Radio System Needs Assessment

FINAL REPORT

SUBMITTED JUNE 2017 TO:
SHENANDOAH COUNTY, VIRGINIA

MissionCriticalPartners
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EXECUTIVE SUMMARY

Mission Critical Partners, Inc. (MCP) respectfully submits this Radio System Needs Assessment report to Shenandoah County, Virginia. Shenandoah County (County) contracted with MCP to assess its existing ultra-high frequency (UHF) conventional analog radio communications system. The goal is to determine the best approach for enhancing or replacing the current system, to improve radio communications within the county. The assessment includes a review of how the Shenandoah County Department of Emergency Communications (DEC) interfaces with the radio communications system.

The DEC provides Enhanced 911 (E911) services for all communities in the county, and dispatching services for five law enforcement agencies and 12 fire/rescue departments. The DEC also handles requests for other local government entities and is in regular communication with the Virginia State Police and adjoining public safety agencies.

The public safety first responders—law enforcement, fire, and emergency medical services (EMS)—within Shenandoah County long have been aware of radio system deficiencies that can and have negatively impacted the ability of first responders to communicate during both routine and critical incidents. First responders provided MCP with numerous examples of active law enforcement, fire and EMS incidents where radio messages were not heard at all or were not understandable. Operationally, the current 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.

In addition, the inability of users on different channels to reliably hear and talk to other field personnel or dispatch 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 large structure fire or a severe weather event. Consequently, the ability of first responders to communicate when the need is greatest is hampered severely.

The current public safety radio system uses three sites and operates on UHF frequencies in conventional analog mode. Various elements of the system have been installed over the last 20 years. Based on the information gathered, MCP determined numerous critical issues affecting the current 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 radio system performance.
- Interoperability is limited both within the county and with external agencies. This makes agency-to-agency communication cumbersome and less than reliable.
- The current system design includes single points of failure that can leave first 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 susceptible to failures.

- Channel capacity is very limited due to the conventional design, with channels being transmitted from only one site and a limited number of available frequencies.
- Modern radio safety features, such as an emergency button and encryption for specialty units, are unavailable today.

In summary, the current system's limitations today include insufficient:

- Coverage
- Capacity
- Redundancy
- Security and control features
- Interoperability

Mitigating or eliminating these limitations and deficiencies should be the requirement of the selected communications system solution.

The existing communications system cannot be upgraded to meet these requirements in its present configuration; thus, the above performance limitations and concerns will continue without an investment in a new system.

Solution Options

MCP evaluated several available public safety technologies to determine solutions that optimally would address the identified performance gaps. The analysis focused on solutions that would improve radio communications within the county and balance performance improvement with cost considerations. Two different solutions were explored in detail, as follows:

- **Option 1**—Implementing a new UHF P25 conventional simulcast 5 site 10-channel system
- **Option 2**—Implementing a new UHF P25 Phase II 5 site 6-channel trunked simulcast system

Section 5.1 of this report describes these two options in greater detail. Both largely would resolve the coverage limitations of the existing system by providing substantially increased coverage and reliability through the addition of a third radio site and by moving to a simulcast design. Each also would improve both operability, which we define as day-to-day ease of use, and interoperability, which is the ability of users to communicate with other agencies when they need to do so.

MCP is recommending **Option 1** as the preferred choice, as it would resolve all of the significant deficiencies present in today's system at a lower overall cost. While **Option 2** also would leverage technology that shares channels and allows for a much greater level of flexibility to meet functional and agency talkgroup needs, it also is the costlier of the two options, primarily because the cost of mobile and portable radios are higher when the trunking feature is included. If the County were to choose **Option 2**, a possible alternative configuration for implementing a trunked simulcast system would be to

share some elements of the infrastructure with Page County, if it also chooses a trunked radio system design. This sharing of infrastructure could result in a modest infrastructure cost reduction when compared with two separate trunked systems.

Because both options will resolve all of the significant system deficiencies, and each has unique merits, MCP recommends that the County's request for proposals (RFP) document solicits proposals for both system designs. In this way, the differences in pricing can be weighed against the differences in performance and features.

The highlights of the UHF conventional simulcast system (**Option 1**) include:

- It is the most cost-effective way to significantly reduce today's system coverage deficiencies
- Moving to a simulcast system will greatly enhance and simplify the way in which both dispatchers and field personnel use the system
- Through the addition of new channels, it will address the need for more countywide channels for law enforcement, fire/EMS and for special events
- It would provide for a standards-based (P25) enhancement to interoperability
- It would enable patching of other frequencies to a countywide special-event channel, making interoperable communications more reliable

Either Option 1 or Option 2 will require the replacement of existing portable and mobile radios.

The viability of **Option 1 is** dependent on the County's ability to license the necessary number of new UHF frequencies for the simulcast system. While an initial search indicates that this will be possible, the detailed process of acquiring these frequencies and license approvals only can occur after the system design is finalized.

Any new system design that significantly will resolve known system performance issues also will require the addition of new equipment at the DEC/public safety answering point (PSAP) facility, along with the construction of a new tower at that location. Due to numerous limitations regarding the size and configuration of the existing facility, a significant renovation to the north wing of the county government center, which currently houses the DEC/PSAP likely would be required. An alternative would be to place the new tower and a separate equipment building somewhere else on the complex.

Alternatively, the County could consider relocation of the DEC to an alternate location, for example collocating the DEC/PSAP in conjunction with the new office complex for the Sheriff's Office that is being considered. Such a study would be new scope beyond the radio system needs assessment, but can be completed easily within a reasonable timeframe if determined to be necessary.

Because a portion of the county falls within the Green Bank National Radio Quiet Zone (NRQZ), an extra level of coordination and approvals will be needed after a system design is finalized. Either system option will require this extra coordination and approval effort; however, **Option 1** will require

that more frequencies would be available and licensable. If the total number of UHF frequencies necessary to support **Option 1** were not available, but enough to support **Option 2** were, then the County would need to select **Option 2**.

Cost Estimate Summary

The costs in this report use list pricing for equipment. 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 the more conservative list pricing to create cost estimates to ensure that actual costs will be lower than the estimates, not higher.

Table 1 below summarizes the estimated costs for the options presented.

Table 1: Estimated Costs

System Option	Radio and Microwave System	User Equipment	Project Management/ Implementation Oversight	Project Total
Option 1 – UHF P25 conventional simulcast system	$5,302,003	$2,307,422	$400,000	$8,009,425
Option 2 – UHF P25 Phase II trunked simulcast system	$6,450,127	$3,157,082	$400,000	$10,007,209

Next Steps and Key Recommendations

The current radio system has numerous performance and safety deficiencies that have the everyday potential to negatively impacting the ability of public safety first 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:

- Select a system design option or wait until pricing for both options is received before making that decision
- Develop a preliminary system specification and RFP and plan for funding
- Consider a preventive maintenance effort for the mobile field units to ensure that they are operating optimally during the interim period before a new system is implemented
- Move forward with final RFP development and the procurement process once the project is authorized and a funding source is available

The typical implementation period for a radio system is 12 to 24 months after 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.

It is commonplace for mobile radio installations to develop conditions that can reduce performance over time. To ensure that these field radios are performing optimally during the period that it will take to implement a new system, a round of preventive maintenance for mobile radios is recommended. The optimization effort should include checking the radios' electrical wiring, battery connections and grounding. Radio receive and transmit parameters should be confirmed to be within specifications and, most importantly, the antennas, antenna mounts and feed lines should be carefully checked to ensure they are operating at maximum performance.

Regardless of the system option chosen, to obtain the best possible pricing and value, MCP recommends that the County proceed with a competitive procurement process. However, an RFP typically is not issued, and a procurement process is not initiated, until authorization for the project has occurred and project funding has been established.

Our budgetary estimates also include a project contingency of 5 percent of the 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.

MCP fully understands the public safety communications challenges faced by Shenandoah County and what needs to be accomplished to provide a long-term solution that will satisfy the needs of first responders in the County for years to come. Our focus within this report is to provide the County with the background information, explanations, and recommendations necessary to support your decision-making process. We stand available to assist the County with its procurement and implementation needs.

1. INTRODUCTION

In response to public safety providers voicing their concerns to local elected and appointed officials, this detailed study and analysis of Shenandoah County's public safety radio communications system needs was commissioned. MCP was tasked with evaluating the current communications system and recommending options and solutions to mitigate any identified deficiencies and concerns. 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.

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 early March 2017. 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.

2.2. PUBLIC SAFETY AGENCY REPRESENTATIVE INTERVIEWS

MCP conducted both group and individual meetings with a cross section of public safety agency representatives across the county. We met with first responders from law enforcement, fire, and EMS agencies. The purpose of the meetings was to discuss the plans and gather feedback from various agencies regarding the existing communication systems, and to understand performance and operational requirements for any new or enhanced communications systems.

2.3. RADIO SITE SURVEYS

Radio site surveys were conducted to inventory 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. Analysis
5. Recommendations
6. Next Steps
7. Conclusion

The Findings section details all of the information gathered regarding the current 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 to addressing the needs of the public safety community. The Next Steps section includes conceptual system designs, cost estimates, and procurement recommendations. 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 current 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, Inc. The system is serviced and maintained by Clear Communications.

3.1.1. Current System Design

Shenandoah County's primary public safety radio communications system today consists of conventional UHF repeaters operating from three sites within the county. All repeaters operate in the narrowband analog mode.

The Zepp site is located in the west-central part of the county, and supports repeaters for fire/rescue dispatch, fire/rescue operations, law enforcement, government, and MED 10 (medical evacuation channel).

The Deer Head site is located in the southwestern portion of the County, and supports repeaters for fire/rescue dispatch, Deer Head operations, law enforcement operations and government.

The Fort Valley site is located in the eastern valley, and supports repeaters for fire/rescue dispatch and a shared channel for law enforcement and government.

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 coverage studies of Shenandoah County's communications system. Coverage studies were 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).

MCP's baseline existing coverage estimate was completed using the actual ERP levels of the system. These levels were provided by Clear Communications, the County's maintenance provider.

3.1.3. Capacity

Capacity on today's system is limited in several ways. There are no frequencies that 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 primary dispatch, there are only a limited number of operational channels 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 either needs to provide for a sufficient number of countywide channels, or be a trunked system design that provides for unlimited talkgroups.

3.1.4. Subscriber Radios

Subscriber units (mobile, portable, and control station radios) within the county are owned by each operating agency. The subscriber radios constitute a sampling 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 from each public safety agency within the county. A total of 234 mobile radios, 552 portable radios, and 27 control stations are in use on the County system.

Table 2 below details the number of subscriber radios utilized by each agency today.

Table 2: Shenandoah County Radio Subscriber Summary

Discipline	Agency	Mobile	Portable	Control Stations	Total
Law	Shenandoah County Sheriff's Office	40	140		
Law	Mt. Jackson Police Department	5	7		
Law	New Market Police Department	10	6		
Law	Strasburg Police Department	14	24	1	
Law	Woodstock Police Department	10	18		
Total Law					**275**
Fire	SCFR	18	24	1	
Fire	Conicville Fire Department	6	25	1	
Fire	Edinburg Fire Department	4	21	1	
Fire	Fort Valley Fire Department	5	27	1	
Fire	Mt. Jackson Fire Department	7	29	1	
Fire	New Market Fire Department	9	19	1	
Fire	Orkney Fire Department	10	28	2	
Fire	Star Tannery Fire Department	7	14	1	
Fire	Strasburg Fire Department	10	38	1	
Rescue	Strasburg Rescue	5	13	1	
Fire	Woodstock Fire Department	7	23	1	
Rescue	Woodstock Rescue	5	30	1	
Total Fire/Rescue					**397**
Gen County Govt.	Shenandoah County Admin	0	1	0	
Gen County Govt.	Shenandoah County Planning	5	1	0	
Gen County Govt.	Shenandoah County Public Works	12	8	1	
Gen County Govt.	Shenandoah County Landfill	18	2	1	
Total Gen County Govt.					**49**
Public Works (PW)	Mt. Jackson Public Works	0	2	0	
PW	Strasburg Public Works	0	32	0	
PW	Woodstock Public Works	21	7	6	

Discipline	Agency	Mobile	Portable	Control Stations	Total
Total PW					**68**
E911	Shenandoah County DEC	6	13	5	
Total DEC					**24**
	Total Subscribers	**234**	**552**	**27**	**813**

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 first 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.

Shenandoah County utilizes three tower sites for its primary law enforcement and fire/rescue channels today. Figure 1 on the next page presents a map of the site locations, while Table 3 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.

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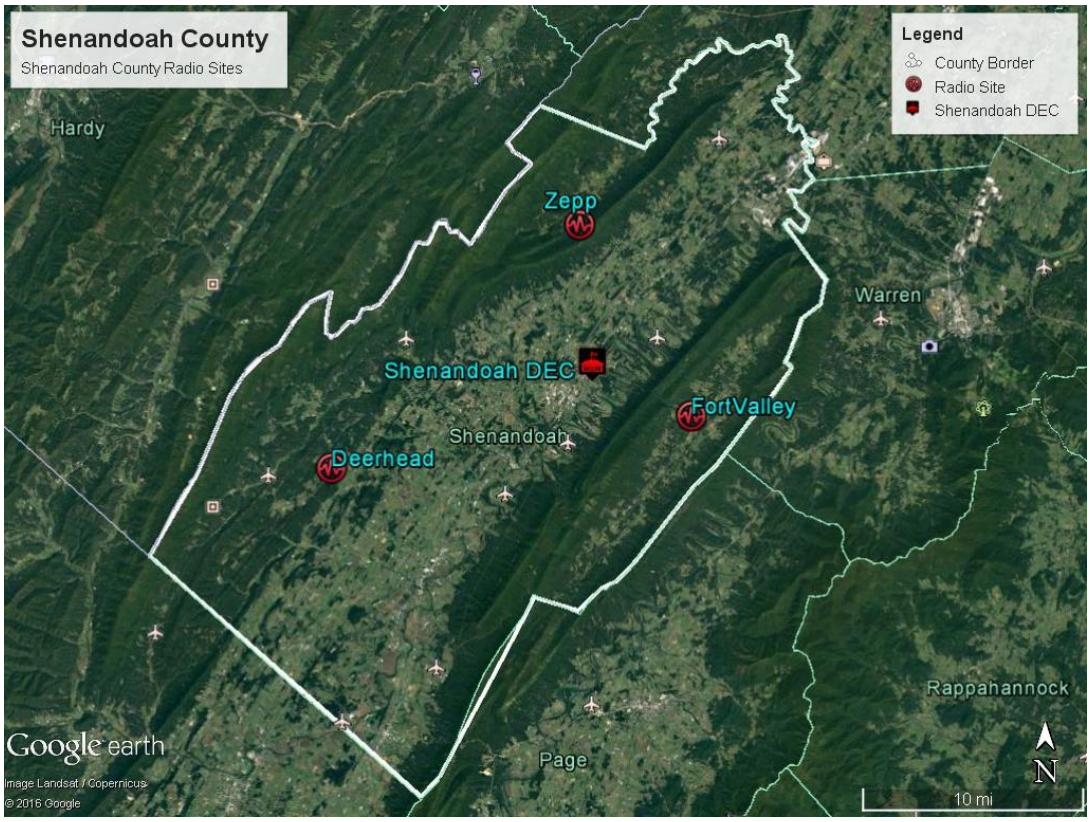


Figure 1: Shenandoah County Radio Sites

Table 3: Current Tower Use

Site	Sherriff Law	Fire Rescue	Fire Rescue Ops	Govt.	Law/Govt.	Deer Head Ops	MED 10
Zepp	Tx/Rx	Tx/Rx	Tx/Rx	Tx/Rx			Tx/Rx
Deer Head	Tx/Rx	Tx/Rx		Tx/Rx		Tx/Rx	
Fort Valley		Tx/Rx			Tx/Rx		

MCP visited Shenandoah County's radio sites that provide voice communications to public safety personnel and first responders. MCP performed site evaluations on existing systems, communication sites, and supporting facilities. These included, at a minimum, components such as the tower, shelter, power, cable and wiring systems, antenna systems, HVAC configuration, 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 grounding, site fencing, and tower foundation. However, the Zepp site has some wear on the tower foundation and would require further review for possible repair. Each of the sites was grounded to Motorola R56® standards, though two sites could use some minor improvements.

None of the sites was alarmed or actively being monitored. All sites within Shenandoah County were limited in equipment rack space inside the facility to accommodate additional equipment.

The tower structure at the DEC was loaded heavily and most likely would need to be replaced or strengthened, as well as increased in height, to accommodate additional appurtenances. Due to space limitations, if a new tower were to be installed it may need to be placed farther away from the building, in which case a new equipment shelter also would be required. A new shelter at the DEC also would address the concern that very limited open space currently exists in the DEC equipment room. Consequently, it is very likely that the County will be required to invest in communications shelters for the two new sites.

MCP recommends that monitoring and alarms be included in the new radio system and that any equipment installed at the sites follow the standards in Motorola R56®, Harris Site Grounding AE/LZT 123 4618/1 R3A, or equivalent grounding specification, and the National Electrical Code (NEC) standard for the installation for electrical wiring and electronics. A more detailed breakdown of site conditions and recommendations in Appendix A. Recommended site enhancements were included in pricing for the proposed options.

3.1.6. Central Dispatch Center

The Shenandoah County E911 Center, operated by the Department of Emergency Communications (DEC), is the primary public safety answering point (PSAP) and dispatch center for all public safety agencies within the county. The DEC is equipped with four dispatch console positions, and desires to add a fifth position. Staffing levels vary by shift and unique activity needs. Each of these positions serve both call-taker and dispatch 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

Shenandoah County currently has four Motorola Centracom Elite consoles for main dispatch operations. All positions are configured in the same manner. Because these consoles have been discontinued by the manufacturer, they will need to be replaced with consoles that can support a P25 infrastructure.

3.1.7. Equipment End of Life

Within a radio communications system, each individual system component receives a period of support from its manufacturer during which time component repair 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 Shenandoah 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. Table 4 below summarizes the EOL dates for the primary system components utilized in Shenandoah County.

Table 4: EOL Dates for System Components

Component	EOL Date
Quantar base station/repeater	December 2020
MTR 2000 repeater	March 2018
Centracom Elite Dispatch Control Center	Discontinued – December 2013
CMD 750 Mobile	Discontinued – June 2015
CDM 1250	Discontinued – June 2015

3.1.8. System Resiliency and Single Points of Failure

The majority of radio infrastructure utilized in Shenandoah County is approximately ten years old. The typical lifecycle for radio system components is 10 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 first responders.

System resilience has a direct tie to site resiliency. Shenandoah County's two mountaintop sites are lacking several features that could reduce greatly the resilience of the site and therefore the system. 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 Shenandoah County public safety radio communications system today has no direct connectivity or backhaul between the site and the dispatch center. System configuration consists of mountain top repeaters controlled by subscriber units in the field or control stations at the dispatch center.

The County's system configuration does not provide a transport path for site and remote alarms to be sent to the dispatch center. The best options for system connectivity would be to implement a microwave system or to connect sites via a fiber-optic network. Microwave or fiber also would be the preferred connectivity for a simulcast radio system design. Microwave generally is less costly to implement, but in the case of Shenandoah County, there is a major local fiber-optic network provider that may consider allowing connectivity through its network at a lower cost.

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 with agencies outside of public safety with which communications may be required.

This section includes a description of technological solutions utilized within Shenandoah 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.

To communicate with an agency on another frequency band, users must relay information through dispatch, or in some cases can request console patching when that other frequency is available in dispatch.

State of Virginia Agencies
The Virginia State Police (VSP) operates a very-high frequency (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. VSP troopers assigned to the county also have separate portable radios with county frequencies, but on today's system coverage can be limited. Troopers are dispatched by VSP and switch to using the County's portable radios when they arrive on scene and need to talk directly to County or local law enforcement personnel.

Other Adjacent Counties

The Shenandoah County radio system operates in the UHF band. Adjacent public safety agencies using different frequency bands have been reported as a source of interoperable communications problems. Law enforcement agencies in Shenandoah County are not able to talk directly to these adjacent agencies without the use of a radio that can operate on a frequency band other than UHF. Dispatch often will serve as a relay between the agencies, which is an inefficient use of radio resources. This lack of direct ability to monitor important calls also can create circumstances where responding units may not receive important life-safety information while en route to an incident.

3.1.11. Maintenance

Maintenance on the County-owned radio infrastructure is provided primarily by Clear Communications, which has a branch office located in Harrisonburg, Virginia. Clear Communications is an authorized Motorola service center. Yearly preventive maintenance checks are performed on the infrastructure equipment by Clear Communications personnel.

Subscriber radios are owned and maintained by each municipality or agency. Discussions with several law enforcement representatives and other municipality personnel indicated that they do not have preventative maintenance contracts in place for their subscriber equipment.

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

Clear Communications' on-call technicians are based throughout the entire central Virginia region. If the local technician who resides in Shenandoah County is not on call or otherwise available, it is possible that an on-call technician may take up to four hours to arrive on site for an after-hours emergency call. With the ongoing need to provide preventive maintenance of the 800-plus subscriber units, having a County-employed radio technician under the Department of Emergency Communications may be an option worth considering. Longer-term this could be a cost-neutral or cost-savings option depending on how future maintenance contracts are negotiated.

3.1.12. User Agencies

There are 12 fire/rescue departments and five law enforcement agencies that use the primary law enforcement and fire/rescue radio system today. Other municipal agencies, most County departments and the school system use different radio resources.

4. ANALYSIS

The following section analyses 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 within 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 are able to 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 fire walls, 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. Shenandoah County Coverage

MCP performed propagation modeling for the existing Shenandoah County system. This modeling shows both mobile and portable coverage deficiencies in numerous areas. Indeed, portable coverage with 6 dB of building attenuation added to simulate the loss associated with a wood-frame house shows even more pronounced coverage deficiencies of the current system. Coverage maps for the existing system can be found in Appendix B.

A simulcast transmit system with voted receive signals and additional sites would provide stronger countywide coverage. Coverage maps for the proposed simulcast system design can be found in Appendix C.

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 are typically 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 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 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 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. Shenandoah County Capacity

The County currently has approximately 800 subscriber radios. Shenandoah County currently uses two dedicated law enforcement channels and two dedicated fire/rescue channels, however, none of these channels provides countywide coverage and so there are many areas where only one of the two channels can be used reliably. There are additional tactical channels available, but they only provide reliable coverage when units are in close proximity to one another. 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 232 active users, which equates to approximately 25 percent of all potential users 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.”

Table 5 below summarizes the results of the Erlang C calculations.

Table 5: Erlang C Calculations

System Erlangs	# Of Active Users	Average Call Duration	# of Calls per Hour	Acceptable Queued Call Delay (in seconds)	Maximum # of Talk Paths	
1.2889	232	4.0	5.0	1.0	7	
Number of Voice 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**
7	0.00	0.00	0.00	0.24	0.00	0.0%
6	0.00	0.00	0.00	0.31	0.00	0.1%
5	0.01	0.00	0.01	0.40	0.00	0.4%
4	0.05	0.02	0.07	0.51	0.02	2.4%
3	0.17	0.13	0.39	0.65	0.11	10.9%
2	0.51	0.92	2.84	0.84	0.42	42.3%

Based on these results, a trunking system with at least five talk paths is necessary to provide an adequate level of capacity for Shenandoah County. One additional channel is required for the control channel, necessitating a total of four channels for a P25 Phase II radio system. This design would provide the County with six Phase II Time Division Multiple Access (TDMA) talk paths, plus one additional channel for the control channel.

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 major 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 an Interoperability Continuum that 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 first-responder 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 below.

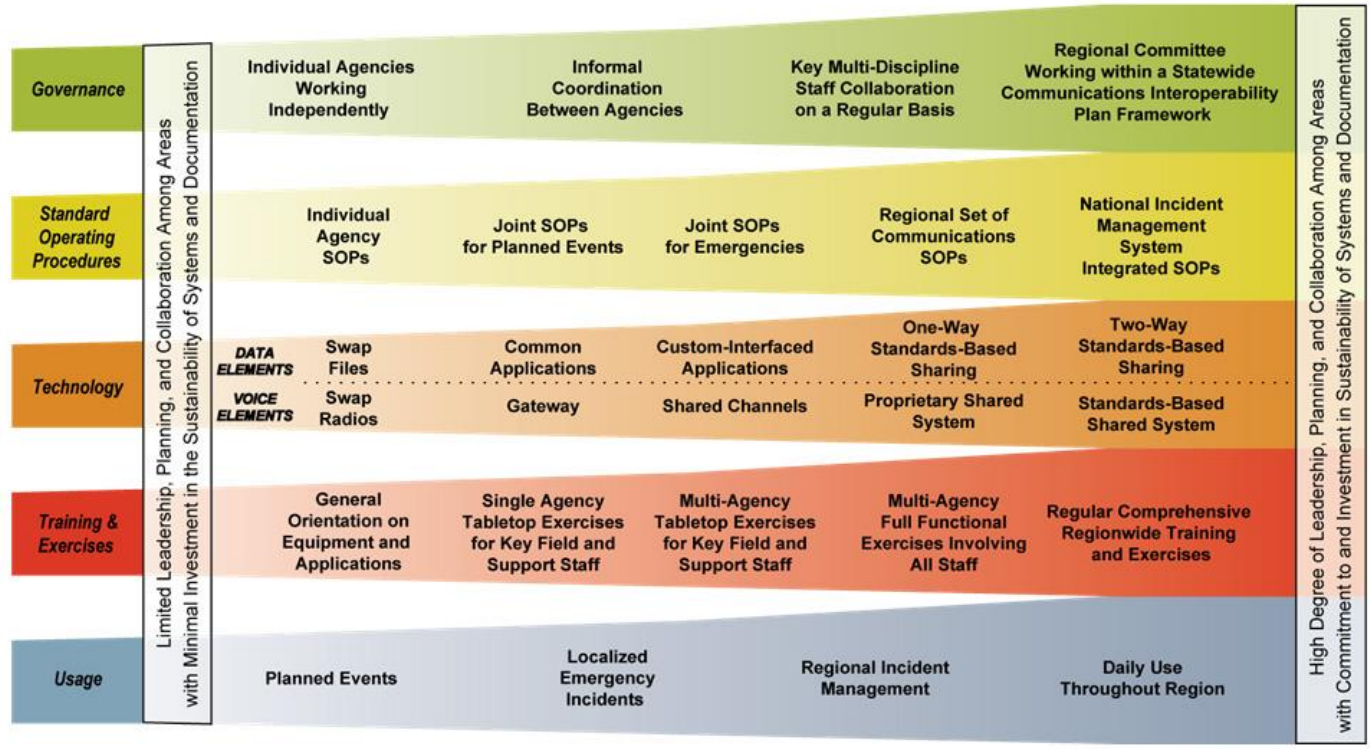


Figure 2: SAFECOM Interoperability Continuum

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 megahertz (MHz) channel used by Agency A can be connected to a group of users on a UHF channel used by Agency B. The interconnection is created when two or more radio channels or voice 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 dispatch operator 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 equipment.

DEC also currently operates a mobile communications and command vehicle (called IS-10), which has a mobile gateway device. Unfortunately, the device was not provided by the State, and therefore is not supported by the vendor, nor do any current personnel within DEC have familiarity with it. Replacing that device with a device supported by the vendor, as recommended by the State, will allow local dispatch of said equipment for small- to moderate-sized incidents, without the wait associated with requesting State assets during larger incidents. State assets can be requested at a later time to further enhance the local capabilities.

The Shenandoah County DEC 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*. The current Needs Assessment is being conducted using funds from this program. These requirements will continue for all future grant years FY18 and beyond, and need to be incorporated into any grant proposal submitted by Shenandoah 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 Project 25 (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.

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 is so significant that the receiver interprets a “1” as a “0” or vice versa (this is known as a bit error). Digital systems are able to reconstruct the original 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 spectrum 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 both 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-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 currently 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 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 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 overlap. It is in these areas where the potential for sites to interfere with each other can occur if 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.

Table 6 below summarizes the strengths associated with a conventional simulcast system.

Table 6: Conventional Simulcast System Strengths

Strengths
Design can provide single-channel coverage over a wide area
Flexible design can be used to enhance coverage where necessary through the addition of additional radio sites
Voted audio assures best available audio is retransmitted
System is spectrally efficient, reusing frequencies at multiple radio sites
Less expensive than trunking systems
Backhaul and coverage design provides upgrade path to trunking system in the future

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 similar to 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. Due to this reason, it is especially important that backhaul networks be designed to a very high fault-tolerant design, with high reliability levels, when accommodating simulcast systems.

Table 7 below summarizes the strengths associated with a simulcast trunking system.

Table 7: Simulcast Trunking System Strengths

Simulcast Trunking Strengths
Wide-area coverage solution that is capable of supporting relatively small systems up to statewide and multistate systems
Scalable capacity to meet the needs of many users
System can be operated in conjunction with multicast trunking systems and single-site conventional systems
Additional features (compared with conventional systems)
The most spectrally efficient system design available

Option 2, the implementation of a new 700 MHz trunked simulcast P25 system would be a full-featured solution; however, it also would be the most expensive alternative considered in this report.

4.4.5. Shared Systems

Shared systems provide a way for multiple agencies to share common system components in order 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 two systems.

P25 trunking systems provide the greatest opportunity for system sharing because central control equipment used on P25 systems often can accommodate a far greater level of users than is typically 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 has yet to take hold. 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 has 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 first responders. However, much of the details behind the FirstNet build-out have yet to be defined, including costs to end-user agencies.

LTE itself is a wireless network providing high-speed data to subscriber devices. The benefit to public safety concerns the applications that will run over this network; however, only a handful of these applications exist today. 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 the equivalent quality of service (reliability) provided by current public safety LMR voice systems, and does not provide direct unit-to-unit simplex operation. Because of these significant limitations, if LTE ever is able to take the place of narrowband voice systems, it certainly will not be any time in the near future.

While there would be benefits to an LTE broadband system within the county from a data perspective, the decision is distinct from the radio system procurement, as LTE is not yet mature enough to serve as a viable voice radio system alternative.

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 Tables 8-11 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 8: 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 9: Maintenance Equipment Lifespan

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

Table 10: 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 11: 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.

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 conducted an inspection of radio sites in Shenandoah County. Each evaluation focused on installation practices, site conditions, notification systems, and redundancy of critical elements. These inspections were grounded in industry best practices and standards for critical communications facilities, primarily Motorola R56® *Standards and Guidelines for Communication Sites*.

R56® generally has been adopted throughout the industry for common use in site construction. All vendors have products that comply with the standard, or which at least track very closely to R56®. Non-compliance with R56® standards and guidelines 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 the R56® standards and guidelines 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 up by a generator, fixed or portable, and sufficient direct current (DC) power via a DC plant or 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

Most deficiencies found at the radio sites were found on the external and internal grounding systems. MCP recommends that site grounding be brought up to current standards with a system refresh. Equipment warranties sometimes will not apply if the equipment is not grounded according to industry standards.

4.7.2. Uninterruptible Power Supply (UPS)

A 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 region install a UPS or a DC battery power plant in the new 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 less radio sites than systems constructed in other frequency bands. However, the VHF band is more susceptible to interference and 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 and the potential for interference, the VHF band is not recommended for the County.

4.8.2. UHF

The UHF frequency band covers the range from 450 MHz to 470 MHz. The lower portion of the band includes the general public safety and industrial/business frequency pools. The UHF band provides fixed offsets between transmit and receive frequencies, thus supporting the use of repeater systems. Preliminary research indices that additional UHF frequencies may be available; however, more in-depth frequency availability research will need to be conducted by the vendor that will be designing the system.

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 Shenandoah County. The band is not heavily encumbered and frequency assignments would be available. However, obtaining these frequencies will require authorization from the Regional 700 MHz Planning Committee.

Most current production subscriber radios are capable of operating 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 Shenandoah County can construct in this band. The system must be digital and must permit subscriber operation on conventional interoperability channels in the P25 mode.

Further, a 700 MHz system would require far more sites than a UHF system, at significant added cost. Consequently, the use of 700 MHz frequencies in Shenandoah County is not recommended

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 regional planning committees (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 on other systems; therefore, the use of this spectrum band is not recommended.

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.

No backhaul exists between the County's three radio system sites and the DEC. Instead, mobile radios and control stations communicate with the DEC through the mountaintop repeaters that are located at each of the sites.

4.9.1. Leased Phone Lines

Leased telephone lines are the simplest form of backhaul connectivity. To interconnect two radio sites, or a radio site and a PSAP, an agency may lease a copper pair or T1 line from the local telephone company. A single T1 line typically is capable of supporting the bandwidth requirements of a small- to moderately sized trunking system, while a two-wire circuit can support a single voice channel. By leasing the T1 line for a monthly fee, the user has guaranteed bandwidth on the network. The specific fee depends on the length of the connection. T1 lines are subject to the reliability of the public switched telephone network (PSTN), which utilizes a combination of copper wires and other media, such as fiber.

Leased T1 circuits have proved to be adequate for many radio systems. However, because there are no alarming systems on leased circuits, no notification is provided when a circuit failure has occurred. A circuit failure on the existing system will result in a loss of a radio site or sites, depending on the severity of the outage. The circuits only will support individual voice channels, and do not provide the capacity necessary to support higher-bandwidth applications such as trunking. Moreover, additional lines are required for each channel, which results in higher monthly fees.

4.9.2. 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 is certainly in excess of 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.

4.9.3. 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 line. 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 lines, 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 be 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 five site system can be found in Appendix D.

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 faced by the 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 a request for proposal (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 very limited both within the county and with external agencies. This makes agency-to-agency communication cumbersome and unreliable.

3. Increase system channel capacity
    - Channel capacity is very limited due to the conventional design, with channels being transmitted from only one site and 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 first 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. SYSTEM OPTIONS

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 two design options that, at a minimum, satisfy these criteria.

The sections that follow identify the different technology options that MCP believes would satisfy all or most of the needs of system users. The two different solution options for replacement of the current public safety voice radio systems examined are:

1. Implementing a new UHF P25 conventional simulcast system
2. Implementing a new UHF P25 trunked simulcast system

5.1.1. Option 1—Implementing a new UHF P25 conventional simulcast system (Recommended)

Option 1 is a UHF P25 conventional simulcast system. Building out a simulcast infrastructure would greatly improve system coverage and reliability. Additional new channels could be provided to improve capacity, and all channels would be available countywide. Methods of interfacing UHF, VHF, and 800 MHZ channels could be developed. Adequate UHF channels appear to be available but there is always some uncertainty when new frequency acquisition is needed for a solution.

This option would require both new infrastructure and radios. A three-site design is anticipated to adequately improve coverage and reliability.

Table 12 below summarizes the strengths of this option.

Table 12: UHF P25 Conventional Simulcast System Strengths

Strengths
Countywide coverage with a five-site design
Improved coverage and usability through the implementation of a simulcast design. Improved coverage by adding a third site.
Improved capacity through the addition of new UHF channels
Improved reliability through overlapping site coverage, fault-tolerant design, and properly constructed radio sites
Improved security and control through system keys, subscriber ID restrictions, and encryption capabilities
Reduced costs through less expensive base stations, lack of trunking control equipment, and non-trunking radios

A simulcast UHF system would satisfy the critical system criteria defined by MCP, as identified by system users.

5.1.2. Option 2—Implementing a new UHF P25 trunked simulcast system

A P25 Phase II (TDMA) trunked simulcast system would provide the greatest level of capabilities for system users, but is also the higher-cost option of the two. 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 five talk paths will be necessary to provide an adequate level of capacity. This capacity level can be obtained through the usage of six frequencies with TDMA operation. Each channel would be available for access at every site. MCP estimates that three radio sites will be required to provide a reasonable level of coverage and performance. Propagation studies have been provided in Appendix B and Appendix C.

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 UHF, P25 Phase II, trunked simulcast system would require the complete replacement of the County's existing equipment, including fixed infrastructure and subscriber units, though some of the existing radio sites and supporting facilities could be reused. At least one new existing site would need to be added to the system to provide improved coverage under Option 2.

Table 13 below summarizes the strengths and weaknesses of this option.

Table 13: UHF, P25 Trunked Simulcast System Strengths

Strengths
Countywide coverage by utilizing approximately five radio sites (includes the use of three existing sites)
Enhanced interoperability, both within the county and with external agencies
Improved capacity and flexibility through use of trunking architecture and additional UHF channels
Improved reliability through overlapping site coverage, fault-tolerant design, and properly constructed radio sites
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[1]
Flexible standards-based architecture to support future expansion and technology refreshes

5.1.3. Flexible Procurement Process Recommendation

To provide the County with the most flexible approach to selecting the best system solution, it is suggested that the system specification request Option 1 as the baseline proposal, but also include a proposal for Option 2. In this way, the differences in pricing can be weighed against the differences in performance and features.

[1] Over-the-air programming.

5.1.4. System Coverage

If either UHF simulcast system is implemented, MCP recommends 95 percent mobile coverage in all of the high traffic areas of the county and in-building (6 dB of attenuation) portable coverage in the population centers and along major roadways. These coverage criteria can be applied to both Options 1 and 2. Appendix C provides coverage prediction maps that compare current coverage to the predicted coverage of the new system.

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 travelled areas located in areas of marginal coverage, MCP recommends the use of a UHF portable repeater that could be deployed and activated to provide local-area coverage for incidents such as a search-and-rescue operation. Such a repeater could be added to the equipment in IS-10, which would enhance the capabilities of that County-owned resource.

Appendix E provides a list of buildings where public safety personnel have found radio communications to be unreliable on the current system.

5.1.5. System Capacity

System capacity differs depending on whether the County selects a trunked or conventional architecture, and is based on the specific design.

For a trunked network, capacity is determined based on 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. 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 five talk paths are necessary to provide a GoS of 1 percent.

If the County procures any features that utilize the P25 data backbone, additional capacity will be needed to support these features.

5.1.6. Interoperability Features

The DEC should 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.

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.

Subscriber radios utilized within the county today are not capable of P25 operation nor are they trunking capable. Therefore, all subscriber radios will need to be replaced if a P25 conventional or trunking system is implemented. MCP has based system cost estimates on a one-for-one replacement of each existing radio based on the different options.

5.2.1. 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 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

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

- Separate volume and channel adjustment knobs
- AES- and DES-capable

5.2.1.1. Encryption

Encryption is often desired by law enforcement agencies. Standards-based AES digital encryption is the most secure encryption available for public safety radios and is the standard encryption per P25 specifications. AES is only available on P25 trunking options. 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 the 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, while other agencies implement it on all radios. 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.

5.2.1.2. 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 between 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 feature. An example of such a proprietary feature is described below.

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 amount 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.

5.3. 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 match the radio system vendor. 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.

The current console system supports an interface with the computer-aided dispatch (CAD) system that could allow the CAD system to automatically select the appropriate paging tones for fire and EMS dispatch; however, that capability is not currently installed. By adding this feature, it would speed up the dispatching process and reduce the potential for human error.

5.4. 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 model logging recorders are capable of recording this data. Certain model 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 NICE recording system at the DEC should be replaced to be compatible with a new P25 radio system.

5.5. 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. T1 circuits do not typically 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 DEC. 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 for Option 1 or Option 2 will permit a failure to occur at any one tower site on the ring, while still 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 $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.

5.5.1. 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 of the radio equipment. This is a typical configuration in new systems and reduces the necessity of a UPS system at the sites.

5.6. REDUNDANCY AND SURVIVABILITY

Both of the options proposed by MCP 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 or 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.

5.7. 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 either new system will include additional system components, which result 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 County 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.

5.8. CONCEPTUAL SYSTEM DESIGNS

MCP has developed conceptual system designs for Options 1 and 2 that include the selection of radio sites to provide the recommended level of coverage enhancements.

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

5.9. COST ESTIMATES

MCP developed cost estimates for each of the radio system options. The sections that follow identify the cost summaries for each option as well as the high-level assumptions for each option.

The costs in this report use list pricing for equipment. 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 the more conservative list pricing to create cost estimates to ensure that actual costs will be lower than the estimates, not higher.

Our budgetary estimates also include a project contingency of 5 percent of the 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 includes all necessary software, antenna, single-unit charger, and remote speaker microphone. For mobile radio pricing MCP includes 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 cost for encryption was not included in subscriber price estimates. For agencies interested in purchasing encryption, an estimate of $475 per radio should be used.

Table 14 below summarizes the costs associated with each of the identified options, including microwave backhaul, user equipment and project management and engineering. Budgetary numbers are provided for each option.

Table 14: Estimated Costs

System Option	Radio and Microwave System	User Equipment	Project Management/ Implementation Oversight	Project Total
Option 1 – UHF P25 conventional simulcast system	$5,302,003	$2,307,422	$400,000	$8,009,425
Option 2 – UHF P25 Phase II trunked simulcast system	$6,450,127	$3,157,082	$400,000	$10,007,209

5.9.1. Option 1 – UHF P25 Conventional Simulcast 5 site 10-Channel System

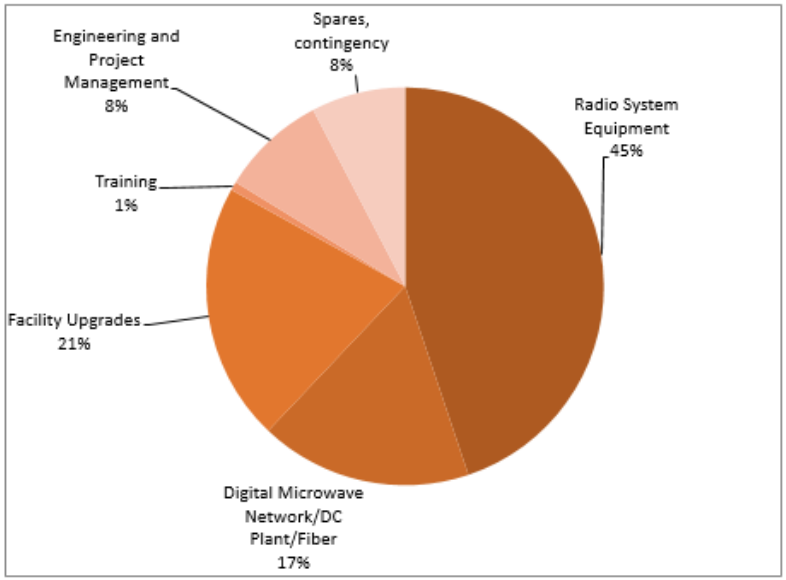
Assumptions include the following:

- Total of five sites with ten channels at each site
- Simulcast transmit and voted receive signal at all sites
- Structural analysis and modifications for all towers to latest TIA-222 revision G standard[4]
- Loop-configured microwave network connecting all radio sites and dispatch
- 100-foot tower and shelter at the Shenandoah County DEC—a 100-foot tower and shelter are needed to support microwave connectivity
- Tower replacement at the Fort Valley site to increase height to 200 feet
- Miscellaneous enhancements to the Zepp and Deer Head sites
- New shelter, generator, and upgrades at two new leased locations
- New shelter at Deer Head location
- Replacement of 552 portable radios, 336 mobile radios, and 27 control station radios
- Vendor project management and engineering
- Recommended spares
- 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, OTAP, ¼-wave antenna, single-unit charger, and remote speaker microphone
- Six new P25-compatible radio consoles and workstations
- New digital logging recorder and interface
- Project management for implementation oversite
- Five years of system maintenance as an option

[4] Telecommunications Industry Association.

Option 1: P25 Conventional Simulcast, 5-Site, 10-Channel System

Radio System Equipment	$2,341,156
Digital Microwave Network/DC Plant/Fiber	$900,000
Facility Upgrades	$1,095,984
Training	$36,800
Engineering and Project Management	$448,062
Spares, contingency	$399,401
SUBTOTAL -Infrastructure	$5,221,403
Portable Replacements	$1,458,651
Mobile/Control Station Replacements	$848,771
SUBTOTAL -User Equipment	$2,307,422
Project Management/Engineering	$400,000
Freight/Performance Bond	$80,600
GRAND TOTAL	**$8,009,425**
Options:	
5-Year System Maintenance	$503,845
Current System Testing: Vehicle Testing Per Unit	$216



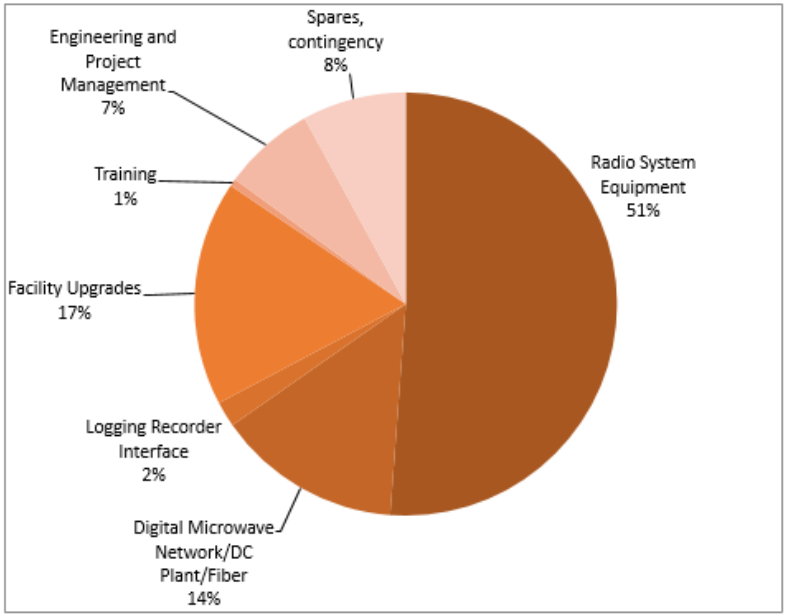
5.9.2. Option 2 – UHF P25 Phase II Trunked Simulcast 5 Site 6-Channel System

Assumptions include the following:

- P25 Phase II Trunked system using five sites, with 6 channels at each site
- Structural analysis and modifications for all towers to latest TIA-222 revision G standard
- Loop-configured microwave network connecting all radio sites and dispatch
- Tower replacement at the Fort Valley site to increase height to 200 feet
- Miscellaneous enhancements to the Zepp and Deer Head sites
- New shelter, generator, and upgrades at two new leased locations
- New shelter at Deer Head location
- Replacement of 552 portable radios, 336 mobile radios, and 27 control station radios, all to include optional trunking software.
- Vendor project management and engineering
- Recommended spares
- New 100-foot tower and shelter at the Shenandoah County DEC—a 100-tower and shelter are needed to support the loop microwave system as well as interfacing the Shenandoah County ECC to the trunked radio system. Current tower and equipment room are insufficient to support future needs.
- Simulcast paging system—this is required because paging cannot be supported over a trunked radio system.
- Current tone-and-voice pagers could be reused.
- Six new P25-compatible radio consoles and work stations
- New digital logging recorder and interface
- Project management for implementation oversite
- Five years of system maintenance as an option

Option 2: P25 Phase II Trunked Simulcast, 5-Site, 6-Channel System

Radio System Equipment	$3,262,583
Digital Microwave Network/DC Plant/Fiber	$900,000
Logging Recorder Interface	$125,000
Facility Upgrades	$1,095,984
Training	$36,800
Engineering and Project Management	$448,062
Spares, contingency	$506,097
SUBTOTAL -Infrastructure	$6,374,527
Portable Replacements	$2,054,658
Mobile/Control Station Replacements	$1,102,424
SUBTOTAL -User Equipment	$3,157,082
Project Management/Engineering	$400,000
Freight/Performance Bond	$75,600
GRAND TOTAL	**$10,007,209**
Options:	
5-Year System Maintenance	$429,438
Current System Testing: Vehicle Testing Per Unit	$216



6. NEXT STEPS

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

- Select a system design option
- Develop a preliminary system specification and RFP, and plan for funding
- Move forward with final RFP development and the procurement process once funding is available

Upon selecting the desired radio system option and identifying appropriate funding, planning and procurement activities can proceed.

The typical implementation period for a radio system is 12 to 24 months after 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.

MCP understands that there are multiple options available to the County, including some that may involve waiting a significant period of time before any action is taken. Among several points to consider in this regard is the fact that interest rates for bond issues right now are extremely low, resulting in lower borrowing costs for capital projects. A delay in the project could thus result in higher borrowing costs, especially if action is not taken for several years. Also, the cost estimates contained in this report are reflective of the current radio equipment market and current competition levels. There is no guarantee that the deals available today will be available several years from now.

6.1. SECURE FUNDING

To move forward with the procurement, funding will need to be secured for the new system. Based on the County's desired system option, a budgetary commitment should be secured. The cost estimates provided 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

6.2.1. Competitive Procurement (RFP)

Competitive procurements typically yield the best overall system value when multiple vendors are capable of offering equivalent or near-equivalent products.

If the County elects to proceed with a competitive procurement, MCP recommends a single RFP that will permit vendors to respond to all system components or individual components.

7. CONCLUSION

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

Local elected officials and senior staff wisely have 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 solutions. The radio communications system is in desperate need of improvement. The typical implementation period for a radio system is 12 to 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 – Shenandoah County Site Reviews

SHENANDOAH COUNTY SITE REVIEW

DEER HEAD SITE

The Deer Head site is located off Tower Mountain Lane, atop Mountain Jackson in the southern region of the County. The tower and building are owned and maintained by Shenandoah County. The tower is a fire tower at a height of 75 feet. The building is an 8-foot x 12-foot block construction. The compound is 30 feet by 40 feet. Both the tower and shelter are in good condition. The building houses the fire dispatch channel, fire tactical channel, law enforcement channel and a government channel using Motorola Quantar base stations/repeaters. There also is a school system repeater controlled by a T1 line and a T-Marc 340F Ethernet-to-analog converter.

The building was in good clean condition and is sufficient for housing public safety radio equipment; however, space was limited and would not be able to accommodate additional equipment should microwave or additional racks of equipment be added. There are four entry ports, with each being used for transmission cables; however, an entry port boot could be used for additional cables depending on size. No other tenants are present at the Deer Head site. The site does have T1 connectivity, but it only is used by the school system. There is no presence of microwave or fiber at the site for backhaul.

Grounding

The tower, tower legs, ice bridge, antennas, propane tank, and generator all appear to be properly grounded. 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. In addition, a ground halo is present. The radio site's exterior and interior grounding appears to have been done to Motorola R56® standards. There are some signs of past grounding that has been left in place. MCP recommends removing any past grounds that are not actively protecting the tower, equipment or the shelter. New equipment should continue to follow Motorola R56®.

Alarms

The Deer Head site does not have equipment, environmental, site entry or other monitored alarms related to the radio site. Shentel actively monitors a generator power-up alarm and notifies DEC by telephone whenever the generator powers up. This is the only alarm that is present and/or monitored for this site.

Climate Control

The Deer Head site has an electric heater mounted on the building wall. The HVAC system is a split-type system manufactured by LG. Telecommunication. Equipment is sensitive to extreme temperatures. To maintain the proper temperature in the event of a cooling system failure, MCP recommends installing an exhaust fan system that is triggered when the internal temperature of the building reaches a defined maximum level. This will help reduce the risk of equipment overheating and

failing due to an HVAC system outage, which is key to preventing premature equipment failure and extending the life of the radio equipment.

Electrical Surge

The building is protected with a Zone Master 150, AC Surge Arrestor, protecting the electrical feed coming into the building. The Zone Master 150 is suited to protect both small and medium service panels, and would be sufficient to protect the current building. There are surge-suppression devices installed on all incoming coaxial lines. Future coaxial lines also should have surge-suppression devices installed and grounded to reduce the risk of lighting or other electrical surge entering the building.

Generator Power

The Deer Head site has a Generac 20 kilowatt (kW) propane generator located adjacent to the building that supplies power in the case of a commercial power failure. The generator appears to be in like-new condition and properly maintained. The generator capacity would be sufficient to accommodate future needs of the radio system. Inside the shelter there is a 100-amperes automatic transfer switch. There are 11 direct current (DC) batteries labeled “Shen Co Schools” with an installation date of August 17, 2015. It is unknown whether the batteries supply DC power to Shenandoah County’s radio equipment.

Figure 1: Deer Head Fire Tower and Antenna

Figure 2: Deer Head Equipment Cabinet

FORT VALLEY SITE

The Fort Valley Site is located at Fort Valley Fire Department off Fort Valley Road. The site is between Seven Bends and Shenandoah River state parks in the eastern region of the county. The supporting structure is a 75-foot monopole located approximately 15 feet from the fire hall. The building and monopole are both owned by the Fort Valley Fire Department. The fire hall is a brick-and-mortar commercial-grade building in good condition. The monopole appears to be well-maintained with minimal signs of wear. The transmissions cables are buried from the monopole through an underground conduit to the fire hall. There is an equipment cabinet that houses the fire dispatch channel and the law enforcement channel. There are four DC batteries at the bottom of the cabinet that appear to power the radio equipment. Atop the cabinet is a control station using a Motorola CDM 1250 mobile radio. There is minimal amount of room for expansion. If the County elects to add equipment, MCP recommends relocating the equipment to a dedicated equipment room, or purchasing a dedicated communications equipment shelter.

Grounding

The monopole appeared to be grounded to Motorola R56® standards with a mounted master tower ground bar and a single-point ground routed directly to the earth grounding electrode system. Much of the coaxial cabling was not visible; however, we observed a grounding wire inside the cabinet leading up through to the ceiling. We recommend any new equipment installed in the fire hall or on the tower be installed in accordance with Motorola R56® or other similar standard and in accordance with the National Electrical Code (NEC) standard.

Alarms

It is unknown whether the Fort Valley Fire Department building is alarmed; however, it is locked with the equipment in an office that also could be locked. In addition, the cabinet is capable of being locked; however, there are no alarms on the cabinet. MCP did not find any additional alarms on the equipment, environmental system, or building. The absence of alarms adds risk because there would not be advance notice of a system failure due to equipment malfunction or environmental issue, or of a building intrusion.

Climate Control

The equipment is stored in a typical office setting in a climate-controlled building that uses a central heating and air-conditioning system. The room temperature is maintained between 68 and 72 degrees Fahrenheit (F), which is optimal for keeping electronic equipment from overheating and for preventing moisture build-up. Maintaining the temperature and humidity in a site is important to prevent condensation of moisture on and in the equipment, which could result in equipment failure and reduce equipment service life.

Electrical Surge

The fire hall is fed with commercial power by the local electricity service provider. It is unknown whether the main feed to the building is protected with a transient-voltage surge suppressor. Currently, wall-

outlet-type surge protection is used to power equipment in the cabinet. These types of surge protectors do provide additional protection and should continue to be used.

Backup Power

Fort Valley Fire Department is using a 20 kW Generac propane generator for backup power. The generator appears to be in new condition and well-maintained. It is unknown whether the generator provides backup power to the entire building or to specific outlets. We recommend determining the load and what outlets are being fed by the generator prior to installing new equipment in the fire hall.

Figure 3: Fort Valley Fire Department Monopole

Figure 4: Fort Valley Fire Department Equipment Cabinet

ZEPP SITE

The Zepp site is owned by Shenandoah County and is located on the northern region's mountain range near Back Road. The 35-foot by 40-foot compound contains a 20-foot by 12-foot concrete brick shelter that houses communications equipment, a 12-foot by 12-foot steel building that houses the generator, and an 85-foot self-supporting lattice tower. There is also an external 500-gallon propane tank.

The compound is tight and would not be able to accommodate an additional shelter without expanding the compound. The exterior of the shelter appears to be in good condition. The barbed wire on top of the fence surrounding the compound is in poor condition and would need repair to enhance security measures. The tower appears to be in good shape and is medium- to heavily loaded with nine appurtenances. A tower structural and loading study is recommended before installing additional antennas or microwave dishes. The tower foundation piers show signs of cracks and wear and should be addressed in the near future.

The interior of the metal building housing is in good working order with minor debris, which is typical of shelters housing generators. The brick building looks to be well-maintained with no signs of leaks or insect intrusions. Shenandoah County uses the Zepp site for its fire dispatch channel, Fire Operations channel, Law Enforcement channel, a Government channel, and a Med 10 channel. The shelter also houses equipment for the school system's UHF radio system and a tenant with FM broadcast equipment using frequencies in the 88 megahertz (MHz) to 103 MHz range. There is a T1 line to the building being used by the school system. No other forms of backhaul were available. There are two available entry ports; however, rack space in the building is limited.

Grounding

The tower, building exterior, propone tank, and generator shelter appear to be grounded; however, there are instances where grounding could be improved. One area would be the external entry port where grounding kits should be installed prior to entering the building. Both the shelter building and the equipment building were observed with proper grounding using Motorola R56® standards. These standards or equivalent standards, along with the NEC standards, should be continued to be followed when installing new equipment.

Alarms

The Zepp site is not monitored for environmental alarms, equipment failures, or site alarms. The equipment building does have a padlock and key system, but no alarms are present for unauthorized site access, or alarms that would notify personnel of a generator failure, or rise in temperature within the equipment building. Without alarm monitoring and notification, the County does not have the capability to provide a response to the failure within a reasonable amount of time. For example, if the generator fails to start, it may take days or weeks before personnel are aware of the issue. Alarms are critical to reducing risk and thereby reducing the response time to react when equipment fails, environmental factors are present, or when securing a radio site. Shentel actively monitors a generator power-up alarm and notifies DEC by telephone whenever the generator powers up. This is the only alarm that is present and/or monitored for this site.

Climate Control

Climate control is solely provided to the equipment building using a split-type HVAC system installed in the side wall. In the event of an HVAC failure, MCP recommends the installation of an exhaust fan that is triggered by a rise in temperature within the building, to reduce the potential of the equipment overheating, which could result in equipment failure.

Electrical Surge

Wall-unit-type surge-protection devices are used at each of the outlets protecting the plugged-in equipment. The main commercial feed is using a LEA international surge-suppression device. Also, DC batteries were present, installed within the last two years.

Backup Power

The metal building housed an Onan 20 kW propane-type generator and an Onan automatic transfer switch that powers the neighboring equipment building. The generator should be sufficient to power both current and future equipment.

Figure 5: Zepp Tower

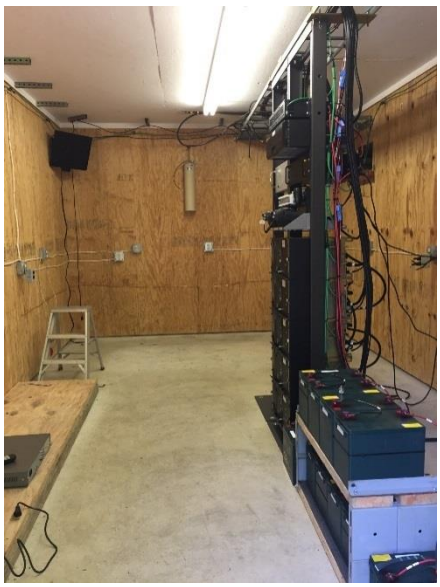


Figure 6: Zepp Equipment Shelter Interior

SHENANDOAH DEC SITE

The Shenandoah Department of Emergency Communications (DEC) site is located at 600 Main St., Woodstock, Virginia, in the central region of Shenandoah County. Adjacent to the EOC building is a 20-foot by 20-foot compound containing a heavily loaded, light-duty 60-foot self-supporting lattice tower and a generator. The building and tower are both owned and maintained by the County. The equipment resides in an equipment room in the DEC building, which is a commercial-grade brick-and-mortar building.

The coaxial cables extend from the tower through underground conduit into the designed equipment room. The tower is in good shape and appears well-maintained; however, with more than 11 appurtenances, it appears heavily loaded and could fail a structural study. MCP recommends that a structural study be performed, or that the County considers deploying a new tower if it wants to add additional antennas and dishes.

There is a dedicated equipment room within the DEC that houses a mix of radio services and related equipment, including 13 Motorola MTR 2000 base stations, six control stations, and a Mastr II system used in joint venture between the State of Virginia and the National Weather Service's Integrated Flood Observing and Warning System (IFLOWS). The interior of the equipment room had some debris but was in good working order with no signs or leaks or insect intrusion. Space for additional racks would be limited. The space is secure with low risk of unauthorized personnel. In place of entry ports, there are four conduits protruding from the floor, each full of cables. Space is limited for additional cables.

Any new system design that significantly will resolve known system performance issues also will require the addition of new equipment at the DEC/public safety answering point (PSAP) facility, along with the construction of a new tower at that location. Due to numerous limitations regarding the size and configuration of the existing facility, a significant renovation to the north wing of the county government center, which currently houses the DEC/PSAP likely would be required. An alternative would be to place the new tower and a separate equipment building somewhere else on the complex.

Alternatively, the County could consider relocation of the DEC to an alternate location, for example collocating the DEC/PSAP in conjunction with the new office complex for the Sheriff's Office that is being considered. Such a study would be new scope beyond the radio system needs assessment, but can be completed easily within a reasonable timeframe if determined to be necessary.

Grounding

The tower appears to be grounded in accordance with Motorola R56® standards, with antennas grounded to the master ground bus bar and each leg of the tower leading toward the grounding electrode system. The equipment room appears to have been grounded to Motorola R56®. Equipment appears to be grounded to equipment racks, a ground halo is present, and each coaxial cable is grounded to the master ground bus bar. Future equipment should be grounded in accordance with Motorola R56® or equivalent grounding standards, as well as the NEC standards.

Alarms
The County does not use an alarm system designed to give advance warning of a system failure, security breech or environmental issue in the DEC equipment room. MCP recommends the use of an alarm system to increase reaction time and proactively monitor and response to failures or system issues before they escalate in size.

Climate Control
The equipment room is heated and cooled using the building's HVAC system. Because the equipment room is in the same building as the DEC, MCP has no recommendations regarding climate control. The risk concerning equipment failure due to an HVAC outage is far less compared with a remote site, because DEC personnel would be able to react quickly to a failure involving the building's systems.

Electrical Surge
The commercial power input into the equipment room is protected by a Powerware Zone Master 150 transient voltage surge suppressor. The Zone Master 150 is suitable for protecting the equipment room and surges on the incoming electrical feed. There are also coaxial surge-suppression devices installed and grounded. Future coaxial lines also should have such devices installed and grounded to reduce the risk of lightning or other electrical surge entering the building.

Backup Power
The equipment room houses an Emerson uninterruptible power supply (UPS) system with a 40 kilovolt-amperes (kVa) capacity. Outside there is an Onan 150 kVa Gen Set generator placed on top of a fuel tank which provides back-up power to the DEC. MCP recommends loading calculations be done to determine whether the current generator can accommodate the additional loading with new equipment.

Figure 7: Shenandoah DEC Tower

Figure 8: Shenandoah DEC Cabling

Appendix B – Shenandoah County Existing Coverage Maps

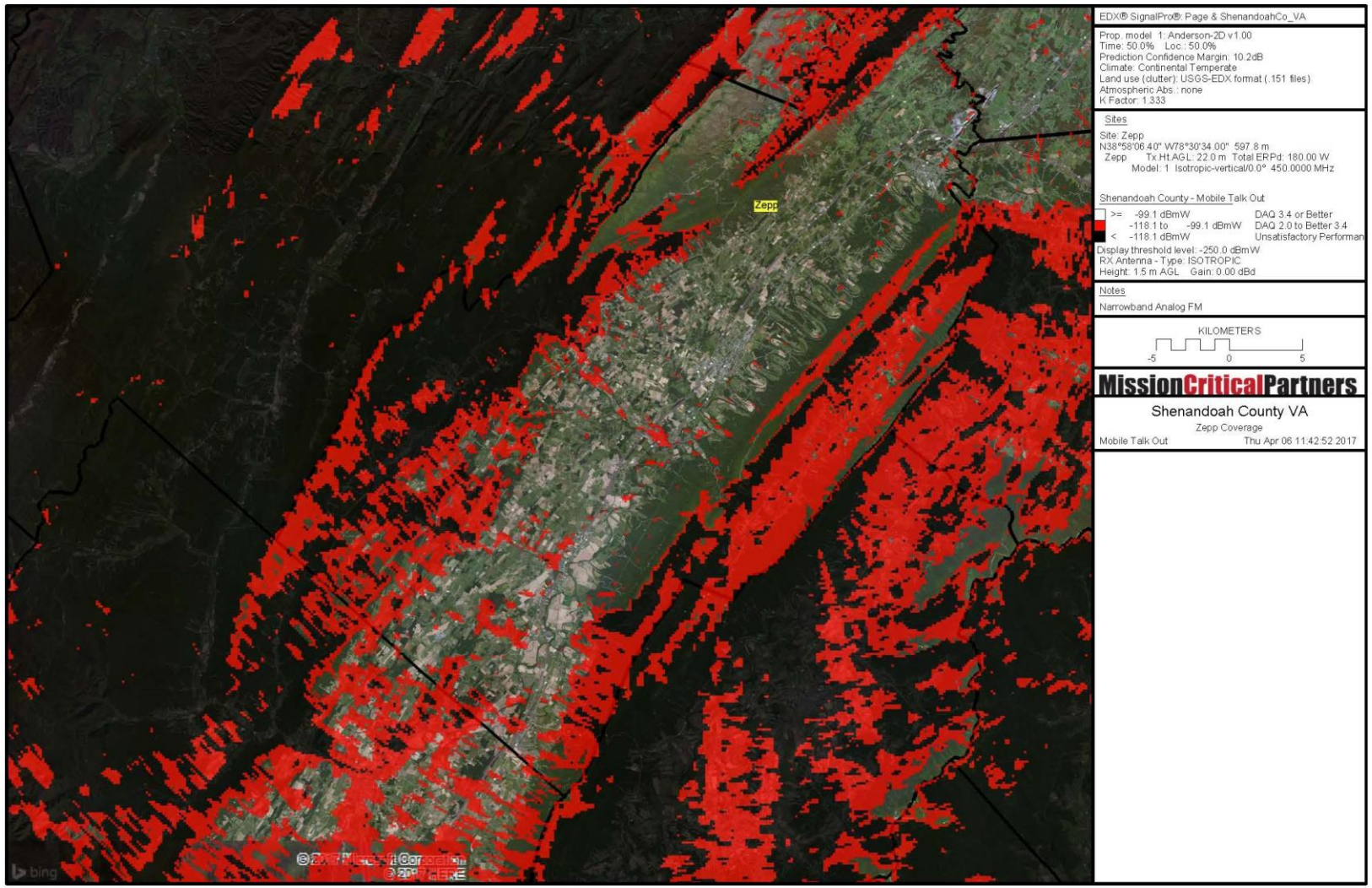
Map Explanation

Areas shaded in red or black show predicted coverage levels that fall below what is typically regarded as a reliable signal level. The larger the area and the more black displayed equate to an area where coverage will be unreliable.

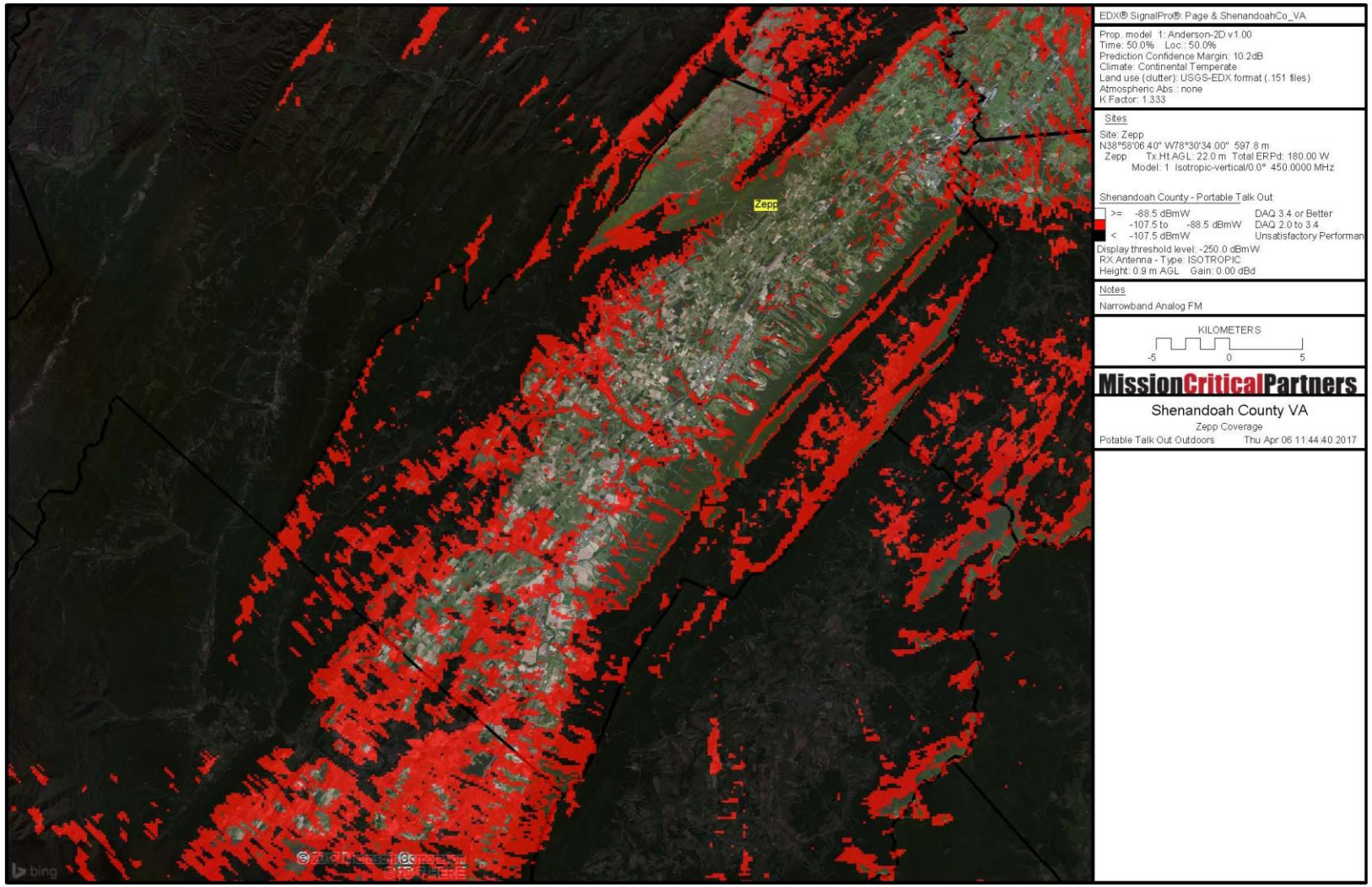
The first six maps in Appendix B show predicted mobile and portable coverage on today's system from the three standalone sites: Zepp, Fort Valley and Deer Head.

The seventh map shows reported radio coverage problem areas. The predicted coverage problem areas align well with the reported problem areas.

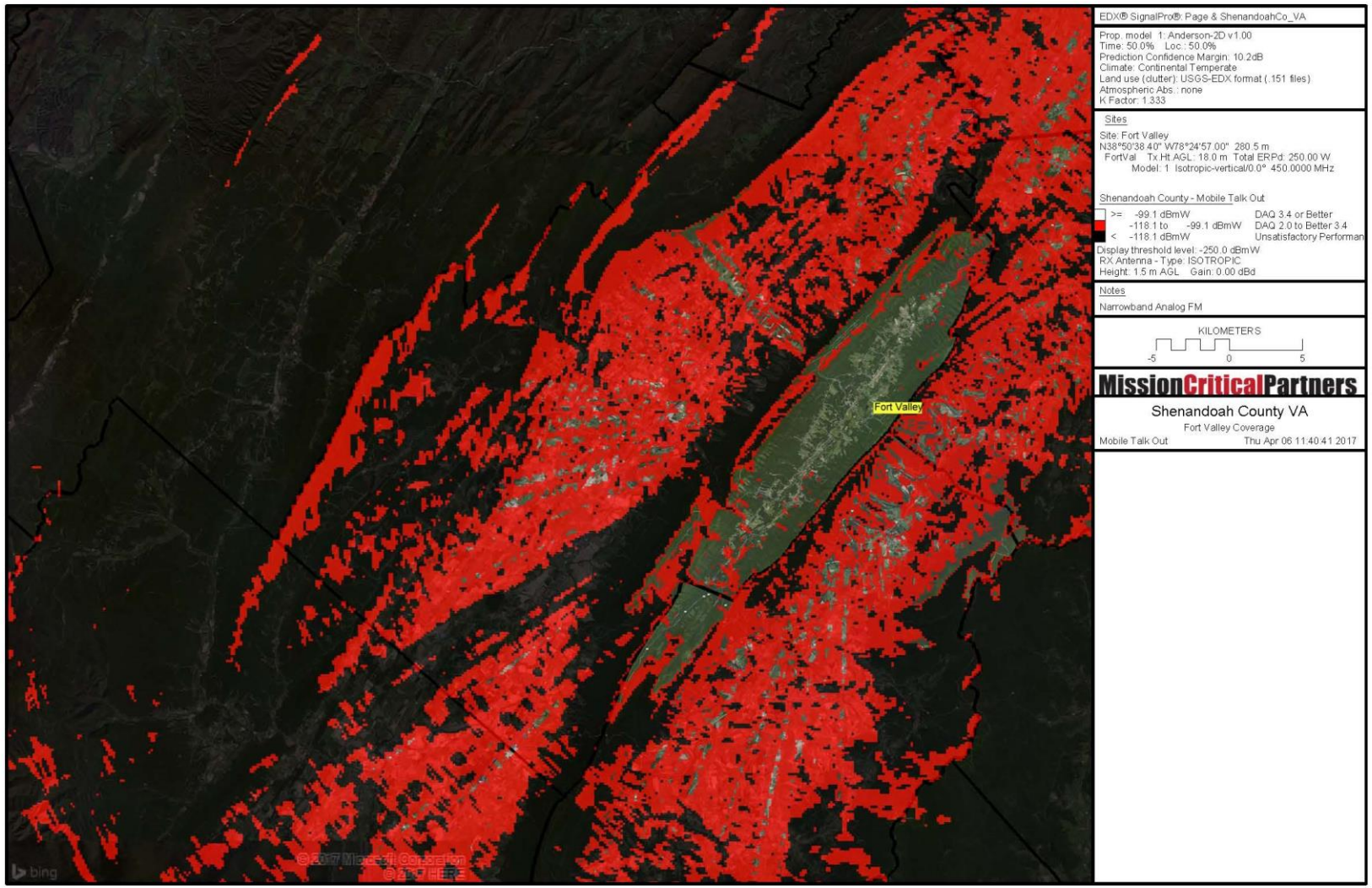
Mobile Talk Out – Zepp Existing Coverage



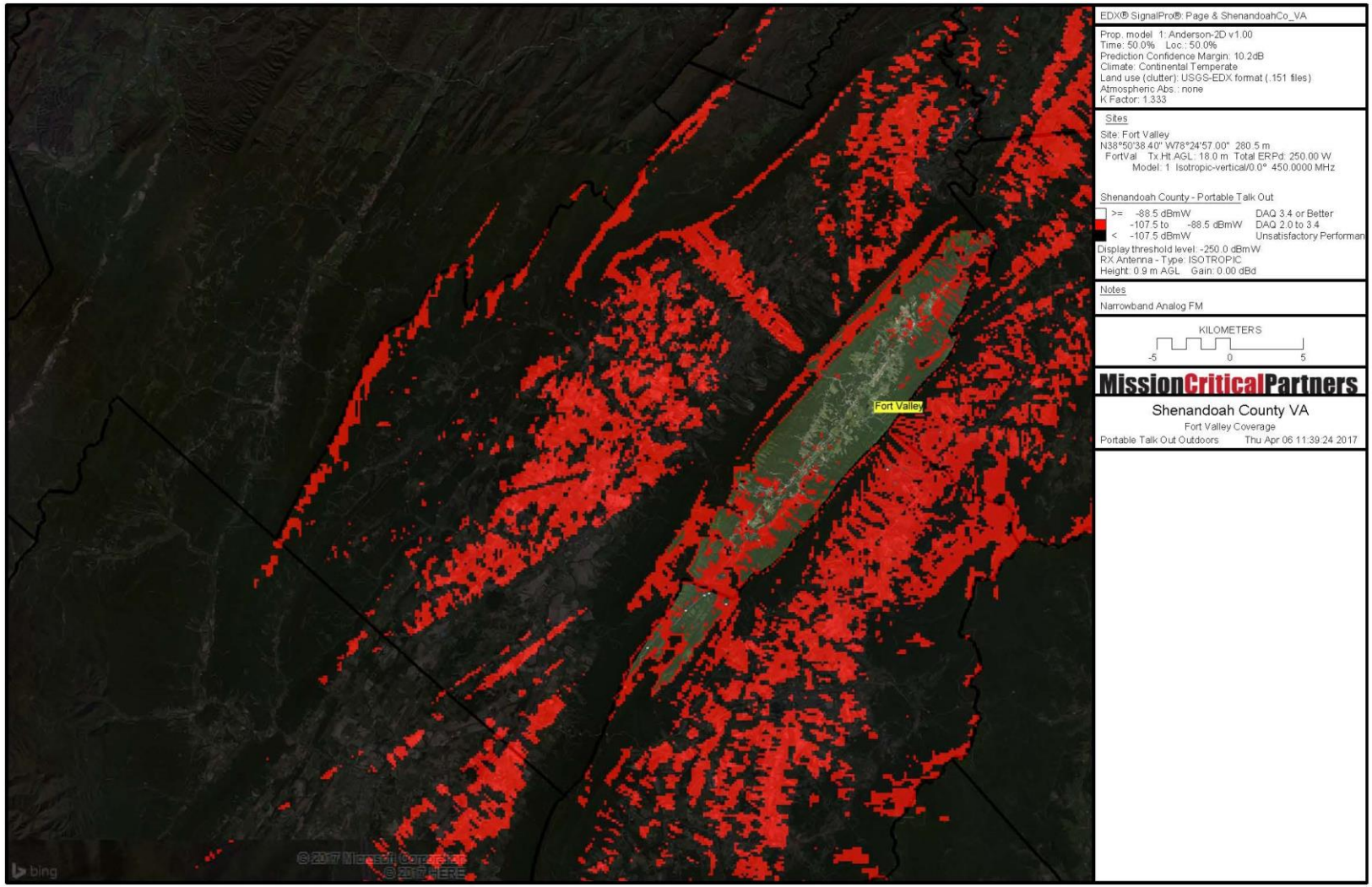
Portable Talk Out – Zepp Existing Coverage



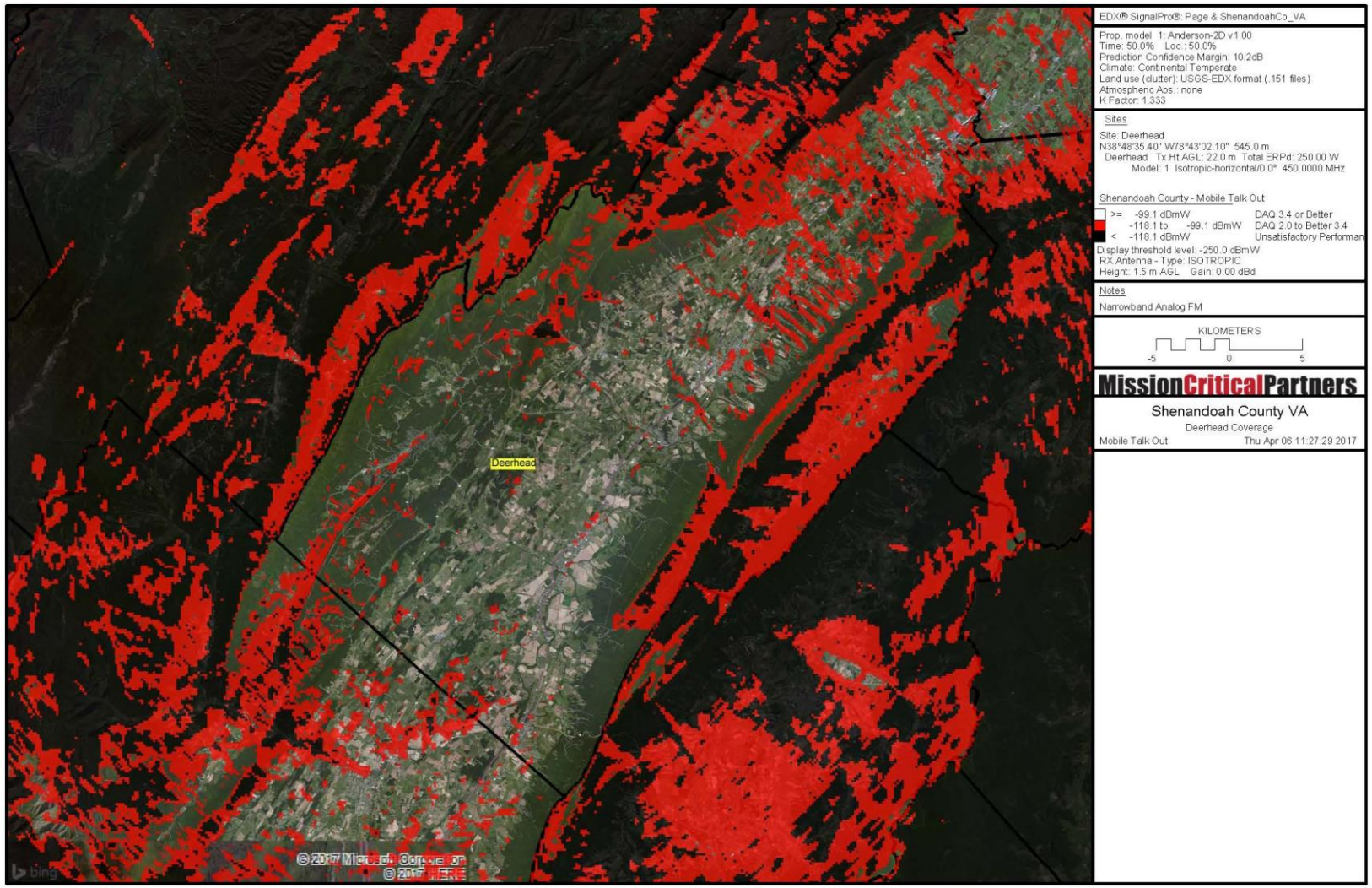
Mobile Talk Out – Fort Valley Existing Coverage



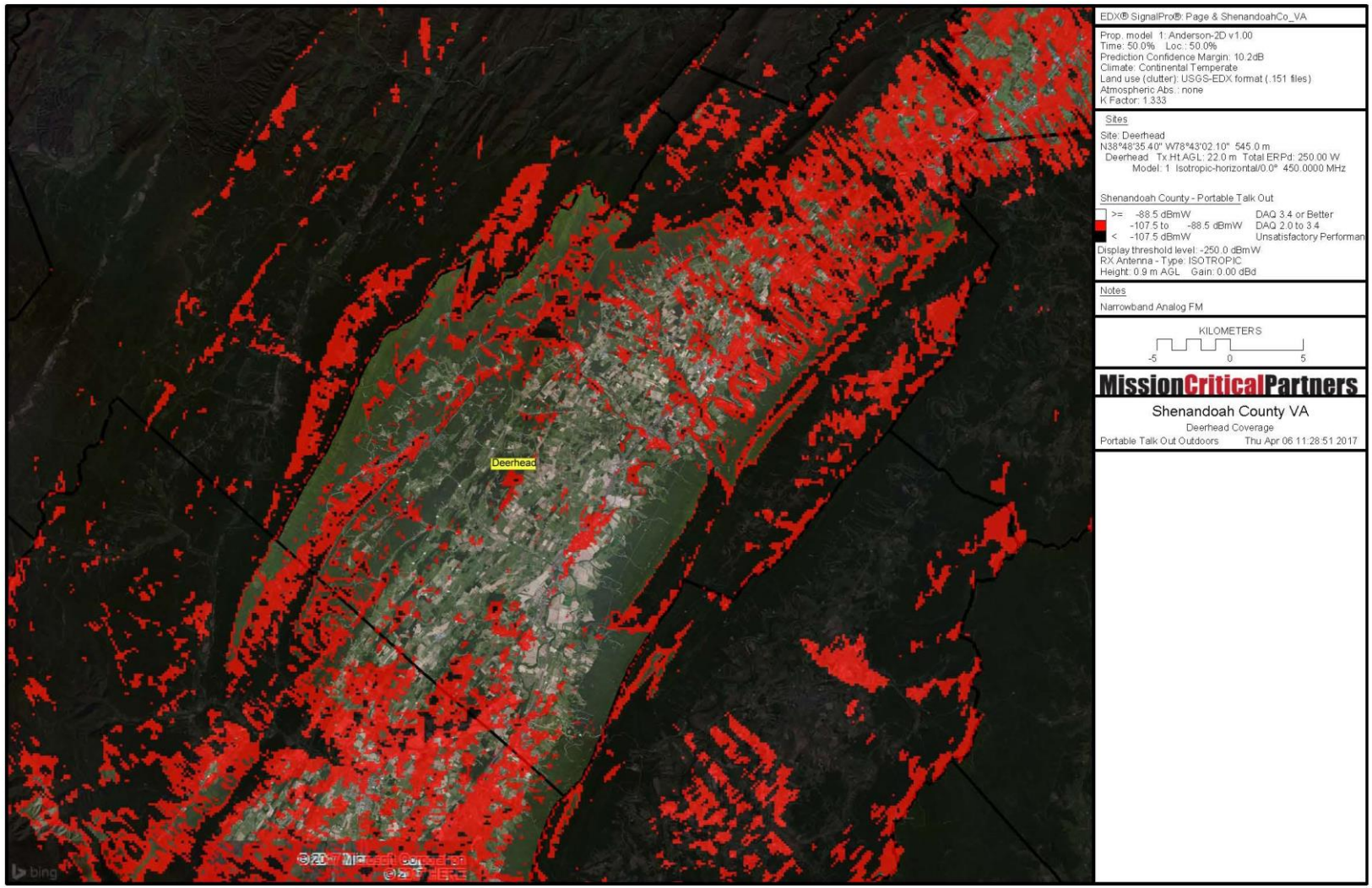
Portable Talk Out – Fort Valley Existing Coverage



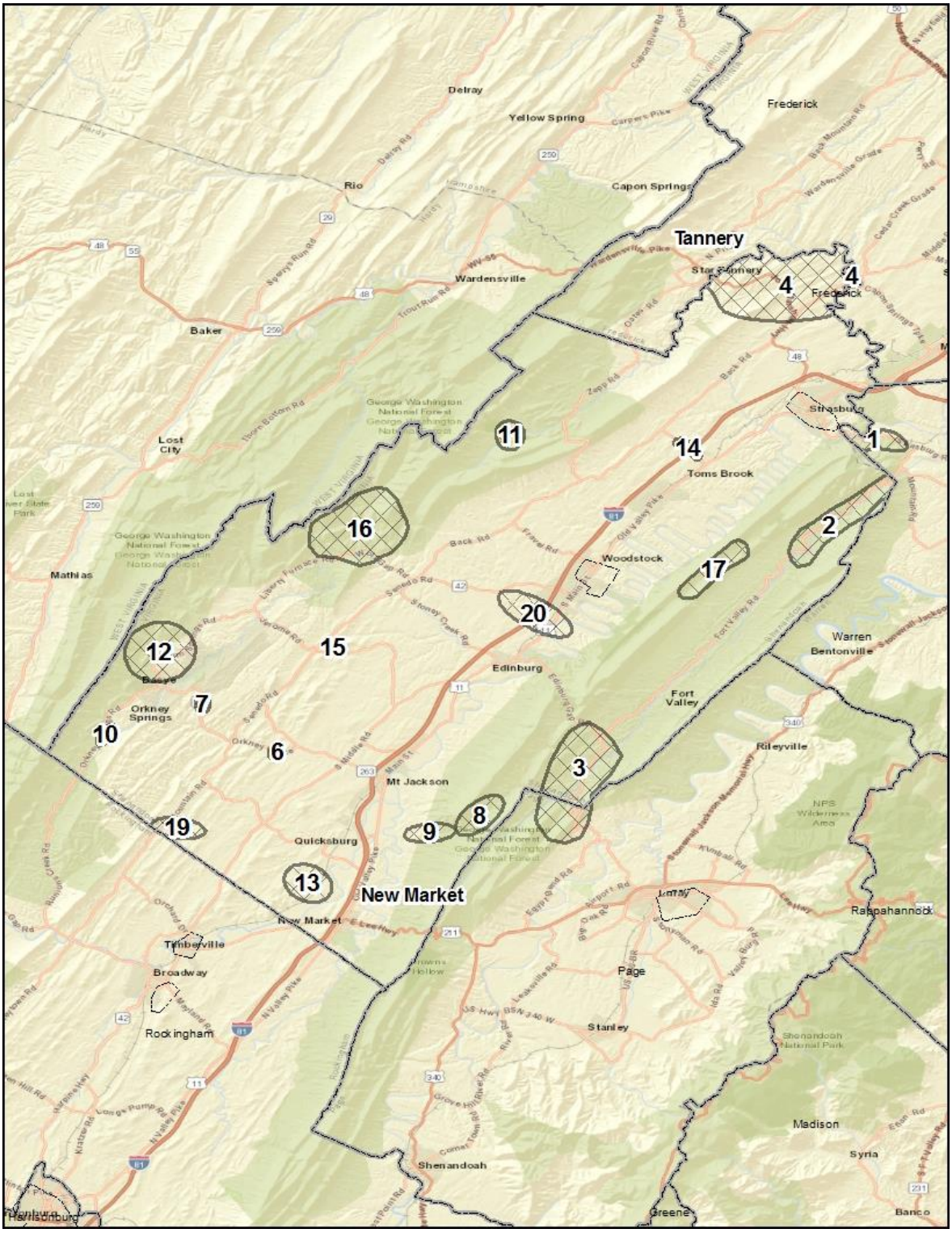
Mobile Talk Out – Deer Head Existing Coverage



Portable Talk Out – Deer Head Existing Coverage



Existing Areas of Poor to No Mobile Coverage Presented by User Group



Appendix C – New Simulcast and Trunking Simulcast System Coverage Maps

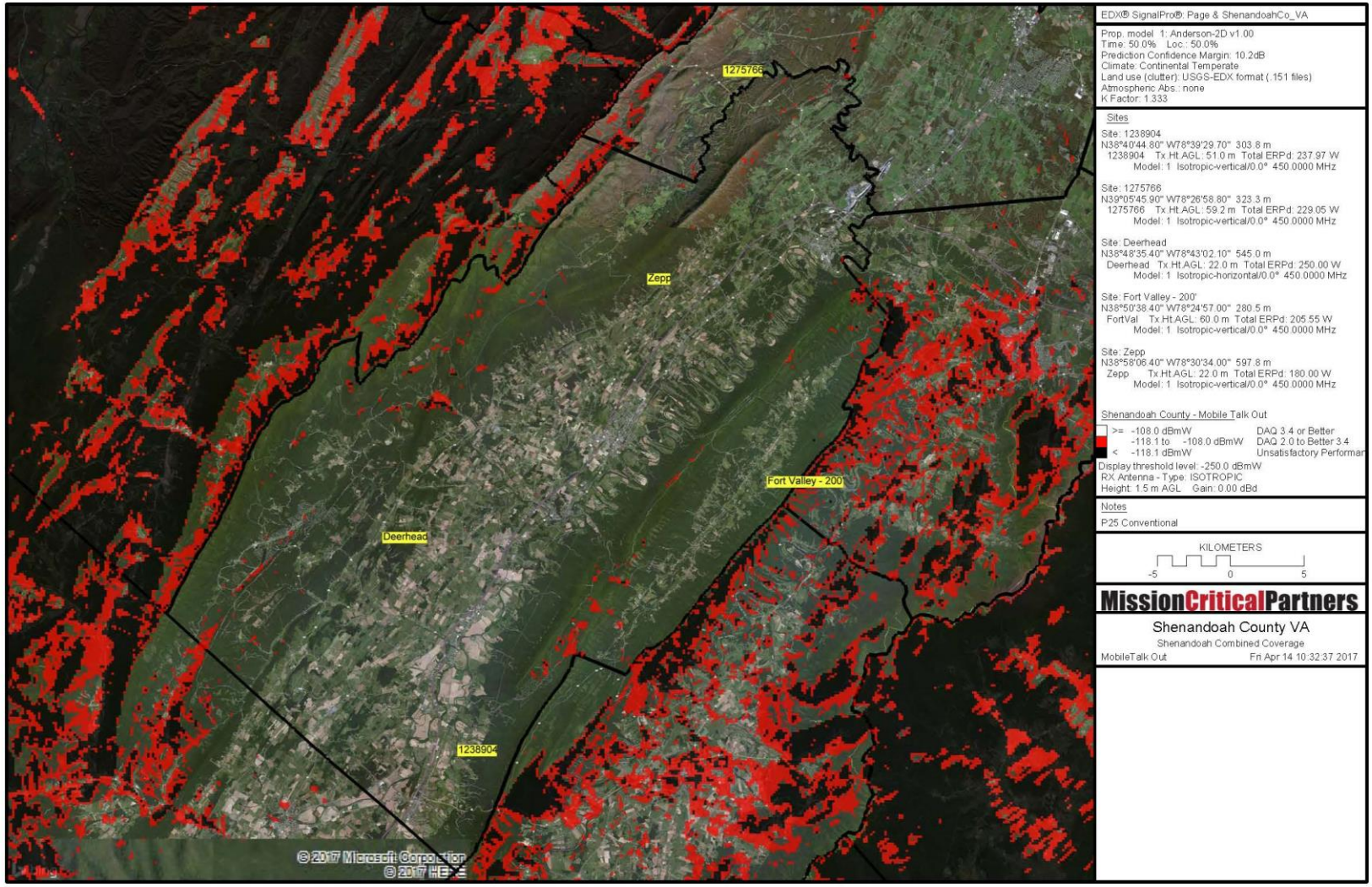
Map Explanation

The first three maps in Appendix C show predicted mobile, portable outdoor, and portable in light buildings coverage on the new five-site simulcast system.

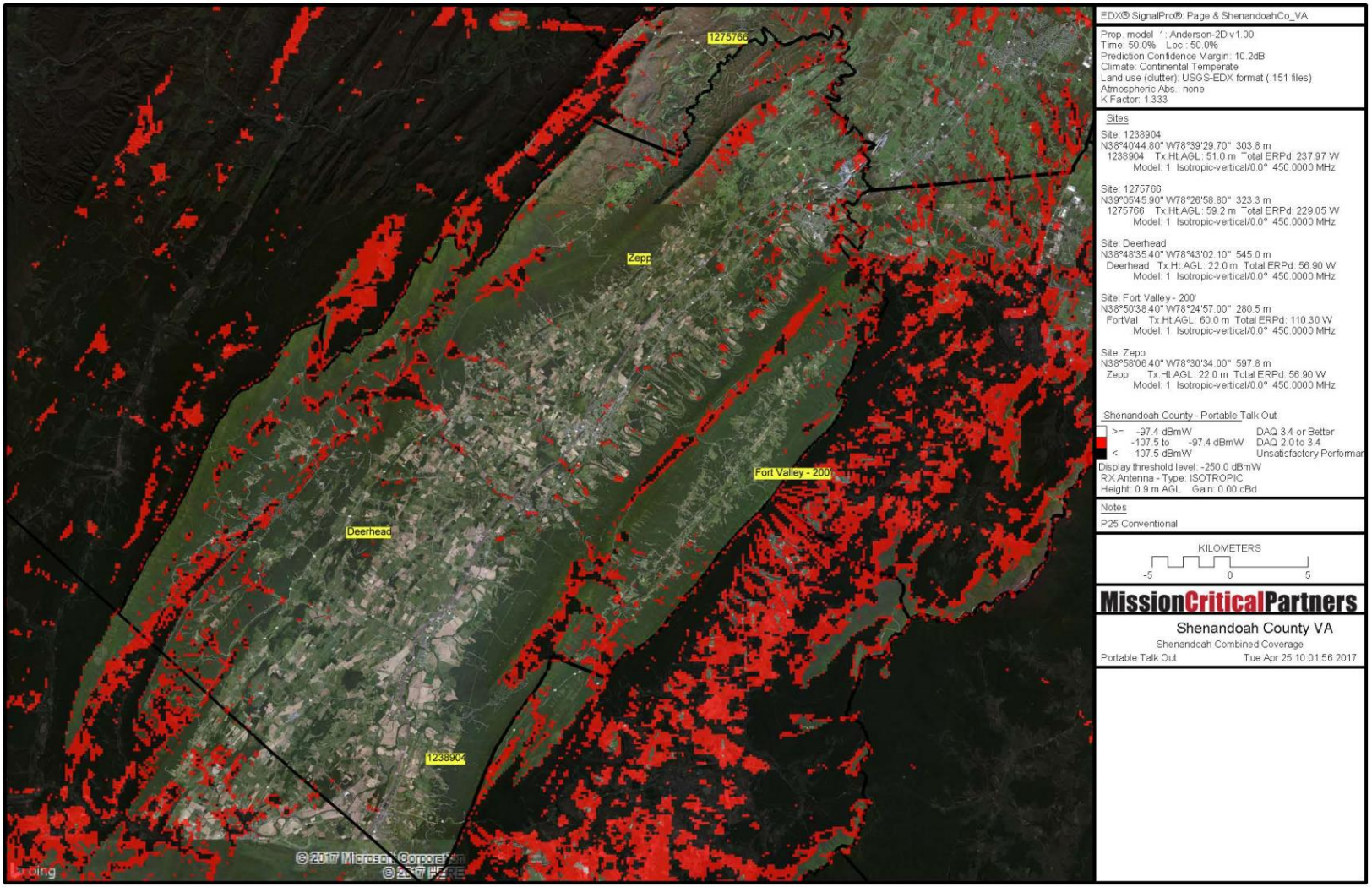
The fourth, fifth and sixth maps provide a side-by-side comparison of existing areas of reported coverage problems to the coverage that would be provided by the new system. They show significantly improved coverage in most of the reported problem areas.

All maps show predicted coverage under a five-site simulcast design.

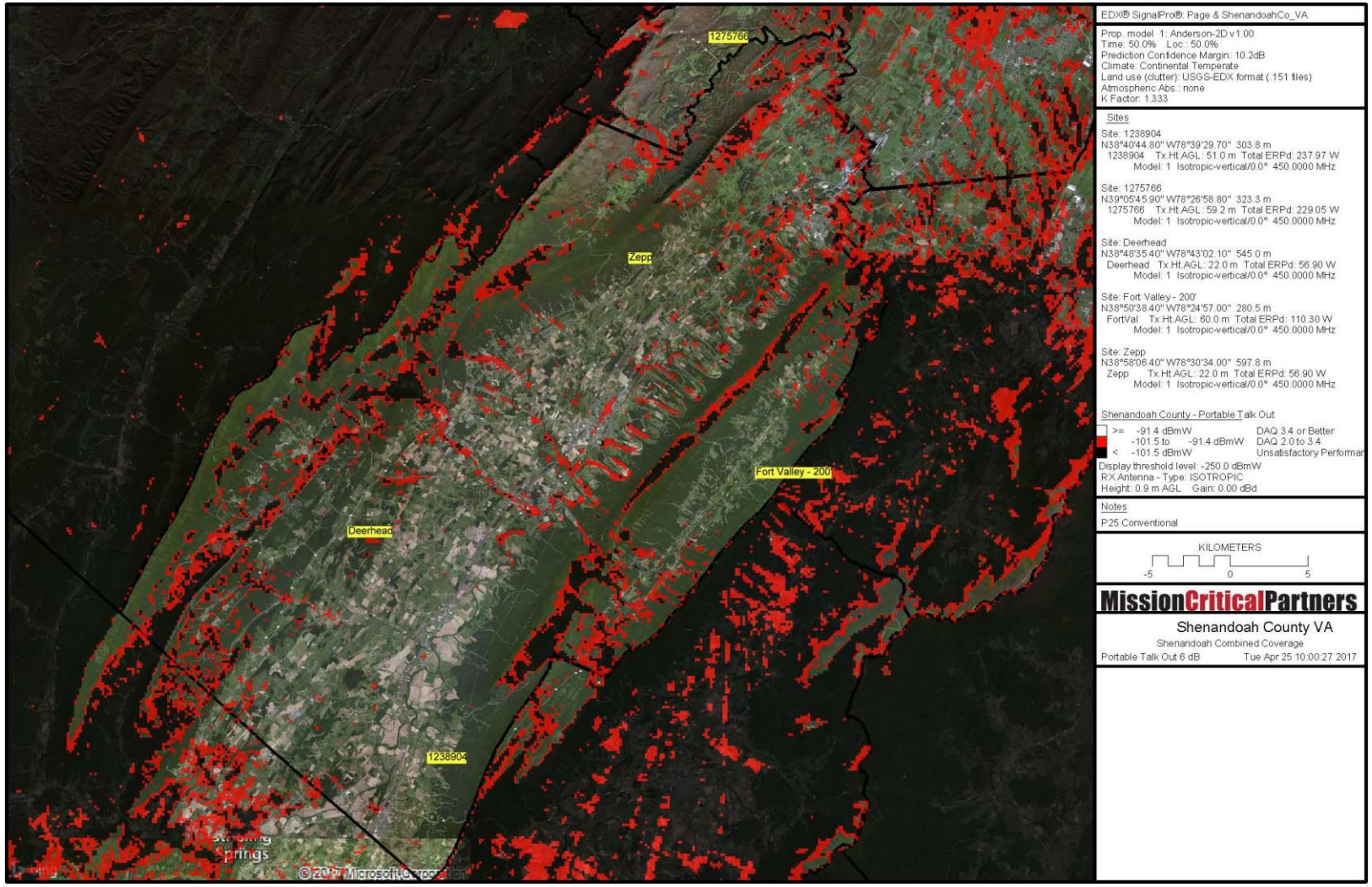
Proposed System Mobile Talk-Out Coverage



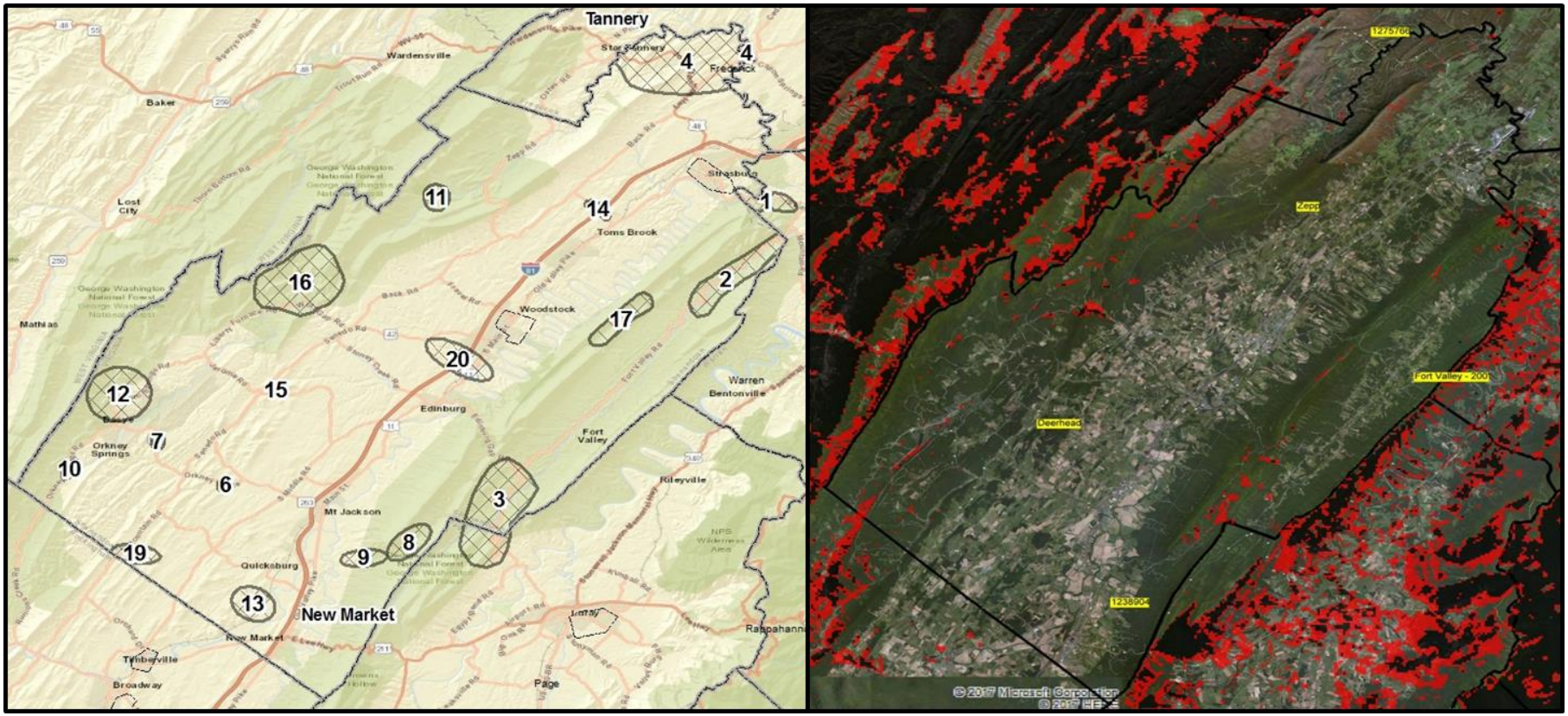
Proposed Portable On-Street Talk-Out



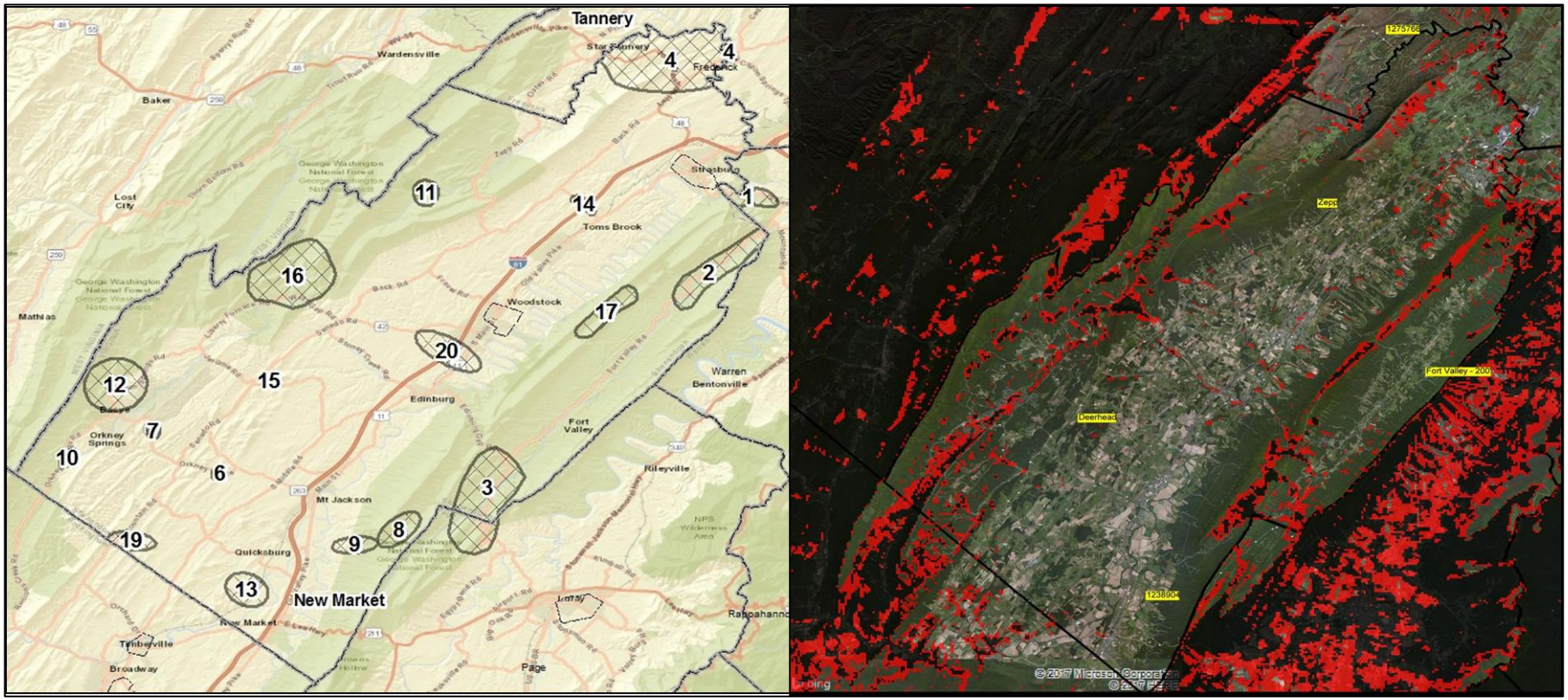
Proposed Portable In 6-dB Building Talk-Out



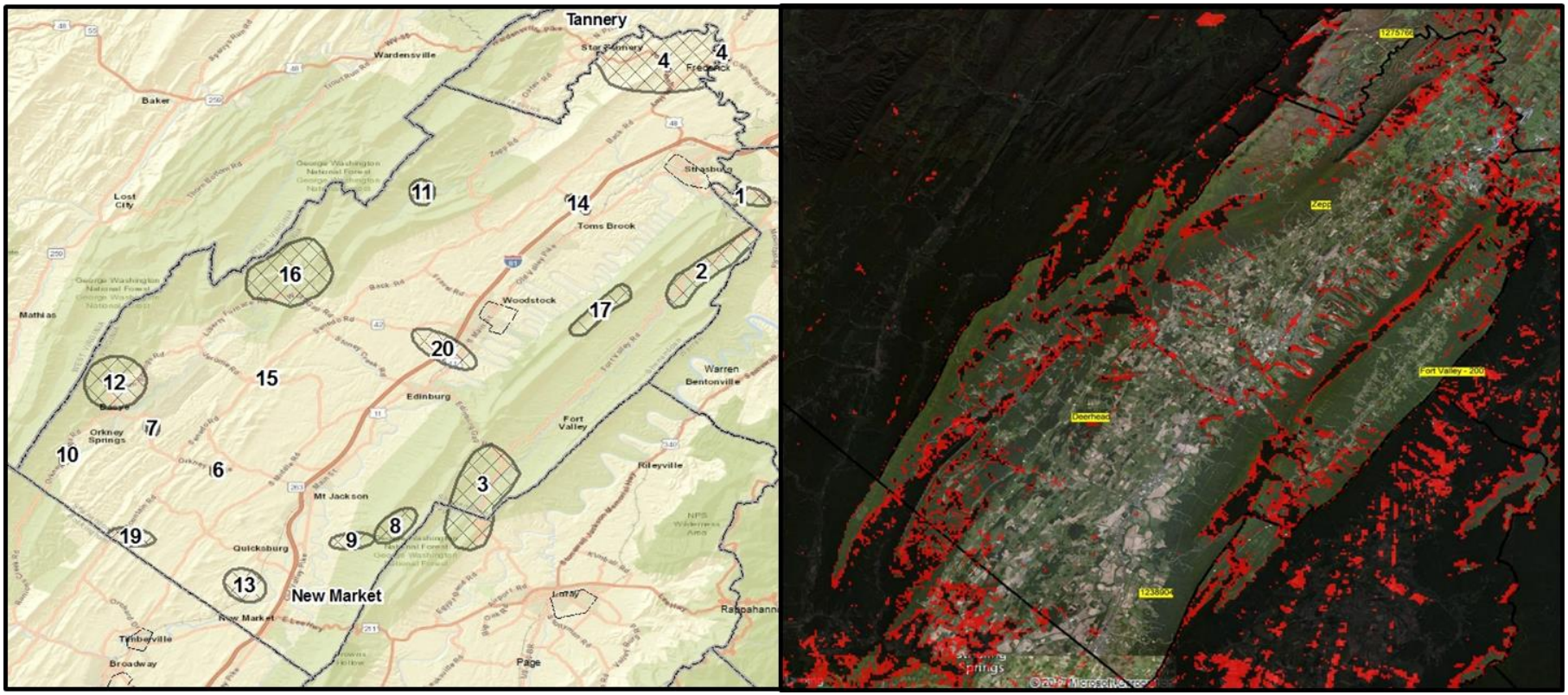
P25 Conventional Mobile Talk-Out – All Sites Proposed



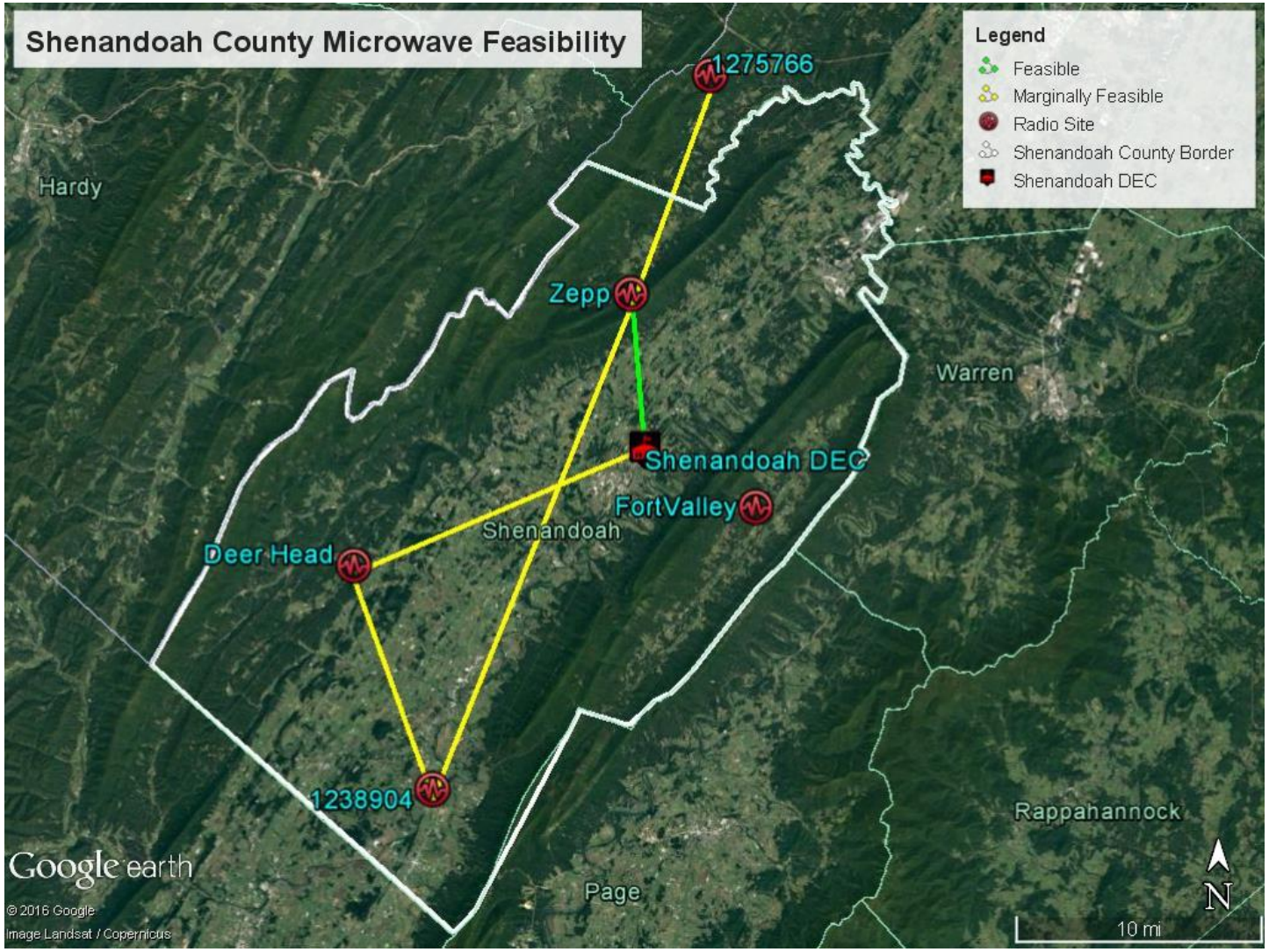
P25 Conventional Portable Talk-Out Outdoors



P25 Conventional Portable Talk-Out 6 dB Buildings



Appendix D – Microwave Paths



Appendix E – Critical Building List

The following table lists building locations that were submitted by public safety agency staff. These are buildings where public safety staff are frequently required to respond to and where past experience has shown that current radio system coverage within these buildings has been unreliable.

Building Name	Address
White Tree Manor	9137 North Congress Street, New Market, VA 22844
Life Care Center	315 Lee Highway, New Market, VA 22844
Quality Inn	162 West Old Cross Road, New Market, VA 22844
Orkney Springs Fire and Rescue	922 Orkney Grade, Basye, VA 22810
Mount Jackson Town Hall	5901 Main Street, Mt. Jackson, VA 22842
Sheetz Travel Center	227 Conicville Road, Mt. Jackson, VA 22842
Shenandoah Memorial Hospital	759 S. Main Street, Woodstock, VA 22664
Central High School	1147 Susan Avenue, Woodstock, VA 22664
W.W. Robinson Elementary School	1231 Susan Avenue, Woodstock, VA 22664
Peter Muhlenberg Middle School	1251 Susan Avenue, Woodstock, VA 22664
Massanutten Military Academy (Lantz, Harrison, Sperry, Riddleberger, Benchoff Halls)	614 S. Main Street, Woodstock, VA 22664
Walmart	461 W. Reservoir Road, Woodstock, VA 22664
Lowe's	1220 Henry Ford Drive, Woodstock, VA 22664
Shenandoah County General District Courthouse	215 Mill Road, Woodstock, VA 22664
Community Theatre	136 N. Main Street, Woodstock, VA 22664
Pleasant View Condos	1282-1292 Ox Road, Woodstock, VA 22664
Skyline Terrace Nursing Home	123 Lakeview Drive, Woodstock, VA 22664
Banks Brothers	932-972 Fairview Road, Woodstock, VA 22664
Shenandoah Co. Circuit Courthouse	109 S. Main Street, Woodstock, VA 22664
McKinney Drilling	173 Lakeview Drive, Woodstock, VA 22664
Dellinger Funeral Homes	159 N. Main Street, Woodstock, VA 22664
New Market Poultry	145 E. Old Cross Road, New Market, VA 22844
Howell Metal	574 New Market Depot Road, New Market, VA 22844
Kennametal	450 New Market Depot Road, New Market, VA 22844
A 4-story Condominium building	1814 Fairway Drive, Mount Jackson, VA 22842
A 4-story Condominium building	1836 Fairway Drive, Mount Jackson, VA 22842
A 4-story Condominium building	1856 Fairway Drive, Mount Jackson, VA 22842
Massanutten Manor	100 Massanutten Manor Circle, Strasburg, VA 22657
Mercury Paper	495 Radio Station Road, Strasburg, VA 22657

Building Name	Address
IAC Complex, Strasburg	
– IAC Plant 1	806 E. Queen Street, Strasburg, VA 22657
– BIG & LIL DS	728 E. Queen Street, Strasburg, VA 22657
– IAC PLANT 3	744 E. Queen Street, Strasburg, VA 22657
– IAC PLANT 4	871 E. Queen Street, Strasburg, VA 22657
R R Donelley	1 Shenandoah Valley Drive, Strasburg, VA 22657
Americold	545 Radio Station Road, Strasburg, VA 22657
All County Schools (public and some private)	
– Charter House School	508 Piccadilly Street, Edinburg, VA 22824
– Triplett Tech School	6375 Main Street, Mount Jackson, 22842
– Shenandoah Valley Academy	234 W. Lee Hwy, New Market, VA 22844
– Sandy Hook Elementary School	162 Stickley Loop, Strasburg, VA 22657
– Signal Knob Middle School	687 Sandy Hook Road, Strasburg, VA 22657
– Strasburg High School	250 Ram Drive, Strasburg, VA 22657
– Ashby Lee Elementary School	480 Stonewall Lane, Quicksburg, VA 22847
– North Fork Middle School	1018 Caverns Road, Quicksburg, VA 22847
– Stonewall Jackson High School	150 Stonewall Lane, Quicksburg, VA 22847
– W. W. Robinson Elementary School	1231 Susan Avenue, Woodstock, VA 22664
– Peter Muhlenberg Middle School	1251 Susan Avenue, Woodstock, VA 22664
– Central High School	1147 Susan Avenue, Woodstock, VA 22664
– Massanutten Military Academy	614 S. Main Street, Woodstock, VA 22664
Fire & Rescue Stations	
– Woodstock Rescue Squad (Co. 5)	132 W. Reservoir Road, Woodstock, VA 22664
– Toms Brook Fire Department (Co. 9)	3342 S. Main Street, Toms Brook, VA 22660
– Woodstock Fire Department (Co. 12)	121 W. Court Street, Woodstock, VA 22664
– Conicville Fire Department (Co. 13)	763 Conicville Road, Mt Jackson, VA 22842
– Fort Valley Fire Department (Co. 14)	7088 Fort Valley Road, Fort Valley, VA 22652
– Edinburg Fire Department (Co. 15)	200 Stoney Creek Boulevard, Edinburg, VA, 22824
– Star Tannery Fire Department (Co. 17)	950 Brill Road, Star Tannery, VA 22654
– Orkney Springs Fire Department (Co. 18)	922 Orkney Grade, Basye, VA 22810
– Mount Jackson Fire Department (Co. 21)	6044 Main Street, Mt Jackson, VA 22843
– New Market Fire Department (Co. 23)	9771 S. Congress Street, New Market, VA 22844
– Strasburg Rescue Squad (Co. 25)	156 E. Washington Street, Strasburg, VA 22657
– Strasburg Fire Department (Co. 51)	163 E. King Street, Strasburg, VA 22657
All Law Enforcement Offices	

Building Name	Address
– Mount Jackson Police Department [same address as Town Hall]	5901 Main Street, Mount Jackson, VA 22842
– New Market Police Department	9418 John Sevier Road, New Market, VA 22844
– Shenandoah County Sheriff's Office	109 W Court Street, Woodstock, VA 22664
– Strasburg Police Department	174 E King Street, Strasburg, VA 22657
– Woodstock Police Department	134 N Muhlenberg Street, Woodstock, VA 22664
County Facilities	
– County Administration Building	600 N. Main Street, Woodstock, VA 22664
– Circuit Court	112 S. Main Street Woodstock, VA 22664
– General District Court	215 Mill Road, Woodstock, VA 22664