AGENDA

FREDERICK COUNTY BOARD OF SUPERVISORS
WEDNESDAY, JUNE 12, 2019
5:30 – WORK SESSION
BOARD ROOM, COUNTY ADMINISTRATION BUILDING
107 NORTH KENT STREET, WINCHESTER, VIRGINIA

1. **5:30 P.M. – Work Session Call to Order**

2. **Discussion: Public Safety Radio System Technical Assessment**

3. **Adjourn**

MissionCriticalPartners
Because the Mission Matters

Public Safety Radio System Technical Assessment

Final Report

PREPARED APRIL 2019 FOR
FREDERICK COUNTY, VIRGINIA

MissionCriticalPartners.com

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Executive Summary

Emergency response professionals working in public safety agencies in Frederick County, Virginia (County)—including law enforcement, fire/rescue, emergency medical services (EMS) and 911 agencies—recognize that the County's public safety radio system is providing less than satisfactory performance. Consequently, the County engaged Mission Critical Partners (MCP) to complete a system needs assessment and to provide recommendations for resolving known deficiencies as identified by system users and MCP.

The emergency responders within the county long have been aware of radio system deficiencies that can and have negatively impacted their ability to communicate during routine and critical incidents. Emergency responders provided MCP with numerous examples of active law enforcement, fire/rescue and EMS incidents where radio messages were not heard at all or were not understandable. The system design, which relies on individual transmit sites that do not provide countywide coverage, results in an operational model that is complicated and system performance that is unpredictable and prone to intermittent problems.

The inability of users on different channels to reliably hear and talk to other field personnel or dispatch also is a critical issue that often creates operational command-and-control problems and is an important safety concern. Meanwhile, insufficient channel availability equates to channel overcrowding during major incidents, such as a severe weather event, or during a busy period when multiple events are occurring simultaneously. Consequently, the ability of emergency responders to communicate when the need is greatest can be hampered.

The system uses various sites and operates primarily on very-high frequency (VHF) frequencies in conventional analog mode. It is supplemented by an ultra-high frequency (UHF) interoperability channel that is an extension of the West Virginia Statewide Interoperability Radio Network (SIRN); some emergency responders and the County dispatch center can monitor and talk on selected SIRN talkgroups. This capability is especially useful for fire/rescue and EMS mutual-aid response that occurs in West Virginia.

Various elements of the County's system were installed over the last 20 years. To further complicate performance issues, the law enforcement channels and component design are different from that of fire/rescue/EMS. Thus, in some areas, fire/rescue/EMS can communicate more reliably than law enforcement.

Based on the information gathered, MCP identified numerous critical issues affecting the County's system, including the following:

- A lack of coverage and unreliable performance exist in many areas within the county. The system design is insufficient to provide reliable public-safety-grade performance. Performance on the system can vary for different functional users (Law Enforcement/Fire) depending on location and which frequency and radio site with which they are affiliated.

- Interoperability is limited within the county due to certain operational factors that can make agency-to-agency communication cumbersome. Interoperability with external agencies when outside the county is addressed primarily through the use of multiband or cache radios that can be used on other systems.

- The system design includes single points of failure that can leave emergency responders with no reliable way to be dispatched or to communicate for an extended period if a failure occurs.

- Channel capacity is limited due to the conventional design, with channels being transmitted from only one site and over a limited number of available frequencies.

- Modern radio safety and control features, such as an emergency button and encryption are not universally available today.

In summary, the system's deficiencies include insufficient:

- Coverage
- Capacity
- Redundancy
- Security and control features

The selected communications system solution should mitigate or eliminate these deficiencies. It is important to note that the existing system cannot be upgraded to meet this requirement in its present configuration; thus, the performance deficiencies will continue without investment in a new system.

Figure 1 below illustrates how the assessment results show actual versus ideal status of each existing system element.

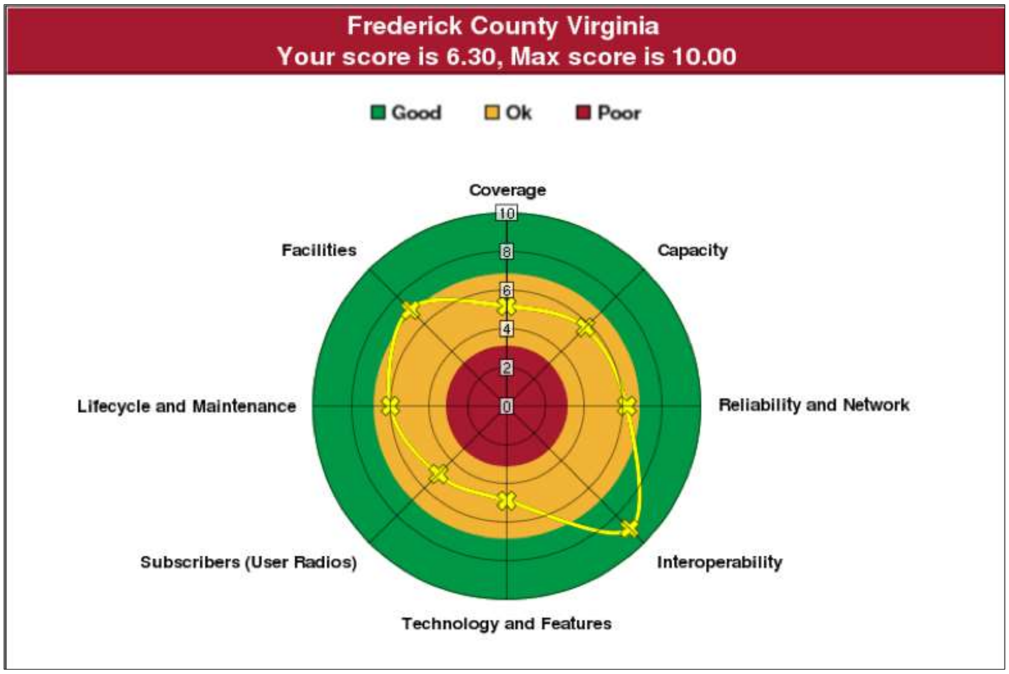

Figure 1: Frederick County Assessment Blueprint Diagram

Best Solution

MCP evaluated several available public safety technologies to identify solutions that would address the identified performance gaps and align with key design considerations. The analysis focused on solutions that would improve radio communications within the county, balance performance improvement with cost considerations and be a prudent investment of public funds.

When selecting the best solution, the following considerations were key factors:

- Will the new system provide the desired level of coverage and reliability?
- Are frequencies available to license for use in the new system?
- Will the new system be standards-based?
- Will the new system support desired safety and operational features?
- Will the new system have an extended life expectancy and be flexible enough to meet future needs?

The best solution that would align with these factors would be:

Implementing a new Project 25 (P25) Phase II, eight-site, six-channel simulcast system.

The details of this conceptual design are found within this report to include expected system performance, estimated costs, recommended next steps, and a preliminary timeline of related activities. A preliminary search of available frequencies indicates that a new standalone system likely would need to use 700/800 megahertz (MHz) frequencies; however, vendors would not be restricted to those frequency bands if they were able to identify other available frequencies. Radios that are capable of using 700 MhZ frequencies are also capable of using 800 MHz frequencies. An adequate number of new 700 MHz frequencies would be available for a new system. If any 800 MHz frequencies were also available, they could be incorporated into the system design.

Design Alternatives and Options

As an alternative to the County building its own new system, a design option exists that may reduce costs and/or provide additional system resilience. However, the alternative design approach would need to meet all key factors listed above for a new standalone system.

An option that may merit additional analysis in the next planning phase is as follows:

- An expansion of SIRN into Frederick County

The following would need to occur during the next planning phase to determine the viability and desirability of this option:

- Analysis of whether it can meet the desired technical and performance requirements
- Analysis of potential cost savings
- Analysis of various business factors to include:
  - Willingness of the other system to consider an appropriate business relationship
  - Initial and ongoing costs
  - Procurement considerations
  - Governance considerations
  - Requirements and guidelines regarding participation, use, maintenance, and future upgrades

Use of Multiband Radios

Today both Fire/Rescue and to a lesser extent Sheriff, make use of some multiband radios primarily to allow for interoperability when they are outside of the County. If the new radio system shifts to the 700/800 MHz frequency band both Fire/Rescue and Sheriff will need to continue to communicate on other bands, primarily VHF and UHF. This can be accomplished in different ways. The two approaches that are in line with current procedures would be to (1) Purchase new multiband radios that could talk on both 700/800 and VHF/UHF. This would allow for the use of one radio, instead of two, however, it is a costly option that could add significantly to the overall project budget, especially if the quantity of multi-band radios needed was high. Option (2) would be to retain enough of the current VHF radios in use today and make them available to the appropriate staff. This option would carry a significantly lower cost but would require a higher level of logistical coordination to ensure that enough VHF radios would be available when needed. A third approach would be a hybrid of number (1) and (2) which would allow for the purchase of some multiband radios and the retention of some VHF radios. The right blend would be determined by operational needs and frequency of use. For the purposes of this report and cost estimation, the cost of all public safety radios being multiband radios (Option 1) has been included in the subscriber options section of the costing tables. Either option (2) or (3) would carry a lesser cost. A summary of the cost for option (1) can be found in section 5.11 Table 11.

Cost Estimate Summary

The costs in this report provide a budgetary estimate for a new standalone P25 Phase II trunked simulcast radio system, a new microwave system, new mobile, and portable radios and project management services. Equipment pricing anticipates a typical level of discounting. In a competitive procurement process, vendors normally will offer a discount of 20 percent to 30 percent, sometimes higher. These discounts may be bundled and include a variety of factors such as discounts off list price, system incentive discounts, customer loyalty discounts, and other creative factors. Due to these variables, MCP uses a more conservative discounting estimate to ensure that actual costs will be lower than the estimates, not higher.

Our budgetary estimates also include project contingency allowances for anticipated infrastructure and site upgrade costs. This contingency is intended to cover items such as unexpected/unusual site foundation costs, land acquisition or lease costs, unusual existing tower structural enhancement costs, possible intermediate microwave site costs, and other items that may not be identified until a design has been finalized and preliminary engineering work completed. The budgetary estimates also include a cost for five years of system maintenance.

The table below summarizes the estimated costs for the recommended solution. A more detailed explanation of costs can be found in section 5.11.

Table 1: New System Estimated Costs

Budgetary Cost Estimates for Capital Investment	
System Description	Standalone P25 Phase II, Trunked Simulcast System
Radio System	$5,076,660
Backhaul	$1,574,191
Facilities	$4,112,259
Subscriber Equipment	$4,164,455
Project Management	$490,112
Total	$15,417,677
Radio System Options	$4,947,821
Grand Total with Options	$20,365,498

The operating expenditures over a five-year term are estimated at $1,851,583. This includes radio system maintenance, monitoring, potential site leases, site maintenance, subscriber maintenance, and other preventive maintenance to keep the system performing at an optimum level of functionality and reliability.

Next Steps and Key Recommendations

The current radio system has numerous performance and safety deficiencies that have the everyday potential to negatively impact the ability of emergency responders to communicate during both routine and critical incidents. Meaningful communication improvements only will come through an investment in a new system and radios. The next steps include:

- Brief the County Board regarding this report's findings and recommendations and request approval to proceed with the next step of the planning process.
- Develop a system specification and request for proposals (RFP)
- Undertake the procurement process to receive and evaluate proposals, select a vendor, select a design option, and negotiate a contract.
- Brief the County Board on the results of the procurement process and seek approval for contract award and project funding.

Anticipated Activity Timeline

The following timeline describes a typical implementation schedule:

- Specification and RFP development – 4-6 months
- Procurement process – 6-9 months
- Implementation – 12-24 months

The typical implementation period for a radio system is 12–24 months after the vendor contract award. With the necessary planning and procurement tasks, it may be two to three years before a new system is implemented and operational.

1 Introduction/Background

1.1 Introduction

In response to public safety providers voicing their concerns to local elected and appointed officials, Frederick County, Virginia (County) hired Mission Critical Partners (MCP) to assess its public safety radio communications system and to recommend solutions to mitigate identified deficiencies. The task is to develop a conceptual plan for improving public safety communications in a cost-effective and logical manner. Reducing costs by leveraging past investments and other communications resources was considered where possible.

1.2 Goals and Objectives

The key goals and objectives for a new public safety radio system identified by the Frederick County emergency response community and County administration include the following:

- Understand the current system and equipment performance gaps and deficiencies
- Develop a new system design that resolves performance gaps and meets the current and future requirements of emergency responders in the county
- Identify options for mitigating the performance gaps that would prove to be viable and desirable while leading to potential cost savings
- Implement a new system design that would be flexible and would have an extended life to ensure prudent use of public funds.

2 Methodology

This section provides a description of MCP's approach to completing the assessment of the County's public safety radio communications system.

2.1 Initial Meeting

An initial meeting was held with local public safety representatives in late November 2018. During the meeting, the project team reviewed the scope of work, agreed on content that would be contained in the deliverables, and established a project schedule. Coordination of staff interviews, site surveys, and the report review-and-presentation process also occurred. Representatives of County public safety departments and volunteer fire departments were in attendance.

2.2 Public Safety Agency Representative Interviews

In conjunction with the project kickoff meeting, MCP conducted both group and individual meetings with a cross-section of public safety agency and senior County management representatives. We met with emergency responders from law enforcement, fire/rescue, emergency medical services (EMS), and 911 agencies. The purpose of the meetings was to discuss plans and gather feedback from various agencies regarding the existing communications system and to understand performance and operational requirements for any new or enhanced communications system.

2.3 Radio Site Surveys

Radio site surveys were conducted to become familiar with the existing system infrastructure, assess the condition of the existing facilities, and evaluate their ability to support new or upgraded equipment in the future.

2.4 Report Development

MCP developed this radio system assessment report based on the information collected. The report is divided into seven primary sections:

1. Introduction
2. Methodology
3. Findings
4. Assessment/Conclusions
5. Recommendations
6. Next Steps
7. Conclusion

The Findings section details all information gathered regarding the existing system and includes technical and operational baselines. The Analysis section includes a description of available radio communications technology and how it could be utilized to the benefit of local public safety service providers. The Recommendations section includes MCP's recommendations for updating the radio communications system with an improved system targeted at addressing the needs of the emergency response community. The Next Steps section includes an explanation of what the next step in the planning process should entail. The report's Conclusion briefly summarizes a suggested strategy for moving forward.

3 Findings

This section provides a detailed description of MCP's findings regarding the existing communications environment within the county.

3.1 Technical Baseline

The technical baseline describes the system and how it operates. The information is objective and is based strictly on MCP's assessment of the system inventory and design. The infrastructure equipment primarily consists of equipment manufactured by Motorola Solutions. The system is serviced and maintained by

Motorola. Additionally, selected staff from County Fire and Rescue and the Sheriff's Department also provide a limited amount of technical and/or preventive maintenance support, particularly concerning mobile and portable radios.

3.1.1 Current System Design

The County's public safety radio communications system today consists primarily of conventional very-high frequency (VHF) repeaters, base stations and voted receivers operating from six sites within the county. All repeaters operate in the narrowband analog mode. With each repeater operation on a separate conventional frequency, users must switch channels manually to access the appropriate repeater depending on their location within the county.

3.1.2 Coverage

MCP utilized computerized modeling programs to conduct a limited baseline coverage estimate of the County's communications system. The fire/rescue/EMS channels and component design varies from that of law enforcement. User feedback indicated that coverage from the main law enforcement repeater located at the North Mountain site was very limited and that this design provided less coverage than the fire/rescue/EMS repeaters. Therefore, MCP modeled the law enforcement coverage provided from North Mountain as the baseline coverage model because this was representative of the most serious system deficiencies. The coverage study was modeled based on system parameters such as transmitter power output, transmission line losses, and antenna gain. These parameters together make up what is referred to as effective radiated power (ERP). The law enforcement coverage study provides an opportunity to compare current coverage, conceptual design coverage and the desired coverage levels that were identified during the project kickoff meeting.

3.1.3 Capacity

System capacity today is limited in several ways. No frequencies are transmitted countywide, as each frequency in use today is only being transmitted from one particular site, and thus only covers a portion of the county.

While there are designated channels at each site for various purposes, there are only a limited number of operational channels exist that can be accessed if primary dispatch channels get overloaded. None of these operational channels are present at each site; therefore, this configuration results in a capacity restriction when multiple events in a given area occur simultaneously. Thus, any recommended system design needs to provide for a sufficient number of countywide channels or be a trunked design that provides for unlimited talkgroups.

3.1.4 Subscriber Radios

Subscriber radios (mobile, portable, and control station) within the county are owned by each operating agency. The subscriber radios constitute a variety of mobiles and portables manufactured by Motorola.

The majority of the agencies do not have maintenance contracts for their subscriber radios. This fact heightens concern over subscriber radio performance. Antenna systems in particular, but also the radio itself, may not be performing as intended. Lack of routine preventive maintenance and testing can result in reduced coverage or intermittent operation.

Routine maintenance arguably is more critical today than in years past, due to the plethora of electronic devices built into the vehicle by its manufacturer and the aftermarket equipment installed by the agencies. Electronic and radio frequency (RF) noise emanating from the vehicle drastically can reduce the radio's ability to properly receive signals. This type of interference often will be detected during routine maintenance, and actions then can be taken to mitigate the interference.

3.1.4.1 Subscriber Inventory

MCP gathered subscriber radio inventory information with assistance from agency staff. The table below details the number of subscriber radios utilized by each agency today.

Table 2: Frederick County Radio Subscriber Summary

Discipline	Mobile	Portable	Control Stations	Total
Sheriff's Office	185	150	2	338
Fire/Rescue/EMS	250	250	2	503
Schools	300	774		1074
			Overall Total	1,913

3.1.5 Radio Sites

Radio sites are a vital extension of the radio system in that they provide a secure space to house the equipment that provides communications to emergency responders. They also provide protection from natural and manmade threats to allow communications equipment to operate at optimum performance. Radio sites are also an important factor when designing a new communications system, as it relates to site reliability, availability and system coverage.

Frederick County utilizes six tower sites for its primary law enforcement and fire/rescue/EMS channels today. The table below provides a summary of site usage by radio channel. "TX" indicates that a channel is transmitted out to mobile and portable radios from that site, while "RX" indicates that audio is received by the site from mobile and portable radios.

Table 3: Current Tower Use

Site	Law Enforcement	Fire/Rescue/EMS
North Mountain	RX/TX	RX/TX
Cross Junction		RX/TX
Cacapon	RX	RX
Brown Lane	RX	RX/TX
Tasker Road	RX	RX/TX

Coverstone is not a tower site but does receive and transmit from the site with antennas on the roof of the building.

MCP visited Frederick County's radio sites that provide voice communications to emergency responders. MCP reviewed existing systems and equipment, communications sites, and supporting facilities. These included, at a minimum, components such as the tower, shelter, power, cable and wiring systems, antenna systems, heating/ventilating/air-conditioning (HVAC) system, grounding systems, space availability, and radio infrastructure. During the visits, MCP found that the sites generally were maintained in good condition, and found few deficiencies related to site fencing and tower foundation. However, some deficiencies related to site grounding were identified.

Most sites were alarmed and actively being monitored and had space available to accommodate additional equipment.

MCP recommends that monitoring and alarms be included in the new radio system for all radio sites and that any equipment installed at the sites follow the standards in Motorola R56®, *Standards and Guidelines for Communication Sites*, Harris AE/LZT 123 4618/1 R3A, *Standards for Site Grounding and Lightning Protection*, or equivalent grounding specifications, and National Fire Protection Association (NFPA) 70, *National Electrical Code* (NEC) for the installation for electrical wiring and electronics. A more detailed breakdown of site conditions can be found in Appendix A.

3.1.6 Central Dispatch Center

The Frederick County 911 Center, operated by the Department of Public Safety Communications, is the primary public safety answering point (PSAP) and dispatch center for all public safety agencies within the county except for the City of Winchester, which operates its own 911 center. The center is equipped with six dispatch console positions. Staffing levels vary by shift and unique activity needs. Each of these positions can support both call-taker and dispatcher functions. Dispatchers are assigned to channels and user groups based on a daily schedule. All dispatchers are cross-trained to dispatch calls for all public safety disciplines.

3.1.6.1 Dispatch Consoles

The County recently upgraded to Motorola MCC 7500 consoles, which can support a new Project 25 (P25) Phase II radio system with some reconfiguration. If a different manufacturer was selected for the new radio system, replacement consoles likely would be part of any such proposal due to the proprietary nature of console integration into a system design. To ensure an equal playing field and an open and competitive procurement process, the conceptual system design explained in this report includes new consoles. If Motorola were selected as the vendor providing the new system, these consoles could be retained, however, certain feature and configuration updates might be required.

3.1.7 Equipment End of Life

Within a radio communications system, each individual component receives a period of support from its manufacturer during which time repair services and spare parts are available. After the vendor ceases to manufacture a specific component, the vendor typically will stockpile excess parts and support the unit for an additional five to seven years on a “best effort” basis. After that period, support for the component can be obtained only through third parties. The ongoing maintenance of equipment that has reached end of life (EOL) may become exceedingly expensive as the availability of replacement parts becomes more limited and may result in extended system downtimes until repairs can be made. Combined with the fact that older components become less reliable, the overall system reliability and recovery times can be expected to worsen.

The primary system components utilized by the County were manufactured by Motorola. Some of these components are approaching the end of the five-to-seven-year maintenance window, after which support from the manufacturer will no longer be guaranteed. The table below summarizes the EOL dates for the primary system components utilized in the County.

Table 4: EOL Dates for System Components

Component	EOL Date
TRK 750 repeater	September 2017
MTR 2000 repeater	March 2018
CDM 750 mobile radio	Discontinued – June 2015

3.1.8 System Resiliency and Single Points of Failure

The radio and microwave infrastructure utilized by the County varies in age. Some equipment recently has been replaced or upgraded, while other components have been in place for a longer period of time. The typical lifecycle for radio system components is ten to 15 years. As equipment ages, failures become more likely due to wear and tear. Devices with moving parts, such as fans and power amplifiers, typically are the first components to experience failures. Accordingly, a system architecture is needed that can accommodate component-level failures without resulting in a catastrophic loss of capabilities for emergency responders.

System resilience has a direct tie to site resiliency. Site entry and site environmental alarms are critical to ensuring the continued operation of the County's public safety radio communications system. Such alarms, when visible at the dispatch center, provide site information such as building/shelter security and environmental information such as temperature alarms, loss of commercial power, generator alarms and fire/smoke sensor alarms.

Without alarms, a dispatch center is blind to situations that may cause a total loss of communications from a site. In contrast, with alarms, the situation can be analyzed, and maintenance personnel can be dispatched to the site before the situation causes a communications failure.

3.1.9 Connectivity/Backhaul

The County's public safety radio communications system uses an older microwave system for connectivity, i.e., backhaul, between the site and the dispatch center.

Due to the age and limitations of the legacy microwave system a new microwave system is recommended as part of any significant radio system upgrade. The cost for a new microwave system has been included in the budgetary estimate for the new radio system. The new microwave system will be a public-safety-grade looped design, which is more resilient than today's microwave system. It is noted that the County has budgeted for a microwave system upgrade in its next budget cycle. While this upgrade would continue to support the current radio system, it would not be capable of supporting the new system as a more complex and robust microwave system would be an integral part of the new system design.

3.1.10 Interoperability

Interoperability refers to the ability of users to communicate with agencies that fall outside of their primary response group. Interoperability may be between different law enforcement, fire/rescue or EMS agencies within the same county, across disciplines, with public safety agencies in neighboring counties or neighboring states, or with agencies outside of public safety with which communications may be required.

This section includes a description of technological solutions utilized within Frederick County to establish interoperability.

Interagency Communications (In County)

Agencies that operate on the same radio bands have each other's channels programmed into their radios today. However, to communicate with an agency on another frequency band, users must relay information through dispatch, which is an inefficient use of radio resources and personnel. In addition, some information may be relayed incorrectly or not at all, which can create circumstances where responding units may not receive important life-safety information while en route to an incident. In some cases, an agency can request a console patch to another agency's frequency—this is the process used to achieve interoperability with the City of Winchester agencies and it is used on a regular basis. But console patches take time to set up, which can be a problem in an emergency when lives and property are at risk and every second matters. This lack of direct ability to monitor important calls without a patch in place can create circumstances where responding units may not receive important life-safety information while en route to an incident. The new system being recommended would be fully capable of providing seamless access to talk groups on either system. Provisioning of this capability would be an operational decision by both system administrators.

State of Virginia Agencies

The Virginia State Police (VSP) operates a VHF trunking system for public safety communications. This system currently is not connected to County frequencies and thus dispatchers must call a VSP dispatch center to relay information.

Mutual-Aid Overlay

Nationwide mutual-aid channels exist that are used for operational communications when other agencies come into Frederick County, and when they do not have Frederick County frequencies or talkgroups in their radios. These channels are known as VCALL and VTAC (VHF), UCALL and UTAC (ultra-high frequency [UHF]), and 7CALL and 8CALL (700/800 megahertz [MHz]). Specific frequencies can be found in the National Interoperability Field Operations Guide (NIFOG), as well as the Virginia Statewide Communications Interoperability Plan (SCIP). It is important that the County plans for a mutual-aid overlay system to improve interoperable communications with all bordering counties and states. This would enable the County to patch the mutual-aid channels via dispatch directly to talkgroup users within Frederick County.

3.1.11 Maintenance

Maintenance on the County-owned radio infrastructure is provided primarily by Motorola, which has technical staff based near Frederick County. Additionally, selected staff from County Fire and Rescue and the Sheriff's Department also provide a limited amount of technical and/or preventive maintenance support, particularly concerning mobile and portable radios.

Subscriber radios are owned and maintained by each agency. Preventive maintenance for the subscriber equipment is arranged on a case-by-case basis.

Regular preventive maintenance checks of mobile radios are a good practice, and that is one of the recommended actions in this report.

MCP suggests that a County-employed radio technician may be an option worth considering in the future. Longer-term this could be a cost-neutral or cost-savings option depending on how future maintenance contracts are negotiated.

4 Assessment/Conclusions

Frederick County 911 has been collecting information from field users regarding radio system performance problems for the past year. Over that time more than 100 different instances of problems were reported, and since some radio problems went unreported, the actual number of incidents is likely much higher than 100. It is helpful to include a sampling of these problem reports to highlight that system use problems are encountered on a regular basis, and often, can involve circumstances that can place both public safety personnel and the public at greater risk. The following examples are reflective of the types of radio issues that were reported.

Date	Issue
March 31	Berryville/First Woods: Deputy attempting to search vehicle. Frederick 911 was unable to copy. (portable)
April 2	Hunting Ridge Rd: Deputy out with a suicidal person. Frederick 911 was unable to copy. (Portable)
April 18	N Frederick/Gainesboro: Deputy out with a domestic disturbance. A lot of static and breaks in traffic. (Mobile)
April 20	Darlington Drive: Deputy out with suspicious situation where the caller was hostile toward Law Enforcement Officer (LEO). Deputy was unable to transmit. (portable)
April 21	Main Street Stephens City: Deputy was out with a suicidal person. Frederick 911 was unable to copy. (Portable)
April 25	Darlington Drive: Incident involving a mental subject that had called to report his house on fire and then was threatening to shoot LEO. Deputies were unable to communicate with each on the scene. (portable)
May 10	Woody's Place: Deputy was out with a domestic situation. Frederick 911 was unable to copy. (portable)
May 14	Coolfont Lane: Deputy was out with a wanted person. Frederick 911 was unable to copy. Deputy was unable to copy Frederick. (portable)

Date	Issue
May 18	Waterford Lane: Deputy was out with subject arrested on violation of protective order. Frederick 911 was unable to copy. (portable)
July 20	Sunnyside Drive: Outside with an intoxicated person Deputy's traffic was not readable. (portable)
August 20	Millwood Pike/McCarty Lane: Traffic stop, Deputy could not hear Frederick 911 checking his status. (portable)
August 20	Lenior Drive: While at an alarm Deputy was unable to copy Frederick 911. Frederick 911 was unable to copy Deputy. He was attempting to run information on subject at the business. (portable/mobile)
August 20	Bald Eagle Drive: Deputy was out with 2 open doors. Inside the building Deputy was unable to copy Frederick 911. Frederick 911 was also unable to copy Deputy. (portable)
Sept 8	Market Street (Red Robin): At the business to remove a subject. Deputy could not copy Frederick 911. (portable)
Sept 14	N Frederick/Chestnut Grove Rd: Traffic stop. Frederick 911 was unable to copy Deputy. (portable)
Sept 2	Peppermint Spring Lane: Deputy out with a possible prowler call. Deputy could not copy Frederick 911. (portable)
Oct 4	Forest Lake Drive: Deputy out with subject making threats to family members that he would shoot LEO. Unable to transmit or copy. (portable)
Oct 23	Forest Lake Drive: Deputy out with assist/fire and rescue. Was unable to transmit to Frederick 911 that it was safe for F/R to continue into the scene. (portable)

The following section analyzes important factors that impact the performance of a radio system.

4.1 Coverage

Adequate coverage is the most important feature of any radio system. Coverage concerns were noted by every agency in the county.

When quantifying coverage in a land mobile radio (LMR) system, two levels must be considered, as follows:

- Mobile
- Portable

Mobile coverage is defined as the geographic area where a vehicular-mounted radio can communicate reliably with the base station at an associated radio tower. Mobile radios use higher power than portable radios, have higher-mounted antennas, have more-efficient antennas, and have antennas mounted free from immediate obstructions. Because mobile radios can receive a weaker signal and transmit with more power, they are able to operate reliably over a wider area than portable radios.

Portable coverage is more limited than mobile coverage. Portable radios typically are limited to transmitter power output (TPO) of three to five watts, compared with mobile radios, which typically have a TPO of 35 to 50 watts. Due to a less-effective antenna system, a portable radio needs significantly more received signal power compared with a mobile radio to clearly receive a signal.

Indoor coverage is the most limited radio coverage level. Public safety radio users often need to communicate within buildings. Buildings further impede the radio wave, making it more difficult for the portable radio inside the building to interpret the signal. A plethora of building factors—such as the type of construction, number of floors, number of windows, location of the building relative to tower sites, placement of firewalls, location of electrical wiring, and the location of the user within the building—impact the path of the radio wave and the ability of the radio to interpret a received signal.

When designing a radio system, buildings typically are quantified as to how much they degrade a radio signal. Because there are so many factors associated with in-building coverage losses, there is no perfect way to quantify such coverage. Typical building losses range from 6 decibels (dB) of signal reduction to 24 dB. Losses within a building may differ dramatically from one location within a single building to another. Radio systems are designed to meet categories of average building-loss specifications. Coverage within individual buildings may be enhanced through bidirectional amplifiers (BDAs) that reradiate received signals from outside the building to inside the building.

The greater the coverage requirement that a system has, the greater the number of radio sites that are necessary. The number of radio sites increases significantly as the coverage requirement increases, dramatically increasing costs. When a vendor is contracted to install a radio system, a coverage requirement typically is defined in the contract. The typical coverage requirement is 95 percent mobile coverage throughout a defined area with required portable coverage varying from system to system. Once the system is installed, the vendor must demonstrate proof of performance by testing the system using a combination of automated and manual coverage-testing tools.

4.1.1 Frederick County Coverage

MCP performed limited propagation modeling for the law enforcement component of the County's radio system. This modeling shows both mobile and portable coverage deficiencies in numerous areas. A coverage map for the existing system can be found in Section 2.1 along with a comparison between the current coverage levels for law enforcement and the anticipated coverage provided by the new conceptual system.

As illustrated in the anticipated coverage map, a simulcast transmit system with voted receive signals and additional sites would provide significantly stronger countywide coverage.

4.2 Capacity

The capacity of a radio system is the system's ability to provide an effective communications path for all users at any time. When a system reaches capacity, the ability of radio users to communicate is inhibited. Capacity on a system is directly related to the number of radio channels in the system. A conventional system assigns one user group for each frequency. In contrast, a trunking system dynamically allocates a pool of frequencies to a pool of user groups as needed, which results in more communications capacity than that provided by a non-trunked (conventional) system.

Capacity on a radio system can be quantified on several levels. The lowest capacity level pertains to how the system accommodates day-to-day radio traffic, which coincides with the number of emergencies, which typically are higher during nights and weekends. Conventional systems may experience capacity problems when multiple incidents occur simultaneously for users on a shared channel. While these incidents do not necessarily occur on a day-to-day basis, they are common enough that systems should be designed to accommodate the higher traffic loads of multiple incidents.

The next capacity level relates to planned events—such as parades, holidays, and sporting events—for which increased radio traffic will be planned. During these events, it is expected that radio usage will be higher. Planned events demanding high radio usage can be accommodated by proper event planning. Radio channels can be assigned ahead of time so that users can properly manage the capacity on the radio system.

The highest capacity level relates to unplanned events—such as natural or manmade disasters—that demand a high level of radio capacity. During these events, it is likely that a radio system must accommodate both the primary users and traffic for mutual-aid personnel arriving from other jurisdictions to support the emergency response. System capacity in these events is the hardest to manage yet can be the most critical.

Like coverage, it is important to design a radio system with a capacity that is adequate to meet user needs. Federal Communications Commission (FCC) guidelines recommend one radio channel for every 70 to 100 users. This is a rough estimate because actual usage depends on the operational requirements of each individual agency. A more accurate estimate of loading for trunking systems is based on Erlang C calculations, which take into consideration the type of users, as well as the frequency and duration of radio calls. Ideally, coverage is designed to meet the capacity needs during the worst-case situation, not just everyday use.

Trunking systems provide more capabilities than conventional systems for managing system capacity. First and foremost, trunking systems are inherently more spectrally efficient than conventional systems, because the dynamic allocations of talkgroups provide a higher rate of channel reuse. Second, priority can be set on trunking systems so that access is denied to less-critical user groups when capacity is reached. Third, features such as dynamic allocation enable radio managers to remotely alter the composition of user groups and their access to the radio system.

4.2.1 Frederick County Capacity

More than 900 law enforcement and fire/rescue/EMS subscriber radios are in use in the county. The County currently uses dedicated law enforcement channels and fire/rescue/EMS channels; however, none of these channels provides countywide coverage and so there are many areas where only one of the channels can be used reliably. There are additional tactical channels available, but they only provide reliable coverage when units are in close proximity to each other. User feedback regarding system capacity highlighted regular instances of channel congestion and the need for more capacity, especially during critical, multiple or large-scale incidents.

4.2.2 Loading for Trunking Systems

Because trunking systems dynamically assign frequencies to active channels, capacity is defined as the probability that the system will not have an available frequency to accommodate a talkgroup request, resulting in the subsequent queuing of the call. Erlang C calculations can be made to determine the appropriate number of channels for a trunking system based on the number of active users, the average number of calls per hour, and the average duration of each call.

MCP performed Erlang C calculations to determine the appropriate number of trunking channels to support the region if a trunking system ultimately is implemented. MCP performed the analysis using 479 active users, which allows for a reasonable amount of growth in subscriber counts. The analysis estimates that approximately 25 percent of all potential users are active on the system at any given time, with an average of five calls per hour, and an average call duration of four seconds. These metrics reflect typical system use. It should be noted that actual system use data is unavailable from the current system, thus a theoretical estimate is utilized in these calculations.

Table 5 summarizes the results of the Erlang C calculations.

Table 5: Erlang C Calculations

System Erlangs	# Of Active Users	Average Call Duration (in minutes)	# of Calls per Hour	Acceptable Queued Call Delay (in seconds)	Maximum # of Talk Paths	
2.6597	479	4.0	5.0	1.0	9	
Number of Talk Paths	**Probability Call Request Blocked**	**Average Queue Depth**	**Average Call Delay**	**Queued Call Delay (in seconds)**	**Arbitrary Call Delay**	**% Calls Exceeding Acceptable Queued Call Delay**
9	0.00	0.00	0.00	0.20	0.00	0.0%
8	0.01	0.00	0.00	0.26	0.00	0.2%
7	0.02	0.01	0.02	0.34	0.01	0.7%
6	0.06	0.05	0.07	0.43	0.03	2.7%
5	0.16	0.18	0.27	0.56	0.09	8.9%
4	0.38	0.75	1.12	0.72	0.27	28.9%
3	0.79	6.20	9.33	0.92	0.73	72.9%
2	--------	--------	--------	--------	--------	--------
1	--------	---------	----------	--------	--------	--------

Based on these results, a trunking system with at least nine talk paths is necessary to provide an adequate level of capacity for Frederick County. One additional channel is required for the control channel, and one additional channel is required for interoperability patching, necessitating a total of six channels for a P25 Phase II radio system. This design would provide the County with nine Phase II Time-Division Multiple Access (TDMA) talk paths, plus one additional channel for the control channel. An attribute of a Phase II design is that it allows for two talk paths on one channel in most cases.

4.3 Interoperability Issues and Standards

One of the primary goals of any communications system is to provide interoperability for emergency response personnel. Interoperability has been identified as a limitation within the county. MCP's assessment of interoperable communications is based on the Interoperability Continuum developed by the federal SAFECOM program and adopted by the Department of Homeland Security (DHS) as the standard for evaluating interoperable communications. The Interoperability Continuum provides a basis for planning both tactical interoperable communications programs and strategic initiatives to improve interoperable communications. Federal grant programs that provide funding for interoperable communications initiatives use the goals and standards encompassed in the Interoperability Continuum.

The information that follows provides a foundation for MCP's approach to assessing interoperable communications.

4.3.1 DHS Security Guidance and Template

The tragic events of September 11, 2001 emphasized the critical importance of effective emergency responder communications systems. The lack of emergency response interoperability is a long-standing, complex, and costly problem with many impediments to overcome. Interoperability is the ability of emergency response agencies to communicate with each other via radio communication systems—i.e., to exchange voice and/or data with each other on demand, in real time, when needed, and when authorized.

SAFECOM is a federal program that provides research, development, testing and evaluation, guidance, tools, and templates regarding communications-related issues to local, tribal, state, and federal emergency response agencies working to improve emergency response through more effective and efficient interoperable wireless communications. SAFECOM has developed an interoperability model consisting of the Interoperability Continuum, which sets goals in five elements considered essential to achieving effective interoperable communications: governance, standard operating procedures (SOPs), technology, training and exercises, and usage. The goals in this continuum have been incorporated into guidelines and requirements for federal funding designated for interoperable communications. The information that follows provides a brief overview of the SAFECOM interoperability model.

In general, interoperability refers to the ability of emergency responders to work seamlessly with other systems or products without any special effort. Wireless communications interoperability specifically refers to the ability of emergency response officials to share information via voice and data signals—again, on demand, in real time, when needed, and as authorized. For example, when communications systems are interoperable, police and firefighters responding to a routine incident can talk to each other to coordinate efforts. Communications interoperability makes it possible for emergency response agencies responding to catastrophic accidents or disasters to work effectively together. Finally, interoperability allows emergency response personnel to maximize resources in planning for major predictable events or for disaster relief and recovery efforts.

Tactical interoperable communications are defined as the rapid provisioning of on-scene, incident-based, mission-critical voice communications among all emergency-response agencies (EMS, fire, and law enforcement), as appropriate for the incident, and in support of an Incident Command System (ICS), as defined in the National Incident Management System (NIMS).

There are a variety of challenges to interoperability: some are technical, some are financial, and some stem from human factors such as inadequate planning and lack of awareness of the real importance of interoperability.

4.3.2 Interoperability Continuum

Interoperability planning should be based on the principles developed by the SAFECOM program including the Interoperability Continuum, which is depicted in Figure 2.

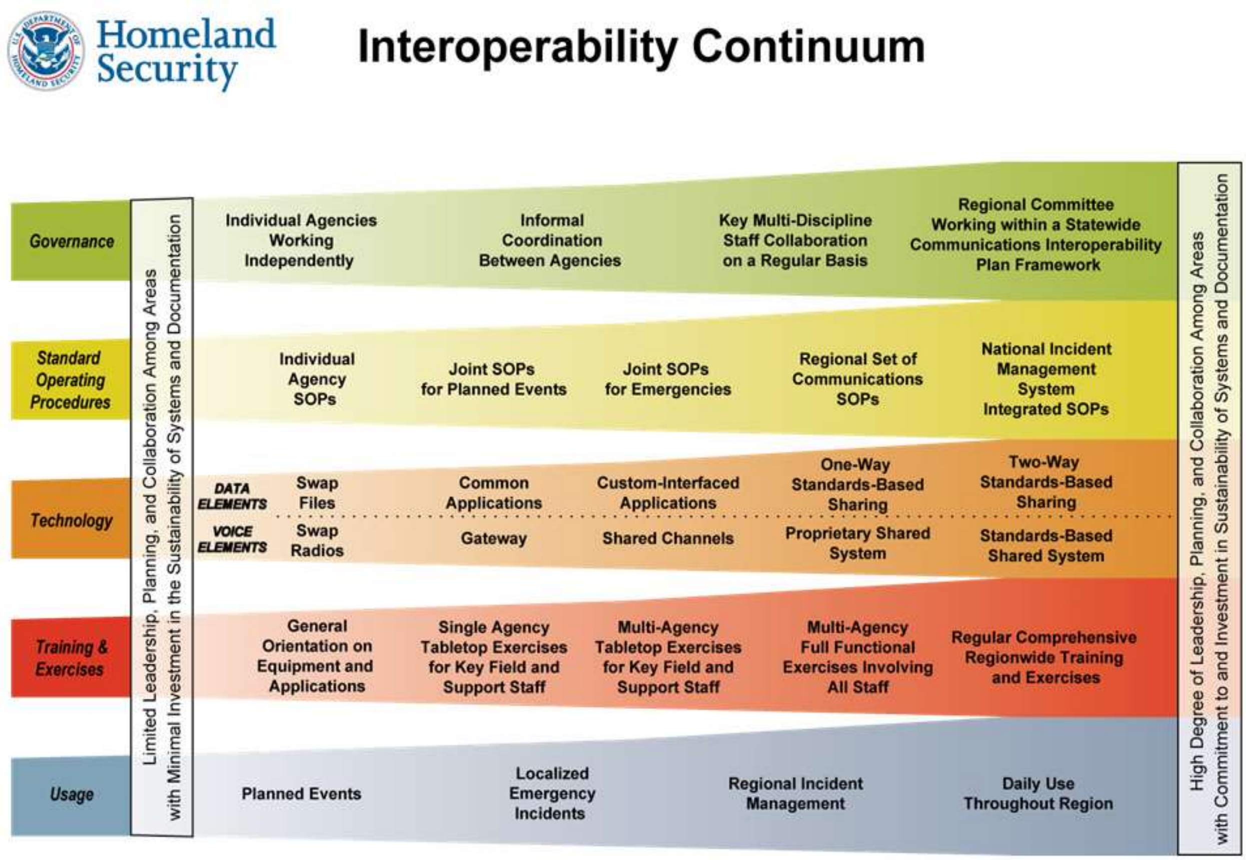

Figure 2: SAFECOM Interoperability Continuum

The Interoperability Continuum was established to depict the core facets of interoperability, according to the stated needs and challenges of the emergency response community. It will aid emergency responders and policymakers in their short- and long-term interoperability efforts, as they plan and implement interoperability solutions.

Making progress in all aspects of interoperability is essential because the elements are interdependent. Therefore, to gain a true picture of a region's level of interoperability, progress along all five elements of the Interoperability Continuum must be considered together. For example, when a region procures new equipment, that region should plan training and conduct exercises to make the best use of that equipment.

4.3.2.1 Interoperable Gateways

Gateway systems provide connections between two or more radio networks, allowing users on one network to communicate with users on other networks. For example, a group of users on an 800 MHz channel used by Agency A can be connected to a group of users on a VHF channel used by Agency B. The interconnection is created when two or more radio channels or talk paths are connected to each other via a gateway device, such as a console patch.

Gateway systems can be configured to support any number of channels. Using gateway systems, usually, through a dispatch console, a dispatcher can select the appropriate channels to interconnect. With many gateways, multiple interconnect sessions involving distinct groups can be established at any given time by the gateway operator. The maximum number of simultaneous interconnect sessions in progress depends on the gateway system.

Gateway systems typically are used in regions where there is overlapping coverage of participating radio communications systems. For example, two agencies responding to an incident can have channels from their respective communications networks interconnected; however, this is only useful if the coverage area of each network includes the incident location. An agency must be able to access its own communications network. Thus, the service areas for a gateway system generally are restricted to the overlapping service area of all participating agencies.

Mobile gateways refer to field-deployable devices that can be used to enhance tactical interoperability. Mobile gateways are the most useful when agencies do not have overlapping coverage and must respond to a localized event such as a rural brush fire. The gateway allows for the interconnection of simplex channels in different frequency bands and permits localized interoperability within the limited coverage area of the gateway transmitters and antenna systems. The problem with these systems is the time delay associated with deploying the equipment and training limitations due to the infrequent use of the equipment.

Frederick County operates a fixed gateway device. The dispatch consoles serve as fixed gateways, permitting patching between any channels that are monitored on the console. The State of Virginia also maintains regional communications assets that include gateways. These assets can be requested and deployed to a local incident. Availability and travel time are factors that will impact the speed of any deployment.

While gateways are an effective method to establish interoperability, they are not the ideal method due to the need for overlapping coverage and the loading of channels in multiple systems. However, situations certainly exist where patching is an effective interoperability tool.

4.3.2.2 Shared Channels

Shared channels refer to common frequencies that have been established and are programmed into radios to provide direct interoperable communications among disparate agencies. To use this option, all user radios must be capable of operating on the same frequency band with the same modulation scheme.

Shared channels and shared systems are the only types of interoperable communications equipment that are always available because no third-party intervention or overlapping system coverage is necessary.

While shared channels can greatly support interoperable communications when other agencies operate on different frequency bands the use of multiband radios or other interoperability tools are necessary to interoperate with these agencies.

4.4 Radio System Technologies

The following are excerpted requirements from the *FY17 Virginia State Homeland Security Grant Program (HSGP) Guidance for Communications Grant Proposals*. These requirements will continue for all future grant years FY18 and beyond and need to be incorporated into any grant proposal submitted by Frederick County. Jurisdictions operating below 512 MHz and not utilizing trunking must retain or have the capability to operate at least one primary base and/or repeater in the analog mode within their system. Logic trunked radio (LTR) trunking does not qualify as trunking. Any new radio system and/or equipment shall be programmed using the Commonwealth's P25 ID Programming Plan.

When procuring equipment for communications system development and expansion, a standards-based approach will be used to begin migration to multijurisdictional and multidisciplinary interoperability. Specifically, all new voice systems will be compatible with P25 standards and the Commonwealth's Link to Interoperable Communications (COMLINC) system.

While it is prudent to follow grant program guidelines when designing a new system or buying new radios in case funding were to be available, it should be noted that available grant funding for new systems has greatly decreased in recent years. Limited funding for certain radio purchases may be available, such as through the Assistance to Firefighters Grant (AFG) program, however, there would be no certainty of those funds being available either.

4.4.1 Analog versus Digital

Analog refers to a method of radio transmission where a continuous audio message is modulated (piggybacked) onto a high-frequency wireless carrier. Because the transmission waveform is continuous, any noise or interference appearing on the wireless signal will be transferred to the decoded audio message. This noise and interference will appear as static. When the signal and noise become significantly high relative to the transmitted signal, the audio message is not discernible among the static.

Digital refers to a method of radio transmission where an audio message is first converted into discrete binary (1 and 0) values using an analog-to-digital converter before being transmitted onto a wireless carrier. When the wireless message is received, the message is passed through a digital-to-analog converter and the original audio message is restored. With digital transmission, noise and interference only will impact the received audio if the noise and interference are so significant that the receiver interprets a "1" as a "0" or vice versa (this is known as a bit error). Digital systems can reconstruct the originally transmitted message perfectly over a farther distance than analog systems. However, once a digital transmission is weak enough that the receiver no longer can discern ones and zeros, the transmitted message very quickly becomes unintelligible.

4.4.2 Project 25

The Association of Public-Safety Communications Officials, International (APCO) P25 standards for public safety digital radio were established under the guidance of APCO and developed under the governance of the Telecommunications Industry Association (TIA). The development of P25 standards involved representatives from local, state, and federal government agencies, in conjunction with industry representatives, who evaluated basic technologies to develop common standards for advanced digital LMR technology for public safety organizations.

P25 is a suite of eight standards intended to help produce equipment that is interoperable and compatible regardless of manufacturer. The P25 standards suite includes the following interfaces:

- Common air interface (CAI)
- Fixed/base station subsystem interface (FSSI)
- Inter-RF subsystem interface (ISSI)
- Console subsystem interface (CSSI)
- Data network interface
- Network management interface
- Telephone interconnect interface
- Subscriber data peripheral interface

P25 has four key objectives:

- Provide enhanced functionality with equipment and capabilities focused on public safety needs
- Improve spectral efficiency
- Assure competition among multiple vendors through an open systems architecture
- Allow effective, efficient, and reliable intra-agency and interagency communications

P25 is intended to make informed decisions easier for users when planning to convert an existing system to digital. Using the P25 standards, vendors' systems can be more readily compared because they use an agreed-upon baseline set of specifications. This allows users to more accurately compare the direct features and benefits of entire systems and individual radio products. It is intended to make bidding processes more competitive among prospective vendors. In addition, users should have the opportunity to mix and match equipment among P25-compliant suppliers because all compliant equipment will use the same standards and work on any P25-compliant system.

DHS in its 2007 Federal Grant Guidance for Emergency Response Communications and Interoperability Grants indicated a strong preference for P25-compliant radio equipment, stating:

"When procuring equipment for communication system development and expansion, a standards-based approach should be used to begin migration to multi-jurisdictional and multi-disciplinary interoperability. Specifically, all new digital voice systems should be compliant with the P25 suite of standards. This recommendation is intended for government-owned or -leased digital land mobile public safety radio equipment. Its purpose is to make sure that such equipment or systems are capable of interoperating with other digital emergency response land mobile equipment or systems. It is not intended to apply to commercial services that offer other types of interoperability solutions.

"Further, it does not exclude any application if the application demonstrates that the system or equipment being proposed will lead to enhanced interoperability. With input from the user community, these standards have been developed to allow for backward compatibility with existing digital and analog systems and to provide for interoperability in future systems. The FCC has chosen the P25 suite of standards for voice and low-to-moderate-speed data interoperability in the new nationwide 700 MHz frequency band and the integrated wireless network (IWN) of the United States Homeland Security, Justice and Treasury Departments has chosen the P25 suite of standards for their new radio equipment. The United States Department of Defense has also endorsed P25 for new LMR systems."

Only where there are compelling reasons to do so will the federal government fund the procurement of non-P25-compliant radio equipment.

The final documents establishing the P25 standard were approved and signed in August 1995 at the APCO International Conference and Exposition in Detroit, Michigan. These are referred to as the P25 Phase I standards; however, P25 is an ongoing project. The current effort referred to as P25 Phase II, has developed standards for narrowband operations using 6.25-kilohertz (kHz) channel spacing. Phase II uses TDMA technology. In April 2007, the majority of the P25 steering committee selected what is referred to as the 12-kilobit-per-second, two-slot TDMA solution for Phase II technology.

According to APCO, this selection not only allows for a graceful migration to Phase II and backward compatibility with Phase I systems, but it also offers advanced capabilities that will result in an even more robust P25 system. This solution was chosen to accommodate ever-increasing needs for spectral efficiency and user capacity in public safety wireless voice and data radio systems while ensuring full-feature functionality and improved audio quality. The P25 Phase II standard is complete, and equipment is being sold today that is Phase II-compliant.

4.4.3 Best Network Architecture Options for the County

The sections that follow discuss the network architectures that MCP believes would best meet the current and future needs of the County and which balance performance and reliability with cost considerations.

4.4.4 Conventional Simulcast

Conventional simulcast systems have very similar architectures to that of voted receiver systems. The primary difference is that all interconnected sites transmit and receive. Simulcast refers to system architectures where the same frequencies are transmitted at multiple radio sites. Designs using this configuration must be developed carefully, as radio sites on the same frequencies will interfere with each other if the timing on the transmitters is not perfectly coordinated. The most ideal method of timing simulcast transmitters uses Global Positioning System (GPS) clocks with high-accuracy oscillators. Audio received by multiple radio sites is voted to determine which audio stream has the best quality. That audio is then sent to all radio sites for retransmission.

A conventional simulcast system provides a solution that can supply coverage from multiple radio sites over a large area. With a simulcast system, a single channel is utilized throughout the entire coverage area. Users roaming throughout the area do not need to switch channels and dispatchers only need to monitor a single channel per user group. Conventional simulcast systems utilize the same subscriber equipment as single-site conventional systems.

The primary limitation with conventional simulcast systems is capacity. For every user group, a repeater needs to be added at each base station. Once capacity needs grow beyond four or five channels, it is typically more beneficial to implement a trunking system. There are potential risks of interference in a simulcast system in areas where radio coverage from multiple sites overlaps. It is in these areas where the potential for sites to interfere with each other can occur if the timing between them is not ideal. Simulcast systems have multiple solutions for achieving transmitter timing, some less expensive and less accurate than others. Less expensive simulcast designs are likely to experience more interference problems in overlapping coverage areas.

Conventional simulcast systems may be implemented in the narrowband analog or P25 digital modes, and are available in the VHF, UHF and 800 MHz frequency bands. However, future regulations imposed on the 700 MHz band will prevent the operation of conventional simulcast systems, unless they are used on the interoperability channels or channel efficiency can be increased.

4.4.4.1 Simulcast Trunking

Simulcast trunking systems operate much like multicast trunking systems. The primary difference is that the same frequencies are reused at multiple radio sites in simulcast trunking systems. Implementation of simulcast circuits requires the introduction of timing circuits. The feature sets provided by simulcast trunking systems are like those provided by multicast trunking systems.

With the introduction of timing circuits, the opportunity exists for interference in simulcast overlap areas. In addition, loss of backhaul connectivity can result in a catastrophic failure. Because sites operate on the same frequencies, a loss of coordination between the sites will limit the ability of the sites to function as independent systems, as the sites will interfere with each other. Typically, simulcast systems are designed to fall back to a more limited number of radio sites that do not share overlapping coverage. Consequently, it is especially important that backhaul networks be designed to a very high fault-tolerant design, with high-reliability levels, when accommodating simulcast systems.

4.4.5 Shared Systems

Shared systems provide a way for multiple agencies to share common system components to reduce costs and increase operational effectiveness. Typically, agencies that share a common response area or border each other receive the greatest benefit from system sharing.

System sharing can range in degree from one common system serving many agencies to separate systems sharing a single radio site that lies on the border between the systems.

P25 trunking systems provide the greatest opportunity for system sharing because central control equipment used on such systems often can accommodate a far greater level of users than typically is required for a single agency.

Agencies that share control equipment have the added benefit of improved interoperability with other agencies interconnected with the control equipment. In this scenario, subscriber radios can be configured to roam to any interconnected radio site as long as the frequency band of the site and the subscriber are compatible.

Shared systems come with the task of developing agreements with the sharing agencies to establish equipment ownership and responsibilities. Additional planning is required in advance of installation to work through these details and establish usage criteria that is acceptable to all parties involved. Governance and SOPs are equally important to ensure consistent usage of the shared system and its resources following implementation.

4.5 Emerging Communications Issues and Trends

4.5.1 Long-Term Evolution and FirstNet

Long-Term Evolution (LTE) is a commercial wireless broadband standard. The standard has been adopted by the public safety community for implementation on mission-critical, public safety-grade broadband networks. While commercial cellular networks are deploying this technology across the country, implementation of private public safety LTE networks still is at a nascent stage. Public safety agencies depend largely today on commercial broadband 3G networks, using wireless air cards, for their data needs.

In 2014, the public safety sector was awarded access to the 700 MHz D Block, accounting for 10 MHz of broadband spectrum. The allocation is immediately adjacent to the 10 MHz of broadband spectrum already allocated to public safety. Congress committed to funding a nationwide LTE network on this 20 MHz block of spectrum. Referred to as the nationwide public safety broadband network (NPSBN)—which is being developed under the auspices of the First Responder Network Authority (FirstNet)—this network is intended to provide nationwide broadband coverage to emergency responders. Some areas of the country and many states have negotiated cost agreements with FirstNet and AT&T, however outside of the legacy AT&T cellular network which offers limited capabilities, for the most part, the new FirstNet network is still in the early stages of being deployed.

LTE itself is a wireless network providing high-speed data to subscriber devices. Part of the potential\ benefit to public safety concerns the applications that will run over this network. There also has been discussion that voice over LTE eventually will take the place of narrowband voice radio systems. However, the LTE standard does not provide a direct unit-to-unit simplex operation which can be an important feature to users. Because of these limitations, the readiness of LTE to take the place of narrowband voice systems is still several years out, and perhaps longer for more rural areas of the Country. To facilitate the transition from LMR to LTE, agencies and network operators will be faced with significant planning and logistical challenges to include talk group planning, interfacing to legacy LMR systems and naming conventions.

While there would be benefits to an LTE broadband system within the county from a data perspective, the decision is distinct from considering its use for day-to-day public safety voice communications.

4.6 System Lifecycles

Two-way radio equipment always has had a replacement lifecycle. The lifecycles of today's robust, feature-rich radio systems particularly have been impacted by rapidly advancing and changing technologies. Based on the typical lifespan of each type of equipment, a general schedule of replacement is shown below in the tables below. Replacement cycles may vary (+/- 25 percent) based on factors such as the need for new technology and general wear and tear. Once equipment reaches the end of its lifespan, it is time to upgrade that equipment.

Table 6: Facility Equipment Lifespan

Facility Equipment	Lifespan
Building (prefabricated)	15 Years
Building (block construction)	20 Years
Towers	20 Years
Generators (small/remote sites)	10 Years
Generators (large/main sites)	15 Years
Grounding systems	10 Years

Table 7: Maintenance Equipment Lifespan

Maintenance Equipment	Lifespan
Fencing	10 Years
HVAC (small/remote sites)	2-5 Years
HVAC (large/main sites)	10 Years

Table 8: Radio Equipment Lifespan

Radio Equipment	Lifespan
Repeaters/base stations	15 Years
Antenna systems	7 Years
Dispatch consoles	10 Years
Mobile radios	10 Years
Portable radios	7 Years
Pager units	5 Years

Table 9: Microwave Equipment Lifespan

Microwave Equipment	Lifespan
Radios	10 Years
Channel banks	10 Years
Battery systems	10 Years
Uninterruptible power systems (UPS) (small battery systems)	2-3 Years

4.6.1 Equipment Lifecycle

Some of the radio equipment in use in the County is more than ten years old, which is near—or in some cases, past—the end of typical replacement periods. Consequently, this equipment will begin to suffer from higher failure rates and the risk of obsolescence from the equipment vendor.

Table 4 in Section 3.1.7 lists selected equipment in use today that has been identified as end-of-life cycle.

4.7 Radio Site Resilience

Modern radio systems tether to radio sites for all of their primary support. A radio site is more than a high point on which to hang an antenna—indeed, a radio system is 99 percent dependent on the site's performance and support. MCP visited each of the radio sites in Frederick County. Each evaluation focused on installation practices, site conditions, notification systems, and redundancy of critical elements. These reviews were grounded in industry best practices and standards for critical communications facilities, primarily Motorola R56, *Standards and Guidelines for Communication Sites*.

Motorola R56 generally has been adopted throughout the industry for common use in site construction. All vendors have products that comply with this standard, or which at least track very closely to it. Non-compliance with Motorola R56 does not make the installation wrong, but it may place the site at an increased risk of downtime or significant site/equipment damage. Consequently, MCP recommends adherence to Motorola R56 when deploying radio equipment.

Key elements that must be considered to ensure a reliable radio site and reduce system downtime from potential failures include:

- Climate control: Air-conditioning sufficient to support the building size and thermal load present; monitoring for low-, medium-, and high-temperature alarms; installation of a thermostatically controlled fan-and-ventilation system.

- Connectivity: Two avenues of connectivity should be present. Reverse loop or multipath microwave; microwave with fiber or copper backup; hot standby microwave; and multiple copper or fiber circuits all are acceptable in meeting this requirement.

- Power: Commercial power backed by a generator, fixed or portable, and sufficient direct current (DC) power via a DC plant or uninterruptible power supply (UPS) system capable of running the site for no less than six hours is required for transmitter sites. The ability to monitor power alarms—such as alternating current (AC) power fail, DC power fail, rectifier fail, generator start, generator run, generator fail, and low battery—should be evaluated.

- Physical site: Availability of temporary resources—such as mobile command posts and cell on wheels (COW) in the event of a system outage—and other site support, such as snow removal and other methods of improving road conditions to facilitate site access, are a must.

4.7.1 Grounding

Some deficiencies were found at selected radio sites regarding the external and internal grounding systems. MCP recommends that site grounding be brought up to current standards with a system refresh, but steps could be taken at any time to correct these potential deficiencies and MCP would recommend doing so through coordination with your radio system maintenance provider. Equipment warranties sometimes will not apply if the equipment is not grounded according to industry standards, plus insufficient grounding can result in equipment failures and repair downtime.

4.7.2 Uninterruptible Power Supply

An uninterruptible power supply (UPS) system typically is used to power radio equipment for a period of time until the facility or equipment generator is able to start and provide power. Radio equipment is at risk of system crashes upon the loss of power even if the generator starts immediately. A sudden loss of power could result in permanent damage to radio equipment. MCP recommends that the county install a UPS system or a DC battery power plant in the new radio system, to protect sensitive equipment in the event of a power failure.

4.8 Frequency Bands and Licensing Considerations

Frequency acquisition is one of the most challenging, time-consuming, and uncertain aspects of any radio system implementation. In many cases, the availability of frequencies can dictate the frequency band in which a system is constructed.

This section addresses the strengths and weaknesses of each available public safety frequency band, as well as the frequency availability in each band.

4.8.1 VHF High Band (150–160 MHz)

The VHF high band frequency range is the oldest of the available public safety frequency bands that is still widely utilized today. VHF radio signals travel over rough terrain farther than signals in other bands; as such, VHF systems constructed in rough terrain require fewer radio sites than systems constructed in other frequency bands. However, the VHF band is more susceptible to interference generally and specifically to atmospheric ducting conditions that have been known to cause heavy interference intermittently. These intermittent conditions affect coastal regions more than land-locked regions.

The VHF band originally was not designed for the use of repeater systems, so repeater pairs must be constructed using individual frequencies located throughout the 150–160 MHz range. The combination of multiple repeater pairs at individual radio sites introduces numerous challenges because of system design constraints. Spacing frequencies so that they do not interfere with each other, and so that they can be combined into single combiner units, significantly restricts the frequencies that can be used.

Due to the lack of available VHF frequencies for a trunking solution, and the potential for interference, the VHF band is not recommended for the County's new radio system.

4.8.2 UHF

The UHF frequency band covers the 450 MHz–470 MHz range. The lower portion of the band 380 MHz – 420 MHz includes government use, including meteorology, military aviation and federal two-way use. 470 MHz – 512 MHz is the T-band used for low band TV channels 14-20 (shared with public safety land mobile 2-way radio in 12 major metropolitan areas scheduled to relocate to 700 MHz band by 2023).

The UHF band provides fixed offsets between transmit and receive frequencies, thus supporting the use of repeater systems. Preliminary research indicates that sufficient UHF frequencies may not be available for a trunked multisite or simulcast system; however, more in-depth frequency availability research will need to be conducted by the vendor that will be designing the system. If a shared system with West Virginia's Statewide Interoperability Radio Network (SIRN) is pursued as an option, the potential pool of available frequencies could be increased. The County also has license applications pending for additional selected UHF frequencies.

The use of the UHF band for a new system is technically feasible, however, MCP does not believe that enough frequencies could be licensed for county-wide simulcast use. If, however, a vendor found enough frequencies a design using UHF could be considered.

4.8.3 700 MHz

Frequencies in the 700 MHz band are pre-paired for repeater operations, with mobile frequencies 30 MHz above the base frequencies. The 700 MHz frequency band provides the most likely source of spectrum for Frederick County. The band is not heavily encumbered and frequency assignments would be available. However, obtaining these frequencies will require authorization from the 700 MHz regional planning committee (RPC).

Most current-production subscriber radios can operate in both the 700 MHz and 800 MHz frequency bands; thus, the frequencies can be used interchangeably.

However, several technical constraints regarding the use of the 700 MHz frequencies will limit the types of systems that Frederick County can construct in this band. The system must be digital and must permit subscriber operation on conventional interoperability channels in the P25 mode. While these constraints must be acknowledged they would not be a hinderance to designing a system that would meet the county's needs. The use of 700 MHz frequencies is the leading prospect for licensing a new trunked simulcast system in the county.

4.8.4 800 MHz

Frequencies in the 800 MHz band are pre-paired for repeater operations, with mobile frequencies 45 MHz below the base frequencies. The frequencies are assigned in licensing pools: the interleaved band (854–

860 MHz) is governed by frequency coordination rules and the National Public Safety Planning Advisory Committee (NPSPAC) band (851–854 MHz) is governed by RPCs.

However, the 800 MHz band is heavily encumbered and frequency acquisition will be more limited. Most available 800 MHz frequencies already have been allocated for use by other systems; therefore, the sole use of this spectrum band is not recommended. If a new system could be designed that would utilize both 700 and available 800 frequencies, that would be perfectly acceptable.

4.9 Connectivity

Typically, connectivity for a public safety communications network is comprised of one or a combination of the following:

- Leased telephone lines
- Fiber-optic cables
- Wireless links (e.g., microwave or RF links)

In most situations, connectivity is a combination of analog and digital circuits that carry voice, data, and control tones between the radio consoles and the network of radio communication sites.

Today backhaul between the County's radio system sites is provided by the legacy microwave system. However, because this system has design limitations that impact capacity, resilience, and reliability, MCP recommends that a new public-safety-grade microwave system design be incorporated into the new radio system design.

4.9.1 Fiber-Optic Networks

Fiber-optic cables provide the highest bandwidth, and the best radio site connectivity, of any medium available today. Extensive fiber-optic networks, however, are not heavily implemented for various reasons:

- Single points of failure within a fiber network require the use of redundant network paths to mitigate the loss-of-service risk
- Running new fiber-optic cable is very expensive and not typically justified solely for a radio project
- Bandwidth on a fiber system can support many broadband data systems—far more than is necessary for a radio system
- Fiber-optic networks that have been implemented primarily are found in major metropolitan areas

Construction of a fiber-optic infrastructure is very expensive and certainly exceeds what is required to run a trunked radio system. Typically, radio systems may be piggybacked on existing municipal or leased fiber networks. Consideration also should be given to assuring that the fiber network provides redundant paths that do not include single points of failure.

4.9.2 Microwave

Microwave networks provide a means to wirelessly connect radio sites and dispatch facilities. Bandwidth on a microwave network is typically greater than or equal to a leased T1[1] circuit. Microwave networks are an excellent alternative where no fixed-line infrastructure is present. In addition, a microwave network can be owned entirely by the agency, will not require the monthly fees of leased T1 circuits, and restoration to service is within the control of the County. Microwave networks, however, do have disadvantages that can be mitigated.

Microwave networks are not subject to reliability concerns resulting from line breakage but are subject to wireless phenomenon such as rain fading. Good design will mitigate this hazard. In addition, microwave dishes may become misaligned in high winds, potentially impacting link connectivity. Good design that requires a higher wind-speed survival rating will mitigate this hazard.

Microwave network capacity is generally higher than the bandwidth requirements for radio systems. The additional bandwidth provides options for other data applications on the network.

A diagram of the anticipated microwave network for the proposed eight site system can be found in Figure 3 below. To make the new system more resilient, a looped microwave design is being recommended. The 911 center is also part of the design because that is where the radio dispatch consoles reside, and they also need access to the microwave network for system connectivity purposes.

[1] Any data circuit that runs at the original 1.544 Mbit/s line rate.

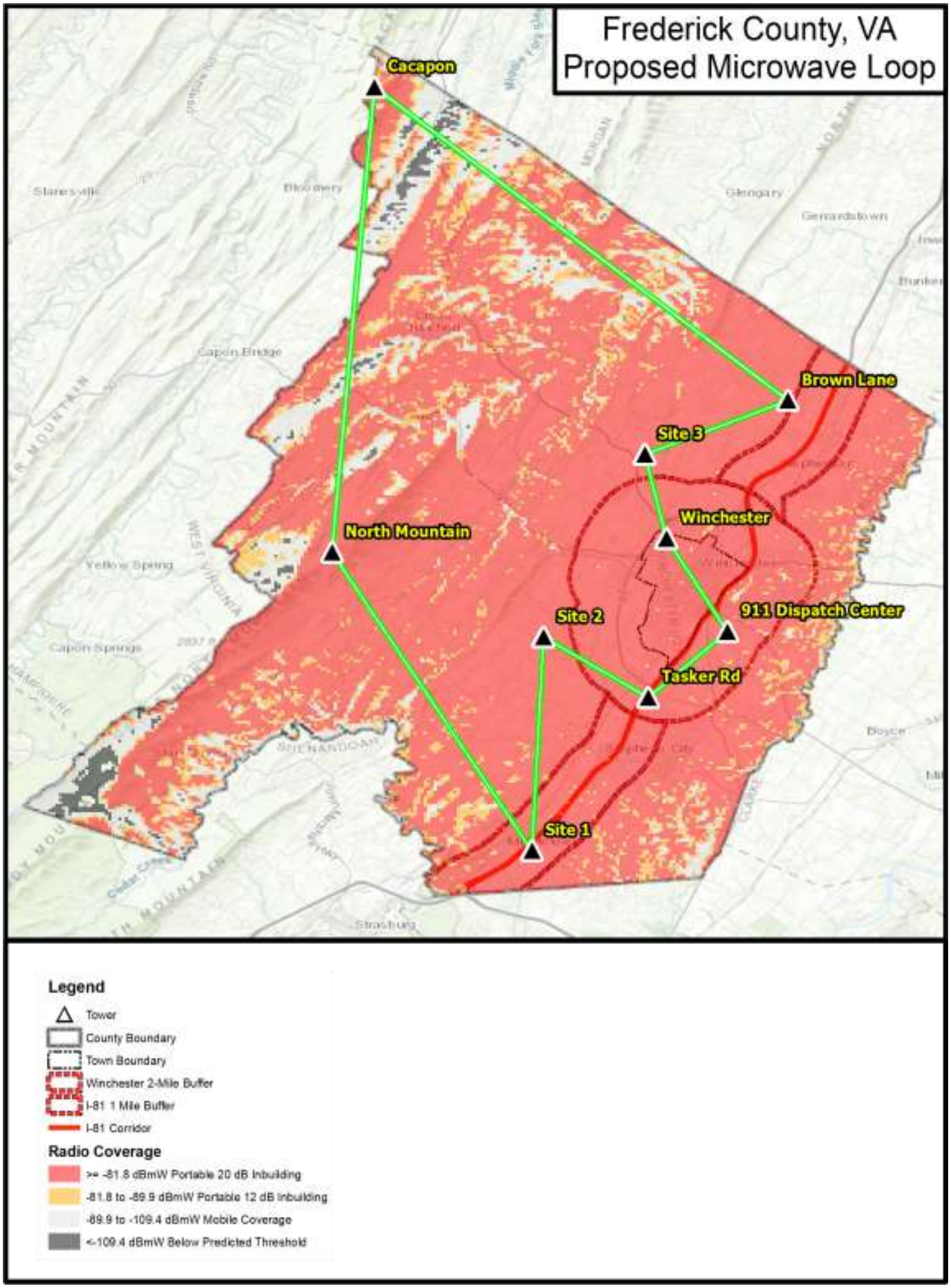

Figure 3: Conceptual Microwave Loop

4.9.3 Paging

Today Frederick County uses one site—North Mountain—to send pages to more than 90 pagers. A mix of Motorola and Unication pagers are used. As part of the new radio system design, MCP recommends that a second paging transmitter be added and that pages be simulcast. This will enhance paging coverage and add a level of resilience to the paging system

5 Recommendations

Based upon MCP's findings concerning the existing system, user feedback regarding requirements for a new system, and analysis of existing technologies and trends, we have developed recommendations to address the issues currently experienced by radio system users within the county. This section outlines the specific system design considerations and recommended components to comprise the new system. These considerations may be incorporated into specifications that will be issued in an RFP for the new system.

The following criteria have been defined as the top priorities of the new system:

1. Enhancing coverage and reliability
   - There is a lack of coverage and reliable performance in many parts of the county. The current system design is insufficient to provide reliable public-safety-grade radio system performance.

2. Enhancing interoperability
   - Interoperability is somewhat limited within the county. This can make agency-to-agency communication cumbersome.

3. Increase system channel capacity
   - Channel capacity is very limited due to the conventional design, with channels being transmitted from only one site over a limited number of available frequencies. This is particularly an issue during a critical incident, large-scale event or when multiple events are occurring simultaneously.

4. Make modern radio safety features available to system users
   - Modern radio safety features, such as an emergency button and encryption for specialty units, are desirable features.

5. Mitigate single points of failure and equipment end-of-life concerns
   - The current system design includes single points of failure that can leave emergency responders with no reliable way to be dispatched or to communicate for an extended period if a failure does occur. Combined with the reduced reliability of aging components, the overall system is at risk.

5.1 Best System Option

It is MCP's assessment that coverage and reliability are far and away the two most critical aspects of the communications system that must be addressed. MCP has identified a design option that, at a minimum, satisfies these criteria.

Implementing a new P25 Phase II, eight-site six-channel simulcast system

A P25 Phase II (TDMA) trunked simulcast system would provide the greatest level of capabilities and features for system users. The typical time required to implement a project of this nature from inception is two to three years. A P25 trunked simulcast system will provide a reliable and flexible platform that can address coverage issues through the installation of additional sites and provide substantially increased capacity.

Based on loading calculations, it is estimated that a total of nine talk paths will be necessary to provide an adequate level of capacity. This capacity level can be obtained through the usage of six TDMA channels. Each channel would be available for access at every site. MCP estimates that eight radio sites will be required to provide a reasonable level of coverage and performance. The new coverage performance criteria were established by the user group during the needs assessment. It blends different levels of coverage across the county, as follows:

- County border-to-border mobile coverage
- 12-dB in-building coverage for the valley portions of the county where there are buildings and roads. (This was the same criteria used in Shenandoah County after MCP worked with its geographic information system (GIS) contact to identify road and building density that applied to the coverage area.)
- 20-dB in-building coverage within the boundary of the City of Winchester and two miles out from that boundary.
- 20-dB in-building coverage along the Interstate 81 corridor and within one mile on either side of that corridor. (These two areas will have some overlap as the interstate runs through the City of Winchester)

Figures 4 and 5 below are coverage maps which demonstrate the anticipated improvements between today's law enforcement system coverage, and the coverage provided by the new conceptual system design.

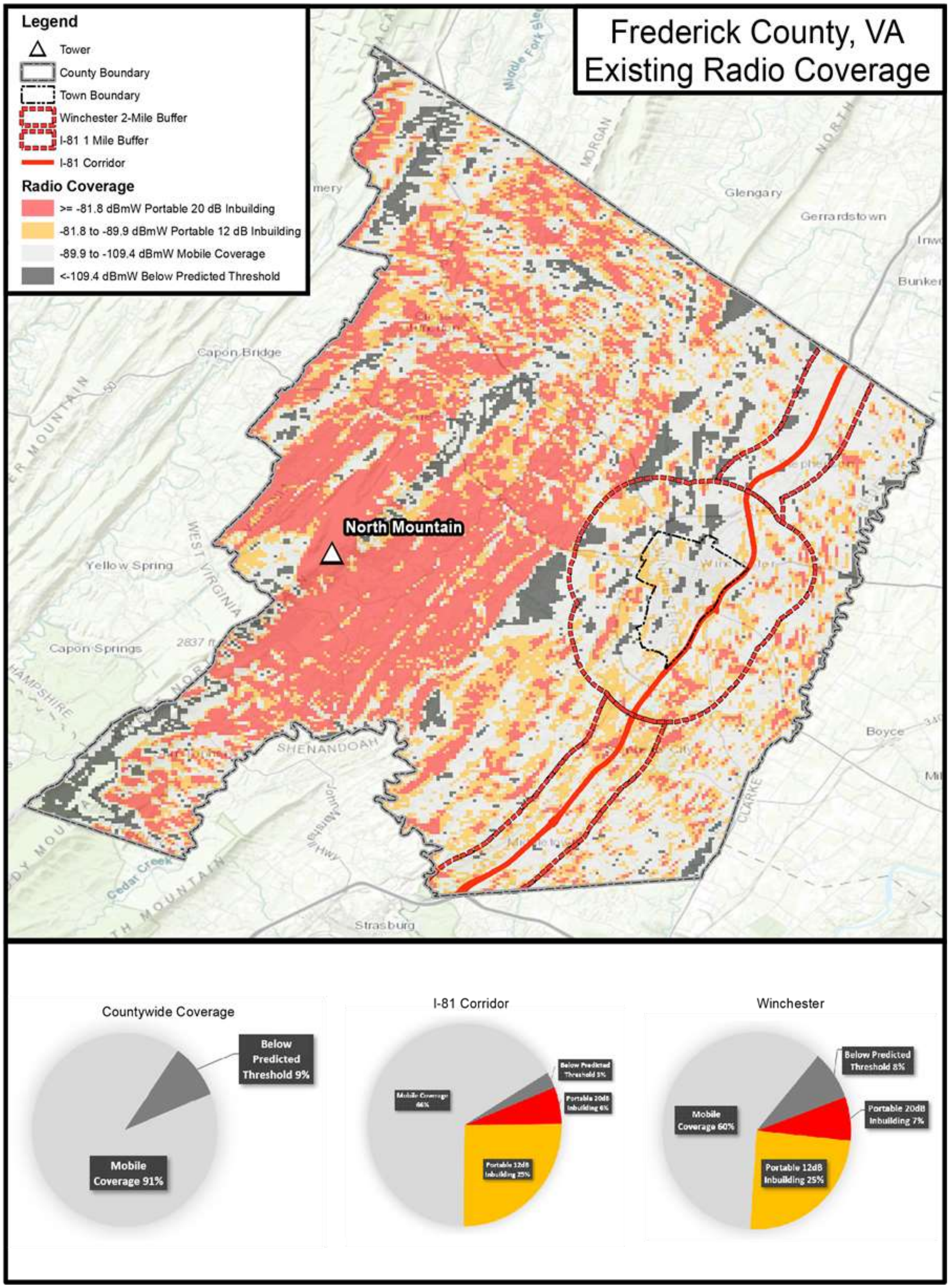

Figure 4: Existing Law Enforcement Radio Coverage

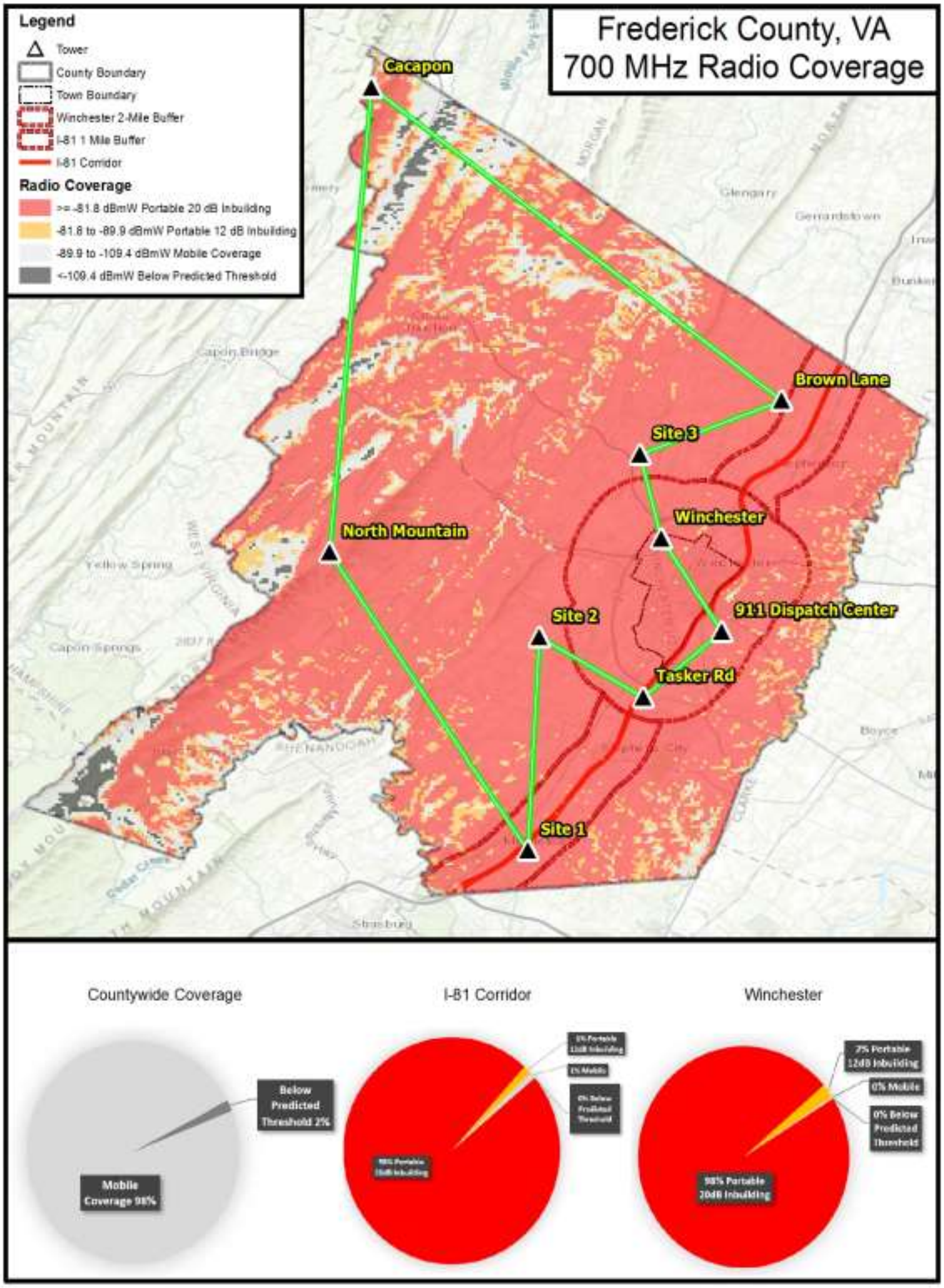

Figure 5: Conceptual System Design Coverage

By migrating to digital technology, system users would benefit from other capabilities provided by the P25 platform. These include redundant configurations with no single point of failure, encryption capabilities, added network security, affiliation control, and unit identifications (IDs).

A migration to a P25 Phase II, trunked simulcast system would require the complete replacement of the County's existing infrastructure equipment and many of its subscriber radios. Some of the existing sites and supporting facilities likely could be reused.

The table below summarizes the strengths of this option.

Table 10: P25 Phase II Trunked Simulcast System Strengths

Strengths
• Countywide coverage by utilizing approximately eight radio sites • Enhanced interoperability, both within the county and with external agencies • Improved capacity and flexibility through the use of trunking architecture and additional channels • Improved reliability through overlapping site coverage and fault-tolerant design • Improved security and control through system keys, subscriber ID restrictions, and encryption capabilities • Capable of providing data backbone to support functions like GPS and OTAP • Flexible standards-based architecture to support future expansion and technology refreshes

If a new system is built, MCP recommends a verification test that includes a combination of automated testing and delivered audio quality (DAQ) tests. The selected vendor would be responsible for verifying performance by demonstrating successful tests throughout the areas of predicted coverage at the appropriate coverage level.

To address providing coverage to very sparsely populated or rarely traveled areas located in areas of marginal coverage, MCP recommends the use of a portable repeater that could be deployed and activated to provide local-area coverage for incidents such as a search-and-rescue operation. This could be a local asset, or the State of Virginia also maintains a few of these resources regionally.

5.1.1 System Capacity

For a trunked network, capacity is determined based on the grade of service (GoS), or the probability of receiving a busy signal. MCP recommends a minimum GoS of 1 percent for a public safety system. This means that, on average, one of 100 calls will experience a system busy during the peak radio traffic hour. Based on the number of radio users within the county and a growth factor of 25 percent, Erlang C calculations indicate that a total of nine talk paths are necessary to provide a GoS of less than1 percent.

If the County procures any features that utilize the P25 data backbone, additional capacity may be needed to support these features. A GOS on the current system is unavailable as system usage data and system queuing or waiting times are not available.

5.1.2 Interoperability Features

The County should continue to utilize frequency patching as needed to accommodate unique incidents where patching is desired. Patching through a gateway is not a means to improve day-to-day interoperability between regional agencies but can be a helpful tool for special or unique events. The addition of channels that would be countywide and simulcast will make patching of frequencies a much more reliable interoperability solution.

Programming of the national interoperability channels is recommended for dispatch and for all subscriber radios, regardless of which frequency band is implemented. These channels are programmed by most agencies across the country and provide common channels that frequently are used for tactical simplex communications and patching during interoperable events. Frederick County does follow these protocols today.

Discussions should occur with the City of Winchester to revisit the viability of shared talkgroups and system talkgroup access and the additional merits they could provide for daily operations between city and county agencies if the County were to move to a P25 trunked system.

5.2 Subscriber Radios

Subscriber radios are one of the most significant components of a communications system. Subscriber radio equipment needs to be compatible with the infrastructure technology implemented by the County and should meet industry standards for durability and reliability for public-safety use.

Most subscriber radios utilized within the county today are not capable of P25 operation nor are they trunking capable, although a small subset are capable of working on West Virginia's trunked SIRN. For costing purposes, and to maintain a level procurement process, MCP has estimated costs for replacing all subscriber radios within the budgetary estimate for the new system. MCP has based system cost estimates on a one-for-one replacement of each existing radio based on quantity information provided by the agencies.

5.3 Subscriber Radio Features

P25-compliant subscriber radios typically are constructed to meet the durability and reliability requirements needed for public safety communications. At a minimum, the following features are recommended for portable radios utilized by public safety users:

- Minimum Mil-Spec F testing
- Model II with liquid crystal display (LCD) and partial keypad
- Emergency call/alert functionality
- Minimum 512 channels
- Minimum of three watts (UHF) output power

- MDC 1200 signaling[2]
- Separate volume and channel adjustment knobs
- AES- and DES-capable[3]

The following features are recommended for mobile radios utilized by public safety users:

- Minimum Mil-Spec F testing
- Emergency call/alert functionality
- Minimum 512 channels
- Minimum 50 watts (UHF) output power
- MDC 1200 signaling
- Separate volume and channel adjustment knobs
- AES- and DES-capable

5.3.1.1 Encryption

Encryption often is desired by law enforcement agencies. AES digital encryption is the most secure encryption available for public safety radios and is the standard encryption per P25 specifications. AES only is available on P25 trunking systems. Other lower-cost encryption options may be available depending on the equipment vendor selected.

It is not necessary to purchase the encryption feature for every public safety radio; however, radios capable of encryption should be purchased so that agencies can activate that feature on radios necessary to support special operations that would benefit from the added security provided by encrypted communications. As there is a cost to adding this feature on a radio, some agencies choose to implement it selectively. Encryption can be implemented on specific talkgroups for use on an as-needed basis. If law enforcement elects to encrypt primary talkgroups, special considerations must be made for interoperating with agencies that may not have encryption-capable radios or access to local encryption keys.

5.3.1.2 Proprietary Features

Proprietary features are those features available on P25 systems that do not conform to the P25 standard. When proprietary features are implemented, those features only will work on subscriber radios manufactured by the same vendor. In many cases, the subscriber radio manufacturer must match the system manufacturer for these features to work.

MCP cautions that the adoption of proprietary features may lock agencies within the county into having only one available vendor from which to purchase subscriber radios, to maintain use of the features. An example of such a proprietary feature is described below.

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[2] Motorola Data Communications
[3] Advanced Encryption Standard; Data Encryption Standard.

Over-the Air Programming

Over-the Air Programming (OTAP) is an optional feature that permits the remote programming of subscriber radios utilizing the P25 data network. OTAP significantly can reduce programming time and effort compared with the typical manual programming of radios.

Careful consideration must be given to system capacity when OTAP is implemented. Each radio will require temporary use of a voice channel to receive OTAP data. OTAP requires a large amount of data and, therefore, substantial data usage for each radio to be programmed. Programming of an entire fleet will require a large number of system resources over an extended period of time. Because voice transmissions take precedence over data, programming times may be further extended.

OTAP-equipped systems and radios are available from multiple manufacturers. However, subscriber radios must match the system vendor, which limits competition for subscriber radios if all radios are to be equipped with OTAP. MCP recommends that the vendor price this as an option.

5.4 Paging

Frederick County has been using North Mountain as a single site for paging for both law enforcement and fire/rescue/EMS. It is MCP's recommendation that Frederick County have a second site for paging and simulcast that site with North Mountain. This would provide the County with enhanced pager coverage along with added redundancy for system resilience.

5.5 Consoles

For P25 systems, the interface between the system and the console remains proprietary for the largest system vendors. Because of this interface, the dispatch console manufacturer will be required to be compatible with the radio system vendor offering. P25 systems permit a direct IP connection between the system and console units, significantly reducing the amount of backroom equipment necessary to provide channel audio to the consoles.

5.6 Logging Recorder

P25 systems provide a significant amount of information along with call audio. This information includes unit ID, affiliated radio sites, talkgroup information, and other data that may be useful in the event that the call needs to be recalled and reviewed in the future. Only certain logging recorders can record this data. Certain logging recorders also are capable of directly interfacing with P25 systems, while others only can support four-wire audio through a control station interface. Control station interfaces can be costly if a significant number of channels are to be recorded, as each channel requires a separate mobile radio to provide the four-wire audio.

The current recording system at the 911 center would be compatible with a new P25 radio system but may need some enhancements and reconfiguration to become fully integrated into a new radio system.

5.7 Backhaul

Backhaul connectivity is a critical component of multisite radio systems. A robust and reliable backhaul network is required to ensure reliable communications.

P25 systems require higher bandwidth than conventional systems. A leased T1 circuit is the minimum bandwidth typically acceptable for P25 systems. Use of T1 circuits reduces capital costs but requires recurring fees. Moreover, T1 circuits typically do not include redundant routing and are subject to failures during high-usage periods.

Based on the desire for a reliable network and minimal recurring fees, MCP recommends that any new backhaul system implement a loop-configured microwave network. The loop should include all radio sites and the 911 center. Such a network will require a greater capital investment; however, the return on investment is typically seven to ten years when compared with fees for leased circuits. The loop configuration proposed will mitigate a microwave system failure that occurs at any one tower site on the ring by permitting continued connectivity to the remaining sites.

Loop-protected microwave backhaul is the desired technology of most agencies implementing trunked radio systems. The underlying reason is that modern trunked radio systems include redundant components at every failure point, virtually eliminating single points of failure. With highly reliable radio equipment, an equally reliable backhaul network is required to fulfill the potential of the equipment.

MCP estimates microwave costs at approximately $150,000 per hop, with the potential for reductions depending on the level of competition. The number of microwave hops depends on the number of radio sites required for the RF design.

5.7.1 DC Plant

Microwave systems are powered through DC plants sized for the load of that connectivity equipment. To provide consistent power for all of the proposed equipment, MCP recommends increasing the size of the microwave DC plant to support the power needs of the radio equipment. This is a typical configuration in new systems and reduces the necessity of a UPS system at the sites.

5.8 Redundancy and Survivability

The recommended system solution proposed by MCP would provide for improved network redundancy and survivability. The use of multiple radio sites will provide a considerable amount of overlapping coverage. In the event of a failure at any one tower site, overlapping coverage from the surrounding simulcast sites will provide a means for users to communicate. In-building or portable coverage may be limited depending on the location of the users, but mobile coverage likely will be available, regardless of where the failure occurs and where the user is located.

Modern trunking systems provide significant levels of system fallback that are not provided in conventional simulcast systems. Control equipment typically is installed with onsite backups that can control the system in the event of a failure to the primary equipment.

A loop-configured backhaul network would ensure reliable connectivity between radio sites. Further, proper radio system construction and installation with component alarming would ensure that radio sites are less susceptible to environmental and manmade conditions.

5.9 Maintenance

MCP recommends that a preventive-maintenance program be included if a new system is implemented.

Recurring maintenance costs can be anticipated to increase when compared with current costs, as a new system will include additional system components, which results in higher maintenance costs.

P25 systems specifically include numerous hardware and software components that must be maintained. Additional maintenance services are available, such as remote monitoring of system alarms and remote technical support, which significantly can reduce the amount of time needed to correct system failures. In addition, the regular update of system software permits bug fixes, the addition of features, and a regular refresh of technology to extend the life of the system.

The first year of maintenance typically is included with any system purchase, with an option to purchase additional maintenance for subsequent years. This maintenance may be contracted with the system vendor directly or with a local radio shop.

The maintenance vendor will depend on the system vendor selected. Maintenance vendors are trained and certified for certain systems; the maintenance vendor will need to be qualified to work on the installed system.

MCP recommends that optional pricing be secured for system maintenance for years two through ten following system implementation. As noted earlier in this report, the County may benefit from adding a radio technician position that could address the ongoing need for portable and mobile radio preventive maintenance. Over the long run, this could be a cost-neutral or cost-savings option, as future maintenance contracts could be negotiated with this local resource in mind.

MCP also recommends preventive maintenance continue on both your current system and radios as it would be two years or longer before a new system could be completed.

5.10 Conceptual System Design

MCP has developed a conceptual system design that includes the selection of radio sites to provide the recommended level of coverage enhancements.

The conceptual P25 simulcast radio system would use eight radio sites to provide coverage. All sites would be connected by a microwave network and all channels would be present at each site.

5.11 Cost Estimates

MCP developed a cost estimate for the recommended radio system. The section that follows provides details and a cost summary as well as high-level assumptions.

The costs in this report include typical discounts. In a typical competitive procurement process, vendors normally will offer a discount of 20 percent to 30 percent. These discounts may be bundled and include a variety of factors such as discounts off list price, system incentive discounts, customer loyalty discounts, and other creative factors. Due to these variables, MCP uses a more conservative discounting estimate to ensure that actual costs will be lower than the estimates, not higher.

Our budgetary estimates also include a project contingency for anticipated infrastructure and site upgrade costs. This contingency is intended to cover items such as unexpected/unusual site foundation costs, land acquisition or lease costs, unusual existing tower structural enhancement costs, possible intermediate microwave site costs, and other items that may not be identified until a design has been finalized and preliminary engineering work completed. The budgetary estimates also include a cost for five years of system maintenance.

For portable radio pricing, MCP included all necessary software, antenna, single-unit charger, and remote speaker microphone. For mobile radio pricing, MCP included all necessary software, control head, antenna, palm microphone, and installation. Spare batteries were not included in pricing but are estimated to cost $140 each.

The budgetary estimate includes line items for both infrastructure and subscriber radio options. The County will decide which of these options to purchase as actual pricing becomes clear during the procurement and contract negotiation process.

The table below summarizes the costs associated with each of the identified options, including microwave backhaul, user equipment, and project management and engineering.

Table 11: Estimated Costs

Budgetary Summary of Costs		
Land Mobile Radio System	800 MHz, P25 Phase II simulcast, 8 sites (trunked), 6 channels (10 talk paths and 1 control channel) Mutual-aid overlay, backup consolettes, dispatch consoles	$5,076,660
Backhaul Network	166 megabits per second (Mbps), ring topology, 6 hops	$1,574,191

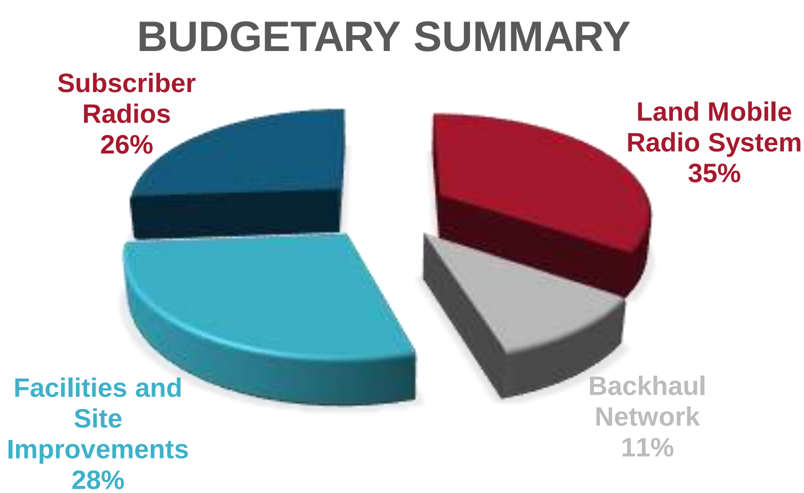
Budgetary Summary of Costs		
Facilities	8 sites; 4 existing and four raw-land (greenfield) sites	$4,112,259
Subscribers	Tier I/II – P25 Phase II trunking operations	$4,164,455
Project Management	Implementation oversight, engineering	$490,112
	Subtotal:	**$15,417,677**
Radio System Options	CSSI, ISSI, PTT application, OTAR, OTAP, encryption	$1,156,672
Microwave System Options	MPLS networking	$90,756
Subscriber Options	Licenses for OTAR, OTAP, AES encryption for law enforcement	$484,652
Multiband Radio Option Law Enforcement*	Multiband Mobiles and Portables for Law Enforcement Upcharge	$1,162,137
Multiband Radio Option Fire/EMS*	Multiband Mobiles and Portables for Fire/EMS Upcharge	$1,756,746
Site-Enhancement Contingencies	Tower modifications at four sites	$296,858
	Total with Options:	**$20,365,498**

* Note: The cost of moving from a single band radio to a multi-band radio is significant and varies somewhat based on the vendor selected. For cost estimation purposes MCP uses a value which would accommodate selection of any of the typical prime vendors. The actual cost paid for this upgrade may be lower based on a competitive procurement process and the typical bundling of discounts.

The following table details the distribution of radios across primary user agencies and functions.

Frederick County Subscriber Count		
Subscribers	Quantity	Cost
Schools		
Portables	774	$1,302,010.42
Mobiles	300	$504,655.20
Sheriff		
Mobiles	185	$540,356.29
Portables	150	$397,273.68
Control Stations	2	$13,912.80
Fire/EMS		
Mobiles	250	$730,211.20
Portables	250	$662,122.80
Control Stations	2	$13,912.80
TOTALS	1,913	$4,164,455.18

Note: Lower cost radio types are used for general government use while a higher cost public safety grade radio is used for Law Enforcement and Fire.



5.11.1 P25 Phase II, Trunked Simulcast, 8-Site, 6-Channel System

Assumptions include the following:

- Total of eight sites with six channels at each site
- Four existing sites and four raw-land (greenfield) sites
  - One raw-land site would have a 260-foot, self-supporting tower, and three sites would have 300-foot towers;
  - Each site would have a generator, shelter, power, site preparations, regulatory work, and site purchasing allowance
  - Grounding updates at all sites and two new shelters at Brown Lane and Tasker Water Tower
  - New generator at North Mountain
  - Site-reuse enhancement allowance for four sites
- Trunking system with simulcast transmit and voted receive signal at all sites
- New paging equipment at new Winchester site; added simulcast paging
- Mutual-aid overlay system with four channels at five sites
- Radio gateways at each site for conventional resources
- Six new radio dispatch consoles to ensure a process that can be vendor neutral
- Six backup consolettes
- Structural analysis and modifications for existing towers to latest TIA-222 revision G standard[4]
- Loop-configured microwave network connecting all radio sites and dispatch
- New shelter, generator, and upgrades at one new location
- Replacement of the following portable radios, mobile radios, and control stations:

Subscribers	Quantities	Cost
Public Safety Mobiles	435	$1,270,567
Public Safety Portables	400	$1,059,396
Local Government Mobiles	300	$504,655
Local Government Portables	774	$1,302,010
Control Stations	4	$27,825
Totals	1,913	$4,164,453

- Vendor project management and engineering
- Recommended spares

[4] Telecommunications Industry Association.

- Mobile radio pricing includes dash-mounted radio control head, P25 software, packet data, OTAP, 3-dB antenna, and palm microphone
- Portable radio pricing includes conventional P25 software, ¼-wave antenna, single-unit charger, and wired remote speaker microphone
- Digital logging recorder and interface upgrade allowance
- Project management for implementation oversite
- System options are as follows:
  - ISSI and CSSI
  - PTT application and 100 user licenses for 20 talkgroups
  - OTAR, OTAP, GPS location services, servers, and licenses
  - Allowance for in-building bidirectional amplifiers and distributed antenna systems
  - MPLS service for microwave network
  - Optional procurement of multiband 185 mobiles and 150 portables for law enforcement
- Subscriber radio options are as follows:
  - AES encryption for law enforcement
  - OTAP
  - OTAR
- Five years of system maintenance as an option, which likely would be a future operational budget item
  - Software and hardware system upgrade agreement
  - Maintenance includes remote technical support, system dispatch, annual preventive maintenance, advanced repair and replacement, security updates, field support, and active monitoring

5.11.2 Lifecycle Budgetary Estimates

Frederick County can anticipate an increase in system-sustainment costs. These costs are attributed to equipment maintenance, upgrades, and facility maintenance. With more-advanced systems such as trunking systems, additional software update fees are required to keep the system at current release. The table below summarizes the estimated lifecycle costs. The upgrade agreement keeps the radio system up to date with the latest revision of software and hardware. Maintenance and monitoring includes remote technical support, system dispatch service, annual preventive maintenance, onsite technical support, security updates, equipment parts replacement and infrastructure repair, and system monitoring. Site maintenance includes site upkeep, annual preventive maintenance checks, and any repairs to the grounding and HVAC systems. Subscriber maintenance includes firmware updates to the subscriber radios, extended warranty work, and programming changes.

Service	Year 1	Year 2 thru 5
P25 System Upgrade Agreement (Hardware/Software)	Included	$526,481
Maintenance and Monitoring	Included	$729,814
Subscriber Radio Maintenance	Included	$77,582

Service	Year 1	Year 2 thru 5
Site Maintenance	$83,040	$351,626
Subtotal:	$83,040	$1,685,503
5-Year Grand Total	**$1,851,583**	

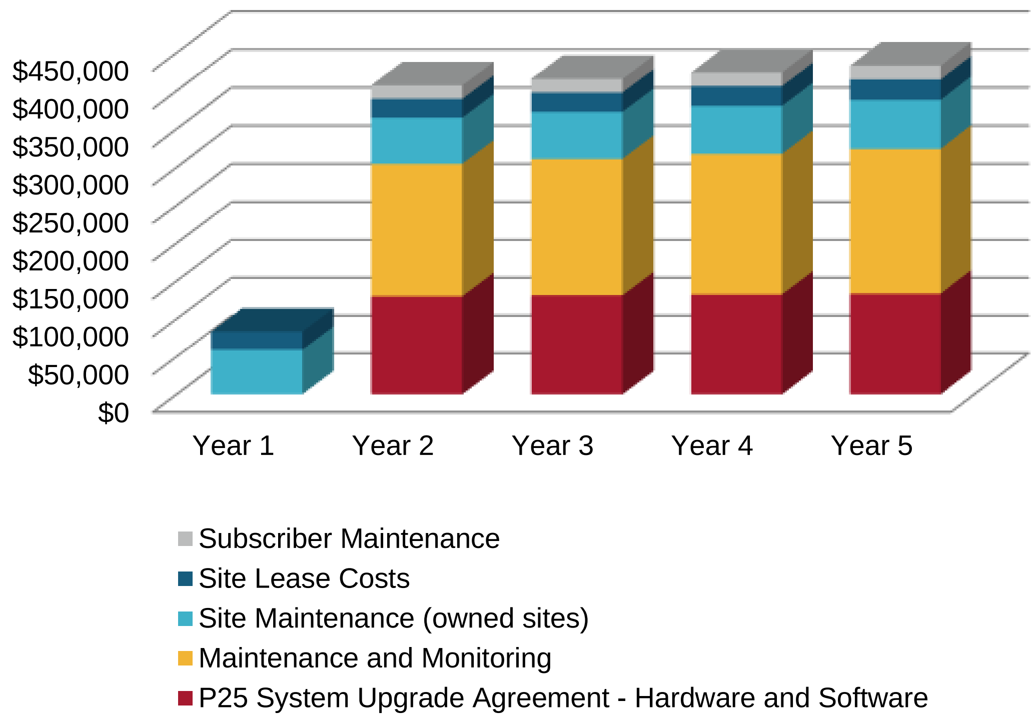


Figure 6: Estimated Lifecycle Cost Comparison by Year

6 Next Steps

The existing radio system has numerous performance and safety deficiencies that have the potential every day of negatively impacting the ability of emergency responders to communicate during routine and critical incidents. Meaningful improvements only will come through an investment in a new system and radios. Key next steps include the following:

- Brief the County Board regarding this report's findings and recommendations and request approval to proceed with the next step of the planning process.

- Develop a system specification and RFP and decide on any desired proposal options.
- Move forward with a competitive procurement process that will result in a selected vendor, the system solution of choice, and a negotiated contract that can be presented to County Administration and the Board for approval.
- The typical implementation period for a radio system is 12–24 months after the vendor contract award. With the necessary planning and procurement tasks, it may be two to three years before a new system is implemented and operational.

Regardless of the solution chosen, to obtain the best possible pricing and value, MCP recommends that the County proceed with a competitive procurement process.

To move forward with a competitive procurement, the County will need to develop system specifications. The specifications will include minimum performance requirements and functional requirements, to put the onus of system performance on the selected vendor.

It is MCP's experience that the RFP should allow vendors one to three months to provide a response, depending on the complexity of the scope of work. Once proposals are received, the proposals will be evaluated and scored based on how well the solutions offered would satisfy the County's requirements, and on the prices offered. Ultimately, a single vendor would be selected for contract negotiations.

6.1 Secure Funding

To move forward with a contract award to the selected vendor, funding will need to be secured for the new system. The cost estimates provided in this report may be used for budgetary purposes. MCP notes that these estimates are intended to be somewhat higher than the actual anticipated costs that will result from a competitive procurement.

6.2 Procurement Options

Competitive Procurement (RFP)

Competitive procurements typically yield the best overall system value when multiple vendors can offer equivalent or near-equivalent products.

7 Conclusion

The public safety radio system users in Frederick County have identified numerous deficiencies that exist today, which can and do adversely impact their ability to reliably communicate during routine and critical incidents.

Local elected officials and senior staff requested a needs assessment to better understand the situation and to receive information regarding options and recommendations that would improve public safety communications capabilities in the county.

With the completion of this report, decisions can be made based on a much better understanding of the needs and potential solution. The radio communications system is in desperate need of improvement. The typical implementation period for a radio system is 12–24 months. Given the necessary planning and procurement tasks, it may be two to three years before a new system is implemented and operational. With the challenges faced by the existing system, time is of the essence.

MCP is available to assist with planning, procurement, and implementation needs as appropriate.

Appendix A - Frederick County Site Reviews

Coverstone Site

The Coverstone site is located off Coverstone Drive in Frederick County. The public safety building houses the Frederick County 911 Center, fire/rescue department, and sheriff's office. The 911 Center, operated by the Department of Public Safety Communications, is responsible for receiving emergency and non-emergency calls within the county and dispatching fire/rescue/EMS and law enforcement units as needed.

All antennas are mounted on the roof of the public safety building. Most are on mounts separated ten-feet apart across the roof. A 20-foot tower is mounted on the roof to hold three microwave dishes that the County uses. Space is limited for any additional equipment or racks.

The dispatch site has six Motorola MCC 7500 consoles and one MCN 8000 server. Backhaul at the site is provided by a Harris TRuepoint 5500 microwave radio.

Grounding

Ancillary components inside the building—such as electrical metal conduits, door frame, heater and equipment racks—are grounded to the building's single master ground bus bar. Also, a ground halo is present. The radio site's exterior and interior grounding appears to comply with Motorola R56.

Electrical Surge

A surge-protection device (SPD) protects the electrical feed coming into the building. SPDs are installed on all incoming coaxial lines. Future coaxial lines also should have SPDs installed and grounded properly to reduce the risk of lightning or other electrical surge entering the building.

Generator Power

The building is backed by a Liebert 65 kilovolt-ampere (kVA) UPS system located in the backroom with the radio equipment. The UPS system capacity would be sufficient to accommodate the future needs of the radio system. Any additional equipment should be recalculated into the UPS system capacity to confirm the power that is available.

Climate Control

The building's HVAC system is controlled by a master controller. The HVAC is on the building's roof.

Backhaul

The Harris TRuepoint system is 13 years old and has two links. One link is to the Tasker Road site and the second link is to the Brown Lane.

Figure 7: Frederick County Building roof

Figure 8: Frederick County Dispatch Center

Cross-Junction

The Cross-Junction site is located inside the Shawnee Canning Company facility. The site was not reviewed by MCP due to a lack of site access. However, the site has one rack with two base stations, one VHF and one UHF. The site's primary use is for fireground communications; it is controlled by the 911 center.

Figure 9: Cross-Junction antenna at cannery building

Cacapon Site

The Cacapon site is in Cacapon State Park on the West Virginia/Virginia border. Cacapon is a receive-only site for Frederick County. The site has a capacity of four T1 circuits. Cacapon uses two T1 connections, one to West Virginia's SIRN radio and the other T1 carries the eight receivers at the site. The microwave backhaul is a Point to Point Ubiquiti 4.9 GHz link on licensed public safety spectrum. The shelter is a prefabricated building with electrical and HVAC. The site is shared with another customer; it has one generator and one propane tank.

Grounding

Ancillary components inside the building—such as electrical metal conduits, door frame, heater and equipment racks—are grounded to the building's single master ground bus bar. Also, a ground halo is present, but it does not comply with Motorola R56. The radio site's exterior and interior grounding need to be upgraded to Motorola R56 or equivalent.

Electrical Surge

An SPD protects the electrical feed coming into the building. SPDs are installed on all incoming coaxial lines, but they do not comply with Motorola R56. The port entry bus bar has the incoming feedlines connected to a single lug. All feedlines to bus bar should have a double lug connection to the bus bar. Future coaxial lines also should have SPDs installed and grounded properly to reduce the risk of lightning or other electrical surge entering the building.

Generator Power

The site is backed by a Cummins Onan Genset 45Kw generator located against the fence along with the 1000-gallon propane tank. Any additional equipment should be recalculated into the UPS system capacity to confirm the power that is available.

Climate Control

The prefabricated shelter has two HVAC units rated at two tons each, with a Bard Manufacturing MC3000 series controller. The MC3000 is a lead/lag controller, so one HVAC unit always is running.

Backhaul

The backhaul equipment is a Harris TRuepoint system that is 13 years old and has one link, which is to the North Mountain site.

Figure 10: Cacapon RX-Only Tower

Figure 11: Cacapon Shared Shelter

Tasker Road Site

The Tasker Road site is a water tank located in Kernstown. The radio equipment is located inside the base of the water tower. The water tower has one cabinet with five base stations and two racks for DC power, networking equipment, and backhaul equipment.

Grounding

Ancillary components inside the water tower—such as electrical metal conduits, door frame, heater and equipment racks—are grounded to the water tower's single master ground bus bar. The radio site's exterior and interior grounding does not comply with Motorola R56.

Electrical Surge

An SPD protects the electrical feed coming into the water tower, but it could not be checked due to the feed lines coming in at the top of the water tower.

Generator Power

The site is backed by a Cummings 40-kilowatt (kW) generator located against the fence along with a 335-gallon diesel fuel tank.

Climate Control

The water tank has no interior climate control.

Backhaul

The backhaul equipment is a Harris TRuepoint system that is 13 years old and has two links. One link is to the Coverstone site and the second link is to the North Mountain site. The drawing given to MCP by Motorola shows the link going to North Mt.

Figure 12: Tasker Water Tower

Figure 13: Tasker Radio Cabinet

North Mountain Site

The North Mountain site is located near Great North Mountain near Pinnacle Ridge. The shelter is prefabricated with a self-supporting guyed tower. The compound is fenced with the tower next to the shelter. Power is provided by Shenandoah Valley Electric Cooperative. North Mountain also has a VHF low-band frequency that connects the site to SIRS for interoperability.

Grounding

Ancillary components inside the building—such as electrical metal conduits, door frame, heater and equipment racks—are grounded to the building's single master ground bus bar. Also, a ground halo is present, but it does not comply with Motorola R56. The radio site's exterior and interior grounding also do not comply with Motorola R56. Doors are not grounded, the master ground bus bar is not grounded properly, nor are the outside gates.

Electrical Surge

An SPD protects the electrical feed coming into the building. SPDs are installed on all incoming coaxial lines, but they do not comply with Motorola R56. Future coaxial lines also should have SPDs installed and grounded properly to reduce the risk of lightning or other electrical surge entering the building.

Generator Power

The site is back up by a 19 Kw Briggs and Stratton standby generator located against the fence along with the 500-gallon propane tank. Any additional equipment should be recalculated into the UPS system capacity to confirm the power that is available.

Climate Control

The prefabricated shelter has one HVAC unit rated at one ton and a small, freestanding LG air-conditioner outside the shelter.

Backhaul

The backhaul equipment is a Harris TRuepoint system that is 13 years old and has three links. The links are North Mountain to Tasker Road, North Mountain to Brown Lane, and a third link Point to Point Ubiquity to North Mountain to Cacapon connected to the TRuepoint. The Ubiquiti link is less than three years old.

Figure 14: North Mountain Site

Figure 15: North Mountain Tower

Brown Lane Site

The Brown Lane site is in Clear Brook at 205 Brown Lane. The site is shared with several other agencies in the compound. Frederick radios sit on a pedestal inside the compound. The site has one 277-foot, freestanding tower that is loaded on the top half of the tower. The site is owned by Shenandoah Mobile Company.

Grounding

Ancillary components inside the pedestal—such as electrical metal conduits, door frame, heater and equipment racks—are grounded to the building's single master ground bus bar.

Battery Backup

Pedestal has a battery back using Eltek Flatpack 700.

Backhaul

The backhaul equipment is a Harris TRuepoint system that is 13 years old and has two links. The links are Brown Lane to North Mountain and Brown Lane to Coverstone. Drawing from Motorola show link going to Coverstone.

Figure 16: Brown Lane Tower

Figure 17: Brown Lane Site