greater the peak traffic, the greater the required bandwidth, which is expressed in terms of bits (of data) per second.

Packet switches read (during transmission) each packet's addressing and sequencing information, and identify the best available routing for the packet. At the receiving end, packets are buffered and reassembled into data streams such that it appears to the receiver that he or she is connected to the sender by a circuit. In reality, the circuit is virtual, giving rise to the term "virtual circuit" or "virtual connection."

In the packet network, redundant channels are not required to ensure delivery because data is divided into pieces with a high probability of reaching their destination in a reasonable time. Because packet data networking is a mature

technology and is ubiquitous in the form of intranets and the Internet, IP networking is readily available.

7.1.1.2 IP Packet Switched Technology for LMR

Basic Protocols

To understand many of the concepts associated with VoIP and packet switched networking, a basic understanding of the Transport Control Protocol (TCP)/IP suite is necessary. The TCP/IP suite operates in a layered fashion to provide data-networking services. The TCP/IP "stack" is based on the open systems interconnection (OSI) model. In this model, each layer communicates to its peer layer across the network and provides service to the layer above it.

The upper layers in the protocol stack provide services describing when the job of moving data is complete and in what language the data is encoded. Adaptation of IP networks to LMR voice involves protocol development primarily in the upper layers. This is where LMR specific features such as broadcast voice calls are implemented. Performance enhancements such as traffic priorities are provided at this layer. This is also the layer that one can expect to find vendor proprietary protocols employed specifically to solve problems or present features.

IP is a connectionless protocol in which packets can take different paths between end points, and packets from different transmissions share all paths. This approach enables efficient allocation of network resources because packets are routed on the paths with the least congestion. Header information ensures that packets reach their intended destinations and helps reconstruct messages at the receiving end. To ensure that all packets reach their destination in a timely manner, a necessity in real-time voice networks, quality of service (QoS) software mechanisms must be employed.

Protocols Important to LMR

VoIP represents a family of protocols used to transfer voice information over packet data networks using the IP. With regard to the well known challenge of latency, two critical factors affect speech quality in packet networks: end-to-end delay and lost or late packets. However, because IP was originally designed and

built to transmit data, it only ensures that all packets are delivered uncorrupted. IP is not concerned with the order of arrival or with latency; these issues are addressed by TCP in the Transport layer.

At the time that IP was developed, networks were not capable of delivering data with the speed required for real-time applications. Today's network technology, however, provides for sending real-time data over packet networks, if appropriate protocols are used to manage the data flow. Three parameters must be managed to provide sufficient QoS for transfer of real-time data: latency, bandwidth, and packet loss/desequencing. These parameters are optimized through enhancements in the end points and protocols.

To address these issues, voice on IP networks uses the Real Time Protocol (RTP) and Real Time Control Protocol (RTCP) to transfer information about sequence and quality of transmission on the network. A new version of IP, known as IPv.6 has been under development for many years. It is anticipated that IPv.6 will recognize voice and data packets and route them with multiple priority levels to improve quality of service (QoS) for voice traffic. Devices using these protocols are called gateways, and act as interfaces between the IP packet network and other protocols and formats, including analog audio.

Several families of standards describe upper level protocols for VoIP. The four most common families include: H.323, Session Initiation Protocol (SIP), Media Gateway Protocol (MEGACO), and Bearer Independent Call Control (BICC). In addition, a proposed standard for LMR is discussed, FSTG/00/08/00 Project 25 Fixed Station Interface Overview and Definition—Conventional Systems. These standard protocols and some vendor specific protocols are necessary within each network subsystem of each vendor's product offering.

7.1.1.3 Key Design Considerations

When evaluating IP voice network offerings, several key factors must be considered. We recommend that these performance areas, and others, be evaluated carefully from all proposing vendors.

A. Voice Coding

Voice coding used in packet networks must provide minimum discernable difference from high bandwidth coding used in circuit switched networks. To achieve this, modeling-type vocoders are employed to provide high-quality speech, at low bit rates, with sufficient robustness for wireless applications.

Improved multi-band excitation (IMBE) vocoder developed by Digital Voice Systems Inc., is a modeling-type low-speed vocoder that provides high-quality speech in mobile radio environments. IMBE is the standard specified for P25 compliant LMR.

B. Network Congestion

In a circuit-switched network there is a one-to-one relationship between calls and TDM channels. Packet switching provides a completely different scenario. A packet network carries messages from many different points to many different points over many different links. This architecture has been referred to as resembling a "web" or a "cloud." As one moves from the edge of the web (i.e., the ingress and egress points of the packet network) inward, the communications links become larger, carrying greater bandwidth, and therefore a greater number of sessions. The deeper one looks into the web or cloud, the more sessions each link carries. Every session has a pattern of packets competing for the available bandwidth in the channel.

While a large network may be implemented in stages, the overall capacity design must be carefully analyzed up front to ensure that the target performance goals will be met.

Any traffic capacity limits must first be encountered in the LMR design (i.e., in the channel capacity for the LMR network). The backbone network must then be designed as a non-blocking network, with a very high grade of service (GOS). Any capacity limitation in an IP packet-switched network will manifest itself in performance degradation for the overall radio system.

C. Noise and Distortion

In a circuit switched network, distortion caused by noise or intermittent connections is virtually non-existent. In a packet network of the same reliability, distortion and dropouts can occur, not due to bad connections but due to lost packets within the network itself. The principal cause of packet loss is network congestion. When instantaneous network capacity is fully used by other data traffic with higher precedence or earlier arrival times, voice packets can be stored temporarily (queued) as long as their "time-to-live" parameter is not exceeded. Once time-to-live expires, the network routing devices throw the packets away. Shorter packet lengths can increase the probability of interleaving with other sessions. However, short packet length increases the number of packets, increasing the likelihood that packet life will expire or "time out." When possible, assignment of high precedence in the addressing portion of voice packets can force the network routing devices to throw away other, non-voice, packets. To the extent that other sessions can tolerate such abuse, this strategy can minimize voice signal distortion. The network must be non-blocking. Providing an extremely high GOS leaves needed capacity for non-time critical applications such as mobile data.

D. Latency

While a network can cleanly encode voice into packets and not lose them, the transmitted audio can still be unsatisfactory if overall delay is too high. For received speech to be acceptable, the end-to-end one-way delay cannot exceed about 150 ms or 300 ms round trip. Network routing delays must be kept small in comparison to the largest contributor, speech vocoding and encryption time.

In addition to fixed delays are variable packet delays. Sometimes referred to as jitter, packet arrival timing and sequencing problems can occur.

Mitigation of network routing delay involves minimizing data size through compression techniques, managing the network size and topology, properly sizing network buffering and queuing elements, and avoiding constantly variable packet routing.

E. Reliability

Two other network requirements are low transmission error rate and total reliability. Communications managers in the law enforcement environment expect 99.999 percent reliability (i.e., approximately 5 minutes of downtime per year). Today's packet networks approach this level of reliability with careful design. Therefore, networks that transport law enforcement communications must be carefully designed and managed.

This dictates that, while network link content may be leased, the network must be a privately owned and operated voice intranet. With sufficient voice prioritization capabilities, data applications can share unused capacity. This is particularly true of two necessary classes of data, network management, and Over-The-Air-Rekeying (OTAR) key distribution.

F. Security

Further, law enforcement demands highly secure communications, with a high level of resistance to eavesdropping or interception. Because packet networks share one "cloud" among several communities of interest and may depend on public carriers, encryption is virtually mandatory. Encryption, however, increases end-to-end delay. Encryption requires extreme care in network design, or overall delay budgets can be exceeded.

7.1.1.4 Advantages of Packet Switched Technology

IP packet switched network technology has the potential to provide significant advantages over traditional circuit switched for a large, multi-agency, shared radio network. The most important of these are described below.

A. Segregation of Regional Users

Packet networks provide "virtual" networks over a common infrastructure, incorporating privacy between all PCWIN participants.

B. Interoperability

IP networks offer the opportunity for linkage to gateways providing basic connections to adjacent jurisdictions and legacy conventional channels.

C. Cost Savings

IP-based packet networks promise potential cost savings through reduction of leased line costs, and reduction or elimination of channel equipment and external interfaces. Channel banks are major cost drivers in wide area system architectures.

D. Network Simplification

Packet networks also offer simplification through standardization and commonality of equipment, augmented by the use of off-the-shelf networking equipment. Because IP is a standard protocol, IP routing equipment is available as a commercial off-the-shelf (COTS) commodity. Simplification improves maintainability.

E. Link Redundancy

Packet networks offer redundancy through the routing capability incorporated in the IP packet structure. In the packet network, each packet carries addressing information, and proper network design provides for multiple paths between each end point. This results in improved overall system reliability.

F. Built-in Switching

Packet networks can provide switching functions normally supported by circuit-based switches. These functions can include wide area audio switching and central logging for wide area systems. Further enhancements include multimedia and data-bearer service support.

G. Voice and Data Integration

This refers to the capability of a system to transport voice and data over the same facilities, on an end-to-end basis. Older systems were designed for voice transmission and later adapted to provide mobile data service. This adaptation required segregating the voice and data paths over the transport network, with the voice and data paths only converging again at the base station. Modern systems using IP over packet-based networks are expected to provide complete end-to-end integration of voice and data over the transport network and over the air. With a fully integrated voice and data system, voice and data signals would only diverge at the radio devices, where they would be reproduced by a speaker in the case of voice, or at an attached data device.

7.1.1.5 Link Media Options

We envision the PCWIN backbone network taking full advantage of all existing assets including microwave links and fiber lines. We will strive to reduce the number of leased lines to avoid high recurring costs. To reach some locations it may be more cost effective to use leased networks. Examination of these tradeoffs will be completed as part of the conceptual design phase. The types of linking media available for the PCWIN backbone include:

- Telephone circuits
- Point-to-Point radio links
- Leased T1 circuits
- Microwave Radio Links
- Fiber Optical Links

Telephone Circuits

Ordinary POTS (Plain Old Telephone Service) through the Public Switched Telephone Network (PSTN) probably accounts for many of the communication links in use today.

Point to Point Radio Links

Recently, high capacity radio link technologies have become available that are designed to avoid recurring costs for short distance hops. Point-to-point VHF/UHF radio links are also commonly used for low capacity circuits.

Leased T1 Circuits

T1 circuits meeting the North American standard digital multiplex hierarchy accommodate 24 voice channels (DS0) in a single 1.544 Mb/s data stream. Each of these DS0 circuits is a nominal 64 kb/s circuit. Pulse code modulation (PCM) is employed in T1 circuits.

Leased T1 circuits are often employed on links where, for one reason or another, microwave radio is not currently available or planned because of economic considerations. (Physical limitations such as blockage along the line-of-sight is also a common reason for using leased T1's.) Even though leased circuits appear to be less costly in the short run, we should remember that recurring charges over a long period of time might have paid for a user-owned microwave system.

Leased lines are inferior to microwave with regard to long-term reliability. Short outages will occur due to line faults and deliberate line switching by the operator. While we target 99.9995% path reliability for a microwave link, we typically have to settle for 99.9% reliability for a leased line. This reliability figure results in considerable downtime over the course of a year, or over 20 years. Another objection to leased circuits is the fact that the public safety agency has no control over the circuits.

The decision as to whether to use leased T1 lines for connectivity to a site has to be carefully considered on a case-by-case basis, and will involve judgment on the criticality of the link, reliability needed, and life cycle cost.

Microwave Links

Digital microwave radio systems have all but completely replaced analog technology. The performance of digital microwave radio systems is superior to

that of analog systems and the per-channel cost of digital circuits is considerably less than the cost of analog circuits.

A variety of protection schemes are employed in microwave radio link design. These include Non-Protected (NP) systems, Monitored Hot Standby (MHSB), space diversity receive, and frequency diversity links.

A non-protected microwave radio is a radio without any redundancy. This type of radio has a single transmitter, a single receiver, and one modem with each of these components being a potential single failure point.

Monitored hot standby radios have redundant transmitter and receiver units with automatic switching from a main component to a standby component upon detection of an equipment failure. The standby components are on the same frequency as the main component.

Space diversity equipment is generally employed on long, or water-crossing, microwave links. Each end of a space diversity link will have the transmitter and the main receiver connected to one antenna and a second receiver connected to its own antenna. Depending on the frequency band and available tower space, these two antennas are generally separated by approximately 20-30 feet of vertical separation. Space diversity provides increased path reliability while providing equipment redundancy protection.

Frequency diversity systems use an additional frequency pair in the same frequency band for a separate transmitter/receiver. Each separate transmitter/receiver is generally configured as non-protected radios. The requirement of an additional frequency pair and the availability of an additional frequency pair are reasons why this form of protection is not very popular. Another form of microwave path protection, which may be employed, is loop or ring protection. The type of hardware employed determines the difference between loop and ring protection. Loop switching equipment usually includes a switch per DS1, which switches between the normal loop direction (clockwise) and the reverse direction (counter-clockwise). The term “ring” is used whenever DACS or Synchronous Optical Network (SONET) equipment is employed. Ring or loop protection is possible if the physical location of these sites is such that a

loop is formed. Generally, a separate non-protected transmitter/receiver is provided for each direction of each site of the loop.

Most new microwave systems are specified as digital microwave radios. Digital microwave radios are available in a wide range of circuit capacities from a few DS1 circuits up to Optical Carrier 3 (OC3) and higher circuit capacities.

Fiber Optic Links

The use of optical fiber as a transmission medium has gained steadily in recent years. The circuit capacity of fiber is considerably greater than that of microwave, and except for right-of-way costs and the cost of installing the fiber, the cost is nearly equal to that of a microwave link. Fiber optic systems require considerable right-of-way, but where the user owns the property where such a system might be employed, fiber optic circuits become very attractive, especially for handling high capacity transmission systems.

While all types of communications systems are subject to some sort of link failure, fiber circuits are subject to being severed by construction crews using backhoes or some other earth moving machinery, than are microwave circuits. A severed fiber usually results in hours of down time if there is no backup path.

ROM Cost – Connectivity Network

Rough Order of Magnitude (ROM) cost of the connectivity network for PCWIN is built into the ROM cost figures for the voice radio, communications center, and mobile data parts of the ROM cost estimates.

7.1.2 Interoperability Network

The Interoperability Network Alternative concerns an overlay enhancement on the above described Connectivity Network Alternative. All of connectivity network considerations apply equally to this alternative. The Interoperability Network Alternative adds a layer of functionality designed to facilitate convenient and controlled radio communications with other users that are involved in a response.

Many PCWIN participating agencies have significant call to interoperate, and therefore intercommunicate, with other jurisdictions in the region. A means for convenient and effective communications is necessary with Federal agencies assisting with major fire fighting, or for Sheriff's Deputies assisting with U. S. border issues. Equally effective intercommunications with public safety in adjacent counties must be within easy reach when needed during major incidents. As we have suggested elsewhere in this report, selection of P25 equipment does not automatically make the desired interoperability happen. It smoothes the technical path but is not the full answer. There are still procedural, chain-of-command, and departmental protocol rules that must be followed in order to execute in an organized fashion. There are also some remaining technical issues such as frequency band differences to overcome.

The answer for many organizations lies in having the technical means to communicate with other groups, but only doing so in a controlled manner. This often this means funneling all intercommunications through dispatch and command and control structures. Most of the time, providing the means for field personnel to simply switch their radios and talk to different responding agency is not the answer.

The interoperability network adds a layer of dispatch-controlled connectivity to the PCWIN countywide radio system. Points of connections can include:

- Legacy radio systems of any description within the county
- Adjacent county radio systems of any description
- Federal radio systems in the region
- The dispatch centers of agencies operating on the above radio systems
- The public telephone system
- Ad-hoc radio systems or command centers set up for special situations and linked into the network

While the function is similar to patch, the implementation is improved. Rather then routing all the desired resources into the PCWIN dispatch environment over dedicated leased or owned wirelines, the resources are tapped at their sources using radio gateway devices. Gateway devices interface radios, consoles, or any manner of audio source, convert the voice to VoIP signaling, thus enabling

transport of the information to any other point in the IP-based PCWIN network. Many of the gateway access points are preplanned

Interoperability system product offerings are available from the major LMR manufacturers. Because the technology is based more on IP network technology than radio, we are starting to observe other vendors such as Cisco entering the marketplace as well.

System integrators are also designing and constructing systems using commercial components such as ACU 1000 devices as radio endpoints combined with other network equipment. We recommend specifying the interoperability overlay in terms of functionality, points of access, and user characteristics thus allowing PCWIN bidder's maximum latitude in their solutions.

Advantages

Interoperability gateway networks can bridge the gaps between radio systems of different bands. In Pima County, band differences will exist between Federal operations, some of the adjacent counties, and some legacy county systems. The network also interfaces radios of different protocols or technology.

Like the "gateway channel" that links several agencies in Pima County today, the interoperability gateway would be dispatch-center controlled. This will allow connections to be established only when authorized and needed. All intercommunications are funneled through dispatch for access control.

Using the IP enabled PCWIN backbone to transport outside communications sources could be a lower cost method than the dedicated leased lines traditionally used to bring patches into dispatch.

This is especially true where radio gateways are placed at existing entry points to the PCWIN network to pick the needed communications. Deliberate provision will have to be made (and paid for) for links to surrounding dispatch centers.

Preplanned provision for interoperability can be useful for routine daily cooperation with outside agencies, special events (using ad-hoc setups), and under emergency scenarios.

Disadvantages

During times when outside traffic is gated on the PCWIN radio system, call traffic levels will increase. This is not unlike the traffic general by Federal users and task force users on Pima County's radio system today. The additional traffic loads should be estimated and factored into PCWIN system design work.

Cost of the interoperability overlay perhaps should be planned and shared on a regional basis. State Public Safety, and adjacent counties might share in the involvement and cost as with mutual beneficiaries.

7.2 Impact Analysis

CTA has completed an Impact Analysis evaluation on the two network system alternatives described above. The Impact Analysis process is explained in detail in SECTION 3 of this report.

7.3 Impact Results – Network Systems

TABLE 7-1, Comparison of Network System Technologies, contains the results of the impact analysis for alternatives 1 and 2 described in this report section.

At the left side of the table are the attributes established earlier in the project. The reference numbers refer to the attribute definitions provided in the User Needs Assessment Report.

Under "CTA Assessment" are three numerical columns with CTA's evaluation of fit for each attribute and each alternative. These values can range from a low of 0 to high of 5. In the center of the table is PCWIN's importance rank for the attribute, an average of the responses returned by all PCWIN agencies. Under Weighted-Ranked Results are three columns containing the weighted results. Each value is CTA's assessment multiplied times PCWIN's rank used as the weighting factor.

Each of the Weighted-Ranked Results columns is totaled at the bottom arriving at an overall score for each alternative.

The totals are summarized below.

	Alternative	Combined Law and Fire Score
1.	Connectivity Network	140
2.	Interoperability Network	158

In these scores, we notice a definite inclination to maximize readiness for outside agency interoperability.

We also examined the rankings in light of the unique requirements individually important to law enforcement agencies and fire departments.

TABLE 7-2 repeats the process, but instead of using overall PCWIN Rank, uses average rankings for just the law enforcement agencies. The alternatives scored as follows.

	Alternative	Law Enforcement Only Score
1.	Connectivity Network	157
2.	Interoperability Network	167

Comparing these results to those obtained from a combined raking, we see virtually the same outcome.

TABLE 7-3 repeats the process, this time using average rankings for just the fire departments. The alternatives scored as follows.

	Alternative	Fire Departments Only Score
1.	Connectivity Network	139
2.	Interoperability Network	160

Clearly, the Fire Fighting community is a driving factor behind the call for enhanced interoperability. This is consistent with the high attribute rankings regarding many of the interoperability attributes reported by fire departments.

Our overall recommendation for network technology is to include a first class network backbone as the foundation for the new PCWIN radio system. This includes selecting both alternatives 1 and 2.

Utilize mixed microwave and fiber optic construction maximizing re-use of newer parts of existing County and City network assets. Design for public safety grade reliability using loop topologies and path protection to ensure redundant routing to critical locations. Select an IP enabled design capable of carrying all voice, mobile data, and network management traffic. Plan from the beginning for the necessary interoperability nodes and install the gateways that will be needed in the region.

TABLE 7-1
IMPACT Analysis Results - Network Technologies
Combined Law and Fire

		CTA Assessment			Weighted - Ranked Results	
		Connectivity Network	Interoperability Network	Combined Law Fire	Connectivity Network	Interoperability Network
Ref. No.	ATTRIBUTE	Alt 1	Alt 2	RANK	Alt 1	Alt 2
43	Reliability/Failure Hierarchy	3.6	3.8	4.6	16.4	17.4
42	Survivability	3.6	3.6	4.5	16.1	16.1
21	Simplified User Operations	3.8	3.8	3.9	14.9	14.9
37	Future Expansion	3.6	4.0	3.9	14.2	15.7
14	Interoperability through Dispatch	2.8	3.8	3.9	10.9	14.8
24	Dispatch Coverage	3.6	3.6	3.9	13.9	13.9
11	Voice Security	3.6	3.4	3.8	13.7	13.0
13	One System Serves All Agencies	3.6	4.0	3.4	12.4	13.7
16	Interoperability with State Agencies	2.8	4.0	3.3	9.3	13.3
15	Interoperability with Adjacent Counties	2.8	3.8	3.3	9.1	12.4
17	Interoperability with Federal Agencies	2.6	3.8	3.3	8.5	12.4
39	Microwave Connectivity	3.8	4.0	3.2	12.3	12.9
38	Owner-Controlled Backbone	4.0	3.8	3.2	12.9	12.2
12	Operational Boundary Transparency	3.4	3.8	3.2	10.9	12.2
41	Regional Connectivity	2.8	4.0	3.2	8.9	12.7
40	Microwave Additional Capacity	3.8	4.0	3.0	11.4	12.0
25	One Mobile Data Network Serves All Agencies	3.6	4.0	2.9	10.4	11.5
44	Single Points of Failure	3.4	3.6	2.0	6.8	7.2
	CTA TOTAL	61	69			
				WEIGHTED - RANKED TOTAL	140	158
				OVERALL RANK	2	1
					Connectivity Network	Interoperability Network

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

TABLE 7-2
IMPACT Analysis Results - Network Technologies
Law Enforcement

		CTA Assessment			Weighted - Ranked Results	
		Connectivity Network	Interoperability Network	Law Enforcement	Connectivity Network	Interoperability Network
Ref. No.	ATTRIBUTE	Alt 1	Alt 2	RANK	Alt 1	Alt 2
43	Reliability/Failure Hierarchy	3.6	3.8	4.8	17.3	18.3
42	Survivability	3.6	3.6	4.8	17.3	17.3
44	Single Points of Failure	3.4	3.6	4.6	15.8	16.7
21	Simplified User Operations	3.8	3.8	4.3	16.2	16.2
37	Future Expansion	3.6	4.0	4.2	15.1	16.7
24	Dispatch Coverage	3.6	3.6	3.8	13.7	13.7
11	Voice Security	3.6	3.4	3.8	13.7	13.0
14	Interoperability through Dispatch	2.8	3.8	3.7	10.4	14.2
39	Microwave Connectivity	3.8	4.0	3.6	13.8	14.5
12	Operational Boundary Transparency	3.4	3.8	3.5	11.7	13.1
13	One System Serves All Agencies	3.6	4.0	3.4	12.1	13.5
38	Owner-Controlled Backbone	4.0	3.8	3.4	13.5	12.8
40	Microwave Additional Capacity	3.8	4.0	3.3	12.4	13.1
17	Interoperability with Federal Agencies	2.6	3.8	3.1	8.0	11.7
41	Regional Connectivity	2.8	4.0	3.1	8.7	12.4
16	Interoperability with State Agencies	2.8	4.0	3.0	8.4	12.0
25	One Mobile Data Network Serves All Agencies	3.6	4.0	3.0	10.8	12.0
15	Interoperability with Adjacent Counties	2.8	3.8	2.9	8.1	11.1
	CTA TOTAL	61	69			
				WEIGHTED - RANKED TOTAL	157	167
				OVERALL RANK	2	1
					Connectivity Network	Interoperability Network

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

TABLE 7-3
IMPACT Analysis Results - Network Technologies
Fire Departments

		CTA Assessment			Weighted - Ranked Results	
		Connectivity Network	Interoperability Network	Fire Departments	Connectivity Network	Interoperability Network
Ref. No.	ATTRIBUTE	Alt 1	Alt 2	RANK	Alt 1	Alt 2
43	Reliability/Failure Hierarchy	3.6	3.8	4.4	15.9	16.8
42	Survivability	3.6	3.6	4.3	15.3	15.3
44	Single Points of Failure	3.4	3.6	4.2	14.1	15.0
14	Interoperability through Dispatch	2.8	3.8	4.0	11.2	15.2
24	Dispatch Coverage	3.6	3.6	3.9	14.0	14.0
37	Future Expansion	3.6	4.0	3.8	13.6	15.2
21	Simplified User Operations	3.8	3.8	3.7	14.2	14.2
16	Interoperability with State Agencies	2.8	4.0	3.5	9.9	14.1
13	One System Serves All Agencies	3.6	4.0	3.5	12.5	13.9
15	Interoperability with Adjacent Counties	2.8	3.8	3.5	9.7	13.2
17	Interoperability with Federal Agencies	2.6	3.8	3.4	8.8	12.8
41	Regional Connectivity	2.8	4.0	3.2	9.0	12.8
38	Owner-Controlled Backbone	4.0	3.8	3.1	12.5	11.8
12	Operational Boundary Transparency	3.4	3.8	3.1	10.4	11.6
39	Microwave Connectivity	3.8	4.0	3.0	11.4	12.0
40	Microwave Additional Capacity	3.8	4.0	2.8	10.8	11.4
25	One Mobile Data Network Serves All Agencies	3.6	4.0	2.8	10.1	11.3
11	Voice Security	3.6	3.4	0.0	0.0	0.0
	CTA TOTAL	61	69			
				WEIGHTED - RANKED TOTAL	139	160
				OVERALL RANK	2	1
					Connectivity Network	Interoperability Network

Ranking Scale:
0 - Required function (Attribute Does Not Exist)
1 - Required function (Available but Totally Insufficient)
2 - Generally inadequate (Unacceptable Alternative)
3 - Marginally Adequate (Approximately 60% Functionality)
4 - Reasonably adequate, (A Good Alternative)
5 - 95% of Function / Attribute Available (Excellent Alternative)

8.0 RECOMMENDATIONS

CTA has carefully analyzed the most viable technology alternatives that might be considered for construction of the PCWIN Regional Communications System. The total network was divided into five technology and operational areas in order to fully evaluate specialized options available in the Land Mobile Radio marketplace. A panel of CTA engineers and operations specialists then began the exercise of meshing PCWIN agency needs rankings with the various alternatives. The combination of CTA's experience along with PCWIN agency inputs meshed in CTA's Impact Analysis Process yields a numerically validated viable alternative selection for each of the five areas. We summarize our recommendations from the System Alternatives Analysis and direct the reader to the preceding report sections for more detailed information.

8.1 Voice Radio System

Select Alternative 1, Trunked Radio – Project 25 Technology

8.2 Mobile Data System

Select Alternative 1, Stand-Alone Mobile Data, Expanded Broadband Network

8.3 Communications Center

Select Alternative 2, Co-Location of separate dispatch organizations

8.4 Asset Location

Select Alternative 2, GPS-based asset location countywide

8.5 Network System

Select a combination of Alternatives 1 and 2, Countywide connectivity network as the backbone for the PCWIN network with interoperability gateways for regional connectivity.

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[i] *9-1-1 Networks in the 21st Century, The Case for Competition.* SCC Communications Corp, Boulder, CO, February, 2001.

[ii] *Wireless 9-1-1 and Distress Calls*. WOW-Com: Industry Issues and Answers. Cellular Telecommunications and Internet Association. 2001.