WISCOM REPORT

Technical Issues Report, WISCOM Analysis, and Sustainability Plan

"Funding for this study is provided by a grant from the US Department of Homeland Security, and the Wisconsin Department of Justice."

State of Wisconsin

TABLE OF CONTENTS

EXECUTIVE SUMMARY

TUSA Consulting Services, LLC (TUSA), along with their partner Carl, Riggs & Ingram, LLC (CRI), was contracted by the State of Wisconsin's Department of Justice to provide professional consulting/planning services for the development of a sustainable plan that assesses, quantifies and provides prioritized recommendations regarding the current Wisconsin Interoperable System for Communications' (WISCOM) governance, operations, staffing, technology, infrastructure and a sustainable business model.

The project also included developing recommendations to solve the technical issues being experienced by some daily users of WISCOM. The State requested the investigation focus on three specific areas: the City of Greenfield, Sawyer County, and Kewaunee County.

The goal of this document is to provide a strategic and sustainable operations plan for a statewide interoperable radio network that will include an assessment of current staffing, technology, and financial business model; as well as provide recommendations for a plan that will be used by DOJ and its strategic partners as a roadmap towards achieving the mission and vision of WISCOM as stated in the Wisconsin Statewide Communications Interoperability Plan (SCIP). Finally, this document provides recommendations to solve some of the problems affecting WISCOM daily users.

Background

The Wisconsin Interoperable System for Communications (WISCOM) is a shared network that first responders in communities across the state may use to communicate for the daily mission, during a major disaster or large-scale incident. While home rule in Wisconsin allows for local control of communications networks, WISCOM allows for connectivity of those networks when the local network exceed their local resources, while still respecting home rule. The end result is an in-depth communications network that can support local needs, major disasters, or large-scale incidents.

WISCOM is a VHF (Very High Frequency), digital P25 (Project 25) radio network, comprised of 116 sites (per the provided WISCOM network map updated December 2016), that currently supports over 23,000 radios registered on the network to be used in an interoperable situation. The network was initially built to support 95% mobile coverage across the state, while also allowing other agencies the ability to join and enhance the portable coverage with additional sites. The network supports each site with up to four simultaneous conversation paths during an incident, dramatically increasing the current capacity available with statewide mutual aid channels and allowing first responders from any area of the state to assist another community without losing communications capabilities.

WISCOM has faced challenges, many of which are typical of large-scale network implementations. Many of the bad experiences encountered by users have previously been addressed, but negative perceptions may remain. There are also current challenges that WISCOM is facing, including that the network has not been properly funded or staffed the way other states have supported their radio projects.

WISCOM has been a catalyst for many success stories throughout the State, including supporting the Democratic Debates held at the University of Wisconsin – Milwaukee on February 11, 2016. It has also fulfilled its mission of providing interoperable communications when a windstorm took out wireless, landline, and 9-1-1 networks in Bayfield and Douglas Counties. WISCOM was used to coordinate public safety communications activities between and within the counties.

TASK 3 – REPORT AND PLAN TO ADDRESS THE TECHNICAL ISSUES BEING EXPERIENCED BY SOME DAILY USERS OF WISCOM

TUSA Consulting Services, LLC, along with their partner Carl, Riggs & Ingram, LLC, were retained by the State of Wisconsin's Department of Justice to develop recommendations to solve the technical issues being experienced by some daily users of WISCOM. As part of their investigation, TUSA Consulting Services was asked focus on three specific areas identified by the state: the City of Greenfield, Sawyer County, and Kewaunee County.

Investigation Methodology

TUSA conducted a comprehensive investigation into the problems affecting the City of Greenfield, Sawyer County, and Kewaunee County. As part of our investigation, TUSA utilized our proprietary approach we call the three I's: Investigate, Interview, and Inspect. By using this approach, TUSA was able to fully document and understand each problem that was revealed and how they may be connected.

During the investigation stage, TUSA collected all the information that Wisconsin had on its existing network. This included call volume report data, FCC licenses, site coordinates, alarm reports, hardware and software revisions, and optimization data. We then cross referenced this with information provided by the manufacturer, in this case EF Johnson, and from data we collected from the FCC licensing database. This allowed us to identify some problems before starting the other stages.

For example, when investigating the PTT report data, we noticed there was an anomaly in the data. The Deerfield site showed in line 365 of the data that the number of airtime seconds is 21820. In the channel plan, it shows Deerfield as having 5 channels. Taking four of those channels (one is allocated as control) times 3600 seconds per hour, it results in a total capacity of 14400 seconds. Thus the data is showing that site is using over 151 percent of its actual capacity. We shared this with EF Johnson and they agreed the data looked unusual. Their team concluded it appears something significant changed about 7/20/16 with the average call length taking a significant leap upwards about one month later.

During the interview stage, TUSA felt it was important to talk to the user community, the state, and EF Johnson. For the user community, TUSA distributed an online questionnaire to the users in the City of Greenfield, Sawyer County, and Kewaunee County. The online questionnaire asked basic questions about what users liked and did not like about the WISCOM network. It also asked them about coverage and other problems radio users may be experiencing. In total, TUSA received only twelve (12) surveys. While we would have preferred to have received a larger sample, TUSA was able to collect enough information to render an opinion, based on the strength of the interview with state staff.

TUSA also requested phone interviews with the user communities, but because of resource constraints, the Department of Justice was unable to accommodate this request. As a workaround, TUSA followed up via email with the twelve (12) respondents. TUSA also had a lengthy conversation with state staff and they were very candid about the problems radio users were experiencing. TUSA also had a conversation with David Spenner and Larry Emmett of EF Johnson, which was very good in understanding the history of the project from the vendor's perspective.

Finally, during the inspection stage, TUSA visited the sites that serve the City of Greenfield, Sawyer County, and Kewaunee County. We requested that the State have their technical staff (or a local service shop) perform a preventative maintenance service to allow verification of proper operation of these sites. A list of tests were provided by TUSA and understood by the state's technical staff to be performed at each site. During the preventative maintenance service, Tusa Consulting also performed its own inspection, and reviewed alarm reports, as well as performed radio operations on the respective sites.

This was beneficial because we were able to replicate some of the problems the user community and State staff revealed during the interview stage. For example, in Kewaunee County we were able to replicate the missed call issue. We heard the call on one radio, but it was not received on another radio. EF Johnson personnel witnessed this event and provided detailed call and site data to their corporate technical engineering staff for investigation.

Problems Identified by Users

TUSA Consulting Services reviewed the responses received by the User Community in the City of Greenfield, Sawyer County, and Kewaunee County. The complete set of user responses can be referenced in Appendix A. After reviewing the data, there were four issues that seemed to be consistently apparent – coverage issues, missed transmissions, training issues, and capacity issues. There were other issues noted such as, poor quality radios, poor scanning between analog conventional and trunked digital transmissions, and lack of dual band solutions, but those comments were infrequent.

Coverage Issues – Coverage is the most important aspect when designing a radio network, and without adequate coverage it prevents the first responder from being able to reliably complete his or her mission critical job. Coverage was the number one complaint of all the users that responded to the survey. Sawyer County characterized the overall coverage as poor to moderate, with many complaints about the inability to talk in buildings. Kewaunee County stated they have poor portable radio coverage and the situation threatens the safety of their police officers and firefighters. The City of Greenfield stated that there are some dead areas within the city.

Not everyone was critical on the coverage. The town of Hayward Fire Department said locally, coverage is good, and they are impressed with how well the portables work. Hayward Fire also mentioned that while coverage is good for them, they are aware of some coverage issues countywide, and would recommend that WISCOM identify the areas lacking good coverage and improve it. The City of Algoma also characterized the coverage as being ok.

Missed Transmissions – Another complaint of the users was missed or partial communications. A majority of this seemed to center around the users in Kewaunee County. Casco Fire Department complained about missing radio messages from other users, as well as receiving garbled messages. Luxenburg Rescue also complained of missed transmissions.

Training – Training was another problem identified by WISCOM users. One user in Sawyer County stated not all radio users know how to operate their radio. Another said training in the beginning was almost non-existent, except for watching a video that seemed more like why someone should join WISCOM. Another user

in Sawyer recommended that the State should help users understand the limitations of WISCOM, which points to training. The City of Greenfield also reported there was no formal training. In Kewaunee, one user stated Radio technology has become too advanced, especially for the volunteer firefighter who may use a radio once per month, or even once a year for that matter.

Capacity – Another issue brought up by the user community is a perceived capacity issue. The City of Greenfield stated their users are experiencing bonking. Kewaunee County stated when an incident with multiple agencies occurs, it is almost impossible to connect to the system and talk.

Problems Identified by State's Technical Staff

On September 02, 2016, TUSA conducted a conference call with State staff to discuss the problems with the City of Greenfield, Sawyer County, and Kewaunee County. While the purpose of the call was to talk about problems for those three areas, there was some bleed over into problems experienced throughout the State. The problems were broken up into multiple categories.

Base Station Issues – One area of concern for the state was with the EF Johnson base stations. A base station is a combination of a radio receiver and radio transmitter that takes incoming transmissions and rebroadcasts them at a higher power. The majority of the base stations that were installed at WISCOM sites are the older 3800 base stations. The state staff were concerned that those base stations might be approaching end-of-life. EF Johnson announced on November 30, 2016 that the 3800 series base station was at end-of-life (See Appendix C).

The state staff also identified issues with the newer 4100 and 4200 series base stations. These base stations often give the wrong readings and the state has observed a high failure rate with them. One of the biggest concerns with these base stations is the digital boards struggle to sync with each other and there is a lot of jitter causing high mod fidelity (the degree of closeness to which the modulation follows the desired ideal theoretical modulation). This caused EF Johnson to implement an external timing source to these base stations to stabilize their technical operation.

The state staff also discussed how the 4100 base station seemed to cause compatibility issues with certain types of subscriber radios. For example, the Tait 9400 would not register with the 4100 series repeater due to high mod fidelity. The Kenwood radios would engage in excessive background hunts for other sites, and sometimes even lose contact from the sites with the 4100 base station. This did not happen with the 3800 base stations.

A majority of the base stations deployed throughout Wisconsin are the older 3800 base stations. Sawyer County is using the 3800 base stations. In Kewaunee County, West Kewaunee is using the 3800, but the Algoma and Luxenburg sites are using the 4100 base stations. The City of Greenfield is using the 3800 MHz base stations for control channels at the 800 MHz site, and the 4100's for voice channels with a Spectracom oscillator to help with stability of the base stations. Initially five 4100 base stations were installed at the 800MHz site, but the state had to reinstall two 3800 base station repeaters in place of the 4100 to stabilize the control channels at the site and resolve the radio subscriber issue described. All the VHF channels are using the 4100 base stations for the site at Greenfield.

Finally, the state staff communicated that they are still waiting for complete technical documentation from EF Johnson on the base stations. This includes information on how to properly align and tune them. As of the time this report was written, the state has informed TUSA they have not received this information.

Network Management System (NMS) Issues – The technicians were concerned about the NMS and identified three problems that needed to be addressed. The first is the NMS is constantly getting bogged down. The state staff discussed concerns that the computer may not have enough processing speed, or the network may not have enough bandwidth to support the connectivity between the primary and secondary NMS. The second issue is the NMS sometimes displays inaccurate statuses. The third issue is a redundancy issue, including problems with the primary and secondary units. The state has been communicating this to EF Johnson, but the state said EF Johnson has been slow in providing any resolution.

One other problem the state staff identified was concern whether the radio alarms were reporting accurately to the NMS. Multiple false alarms were being experienced that led the technical staff to quit looking at the alarm network due to the false alarms taking up too much technical time for review.

Training – The technicians said there was concern over the lack of technical training. The original training was performed in 2012 in Texas. The state said the instructor skipped around to different topics. The class was really hard to follow, and there was no agenda. For example, the instructor would be talking about a topic on page 32 and would tell them to turn to page 64 and would start talking about a different topic.

Missed Transmissions – The state staff were also concerned about missed transmissions. For example, sometimes a call makes it to one site, but not to other sites that had radios logged into the same group. The state reported that EF Johnson has been troubleshooting this issue with data sniffers at respective sites, but it has been difficult working with EF Johnson trying to diagnose the problems.

Problems Identified by TUSA Consulting Services

During the week of September 19, 2016, TUSA senior consultants Bob Sutphen and Dean Hart were on hand to witness the optimization and preventative maintenance being performed on the sites serving the city of Greenfield, Sawyer County, and Kewaunee County. TUSA had requested this work after seeing a lot of state owned sites not following best practices. TUSA's consultants became concerned when the state did not have any preventative maintenance documentation or site baseline optimization information.

The WISCOM technical team conducted the tests at the Greenfield, Kewaunee West, Hayward, and Meteor Sites. Bay Electronics performed the tests at the Kewaunee East, Luxemburg and Algoma sites. Duluth Superior Communications performed the work at the Pipestone Site.

Prior to arriving on site, TUSA submitted a test document to WISCOM for review and approval (See Appendix B). After observing the tests and reviewing the data, along with our own physical inspection of the sites, TUSA has discovered a series of problems that can be categorized into four areas – Installation issues, Optimization issues, Intermod issues, and FCC issues. A complete and detailed report of our findings can be found in Appendix D.

Installation Issues – A lot of the sites that TUSA observed did not follow industry best practices when it comes to installing site equipment. This theme is part of a larger systematic problem TUSA discovered when visiting other WISCOM sites throughout the state (See Appendix E). When installing equipment in racks, the installer should have followed an industry standard, such as Motorola's R56[1] manual, or a standard proposed by EF Johnson.

Optimization Issues – All of the sites TUSA reviewed had not been properly optimized and no periodic Preventative Maintenance (PM) had been performed. The State also did not have any documentation to show an optimization baseline for network performance. The actual optimization that took place while TUSA was present showed a lot of problems, including receiver multicoupler bandpass filters not set to their correct values, transmitter outputs not set to the correct ERP, and transmitter combiner filters not tuned to the center frequency. The PM also revealed a bad Tower Top Amp at Greenfield, and transmission line connectors at Pipestone not properly mated to the transmission lines.

Intermod Issues – A number of sites experienced intermodulations that can cause degradation on both transmitters and receivers. Intermodulations can be caused from two or more transmitters generating a secondary frequency that is the same, or close to one of receive frequencies causing receiver desensitization, or on one of transmit frequencies causing distortions on that frequency.

Another type of intermodulation not directly generated from the five transmit frequencies is caused by Passive Intermodulation (PIM). PIM is a non-linearity product found in radio frequency assemblies. Additional testing is required to determine the root cause of the problem. Causes of PIMs can occur due to: 1) loose connectors; 2) faulty jumper cables, filters, and antennas; 3) bad solder joints and 4) ceiling grids, rusty rebar in concrete, and rusty bolts in the building structure[2].

While not required as part of our scope of work, TUSA conducted an intermod study on Kewaunee East to see if there are indeed intermod issues. The transmitters at this site had intermod hits on 155.370, the intercity frequency, the mutual aid 155.475, and the paging frequency. This engineering analysis provided and demonstrated an intermod problem (See Appendix D).

FCC Issues – There are several FCC issues that were discovered. A lot of the sites are not optimized to the correct effective radiated power (ERP) that is listed on the FCC license. In one case, the site is potentially transmitting in violation of FCC regulations because the FCC license is for 15 watts and the ERP out of the antenna is 62 watts. This potential violation could result in the state, or site owner, incurring fines of up to $10,000 a day. Also, during our table top comparisons of the sites' frequencies to the applicable FCC licenses, there were some variances that arose at each of the sites.

[1] Motorola, Standards and Guidelines for Communications Sites, 68P81089E50-B, 9/1/05

[2] Passive Intermodulation, Bird Systems/Applications Engineering, www.bird-technologies.com

The following are our recommendations, budget, and timeline for addressing the problems associated with the City of Greenfield, Sawyer County, and Kewaunee County. Some of the budgetary numbers presented are based on what TUSA has seen other clients pay for similar services, but we recommend the State consider competitive bid for these services from a detailed specification. Also it should be pointed out that TUSA has presented options as part of the overall sustainment of the network, and those options are different than what is listed here. TUSA recommends that the State focus on fixing the problems of WISCOM throughout the state, and not just these three specific areas.

Issue #1 - Coverage

Proposed Solution: To address coverage shortfalls, TUSA recommends that the State of Wisconsin perform a coverage study analysis on the current statewide radio network to identify which areas would benefit from adding a site. It is reasonable to assume that if the City of Greenfield, Sawyer County, and Kewaunee are experiencing coverage issues, so are other users in the state. Consideration should be given to enhancing portable coverage in urban areas, as well as mobile coverage for daily users traveling across their regions. After this analysis has been conducted, the State of Wisconsin could then address the coverage problems affecting WISCOM users by adding additional sites. However, being interference free and having an optimized network to the approved FCC licenses are key components to ensure coverage enhancement sites are truly needed.

Budgeted Cost: There are two components here: the cost of the study and the cost to add sites. A single site coverage modelling with plots depicting mobile and portable on-street/in-building coverage would run about $1,500-1,800 per site. The cost to add sites ranges, according to the challenges of the site location. For example, EF Johnson has given us a budgetary number of $290,000 to add equipment for a five channel multicast site, co-locating on an existing tower and using an existing shelter. If the site involves construction of a new site from the ground up, the budgetary costs would be around $663,000 for the tower, shelter, generator, and other costs.

Estimated Timeline: The study should be able to be completed within 30 days after receiving all necessary site information from the State of Wisconsin. The timeline to add a new site is a little more complicated depending on whether it is a construction of a new site from the ground up, or a co-location. EF Johnson has stated that once they have a purchase order they can add a new co-located site in 26 weeks, and a construction of a new site from ground up in 34 weeks. Again, the frequency plan must be in order and sites optimized, to the approved FCC licenses, to ensure coverage predictions are accurate.

Issue #2 – Missed Transmissions and Dropped Calls

Proposed Solution: EF Johnson has reported to us they are actively looking at the dropped call issue. A dropped call can occur due to issues at different areas of the infrastructure such as the network, RF or application. EF Johnson is currently working on a few specific areas that will help narrow the issue down and allow them to pinpoint whether these issues are caused by network or RF-related root causes. In addition, EF Johnson will work with the WISCOM techs to be able to capture more detailed network traffic data (using existing WISCOM troubleshooting servers/sniffers) during these scenarios, so it helps in narrowing down the

missed calls and messages if they are indeed traversing the network. In parallel, EF Johnson would also strongly recommend that the State perform an audit of the network, with support from EF Johnson that allows them to evaluate the core infrastructure of WISCOM on top of which the ATLAS infrastructure resides. This will help them isolate the issue and resolve it.

Budgeted Cost: There is no cost for EF Johnson to look into this issue. Please refer to Issue #7 for the cost to perform the Health Check, which includes the network audit.

Estimated Timeline: On December 08, 2016, EF Johnson gave TUSA an update and said they will understand the timeline once the engineering team receives wireshark captures and other troubleshooting data to analyze and identify the root cause of the problem. This has been in process since August 2016.

Issue #3 – Capacity

Proposed Solution: The State of Wisconsin should conduct a statewide traffic analysis and load study to see what areas would benefit from having additional capacity added. TUSA is concerned that major new users are being added, like State Patrol, without an evaluation to see if the network can handle the call capacity. After the traffic analysis has been conducted, the State should consider adding new channels (based on frequency availability) to those areas identified in the study. Some of the reported bonking or channel availability could also be the result of users not gaining access to the network because someone is currently occupying a talkgroup. This would be addressed with proper training (See Issue #4).

Many WISCOM sites have analog gateways that allow conventional VHF to directly patch to the digital trunked radio network. These gateways provide some levels of interoperability and the ability for WISCOM users to scan other VHF conventional radio channels. However, this may have not been planned in the channel counts for the sites affected and can cause busies or channel loading issues on sites. This would need to be addressed as part of the traffic analysis and load study.

Budgeted Cost: A typical traffic analysis and load study can be performed by a consulting firm with accurate reports from the network management system. The costs for the analysis and report from the consultant would be estimated at $50,000 for the entire state review. Adding a new 4500 base station (including software license and installation) costs around $45,700, however this product will not be released to the general public until September 2017.

Estimated Timeline: A typical traffic analysis and load study should be able to be completed within 60 days after receiving all necessary and accurate reports for the site information from the State of Wisconsin. The typical time for installing a new base station is 18 weeks from the time the purchase order is issued, based on the assumption that a site is ready for the new equipment.

Issue #4 – Training

Proposed Solution: The original Memorandum of Understanding (MOU) between OJA and DOT: Section 2.3 states “OJA will provide for outreach and training to user agencies and local units.” TUSA recommends that the state dedicate a staff member to oversee all aspects of training. In addition, we recommend that the state explore video training. Video training allows users to access videos 24 hours a day, 7 days a week, and the videos can be viewed anywhere, including smart phones, tablets, and mobile data terminals. The other

advantage with training videos is it's a controlled message, meaning that everyone in the state receives the same message. It also protects Wisconsin from a liability perspective, because no one can claim they have not been trained on a particular issue covered in the video.

Budgeted Cost: The cost to produce training videos widely varies. The Commonwealth of Pennsylvania paid $54,000 to have videos produced that covered three of their subscriber devices. Based on our knowledge, a firm with experience producing public safety videos would probably charge around $120,000 to $150,000 to develop videos on every model of radio that Wisconsin has deployed. This would also include updating the overall WISCOM video, and producing several fleetmap videos.

Estimated Timeline: A project of this size should be able to be completed within 120 days.

Issue #5 – Base Stations (3800, 4100, 4200)

Proposed Solution: EF Johnson announced on November 30, 2016 that the Atlas 3800 repeater was at end-of-life, and the company has no plans to maintain software releases or bug fixes on this product. In addition, EF Johnson can no longer guarantee continued availability of parts, components and full units for repair and replacement of these components. This is a significant development that affects the WISCOM network. In addition, EF Johnson stands behind the performance of the 4100 and 4200 repeaters.

In discussions with EF Johnson, they have developed a new repeater, the ATLAS 4500. The ATLAS 4500 will replace the 2600, 3800, 4100 and 4200 repeaters. The ATLAS 4500 is fully backwards compatible with WISCOM's infrastructure and is a drop-in replacement for existing repeaters. EF Johnson is proposing a hardware refresh plan to the State that will gradually replace existing repeaters with the ATLAS 4500. The hardware refresh guarantees that EF Johnson can continue to support the WISCOM network as equipment becomes obsolete.

Budgeted Cost: EF Johnson has provided TUSA Consulting Services with a proposal for network upgrade, maintenance, and support (See Attachment G). The cost for doing the hardware refresh is as follows:

Date	HW Refresh w/Hardware Care
2018-19	$ 2,101,397.69
2019-20	$ 2,104,139.75
2020-21	$ 2,086,623.99
2021-22	$ 2,140,768.38
2022-23	$ 2,190,698.73
2023-24	$ 2,317,120.29
2024-25	$ 2,317,120.29
2025-26	$ 2,317,120.29
2026-27	$ 2,317,120.29

Estimated Timeline: In the schedule above, EF Johnson would replace all 3800, 4100, and 4200 repeaters by 2027.

Issue #6 – NMS Issues and Alarms

Proposed Solution: EF Johnson plans to address WISCOM issues regarding the NMS. Specifically, EF Johnson plans to address current issues with the implementation of radio check and radio inhibit operation, as well as enhancements to the alarming and reporting capabilities through the NMS. In addition, EF Johnson's long-term roadmap includes re-architecting the NMS to be more suitable for large-scale operations such as WISCOM.

Budgeted Cost: No cost associated with correcting this.

Estimated Timeline: EF Johnson plans to provide a NMS patch within the next 60 days to provide fixes for certain mobility issues. For the other NMS issues, EF Johnson plan to include those fixes in their next major release 17.1, scheduled to be released during May – June 2017.

Issue #7 – Installation and Optimization Issues

Proposed Solution: TUSA recommends having EF Johnson perform a health check on the WISCOM network. This will baseline the condition of the entire network and confirm that all sites are performing within specifications and are installed properly. Health checks will be performed at every site within WISCOM and will be performed by EF Johnson personnel in conjunction with state personnel. Once the health check has been completed, the results will be compiled and shared with the State for deficiencies that need to be corrected. If requested by the state, EF Johnson will provide a quote to correct items identified.

The health check will cover the following at each RF site:

- Annual Preventative Maintenance level inspection
- Site cleaning
- Installation and cabling check
- Firmware and hardware check
- Deficiency identification
    - Correction of minor deficiencies - EF Johnson will correct minor deficiencies at every site, but major repairs and equipment that is out of warranty will not be covered.
- Point to Point Network Audit

Budgeted Cost: EF Johnson has stated they will perform the health check for $341,020.00. The budgetary cost to correct deficiencies is unknown at this time. However, from the preventative maintenance checks performed by the state and TUSA, funds will be necessary for corrections. At this time a $500,000 budget is recommended for parts and labor.

Estimated Timeline: EF Johnson anticipates this taking 180 days to complete the health check of all sites.

Issue #8 – FCC Issues

Proposed Solution: As stated earlier in the report, the State of Wisconsin's current operation put it at risk of violating FCC rules. WISCOM should conduct a statewide audit of the FCC licenses and adjust the transmitter outputs to set the ERP to what is listed on their FCC Site Licenses. In addition, for those sites that have ASR

numbers on the FCC Licenses, a sign should be posted on the site gate with the ASR number and contact telephone number on it.

Budgeted Cost: The maximum penalty is $10,000 a day per transmitter at each site. Just a single site could cost the state (or site owner) over $70,000 each week. This could result in FCC fines exceeding the overall cost of the WISCOM network.

Estimated Timeline: The timeline would need to be determined by the availability of State staff to review the licenses and readjust the power to the proper levels determined by the FCC licenses.

Issue #9 - Intermod

Proposed Solution: WISCOM should consider performing tabletop intermodulation audits for each state site, then decide if it would be beneficial to change a frequency or set of frequencies at the site to improve coverage and audio quality.

Budgeted Cost: If the State has the software and tools, they can perform this in-house. If they choose to outsource this, an average cost would be around $1,200 to $1,500 per site (assuming the state has all information, including how the filtration system for that site is configured, all frequencies for the site, and a list of all users).

Estimated Timeline: It typically takes a day to turn around an intermod study with an estimate of 180 days for the WISCOM network.

TASK 4 – REPORT AND ANALYSIS OF CURRENT WISCOM OPERATIONS, INFRASTRUCTURE, EQUIPMENT, TECHNOLOGY AND FINANCIAL SUPPORT COMPARING AGAINST SIMILAR STATEWIDE RADIO NETWORKS.

TUSA Consulting Services, LLC, along with their partner Carl, Riggs & Ingram, LLC, were retained by the State of Wisconsin's Department of Justice to conduct a baseline analysis of the current WISCOM operations model that will address 'Issues and Opportunities' in the following areas: Personnel Levels, Infrastructure and Equipment, Network Technology, Maintenance and Support, and an Assessment of the current funding.

TUSA will use this audit to provide an analysis on the current insourced state management staff and technical staff with comparison to other statewide network operations. The results will allow for recommendations on the on-going maintenance and ability to add new users to the WISCOM network, with the ultimate goal of creating an operable/interoperable, reliable radio network supporting current and future public safety users in the state.

How WISCOM Compares to Other States

TUSA Consulting Services interviewed a series of states so we could provide a comparison to other similar networks. The States interviewed included Minnesota, Michigan, Illinois, Indiana, and Ohio. We also pulled

from previous work and included Missouri. Missouri is important because they are extremely similar to Wisconsin's network. They are a statewide VHF network that uses 700/800 in urban areas.

System Overview

	Manufacturer	System Type	Frequency	Date of Commission	Deployed Sites
Wisconsin	EF Johnson	P-25	VHF/800 MHz	2012	116
Missouri	Motorola	P-25	VHF/700 MHz	2013	90
Illinois	Motorola	P-25	800 MHz	2007	250
Indiana	Motorola	P-25	800 MHz	N/A*	153
Michigan	Motorola	P-25	800 MHz	1997	247
Minnesota	Motorola	P-25	800 MHz	2004	450
Ohio	Motorola	P-25	800 MHz	N/A*	300

All of the states we talked to were in the process of adding additional sites to their network to enhance coverage, and support the overall user growth.

Coverage and Users

	Original Coverage	Current Coverage	Total Users
Wisconsin	95% mobile	95% mobile	26,100
Missouri	95% mobile	> 95% mobile	23,000
Illinois	95% mobile	98.3% mobile	45,000
Indiana	95% mobile	> 95% mobile	62,000
Michigan	97% mobile	95% portable	76,000
Minnesota	95% mobile	> 95% mobile	114,000
Ohio	95% mobile	> 95% mobile	100,000

The coverage for Missouri, Indiana, Minnesota and Ohio now exceeds 95% mobile because they have been adding sites to the network; however, none of these states had performed a coverage analysis to tell what the current coverage is, with the exception of Illinois.

Funding and Staffing

	Original Funding	Annual Funding	Business Model	State Provided Staffing
Wisconsin	$43 million	$1,045,000.00	Insource	7
Missouri	$95 million	$5.2 million	Hybrid	36
Illinois	$0.00*	$0.00*	Outsource	2
Indiana	N/A*	$17 million	Hybrid	36
Michigan	$226 million	$40 million	Insource	108
Minnesota	$500 million	N/A*	Hybrid	N/A*
Ohio	$85 million	N/A*	hybrid	25

* Motorola provided the State of Illinois with their radio network and charges users a monthly user fee. The State of Illinois has made no capital investment into their radio network.

** In some cases, States either were either unable to provide the requested information, or they did not want it included in a formal report.

Personnel Levels

TUSA conducted an analysis of the current WISCOM management, technical support and administrative support. A majority of the information came from the interviews with the states. The result of these interviews has allowed TUSA to provide a staffing level comparison between WISCOM and that of other networks of similar scope and size to the WISCOM network, providing examples from other similarly scoped and sized radio networks. When evaluating the staffing levels, it is important to understand the different business models that states often use to staff their radio network. Currently there are three different models:

Insource Business Model – This model keeps all elements of maintenance and sustainment of a radio network in-house. This is a business decision that is often made to maintain control of critical functions or competencies that are essential to the organization's mission. Insourcing is widely used to reduce costs across the organization's fiscal structures. Within the context of this business case, this represents the opportunity to bring essential services inside WISCOM that could traditionally be performed by an outsourced vendor. The State of Michigan is the perfect example of the insource model. They currently have 108 staff members to support their radio network, and no work is outsourced. The state technical staff provide preventative maintenance on the radio and microwave network. They also provide all radio codeplug development and programming.

Outsource Business Model – This model contracts all maintenance and sustainment of a radio network to a third party. Within the context of this example, this represents establishing a portfolio of processes and services by a third-party vendor(s) in support of needs that are beyond the capability of the insource resources. The State of Illinois is the perfect example of an outsource model. The state has two staff members and they outsource the entire infrastructure network and services to Motorola. Motorola even owns the infrastructure of the network.

Insource/Outsource (Hybrid) Model - This model is a combination of the insource and outsource business models. Some aspects of the maintenance and sustainment of the radio network is done in house, and other aspects are performed by a third party. The State of Minnesota uses this approach. They have their own internal staff, technicians, and admin personnel, but they also outsource some of the work out to Motorola.

ANALYSIS OF CURRENT WISCOM MANAGEMENT, TECHNICAL SUPPORT, AND ADMINISTRATIVE SUPPORT

The current model being used by WISCOM is an insource model that includes management staff under the Wisconsin Department of Justice, Communications Unit Organization, and technical staff from WISDOT, Communications Section Organization. The management staff is responsible for the day to day operation of WISCOM. The WISDOT technical staff provides technical support and maintenance for the current conventional Wisconsin State Patrol and Department of Natural Resources VHF radio network and the microwave and fiber backhaul connectivity at these tower sites. The majority of WISCOM sites are collocated at these same WISDOT sites. The current WISCOM management and technical staff is estimated at $2,475,962.23 annually for salaries/benefits and $2,135,000 for vehicles and test equipment.

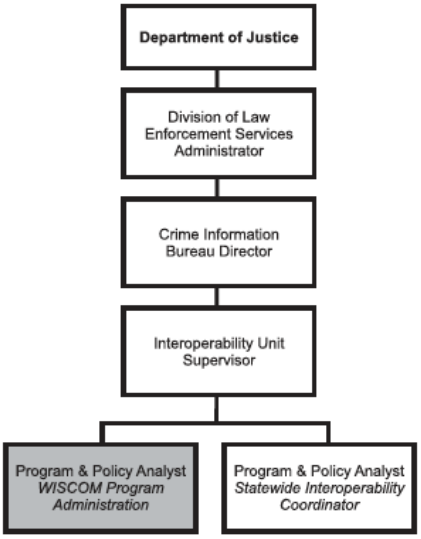
Current WISCOM/WISDOT Management & Technical Staffing													
		Engineering and Communications Section									Interoperability Unit		
Salaries	Position	DOT ENGINEERING CHIEF	NETWORK COMM SUPV	NETWORK COMM SYS ANALYST-ADV	NETWORK COMM SYS ANALYST-ADV LTE (partime staff)	ELECTRICAL ENGINEER-ADV	IS SUPERVISOR 2	IS BUSINESS AUTO SEN	IS NETWORK SVCS SPEC	Frequency Specialist	Program Supervisor	Program & Policy Analyst (Trainer)	Total Personeel
Pay Schedule & Range		81-02	81-03	06-63	06-63	14-13	70-02	07-34	07-33	07-34			
# of Personnel		1	3	18	2	1	1	1	1	1	1	2	32
Average Salary		$91,998.40	$68,182.40	$48,324.64	$21,881.60	$72,800.00	$56,815.00	$56,659.20	$68,640.00	$66,560.00	$63,500.00	$61,000.00	
Benefits 45.31%		$134,317.66	$99,075.85	$70,220.53	$0.00	$105,785.68	$82,557.88	$82,331.48	$99,740.78	$96,718.34	$92,271.85	$88,639.10	
		$134,317.66	$297,227.54	$1,263,969.62	$43,763.20	$105,785.68	$82,557.88	$82,331.48	$99,740.78	$96,718.34	$92,271.85	$177,278.20	
										Total Annual Salaries			$2,475,962.23

WISCOM was primarily designed and implemented by the WISDOT technical staff. Frequency planning, intermodulation analysis, and interference analysis was performed by the state's frequency coordinator/specialist. EF Johnson provided some technical engineering and technical support during implementation. EF Johnson also supplied networking expertise for WISDOT to provide the proper connectivity and configuration on the WISDOT microwave and fiber backhaul.

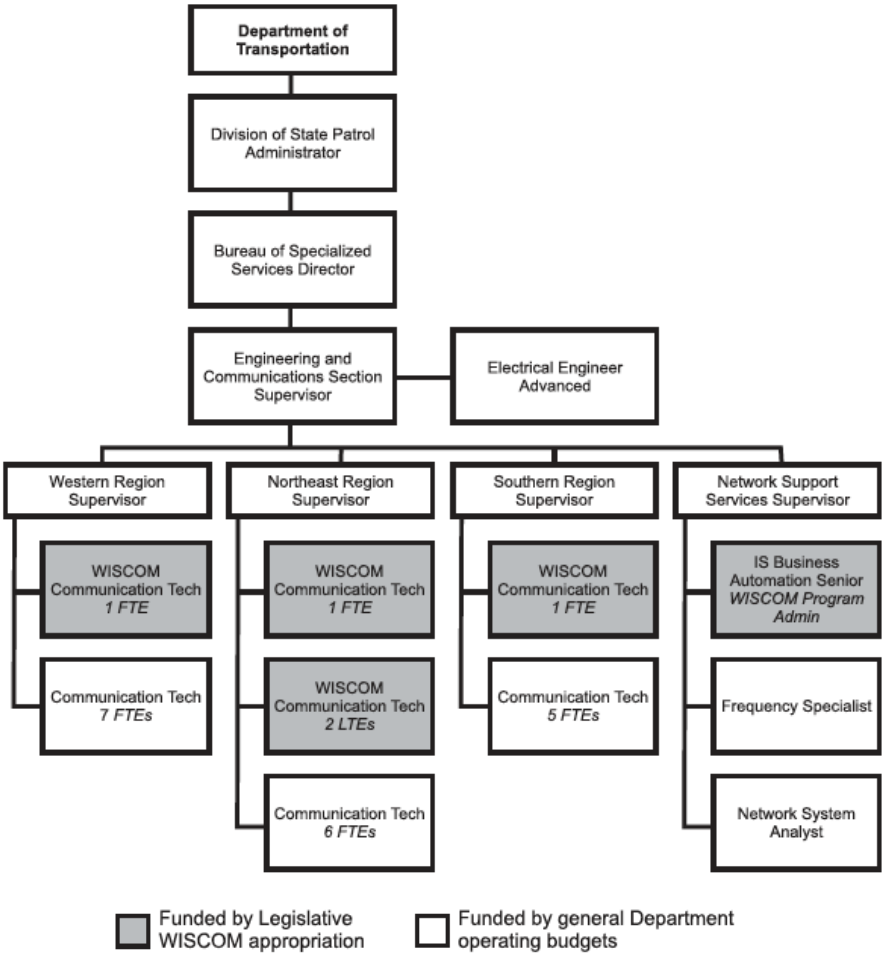
As WISCOM was being implemented, three (3) additional technicians, one in each WISDOT Area Technical Services Unit, were added to WISDOT technical staff to support the WISCOM radio network. The current WISDOT technical staff are still maintaining the conventional State Patrol and DNR VHF radio, microwave and fiber backhaul, and other infrastructure supporting items, such as shelters, towers, site civils (fencing, grounding, etc.), generators, and HVAC. The current WISDOT technical staff also provides some WISCOM support as needed. This same WISDOT staff provides implementation services to WISDOT, or WISCOM sites, as any new sites have been implemented since the start of WISCOM.

WISCOM management staff was also established to create and manage policies and procedures, operational guidelines, and all other duties with establishing governance for interoperability with counties and municipalities within the state.

WISCOM Administrative and Training Staff



WISDOT/WISCOM Technical Staff



The current WISCOM management staff and technical staff have a good understanding of the technical and operational parameters of the WISCOM network. However, this team is considerably under staffed and not

budgeted to properly care for the entire WISCOM radio network. Current WISCOM staffing does not have the engineering resources to support bringing the network to the engineering and industry best practices described in this report.

As counties and municipalities joined WISCOM, sites were designed and implemented by EF Johnson or local radio shops. WISCOM management staff and WISDOT technical staff provide guidance on fleetmapping and programming of the counties and municipalities mobile and portable radio subscribers for the County or Municipality operation, but also in-line with WISCOM interoperability guidelines. Each county or municipality is responsible for on-going maintenance, either by their own technical staff, or outsourced staff by EF Johnson and/or local radio shops.

This model provides an inconsistent methodology for on-going maintenance of sites added by counties or municipalities. There was no requirement found or discussed that required added sites be maintained under a common plan by the state. Other states like Ohio, Michigan, and Indiana all have requirements of how those additional sites will be taken care of. As all WISCOM users rely on sites added to the network, this model is not recommended for the future maintenance and sustainment provided in this report. County and municipalities can assist with added sites and infrastructure for their coverage and capacity needs, but the state insourced technical staff should assume the duties of maintaining the new sites under the same plan for the existing sites.

WISCOM PERSONNEL LEVELS COMPARED TO NETWORKS SIMILAR IN SCOPE AND SIZE TO THE WISCOM NETWORK

Different states have vastly different personnel levels, depending on the type of business model they use. For example, the State of Illinois uses an outsource model and completely outsources all work associated with their radio network. They only have two people to oversee the radio network for the entire State. This is vastly different than then the 6 direct and 26 indirect people that support the WISCOM network. Everything for the State of Illinois is overseen by Motorola. Motorola owns the infrastructure, and they have their own staff to support the network.

Michigan on the other hand is the complete opposite of the State of Illinois. They are also vastly different to Wisconsin. They use an insource business model. For example, they have 108 staff members to support the radio network. They also have their own engineers, tower climbers, and personnel to program radios. They estimate they have around 44 staff members across the state just to support the RF equipment at radio sites.

The State of Indiana is closer in staffing levels to Wisconsin. The State of Indiana has 32 people working for it, although 6 positions are currently not filled. The big difference between the State of Indiana and the State of Wisconsin is Indiana's staff is made up of management and administrative support. They do not have any technicians. The state outsources all technical work to Motorola. Motorola provides 8 technicians to maintain the network.

The State of Ohio has 25 people that work for it. This includes a database administrator, radio programmers, and a couple of technicians. The technicians provide oversight of Motorola's technicians. The State of Missouri, which is very similar to the State of Wisconsin's radio network, was unable to provide the exact total

of personnel that supports the radio network, although they did state they have 9 field engineers and 6 staff members.

SERVICE LEVEL COMPARISON TO OTHER NETWORKS OF SIMILAR SCOPE AND SIZE

In a radio network, downtime typically refers to unavailability of a channel, a site, backhaul or any sub-system of the network that prevents a user from gaining access to the network. Downtime results in the interruption of mission critical communications, which is a lifeline for public safety personnel. Service level contracts define minimum levels of system uptime. As an example, 99.0% uptime reliability would allow approximately 3.65 days of total downtime per year across the network.

Service Level agreements are typically established in an outsourced model to ensure the vendor provides technical support and the appropriate response times to a level that allows for minimal downtime on a public safety communications network. The response times are generally the time it takes for the vendor to respond to a network outage or degradation of service being experienced by the users. Response times are tracked by the amount of time it takes to acknowledge the outage or problem, respond to the outage or problem, and restore the outage or problem.

The standard response times are typically set at 2 hours to respond to a site outage or degraded condition with 6 hours for restoration. The percent of uptime ensures the network is maintained and repaired to a public safety standard. Failure to meet the response time, restoration time, or percent of uptime are assessed with liquidate damages for not meeting the required service levels.

The typical statewide Motorola Service agreement has the following service levels according to the options chosen by the specific customer:

Severity Level	Standard Response Time	Premier Response Time	Limited Response Time	Restoral	Off Deferral
Severity 1	Within 4 hours from receipt of Notification Continuously	Within 2 hours from receipt of Notification Continuously	Within 4 hours from receipt of Notification Standard Business Day	8 hours	Time provided by Servicer *
Severity 2	Within 4 hours from receipt of Notification Standard Business	Within 4 hours from receipt of Notification Standard Business	Within 4 hours from receipt of Notification Standard Business	8 hours	Time provided by Servicer *

Some states have additional requirements. The State of Illinois has to contend with flooding on a regular basis. Flooding has, and continues to compromise, site connectivity in some areas. The state now has a performance metric (service level) in the current contract that requires the use of 3G cellular site links as back-up connectivity for certain critical sites. The latency of the 3G service is low enough and manageable to

support reliable voice operations at any site configured with this back-up solution that loses landline connectivity. Some dispatch centers have also deployed this solution.

While the State of Wisconsin was unable to provide any existing documentation for TUSA to review of current service level agreements between external customers, it is clear from our investigation that the WISDOT technical staff are committed to providing the best services to their public safety users and perform their duties well. WISDOT has an internal service level commitment to support the system, and has a callout procedure they developed. This callout procedure is attached in Appendix H.

Infrastructure and Equipment

TUSA conducted an analysis of the condition of the current WISCOM infrastructure. As part of this, TUSA Senior Consultants Dean Hart and Jim Sullivan traveled across the state and were able to inspect twenty-nine (29) sites the week of April 24, 2016. This allowed TUSA to make a comparison of WISCOM infrastructure equipment versus applicable standards and best practices. A detailed site report can be found in Appendix E.

TUSA also engaged in multiple conversations with EF Johnson to determine the replacement cycles of core infrastructure equipment. We also collected information from both the State and EF Johnson, so we could make an assessment of WISCOM in regards to existing coverage and capacities. Unfortunately, the State did not have a lot of the original design information, so it was difficult to assess the current network versus the original plan. TUSA also found it difficult to render an opinion on the existing capacity because the Push to Talk (PTT) report data had anomalies (See Page 6). TUSA leveraged their interviews with various states to collect information on their coverage and capacities. This has allowed us to provide a comparison of WISCOM to other states.

CONDITION OF CURRENT WISCOM INFRASTRUCTURE EQUIPMENT

The WISCOM infrastructure equipment is comprised of trunked VHF & 800MHz base station repeaters with EF Johnson and CISCO network equipment used to interconnect the various radio sites into a cohesive network/network. The connectivity for the WISCOM sites principally utilizes the Wisconsin Department of Transportation (WisDOT) microwave infrastructure, but also State and commercial fiber networks. The trunked base station and supporting network equipment was purchased from EF Johnson and integrated by the State (with EF Johnson engineering and technical support) into a statewide P25 trunked VHF radio network. Additional VHF and 800MHz sites were added as counties and municipalities joined WISCOM.

P25 Equipment – WISCOM radio sites are primarily comprised of five (5) VHF base station repeaters with a primary and redundant network interface that allows each RF site to communicate with the other RF sites and the Network Management System. Some sites in the urban areas of the state have five (5) 800MHz base station repeaters. The majority of sites also have analog gateways that allow local conventional VHF channels to interface as trunked talkgroups on the network. This allows for communications and scanning of the conventional VHF channels into the WISCOM network.

WISCOM has a primary and redundant Network Management System that maintains the network information such as radio ID's, group ID's and other pertinent network network data. WISCOM has dispatch consoles located at the State Patrol Dispatch facilities and other county and municipality locations.

Shelters – The WISCOM equipment shelters are principally preexisting buildings that were part of the Wisconsin State Patrol VHF conventional radio network, as well as Wisconsin Department of the Natural Resources (DNR) VHF conventional network. These have been integrated and maintained by the WISDOT technical staff. The equipment shelters are structurally sufficient and have adequate space for the equipment housed within them. Some of the shelters inspected require rework or maintenance which may include antenna port entry panels, electrical grounding, cable tray organization, HVAC repairs, and other normal and customary site maintenance. Also, it was observed that at some sites the RF antenna transmission line cabling was incorrectly installed. Some of the shelters that were inspected did not have appropriate cable trays to support the WISCOM equipment wiring that was new at the time. Electrical grounding of equipment racks was inconsistent and in some cases was missing altogether. Those installations were found lacking with respect to normal and customary best practices for communications networks of this type and complexity.

Generators – WISCOM (at the sites inspected) utilizes standby power generators that were already existing and supporting legacy WisDOT and DNR VHF conventional radio equipment and the WisDOT microwave network. It is unknown if any power load studies were completed to determine if the existing standby generators could actually support the added WISCOM equipment loads. It was reported by State staff that generator replacements get placed into an operations budget, but are not part of any formal maintenance/replacement plan. No formal studies have been made at this point to determine if actual replacement, or a higher capacity generator, is needed to adequately support existing radio equipment loads at sites.

The State has communicated to TUSA that the generators at DOT owned facilities are the responsibility of WI DOT/Division of Business Management/Bureau of Business Services/Facilities. Facilities is responsible for the decisions to repair, or replace, these generators as needed. WI Department of Administration controls the funding for small projects like a generator replacement. Currently, WI DOT has scheduled two replacements per biennium. As this information is important to the overall analysis of the generators at the WISCOM sites; TUSA recommends that the generators be considered support equipment of the public safety communications system and have the replacement and maintenance of the generators managed by the WISDOT Engineering and Communications Section, or the future WISCOM management staff.

Towers – The WISCOM towers were already in place and supporting the WisDOT and DNR VHF conventional radio networks and the WisDOT microwave network. These towers are maintained by WisDOT and State Patrol technical staff members. Overall, the towers appear to be structurally sufficient to support WISCOM, the conventional VHF networks, and the WisDOT microwave network. However, it is unknown if any professional engineering structural (load and wind/ice survival) studies were conducted as the different radio and microwave networks were incrementally added to these towers. Industry best practices (EIA/TIA-222G) would require a structural engineering study be completed whenever a physical change, such as the addition of new antenna networks, is completed on an existing tower.

Grounding – Electrical grounding at the majority of sites was in extremely poor condition and in some cases, non-existent. It was reported that lightning issues (i.e., resulting in equipment damage) were recognized early in WISCOM's deployment and as a result, electrical grounding improvements were performed at the affected

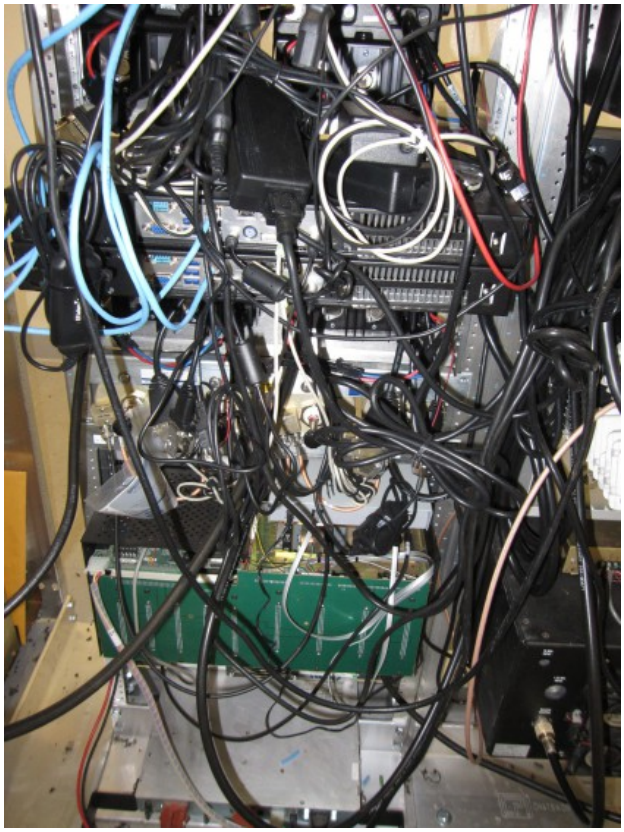
sites. However, TUSA personnel observed significant workmanship and grounding inconsistencies outside of industry-recognized grounding practices and should be corrected.

COMPARISON OF WISCOM INFRASTRUCTURE EQUIPMENT VERSUS BEST PRACTICES

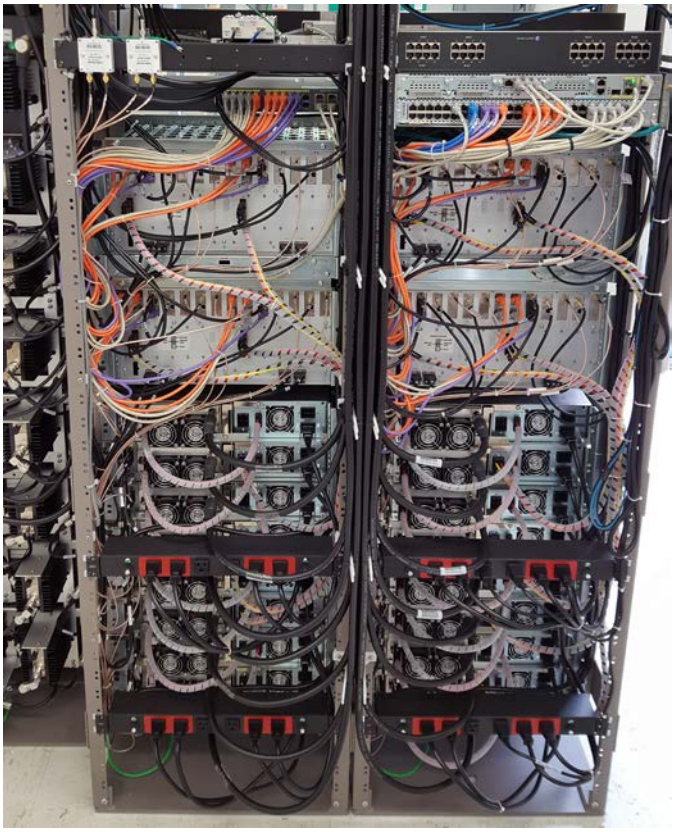
WISDOT technical staff performed all the equipment installations at the core WISCOM sites. Inspections by TUSA found installation inconsistencies between sites in different areas of the State. These workmanship and configuration inconsistencies include the cabling between equipment racks, electrical grounding processes, and other known industry best practices. TUSA personnel conducted site inspections of twenty-nine (29) different tower sites dispersed throughout the State. It was found that the local WISCOM enhancement sites installed and integrated by EF Johnson personnel were more consistent and generally followed industry standards and typical best practice standards.

However, there were local WISCOM enhancement sites installed by EF Johnson oversight of local vendors, where installations did not follow industry best practices. Some issues were observed, but overall the sites that were installed by EF Johnson appear to follow a more detailed and consistent plan as compared to those installed by the State.

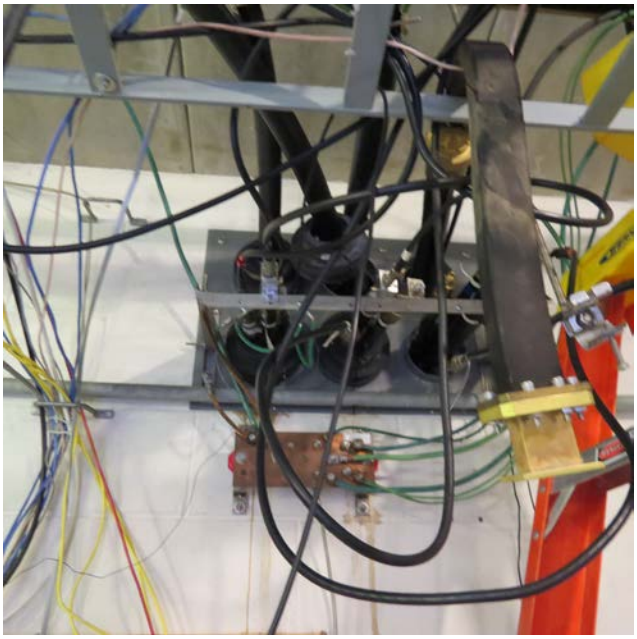
WISDOT engineering established guidelines and specifications for tower infrastructure, shelters, generators, HVAC, grounding, and the microwave network supporting WISCOM and other state needs for the backhaul. Newer tower sites appeared to be following some consistencies, but were still noted as not following industry best practices, as noted in the site summary inspections. An example of this can best be understood by comparing installations performed at two sites.



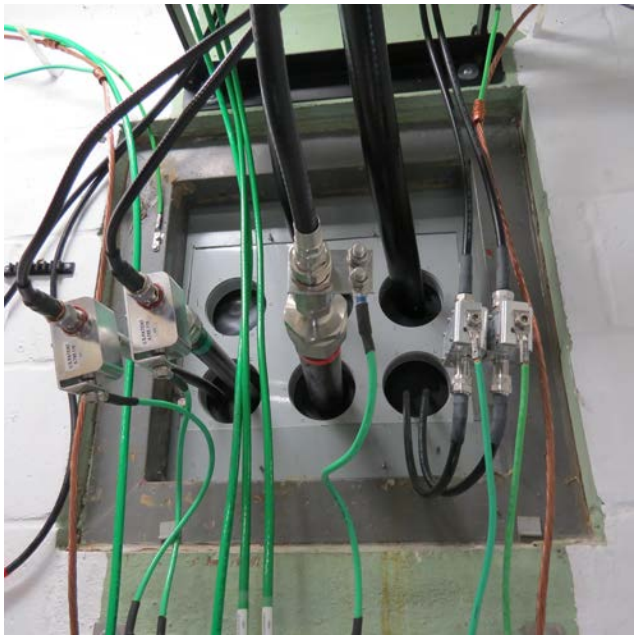
PIPESTONE EQUIPMENT RACK



EQUIPMENT RACK USING INSTALLATION BEST PRACTICES



SPRING PRAIRIE BULKHEAD



BULKHEAD USING INSTALLATION BESTPRACTICES

All WISCOM sites should have established and followed a standard. There are many standards for site installation and shelter installations. For example, with grounding there is Motorola's R-56. There is also TIA 607-B, which is the standard EF Johnson has adopted.

The following shows the standards that EF Johnson recommends all sites be built to:

SITE/SHELTER	
Grounding	TIA 607-B
Power	NFPA-70
Climate Control	569-C (6.6.5.2)\ (ASH RAE class B, section 6.2)
Cable Ways	569-C.
Cable secure	NEMA VE 2-2000 Section 5.6
Tower	TIA 222-G Annex J.
SYSTEM INSTALLATION	
Securing Racks to ground	CPI Bolt down instructions
Cabling Install & Routing	TIA-569-C section 9.3.
Cabling secure	NEMA VE 2-2000 Section 5.6
Cable terminations	Per Cable/Connector Diagram & Instructions
Rack Grounding.	TIA 607-B.
Power	NFPA 70
Surge Suppression / Hardwire	NFPA 70 Section 285, UL 1449,
Coaxial Cable Surge Protection	UL 497C.
Data and Signal Cable Protection	UL497A

REPLACEMENT CYCLES OF CORE EQUIPMENT

TUSA provided analysis for the replacement cycles of the infrastructure core equipment. The replacement cycles of core infrastructure equipment vary by manufacturer. Core radio infrastructure equipment is typically comprised of:

- Base Station Repeaters
  - Combiner and Multicoupler
  - Antenna Networks
  - Simulcast Equipment
- Dispatch Equipment
  - Console electronics
  - Logging Recorder
- Networking equipment
  - Servers
  - Switches
  - Routers
- Backhaul/Connectivity
  - Network

Typically, the network and computer type equipment has a shorter lifecycle than base station equipment. Base station equipment has a lifecycle of 15+ years, as it is not software controlled like the network computer equipment that provides the IP backbone for network database and control of the radio network.

Software for these types of radio networks is updated on a yearly cycle for bug fixes or network type enhancements. As the software is upgraded, the need for new computer hardware to support the software is needed, therefore requiring replacement cycles at a closer interval than hardware type components. Microsoft, Linux, and other operating network software companies usually drive the need for software enhancements to support the network servers and IP backbone.

Software based technology are on a short lifecycle for the hardware. The industry is starting to reflect the following lifecycles in their long term maintenance support plans:

Equipment	Lifecycle (years)
Base Station Repeater	15+
Combiner & Multicoupler	15+
Antenna System	!5+
Simulcast Equipment	15+
Dispatch Equipment	
Console Electronics	3-5
Logging Recorder	5-7
Networking Equipment	
Server	5-7
Switches	5-7
Routers	5-7
Backhaul/Connectivity	15+
Network Equipment	5-7

In comparison of the current WISCOM EF Johnson infrastructure to the typical industry lifecycle of a radio network, the following chart is demonstrated:

Equipment	Industry Lifecycle (years)	WISCOM Achieved Lifecycle
Base Station Repeater	15+	<10
Combiner & Multicoupler	15+	same
Antenna System	!5+	same
Simulcast Equipment	15+	same
Dispatch Equipment		
Console Electronics	3-5	>5
Logging Recorder	5-7	same
Networking Equipment		
Server	5-7	same
Switches	5-7	same
Routers	5-7	same
Backhaul/Connectivity	15+	same
Network Equipment	5-7	same

ASSESSMENT OF EXISTING CAPACITY TO ORIGINAL PLAN AND OTHER STATES

TUSA examined the original plan for capacity. The original plan for capacity had 5 channels per site, regardless of whether the area was rural or metropolitan. The loading of a trunked radio system can be described using the family of equations referred to as Erlang C (Blocked Calls Held). The Erlang equations are the result of studies by Bell Labs in the early days of long-distance telephone trunk traffic and are based on the well-known Poisson distribution which describes radio and telephone traffic well. The basic inputs to these calculations are:

1. Number of users
2. Calls per user per hour (average)
3. Call duration in seconds (average)

Given these inputs, the load offered to a trunked radio system can be reasonably estimated. For example, in a public safety system, the average call duration is typically 6 seconds. The number of calls per user per hour varies widely, but for example can be set to 3. Given 500 users, we can now estimate that the average load offered to the given trunked radio system is (500 X 6 X 3) / 3600, or 2.5 Erlangs.

TUSA has extensive experience in performing traffic studies and analysis and can offer detailed studies and predictions given suitable traffic source data. However, TUSA is unable to render an opinion on the current capacity of any of the WISCOM radio sites on the network. The data provided by the State, which was pulled from EF Johnson's NMS reporting system, contains anomalies, starting in July, resulting in the sites using 150% of the a site's capacity. For example, in the Deerfield site data, line 365, the number of airtime seconds is 21820. In the channel plan, it shows Deerfield as having 5 channels. Taking four of those channels (one is allocated as control) times 3600 seconds per hour, you have a total capacity of 14400 seconds. Thus the data is showing that site as using over 151 percent of its actual capacity.

This isn't an isolated example, either. There are hundreds of lines like this in the data. The typical average call duration is around 6 seconds but there are hundreds of entries of over 200 or 300 seconds. TUSA reached out to EF Johnson to ask them about this. EF Johnson stated the data in the reports seems unusual. Looking at

the graphs on the other tabs, it appears something significant changed about 7/20/16 with the average call length taking a significant leap upwards about one month later.

Because the State has been unable to provide good data for us plug into our erlang calculations, we are unable to provide an analysis of the analog gateways and how much traffic loading they present to the sites, to which the gateways are located. As an advocate for the State of Wisconsin, TUSA did approach EF Johnson about the anomalies found in the data. TUSA scheduled a meeting between TUSA and EF Johnson's Development Engineers for December 13, 2016. One hour before the call was scheduled to take place; EF Johnson canceled due to the availability of the team. On December 19, 2016, EF Johnson contacted TUSA and said they have a little more information, but they are not as far along as they would like on the issue.

When investigating how other states have handled capacity, they have had the manufacture perform the Erlang calculations. The State of Missouri Statewide Wireless Interoperability Network (MOSWIN) used a similar practice like WISCOM. The state desired five (5) VHF channels at 72 VHF sites (multisite) regardless of any channel loading statistics. As this made it simple to create a design for network without any engineering traffic analysis, it did create areas in the state that experience channel capacity issues. These areas were typically the larger metropolitan areas, which required more State Troopers to support. Due to frequency limitations in the VHF range, the ability to add channels to sites were near impossible. Engineering investigated adding a 6th channel to key sites, but no additional channels were added during the implementation phase due to frequency availability.

ASSESSMENT OF CURRENT COVERAGE TO ORIGINAL PLAN AND OTHER STATES

Wisconsin's network was originally built for 95% mobile coverage. If a county or entity chose to come on and become a daily user, they could enhance the coverage in their areas. The 95% mobile coverage requirement is a common baseline requirement for state designed radio networks. All of the states we talked to designed their radio networks to 95% mobile coverage. However, there are two major differences between how WISCOM has handled coverage and capacity, versus other states.

The first major difference is some states have chosen to enhance portable in-building coverage in major metropolitan areas. For example, in Illinois, certain metropolitan areas required 8dB portable in-building coverage. Some of the counties that have joined the network have their own coverage requirements, with the highest one being 18dB in-building coverage. We have seen this in other statewide networks we have looked at. For example, the Louisiana Wireless Interoperability Network (LWIN) for the State of Louisiana provides 95% portable on street coverage, but they have chosen to provide 95% portable in-building coverage throughout 9 of the largest metropolitan areas within the state.

The second major difference is other States have continued to buildout and enhance their coverage past the 95% requirement. Illinois's network was originally built for 95% mobile coverage, but they have continued to add sites and it is currently testing at 98.3% mobile coverage. Indiana's original requirement was 95% mobile coverage, but they too have added sites and have more planned. Minnesota and Ohio also have a 95% mobile coverage requirement, but they have added additional sites and now have better than 95% coverage.

Michigan's network was original built for 97% mobile coverage, but today their network now supports 95% portable on street coverage.

Network Technology, Maintenance, and Support

Today nearly all statewide radio networks are designed and built to support some level of mobile radio coverage statewide. For most states, this falls in the 95 – 98 percent range. While this is an acceptable level of reliability for mobile radio coverage, for portable radio coverage, most states fall well below this level. Officer safety issues are driving more state and local government public safety agencies to require minimum levels of portable/handheld radio coverage on their networks. Most states see portable coverage in the 70 – 80 percent range. Due to the limited transmit power of portable radios, 3-5 watt portable vs. 30 watt mobile, comparable portable coverage requires more sites or alternative technologies to fill the coverage gap for portable/handheld radios.

The need for portable coverage varies by public safety agency and by an individual's role within their respective department. State highway patrol officers typically need coverage in the immediate vicinity of the vehicle as they exit the car during a traffic stop. Fish and wildlife officers leave and may move far away from their vehicle as they move through remote non-populated areas to enforce state wildlife regulations.

Firefighters require portable coverage inside of building structures as they move throughout structure. Wildfire firefighters require portable coverage outside and over a large geography as they disperse to different areas to contain the wildfire. While many of those in public safety need better portable coverage in an outdoor environment, most of them need coverage inside buildings also. Most urban and suburban counties today are requiring radio networks with a minimum level of in-building coverage for portable. State governments have too much geography to cover to implement extensive in-building coverage. The need for more in-building coverage for state users makes collaborating with local governments more important than ever.

Network availability is another performance criterion trending towards higher performance levels. For radio networks, network availability is measured in percentage of uptime. Industry expectations for network level services (e.g. wide area call processing) and site connectivity are a minimum of "five 9's" or 99.999 percent availability. Five 9's translates to less than three minutes downtime per year. Since most P25 radio networks offerings today are built on Internet Protocol (IP) technology, vendors are able to design multiple levels of redundancy into their core processing, even offering geographic redundancy where a split core or fully duplicated core are implemented with full processing capability in two separate locations.

Another important performance trend for networks is the availability of network "dashboards" that provide real-time information on numerous data points from the network. Dashboards can display information on network usage statistics, component health and even user behavioral patterns. Most importantly for the state to consider, these dashboards can assist in monitoring vendor/supplier performance to contracted service levels and metrics. Dashboards are highly customizable and can provide varying levels of detailed information based on the role of individuals authorized to access the dashboard.

SERVICE LEVEL AGREEMENTS FOR INTERNAL AND EXTERNAL CUSTOMERS

TUSA was asked to provide an analysis of the service level agreements for internal and external customers on the WISCOM network. As part of this, we requested all the Service Level agreements from the State. The State was able to provide two documents:

1. WISCOM Statues document
2. WSP/OJA Agreement.

Neither document covered service level agreements, although the WSP/OJA MOU provided a definition of how a service level agreement should be defined. TUSA followed up with the State and was advised no other information was available on this subject. However, EF Johnson provided service level information in the proposal created for the System Upgrade, Maintenance, and Support (See Attachment G). This document provides service levels for response time, routine preventative maintenance, and engineering support.

	Call Acknowledgement Time Business Hours 8AM-5PM CST excluding holidays	Call Acknowledgement Time After Hours or holidays
Major	Immediate	< 30 min
Minor	Immediate	< 2 hours

TYPE OF FAILURE	DESCRIPTION	TYPICAL RESPONSE TIME
Major (Communication Affecting)	Conditions exist that severely affect service and traffic capability which require immediate attention irrespective of time of the day or day of the week	< 4 hours
Minor (Non-communication affecting)	Conditions exist that do not severely affect service and are non-traffic affecting	< 8 hours
Routine	Conditions exist where there is room for system improvement but do not affect the capability of making voice or data calls on the system.	< 24 hours

TUSA would recommend in this type of proposal that the service level agreement provide for system uptime and restoration times for the outsource vendor and the insourced technical staff. This drives the management of spare parts to ensure a site outage anywhere in the state can be restored expeditiously. Consideration should also be given to penalties if any of these service levels are not maintained.

TUSA would also recommend service levels be established on subscriber equipment operating on the WISCOM network. Subscribers should have a yearly preventative maintenance procedure that updates firmware, checks the technical levels of the subscriber radio, and program any codeplug/personality updates that may have occurred over the yearly period. The subscribers must be maintained under the same stringent guidelines as the infrastructure network to operate cohesively and optimally.

These service levels can be done internally by WISCOM technical staff, or outsourced through local shops under guidelines established by WISCOM management. TUSA would recommend a long term extended warranty service plan as the subscribers are procured or through the process of a competitive procurement.

ASSESSMENT OF EXISTING END USER DEVICES UTILIZED ON WISCOM AND RECOMMENDATIONS FOR FUTURE CERTIFICATION TESTING.

As the P25 standards developed and matured, a program was developed and accepted by the industry for certification of all P25 products to include subscribers. This program was called the P25 Compliance Assessment Program (CAP).

TIA-102 has created a standard set of documents that allow for P25 development, but also the ability to test products developed for P25. The CAP focuses on testing a subset of the P25 standards in recognized labs and each vendor provides a Supplier's Declaration of Compliance (SDOC) and Summary Test Report (STR) for each model of subscriber, which is ultimately approved by the Department of Homeland Security (DHS). These documents are maintained by DHS and are typically available on their website. A list of the approved equipment is provided at: https://www.dhs.gov/sites/default/files/publications/P25-CAP-tested-equipment-list-508.pdf.

In discussion with WISCOM and WISDOT technical staff, TUSA was advised that many of the older Kenwood subscriber models have experienced difficulty operating on WISCOM. These Kenwood subscribers went through many rounds of software/firmware updates and in some cases custom software releases occurred for different issues. This means that all of these Kenwood radios may not have the same software release and could experience different issues according to where they operate on the WISCOM network.

It was estimated that 10,000 to 12,000 of these Kenwood radios may exist and are operating on WISCOM today. These radios are typically end of life or have been declared end of life by Kenwood. Any subscriber radio that is being used on the WISCOM network but does not appear on the referenced DHS list should be replaced immediately.

TUSA discussed the subscriber certification with the different states as the interviews were conducted. Each state had a methodology of certifying subscribers before allowing them on their radio network.

The State of Michigan tests all subscriber radios that will be used on their network. While a majority of the radios are Motorola, they also have Harris and Tait. When a new subscriber radio is brought to market, the manufacturer will send them a radio to test. The state then has a standard vetting process that includes CAP testing. Each radio is tested by a radio technical group and an engineering group. The State of Ohio works directly and partners with the State of Michigan and their testing and certification.

The State of Illinois makes sure all new radios pass Motorola's P-25 testing lab, and they have an oversight committee and administrative committee to approve the radios. The radios are reviewed technically to make sure it does not operational problems with STARCOM21.

The State of Minnesota requires all radios to be P-25 CAP compliant. New subscriber radios must go through testing by the Minnesota Department of Transportation (MINDOT). MINDOT then presents their test results to the Operations and Technical committees. Their recommendations are then passed on to Statewide Communications board.

The State of Missouri created a detailed process to certify and allow radios on the MOSWIN network. The process provides detailed specifications for VHF and 7/800MHz subscriber radios. The process verifies the radio has been CAP tested with the vendor providing the SDOC and STR for each radio. The final step requires the vendor to use the subscriber on a series of operational tests on the MOSWIN network. These tests are documented and certified by the vendor for each subscriber that can be used on the MOSWIN network. This detailed process is provided for review in Appendix F.

As all the states use the CAP process for the radio certified on their respective networks, it is important to consider other testing that should be considered as WISCOM continues to work on their process.
Some of the other things to consider are:

- Number of sites
- Number of control channels
- Roaming tables (subscriber & network)
- Number of talkgroup names

All of the vendors have limitations on these parameters. A statewide system can sometimes reach the limits of these parameters and leave the customer with decisions on how to handle the limitations. A couple of examples from Senior Consultant Dean Hart's statewide experience are discussed.

1. State of Florida (SLERS) – although this is an EDACS system, limitations on the amount of sites, talkgroup names, and roaming tables were discovered early in the implementation process. This caused the manufacturer (then M/A-COM to go back to design phase to correct these issues.

2. State of Missouri (MOSWIN) – it was discovered that the control channel table did not allow for all the states sites and control channels in the APX mobile and portable. Motorola corrected this in future revisions of firmware.

The State of Wisconsin should create a boilerplate codeplug/personality that puts all these parameters in the subscriber device to test and ensure the proposed mobile or portable can adequately support full statewide performance. This is also the starting point for what the subscriber will use if the subscriber is certified and allowed for use on WISCOM.

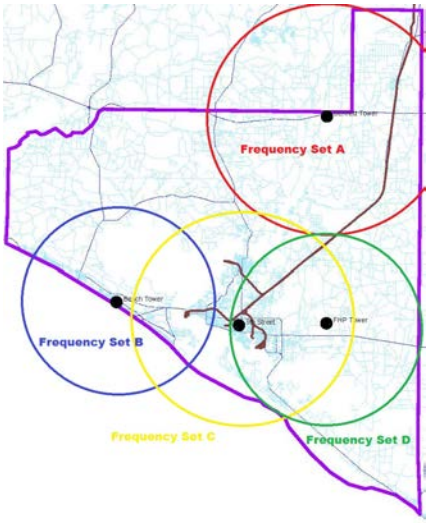
The state must also manage this process and the codeplug/personality boilerplate development and maintenance when changes occur to the network. The codeplug/personality would have the network information (control channels, roaming table, sites, talkgroup names, etc…) to ensure all WISCOM users are operating under a thoroughly tested, consistent, and managed process.

AN ASSESSMENT OF CURRENT MULTICAST/MULTISITE IMPLEMENTATION AND OPINION ON THE AVAILABLE COVERAGE, CAPACITY AND FREQUENCY SUITABILITY FOR INCREASED TRAFFIC LOAD PRESENTED BY DAILY USER ADDITIONS, AS WELL AS DETERMINING WHEN MAXIMUM CAPACITY LEVELS ARE REACHED.

The majority of sites in operation on WISCOM are multisite. Juneau County is implementing a VHF simulcast system which is comprised of five (5) tower sites.

Multi-Site Network

A multi-site network is comprised of radio sites spread throughout a geographic area, each having its own set of radio frequencies. The following is an example of such a configuration:



Multisite Systems Design - Each site has its own set of frequencies

In order to allow communication between users operating in different tower site coverage areas, a means must be provided so that calls within the coverage area of one tower site are retransmitted on another tower site or combination of sites. Such wide area communication is accomplished through an intelligent central "switch" that monitors the site activity of every operational radio unit in the system and dynamically connects users together as needed. A call using a frequency on one site is connected to the appropriate, but different frequency on another. When a call is placed, the central switch determines which sites and frequencies are available to be assigned for that call and temporarily connects them all together via leased lines or microwave circuits. In the case of WISCOM, EF Johnson provides this call routing with a distributed network that places this known call data at each site and therefore does not require a central switch.

The key characteristic of this type of network is that a completely separate set of radio frequencies (channels) is needed at each site. Because inter-site interference is not an issue, site placement is much less critical for a

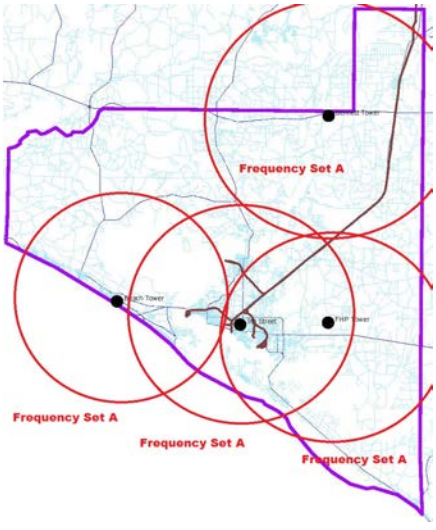
multisite network, compared to a simulcast system. In addition, a multisite network is extremely robust from the standpoint of reliability. In the event of a failure of one or more of the inter-site links, a simulcast site must operate with reduced capacity, or shut down completely. A multisite network can continue to operate at full capacity in the event of such a failure, although with reduced wide area coverage capability. The technical requirements for the communication links connecting the sites are also less critical than for simulcast systems, which can result in lower system implementation and operating cost.

While a primary strength in one regard, the requirement for separate frequency sets for each tower site is also a multisite network's primary weakness. The frequencies available for public safety use are extremely limited. The availability of frequencies can effectively block a multisite system's capability for future expansion, in terms of either coverage or capacity. If additional frequencies cannot be made available, additional sites cannot be added to an existing multisite network to increase its coverage.

Capacity expansion is further constrained by frequency availability as capacity expansion usually requires adding channels to multiple sites in the network. In order to prevent dropped or missed calls, the quantity of channels at each site must be high enough to handle all of the calls that the central switch may route to that site at any instant.

Another issue to consider is the effect of transitioning from one site to another when traveling throughout the service area. Site transitioning has an effect on the apparent coverage performance of a multisite network. In order to ensure that coverage within the required service area is contiguous, the coverage from adjacent sites must overlap each other. As users travel in these overlapping coverage areas, the radio must determine which site provides the strongest signal at that specific location and transition to the stronger site's operating frequencies. This transition is not instantaneous. To prevent missed calls due to excessive transitioning between sites, the transition to the stronger site is delayed until the signal difference between the current site and the new site exceeds a specific signal difference threshold. The net result is that a user may not always be operating on the optimum site. From the user's perspective, system coverage can be sporadically less than expected.

Simulcast Technology



Simulcast System Design - All four sites share the same set of frequencies

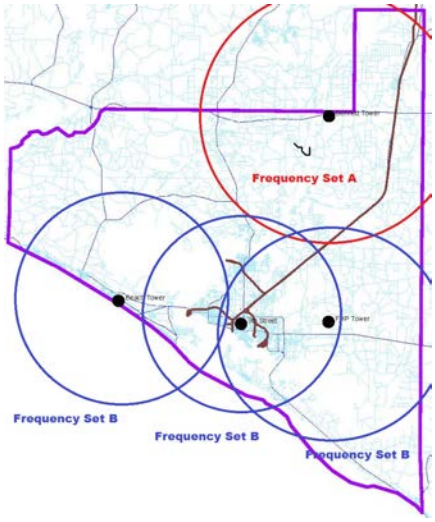
Like multisite, simulcast is a technology that increases coverage beyond that available from a single site by implementing multiple sites throughout the desired coverage area. Simulcast differs from a multisite configuration in that the same frequency set is used throughout a given system. With a simulcast system, a channel's associated transmitter at each site broadcasts the same information simultaneously on the same RF channel as the other sites, hence the name.

The primary advantage of a simulcast system over a multisite network is that simulcast increases coverage without increasing the number of channels necessary to support the system. Also, given the same site configuration, inbound coverage from subscriber units to the base stations is improved over multisite because of the diversity effect of multiple receiver sites monitoring the same inbound frequency, and outbound coverage is improved because there is no site transitioning effect to contend with. From the user's point of view a simulcast system operates exactly like a single site system. There are no zones or site transitions for the user to contend with.

However, as a result of multiple sites transmitting on the same frequency, each site's transmitted frequency, phase and timing must be precisely controlled to prevent destructive interference as signals transmitted from multiple sites overlap. This requirement to precisely control the output signals from each site in order to prevent destructive time delay interference (TDI) makes the implementation and long term support of a simulcast system more complex and costly than for a multisite network. This disadvantage also places constraints on a simulcast system's site placement. With the recent release of linear-simulcast technology (vs. non-linear simulcast), the design of a simulcast is much easier to accomplish with limited TDI constraints.

A simulcast radio system also requires highly stable and reliable inter-site connectivity. If inter-site connectivity is lost in a simulcast system, the affected sites will operate as stand-alone sites with severely limited capacity. This requirement for reliability and stability can usually only be met by a dedicated microwave or fiber optic sub-system. Currently leased circuits, even leased fiber, are not recommended for simulcast, and some vendors will not support simulcast systems utilizing them. From the standpoint of reliability, microwave has proved to be far more reliable and robust than leased circuits in the face of severe storms.

Hybrid Simulcast/Multisite Configurations



Hybrid System Design - A combination of multisite and simulcast systems

The final wide area system configuration is a hybrid design using a combination of multisite and simulcast technologies. This system configuration consists of several simulcast sub-systems, or "cells" connected together in a larger multisite network. From the standpoint of the multisite network, each simulcast cell looks like a single site, but each of these cells has significantly greater coverage than is possible from a single site. This design can provide a system solution when the geographic area is too large to be accommodated by a single simulcast system, and frequency constraints preclude a purely multisite network approach.

With Juneau County providing a simulcast system in the overall WISCOM multisite network design, a hybrid configuration has been created. VHF simulcast is possible and should be considered if the frequencies are limited in the area. However, detailed engineering best practices is required for any proposed simulcast system as it would be for the multisite network.

Finding additional VHF frequencies can be challenging, if not impossible. If VHF frequencies are available and can be coordinated under a detailed engineering best practices plan, then an additional site can be joined with a current multisite to create a simulcast system and improve coverage in a designated area.

TUSA would recommend this be handled on a case by case basis for improving coverage in any area. If an area has a higher building density, such as an urban city and the end customer desires good in-building penetration, then VHF simulcast may not be the most reliable solution. 700/800MHz frequencies have a better in-building penetration characteristic and should be considered for this type solution. This would require users having a multi-band radio to access both the VHF and 700/800MHz parts of WISCOM.

Additional capacity on any site, whether multisite or simulcast, present the same frequency availability challenge. If VHF frequencies are available and can be coordinated to a site and the respective site combiner plan, then adding a channel to a site is practical. Capacity loading on a site is determined by system/site level reports from the network reporting system to determine if additional channels are necessary.

TUSA recommends that EF Johnson identify the issues with the NMS reporting system and provide a fix that allows the state to generate the proper site PTT reports to allow for the proper analysis to determine if additional channels are necessary on a site by site basis.

POTENTIAL USERS OF THE NETWORK AND PLANNING GUIDELINES FOR NEW DAILY USER AGENCY ADDITIONS.

There is no one single model for how a local government would participate on the envisioned network of WISCOM. There are, in fact, many options for local government participation and partnership. The state must be flexible in any potential agreement and the agreement should benefit all parties. Some examples of ways for local governments to participate on WISCOM and share costs are:

- The local government entity buys radios and pays a fee per user to access the network. This fee would be used to maintain and sustain the network provided by WISCOM. The local government could use existing coverage from the WISCOM sites in the area. Increasing the total

number of WISCOM users may provide the opportunity for cost sharing for the service and sustainment of the network;

- The local government entity can subscribe to a radio outsource service and pay a fee per radio device that covers the cost of the radio and the cost to maintain and sustain the network. The local government uses existing coverage from WISCOM sites in the area;

- The local government entity may need to add channels to the existing WISCOM sites to ensure capacity is available for both local government users and state users on these sites. The local government uses existing coverage from WISCOM sites in the area;

- The local government entity has an existing P25 network from the same vendor today and can connect its sites directly to the WISCOM network. No WISCOM sites need to be built or leased in the local government as coverage meets or exceeds minimum WISCOM coverage requirements;

- The local government entity has an existing P25 network today from a different vendor than selected by the state. The local government may connect its P25 core network to the WISCOM network via P25 ISSI[3]. WISCOM sites may still be needed in this scenario. The P25 ISSI may not support all of the features implemented by the selected WISCOM vendor. WISCOM users may only need or want to access this local government network for interoperability events and not as their primary radio service in the local government;

- The local government entity procures additional P25 sites from the selected vendor to place in the local government to enhance coverage from the WISCOM sites already there;

- The local government entity has a proprietary network today and executes a procurement agreement with the state's selected vendor to upgrade the proprietary network to P25 service and connect directly to WISCOM.

Any opportunity to leverage local government infrastructure, or bring more local government users onto the WISCOM network, is a potential opportunity to reduce the cost per user to the state. Other states like Ohio, Michigan, Louisiana and Illinois have had noticeable success with local government participation on their networks. While Illinois is the only outsource model in this list, it is the inclusive governance and the renewable technology investment by these agencies that have led to success in bringing on more local governments and sharing costs for the networks.

The State of Louisiana has also been successful in its approach. Louisiana operates a 125-site 700 MHz P25 radio system known as the Louisiana Wireless Information Network (LWIN). LWIN began in 2005 because of replacement planning for the then obsolete and proprietary 800 MHz analog statewide radio system. The destructive effects of Hurricane Katrina later in 2005 accelerated the replacement of that system. The state is

[3] P25 Inter-subsystem Interface; a suite of standards that defines the wireline connection between two or more P25 networks, enabling a network of networks approach to regional or statewide interoperability.

responsible for all aspects of the 700 MHz P25 radio system except the actual maintenance of the radio system base/repeater equipment and the core network switches.

Below is a list of reasons why LWIN has been so successful in attracting members:

- LWIN is not a law enforcement only system. LWIN is a shared P25 system available to all public safety agencies throughout Louisiana.
- LWIN has created an inclusive governance structure that offers representation for all participating agencies. LWIN leaders also engage in continuous outreach to bring on new members.
- The state of Louisiana charges no user fees for agencies to join LWIN. Each agency buys its own radios, dispatch consoles, and provides their own maintenance.
- Local government participation on the network is so high there is little duplication of radio infrastructure between the state and the local governments. The high participation rate means lower overall operational costs per user.
- LWIN is currently operating with five different P25 radio providers on the network. The state maintains its own radio certification process for P25 radios.
- Regular LWIN governance meetings are held throughout the state, not just in the capital Baton Rouge. This offers more agencies to participate actively in the governance of the network.

Louisiana's model is unique among hybrid business models for statewide LMR networks. Louisiana is one of the few states that have been successful in creating a truly shared network for all agencies and eliminating the tax burden created by duplication of overlapping networks at the state and local government levels.

Assessment of Current Funding

The funding for the operation and maintenance of WISCOM comes from multiple agencies and grant funding sources. This funding model is driven by the use of operational and technical staff supporting WISCOM coming from these multiple agencies, with the majority of these staff having other operational duties outside of WISCOM, supporting other State owned or management communication assets. The WISDOT/WISCOM staffing focuses on daily maintenance and operation of WISCOM and is not designed to efficiently provide funding for expansion or enhancement of the WISCOM network. Historically, to provide enhancement to the WISCOM network, the state has relied on periodic federal grants that can be utilized to offset the cost of network enhancement or expansion. Reliance on federal funding has been a key factor in the ability for the state to develop and establish the WISCOM network in place today.

The current appropriated funding for WISCOM for fiscal year 2016 is $1,045,000. This figure excludes any additional federal pass-through grant funding. The components of that budgeted funding are as follows:

Budgeted Use	DOJ	DOT	Total
Technical and support staff	$ 172,400	$ 390,102	**$ 562,502**
Infrastructure and equipment replacement	78,200	219,396	**297,596**
System technology, maintenance, and support	-	-	**-**
Program support	-	184,902	**184,902**
Total	$ 250,600	$ 794,400	**$ 1,045,000**

As identified in the Current WISCOM Management and Maintenance Staffing Model the cost of the staff that operates and maintains WISCOM is approximately $2.48M annually. The cost of this staff is not all assigned to WISCOM as this staff also supports various other state management communication assets that operate, at times, in parallel to WISCOM. After discussions with WISDOT and the Wisconsin Department of Justice, they indicated that the budgeted funds were not sufficient to cover the expenditure of supporting WISCOM, and that WISDOT funds separate than those specifically designated for WISCOM were expended to support salary and equipment costs incurred to support WISCOM.

For the 2016 fiscal year no funds were budgeted for the support or maintenance of the network technology. After discussion with WISDOT personnel, it was noted that the only time funds would be specifically budged to network support would be when the state contracts with EF Johnson to enhance NMS features, which is not regularly conducted.

In our consideration of the current funding status of WISCOM we have purposefully excluded the consideration of federal grant funds. The purpose of this exclusion is that the state is not in control of the availability or use of these funds on an ongoing basis. The predictability of funding is an integral part of the effective sustainment and future enhancement of WISCOM to meet the state's needs. Reliance on indeterminate future funding potentially limits the resources that can be put into place to effectively carry out the states management and enhancement plans, as these plans potentially involve the increase in state FTE's, significant capital expenditures, or negotiated contract payments for vendor services over multiple state budget cycles. The availability and usage of federal grant funding was critical in the creation of WISCOM, but as the state has no control over the availability of these funds the operation, maintenance, and enhancement of WISCOM should be budged absent of consideration of these funds.

Future sustainment and enhancement of WISCOM will be driven by the priority given to WISCOM by the legislature and the core state agencies involved in the operation, maintenance, and mission critical reliance on the network. Currently the state manages multiple legacy radio networks in parallel to WISCOM for several state agencies. Concerning priorities of the state for funding purposes, there is apparent value in the mission critical service provided by these legacy networks. The state should consider the services that are provided by these legacy networks and determine if the same type and level of service can be provided by WISCOM, then a goal can be identified to bring the enhancements necessary to WISCOM to allow for the retirement of those legacy networks, of which the same level of service can be provided. The potential elimination of parallel networks can potentially free up otherwise designated funding sources for the future sustainment and enhancement of WISCOM.

Our assessment of the current funding of WISCOM is that the budgeted funds are not sufficient to meet the identified needs of the users of the network and the state as a whole. This conclusion is reached by consideration of the three major factors identified above; (a) WISDOT annually expends more funds towards WISCOM than is provided through annual legislative appropriations, (b) significant maintenance and

enhancements are reliant on the availability of federal grant funds, and (c) state agencies maintain legacy radio networks in parallel to WISCOM instead of transitioning to WISCOM for all mission critical operations.

TASK 5 – REPORT AND PLAN FOR A MANAGEMENT, IMPLEMENTATION AND FINANCIAL SUPPORT PROGRAM THAT WILL BE SUSTAINABLE FOR THE NEXT 3/5/10 YEARS

TUSA Consulting Services, LLC, along with their partner Carl, Riggs & Ingram, LLC, were retained by the State of Wisconsin's Department of Justice to provide options on the sustainability and scalability of WISCOM. This includes developing a Sustainable Plan and Recommendations Report for a management, implementation and support program that will be sustainable for the next three, five and ten years. The State also requested recommendations and a strategy for achieving program goals based on the analysis of the same components in Task 3.

The Sustainable Plan and Recommendations Report also needed to include strategies, policies, plans and schedule for Personnel Levels, Infrastructure and Equipment, Network Maintenance and Practices, Multi-cast RF Technology, and Funding Model. The recommendations were for a short term (2016-2019), Long Term (2019-2024), and 2024 and beyond. Since 2016 has passed, TUSA and CRI elected to present a long term, ten year plan that starts in 2017 to satisfy all three time periods.

Existing Conditions, Issues, Opportunities, Future Conditions, and Stakeholder Engagement

In consideration of the current WISCOM P25 VHF radio network, TUSA analyzed the current issues reported by the state and its users. TUSA witnessed detailed technical audits of the three areas and the sites detailed in Task 3 of this report. TUSA also analyzed the infrastructure as part of Task 4 of this report. As individual site issues were discovered at each site, it moves the overall conclusion that the WISCOM network must be looked at holistically, and not just individual issues or sites.

Many of the existing issues have been documented in this report. The State has an opportunity to address the problems so that Wisconsin's First Responders can complete their mission critical objectives. Failure to address these issues, particularly in the immediate near future, could cause WISCOM stakeholders to lose faith and trust in the statewide network, and the vision for true statewide interoperability could be lost.

Personnel Levels

As stated before, the current WISCOM management staff and technical staff have a good understanding of the technical and operational parameters of the WISCOM network. However, this team is considerably under staffed and not budgeted to properly care for the entire WISCOM radio network. Current WISCOM staffing also does not have the engineering resources to support bringing the network to the engineering and industry best practices described in this report.

Our recommendation is the future WISDOT technical staff move to maintaining and sustaining the WISCOM network, as State Patrol has migrated to the WISCOM network. It is understood that the legacy conventional

VHF will be maintained in conjunction with WISCOM for some period of time, but should be dismantled over a period of time as WISCOM becomes the primary communications network.

This future staff should provide services to all sites in the WISCOM network regardless of how the site was funded by local or staff WISCOM agencies. This provides a consistent plan for maintenance of WISCOM sites. As the WISCOM network is very IP centric in the connectivity provided to all the WISCOM sites, it is recommended that three (3) Network Analysts be added to staffing (one for each region) to support all network components for the current and future sites for WISCOM. At least one (1) Network Communications System Analyst from each region should become the subject matter expert (SME) for the subscriber units operating on WISCOM and support all codeplug/personality configurations.

As the State Patrol completes their migration to WISCOM, consideration should be given to merging the WISCOM/WISDOT technical staff with the WISCOM management staff to one government organization in support of the entire WISCOM/WISDOT network.

WISCOM and WISDOT could also create an intergovernmental agreement that drives technical response and priorities based on the operation of WISCOM service levels that are required to support a public safety communications network. WISCOM must be able to ensure and guarantee to all users of WISCOM that the network is supported to the highest service levels available to public safety. The future operations and maintenance staff costs, and organization chart blending and expanding to this model are as follows:

Future WISCOM Operation & Maintenance Staffing

Salaries	Position	DOT ENGINEERING CHIEF	NETWORK COMM SUPV	NETWORK COMM SYS ANALYST-ADV	ELECTRICAL ENGINEER-ADV	IS SUPERVISOR 2	IS BUSINESS AUTO SEN	IS NETWORK SVCS SPEC	Frequency Specialist	Asset Management/Staff Management	Program Supervisor	Program & Policy Analyst (Trainer)	Total Personeel
Pay Schedule & Range		81-02	81-03	06-63	14-13	70-02	07-34	07-33	07-34				
# of Personnel		1	3	21	1	1	1	4	1	2	1	2	38
Average Salary		$91,998.40	$68,182.40	$56,000.00	$72,800.00	$82,160.00	$56,659.20	$68,640.00	$54,184.00	$27,500.00	$63,500.00	$61,000.00	
Benefits 36%		$134,317.66	$99,075.85	$81,373.60	$105,785.68	$119,386.70	$82,331.48	$99,740.78	$78,734.77	$37,400.00	$86,360.00	$82,960.00	
		$134,317.66	$297,227.54	$1,708,845.60	$105,785.68	$119,386.70	$82,331.48	$398,963.14	$78,734.77	$74,800.00	$86,360.00	$165,920.00	
											Total Annual Salaries		$3,118,354.90

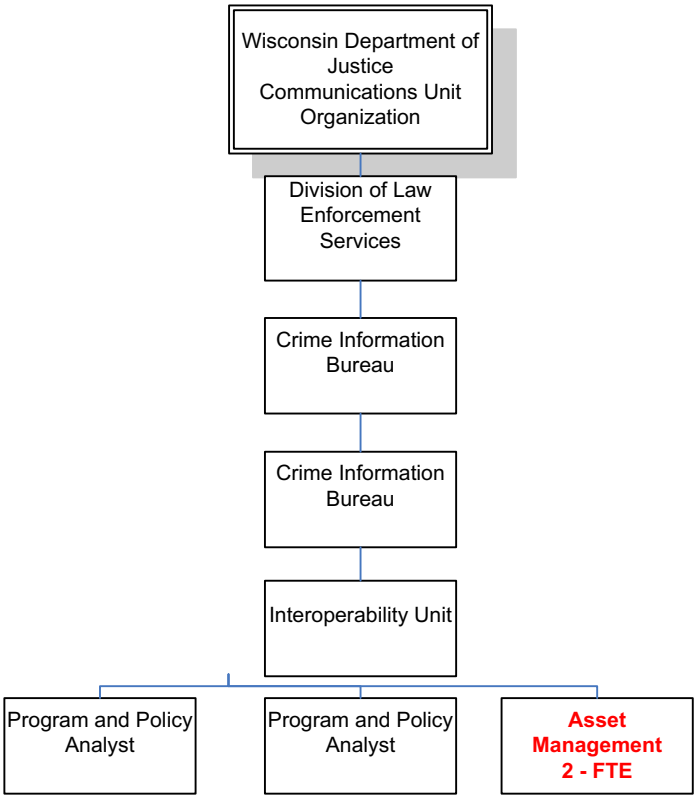
The future WISCOM management and technical staff is estimated at $3.12M annually for salaries/benefits and $2,135,000 for vehicles, test equipment, and training. This plan will support the next ten years of the network, however, as additional agencies join the WISCOM system the staffing levels should be revisited.

Consideration has to also be given to qualifications and salary for the current and future technical staff to maintain a technically qualified insource model that provides operation and maintenance services. The state invests in equipment, training, and tenure for this technical staff. A typical starting technician from a qualified technical trade school or the military should advance to a median salary of around $56,000 upon five (5) years of service to the state. This progression would provide a parallel path to the private sector for the same person. The future budget takes this into consideration.

When the government sector doesn't allow for this type of progression, it becomes very easy for the private sector to recruit government technical staff and save on the costs of training new recruits. However, the government sector will have to continue in recruitment of technical staff and provide training to allow for a qualified staff to maintain their technical systems.

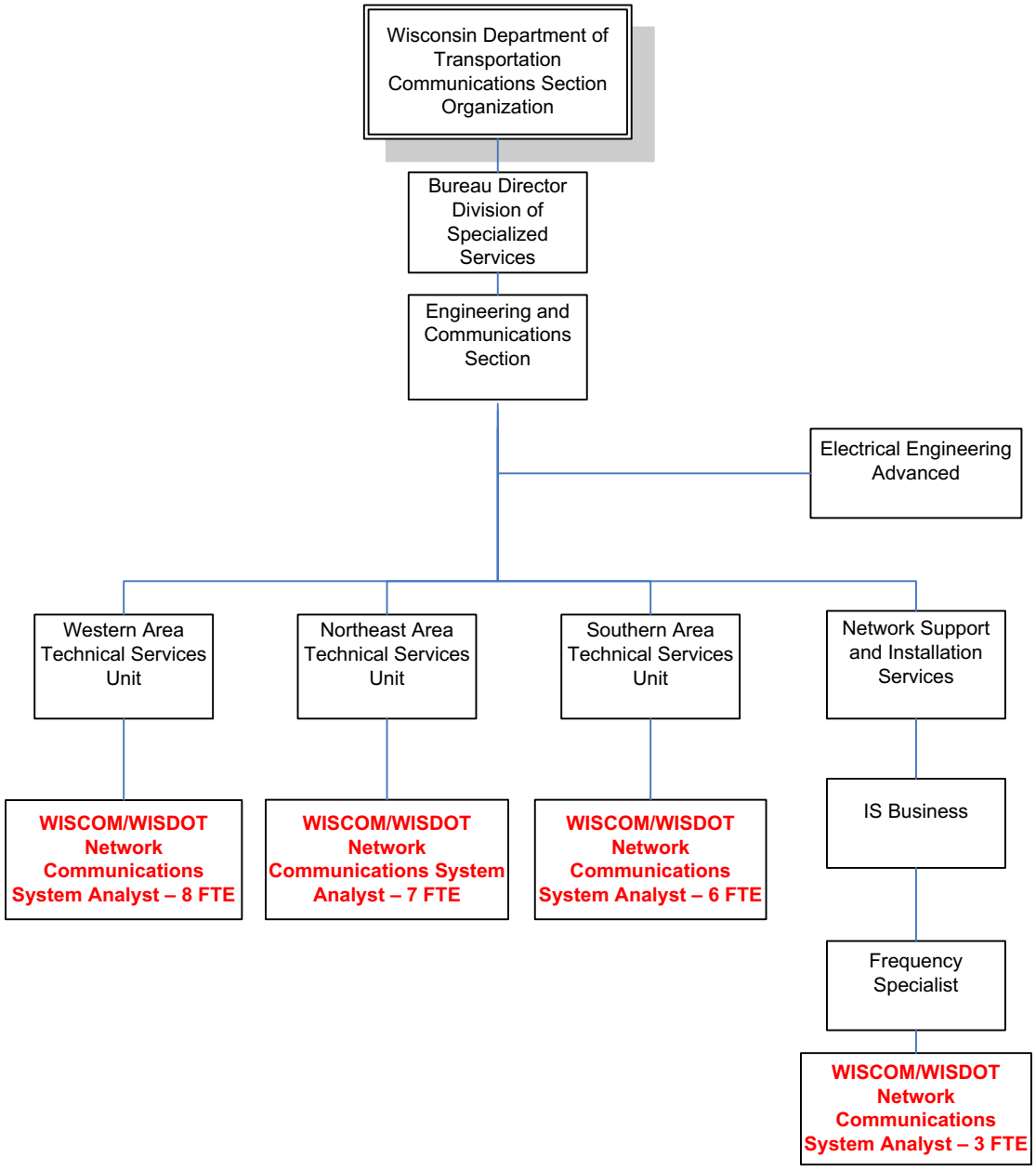
The State of Wisconsin has made the investment and has a good technical staff that can provide on-going maintenance services to the WISCOM system and supporting elements. However, the state should not look to this staff to provide detailed implementation type services. While the staff could do these types of implementation services, they are providing on-going maintenance services to the systems already in place. Implementation services are considered as another group of people and have been recommended as outsource in the recommendations of this report.

Future WISCOM Management Staff



The WISCOM management staff should establish and track a network preventative maintenance plan that would be supported by the WISDOT Technical and Network staff. This plan should be communicated to all users on WISCOM to gain acceptance and support from the user community to promote a positive message about the WISCOM network.

Future WISCOM Technical Staff



Network Maintenance and Practices

As stated throughout this report, there have been many inconsistencies and the lack of best practices in the overall installation, maintenance, and support of the WISCOM system. Establishing a stable network starts with a recommended outsourced staffing program that provides engineering and industry best practices on a site by site basis, with final analysis at a statewide level to include:

1. Intermodulation Analysis
2. Interference Analysis
3. Detailed Frequency Plan
4. Network Optimization and Preventative Maintenance

This is the top priority for WISCOM to become a stable, reliable Public Safety network based on these engineering best practices. The Intermodulation Analysis, Interference Analysis, and Detailed Frequency Plan would need to be farmed out to a qualified engineering firm. The Network Optimization and Preventative Maintenance would need to be performed by either a qualified service shop, or the radio manufacturer.

EF Johnson has given us a proposal (See Appendix G) that addresses the Network Optimization and Preventative Maintenance by performing a health check on the network. This will baseline the condition of the entire network and confirm that all sites are performing within specifications and are installed properly. Health checks will be performed at every site within WISCOM and will be performed by EF Johnson personnel in conjunction with state personnel. Once the health check has been completed, the results will be compiled and shared with the State for deficiencies that need to be corrected. If requested by the state, EF Johnson will provide a quote to correct items identified.

The health check will cover the following at each RF site:

- Annual Preventative Maintenance level inspection;
- Site cleaning;
- Installation and cabling check;
- Firmware and hardware check
    - Deficiency identification (EF Johnson will correct minor deficiencies at every site, but major repairs and equipment that is out of warranty will not be covered);
- Point to Point Network Audit.

The second priority is all sites should be reviewed and analyzed under an engineering best practices study for:

1. Generator Loading
2. Site Civils – grounding
3. Tower Loading
4. HVAC Loading

The costs for this recommended outsourced labor and services is estimated at $10,509,920. This best practices effort is estimated to take one year to perform with the outsource staff remaining available for implementation oversight of the recommend engineering and upgrades of the WISCOM network. The State would have to determine if they wanted to outsource work directly to EF Johnson, or do a competitive procurement for these levels of services.

Engineering Best Practices

	Year 1	Year 2	Year 3	Total
Outsourced Vendor Personnel				
Project management (3 person)	$ 848,640	$ 848,640	$ 848,640	$ 2,545,920
Engineering (2 persons)	565,760	565,760	565,760	1,697,280
Engineering - Frequency/IM Planning	282,880	282,880	-	565,760
IT Staff	282,880	282,880	282,880	848,640
Administration Staff	141,440	141,440	141,440	424,320
Staffing Total	2,121,600	2,121,600	1,838,720	6,081,920
Equpment & Services				
Generator Load (Engineering)	90,000	90,000	90,000	270,000
Site Prep - Shelter, Grounding, Site Civils	1,260,000	1,260,000	1,260,000	3,780,000
Tower Loading (Engineering)	90,000	90,000	90,000	270,000
HVAC Load (Engineering)	36,000	36,000	36,000	108,000
Engineering & Services Total	1,476,000	1,476,000	1,476,000	4,428,000
Engineering Best Practices Total	$3,597,600	$3,597,600	$3,314,720	$10,509,920

During the three years of providing outsourced best practices to bring WISCOM to a baseline best practices level, the WISCOM management and WISCOM/WISDOT technical staff should continue to manage and maintain the WISCOM network and provide oversight to the outsourced engineering staff to understand the best practices method as described.

This technical staff, as the insourced service and maintenance provider, would then be required to maintain the best practices and ensure any new sites are constructed and implemented with these same guidelines. The combined new WISCOM management and WISCOM/WISDOT technical staff are projected for a budget of $2,521,467 annually with a support budget for vehicles, test equipment, and other technical support for this staff of $425,133 annually.

EF JOHNSON TECHNOLOGY REFRESH

EF Johnson has provided a technology refresh and support plan proposal that would provide for an upgrade of base stations and the Network Interface Units (NIU), and with Tier 2 maintenance, and support for the WISCOM state sites on the network. This plan was requested by TUSA as part of the process to create a budget to support and for sustainability. This proposal focuses on support services and an equipment replacement cycle for equipment that was known to becoming for end of life that was just recently formally announced.

The maintenance plan in the proposal is a good plan that allows for:

- Two (2) dedicated EF Johnson qualified technicians to provide Tier 2 support to the WISCOM technical staff. These dedicated technicians would also provide annual preventative maintenance support on the network.
- Software updates and upgrades to address bug fixes and current network features
- Committed on-site response times
- Field Case Management
- Yearly tower and antenna network inspection

The maintenance plan would begin with a network audit performed by EF Johnson to establish a baseline of network support. This network audit would provide detailed testing of each site, similar to what was performed and witnessed by TUSA. This audit would also confirm the network connectivity is adequate to support the WISCOM radio sites and NMS.

The EF Johnson proposal also provides a section that discusses a model for replacement of the subscribers on a seven (7) year cycle, but doesn't contain much detail or specifics, and the pricing varies too greatly to provide any conclusions.

The EF Johnson proposal also allows for replacement of the 3800 and 4100 base stations over a period of time. The 4100 base station would be replaced by WISCOM staff in years two (2) and three (3). The 4200 analog simulcast base station would be replaced in year one (1). The 3800 base station replacement would start in year four (4) and be completed by year seven (7). The NIU's would get replaced in year one (1).

The overall network maintenance and sustained plan is good with a few items that would need to be addressed as part of this proposal.

1. Hardware refresh is for WISCOM describes states sites only. This proposal would need to include all sites as part of the WISCOM network. TUSA confirmed with EF Johnson that all WISCOM sites are covered under this proposal.

2. Network Management System (NMS) – EF Johnson discusses a rework of the architecture of this part of the network, but does not discuss replacing it in the sustainment. The NMS issues would need to be addressed immediately, potentially with replacement.

3. Proposal does not allow for hardware refresh on the dispatch center consoles.

The budgetary pricing for this proposal on a yearly basis and a ten year sustainment total is:

Year	Health Check	Hardware Refresh w/Hardware Care	Software Care w/remote and on-site support	Yearly Total
Year 1	$ 341,020	$ -	$ 1,896,335	$ 2,237,355
Year 2	-	2,101,398	2,027,285	4,128,683
Year 3	-	2,104,140	2,039,645	4,143,785
Year 4	-	2,086,624	2,139,976	4,226,600
Year 5	-	2,140,768	2,339,089	4,479,857
Year 6	-	2,190,699	2,532,595	4,723,293
Year 7	-	2,317,120	2,726,506	5,043,626
Year 8	-	2,317,120	2,740,835	5,057,955
Year 9	-	2,317,120	2,755,593	5,072,713
Year 10	-	2,317,120	2,770,794	5,087,915
Total	$ 341,020	$ 19,892,109	$ 23,968,653	$ 44,201,782

Under this EF Johnson proposal, the state is still responsible for all the engineering best practices described in this report. This would not put EF Johnson in any part responsible for the engineering best practices such as:

- Intermodulation Analysis
- Interference Analysis
- Detailed Frequency Plan
- Generator Loading
- Site Civils – grounding
- Tower Loading
- HVAC Loading

Our top priority listed above would still be the recommendation provided by TUSA, to include the engineering best practices in conjunction with this proposal. The frequency plan would be an absolute necessity before starting any of the work by EF Johnson in their proposal.

COMPETITIVE RFP TECHNOLOGY REFRESH

Upon review of the EF Johnson proposal and the associated costs, TUSA also performed an analysis of refreshing the WISCOM network via a competitive procurement process. Analysis was based on the other P25 manufacturer's equipment and network architecture with a similar program of refreshing/replacing the network and providing a maintenance program, software services plan, and a sustainment plan for a ten (10) year period.

The budgetary pricing for this is:

Competitive Procurement

Infrastructure Refresh/Replacement	$	20,022,000
Dispatch Center Console & Logging Recorder		10,469,250
Hardware/Software Refresh/Sustainment (10 years)		15,552,000
Remote and On-Site Support (10 years)		25,000,000
Total	**$**	**71,043,250**

In making as close of comparison as possible, the following costs show the differences between the EF Johnson proposal and performing a competitive technology refresh, maintenance, and sustainment plan:

Competitive Procurement & EF Johnson Comparison

	Competitive	EFJ
Infrastructure Refresh/Replacement	$ 20,022,000	$ 19,892,110
Dispatch Center Console & Logging Recorder	10,469,250	5,079,000
Hardware/Software Refresh/Sustainment (10 years)	15,552,000	23,968,652
Remote and On-Site Support (10 years)	25,000,000	
Total	**$ 71,043,250**	**$ 48,939,761**

As this comparison shows a significant difference, vendors can become very creative and more cost competitive when such an opportunity is presented. A competitive proposal would allow for the engineering best practices to be included in a specification, ultimately holding the vendor responsible for the network design and proper operation.

The only downside to a competitive procurement would be the cost and time to develop, along with the time for vendor response, proposal evaluations, and contract negotiations. It is estimated that it would cost approximately $500,000 to develop a specification and the time needed for the total procurement process could take a year and a half (1 ½) for a statewide network.

Sustainment Funding Options

Cost Trends have many state enterprises today looking to outsourcing as an effective way to leverage commercial economies of scale to drive costs down for their Information Technology (IT) services. Cloud-based services and Software as a Service (SaaS) have had significant impact to state and local government spending within the last decade, reducing capital and operational expenditures. Radio networks, however, is difficult to fit into many of these current IT models for cost efficiencies. The radio network is not a service used by all members of the enterprise so the ability to achieve economies of scale across the entire enterprise diminishes with fewer participants. The radio network also cannot be offered as a cloud based or software service today. One of the largest cost drivers in the radio network is tower sites. Tower sites must be placed and fixed in the proximity of the users. In more remote areas, tower sites may only be accessed by a few users per hour or even per day. A tower site in an urban area, however, may be accessed by thousands of users per day.

The key to cost savings for the state is through sharing cost with more users on the network. As an example, a county has an 8-site network that provides 95% portable in building coverage countywide. WISCOM may operate two sites in the same County, but only achieves reliable mobile radio coverage in the same geography. If the county joined WISCOM with its eight sites, the state would not need to locate any towers in that county. As part of a potential governance agreement for sharing of the sites by both state and local governments, the state would need to add channel capacity to the existing sites to accommodate state users. Adding channel capacity to existing sites would cost 10-20 percent of what it would cost to build two tower sites and far less than what it would cost to replicate the eight sites the County has today. This also reduces the total number of sites necessary for the state to build to have statewide portable/handheld coverage.

A shared services approach would give local government users and administrators access to any of the services supported by the state core(s). This provides the opportunity to avoid the cost of owning the core elements of a P25 network, and benefits from the shared services available to each user that joins the network. The state benefits from the enhanced portable/handheld coverage provided from the towers owned by the County and could avoid the cost of building additional sites in the county.

There exists an opportunity for cost sharing with the state through local government partnerships. Many local governments have their own municipal or countywide radio network network. Some of these are already P25 networks. If the state and the selected outsource vendor for the P25 network can establish a partnership with a county for shared radio network services, then the state, the vendor and the local government benefit from this agreement. The state benefits by having access to the local government towers and infrastructure. This

eliminates the need for the state to have its own towers or tower leases in that area. The state may also benefits from an increase in number of users on the network, which may translate to cost sharing opportunities for the state and all partner agencies. The local government benefits from reduced infrastructure cost and direct interoperability with state agencies. The local taxpayers benefit from not having to pay for duplication of radio network infrastructure in their area for both state and local government users. The challenges with establishing partnerships of this nature tend to be tied to timing. That being a partnership may not become effectively integrated into the state network until years after initial implementation. Therefore, there is not predictable forecast as to when a partnership might be established. However, the biggest challenge for WISCOM is to create and manage a radio network that is extremely reliable.

Upon any site additions to the WISCOM network, regardless of how a county or municipality might have joined, the state should take responsibility of the site maintenance and sustainment under a consolidated plan. The current model doesn't allow for this and have created some instances where sites are not maintained to the same standards, although all WISCOM users may rely upon the site and the technical equipment for public safety communications.

The provided chart represents the sustainment of future WISCOM funding over a 10-year period compared to the projected annual expenditures associated with sustainment of the network. This model is based on the concept of users of the network paying a periodic fee to support the continued maintenance and sustainment of WISCOM at the required level of coverage and reliability necessary for mission critical public safety communications. As indicated, the funding model only addresses the specific costs associated with the sustainment of the network and not bringing the network up to industry recognized best practices, which is a cost that should be directly borne by the state. This cost shared model estimates a per radio monthly cost of $29.05 over a 10-year period, assuming all 22,759 radios utilizing WISCOM continue to utilize WISCOM and assist in this cost shared model.

	Per Unit Cost		Annual Periods	Unit Count	Cost
LMR Infrastructure Sustainment/Maintenance Plan					
Software Services and Manufacturer Support	$ 19,885	Per Site	10	116	$ 23,066,600
Hardware Lifecycle Refresh	$ 20,465	Per Site	9	116	$ 21,365,460
Insource Current Future Support					
Salaries (State)	$ 2,292,130	Anually	10		$ 22,921,300
Test Equipment Services (State)	$ 74,500	Anually	10		$ 745,000
Vehicles (State)	$ 865,900	Periodic	3		$ 2,597,700
Vehicles Services (State)	$ 136,500	Anually	10		$ 1,365,000
Training	$ 5,000	Periodic	50		$ 250,000
Total Insource Current Future Support					$ 27,879,000
Preventative Maintenance for Infrastructure Support					
Backup Power Systems					
Battery	$ 500	Per Site	10	116	$ 580,000
UPS	$ 500	Per Site	10	116	$ 580,000
Generator	$ 650	Per Site	10	111	$ 721,500
Civil (tower, shelter, fencing, etc..)	$ 1,000	Per Site	10	111	$ 1,110,000
Spare parts (RF, Microwave, other)	$ 1,000	Per Site	10	116	$ 1,160,000
Asset Management Software	$ 225,000	System	1		$ 225,000
Asset software	$ 30,000	Anually	10		$ 300,000
Utilities(Electric)	$ 4,800	Per Site	10	116	$ 5,568,000
Generator Fuel (Normal Operations)	$ 400	Per Site	10	111	$ 444,000
Total Preventative Maintenance for Infrastructure Support					$ 10,688,500
Total Sustainment Cost					$ 82,999,560

Note: These figures were based on the EF Johnson proposal for this funding example. According to the issues noted with the EF Johnson proposal, these cost figures could change.

This funding model provides consistent funding availability for the state to manage WISCOM operations, as well as providing a stable expectation of future expenditures by the users of WISCOM.

FUNDING MODEL FOR SUBSCRIBER SUSTAINMENT

In addition to the network user fee, a similar model can be prepared to account for the cost of the individual subscriber units utilizing WISCOM. Based on the known user count there are 22,759 radio units utilizing WISCOM. Assuming an average hardware cost per subscriber radio unit of $4,669, users of WISCOM could participate in a state organized purchase of subscriber units and bundle the cost of the subscriber unit with the cost of the network user fee. Again, assuming all 22,759 radio units utilizing WISCOM enter into the program the total estimated subscriber cost would equal $106,272,996, but as the cost would be borne by the entity purchasing the radios, the total cost of the subscribers would be paid for over a ten year time period at an estimated cost of $38.91 per month per subscriber. This estimation is based on the utilization of a mid-tier radio with functionality required for public safety, and if a more or less sophisticated subscriber would be required by a user, then the associated user fee would increase or decrease according to the unit's cost.

	Unit Cost	Unit Count	Total Cost
Portable Subscriber	$ 4,632.40	12,320	$ 57,071,168
Mobile Subscriber	$ 4,658.30	10,092	47,011,564
Control Station	$ 6,312.00	347	2,190,264
Total Cost			**$ 106,272,996**

Avg. Cost per Month Per Radio (10 years) $38.91

A statewide combined competitive procurement of the subscribers provides the best way to create a list of WISCOM certified and approved list of mobile, portable, and control station subscribers available to WISCOM. The WISCOM users for current and future purchases could benefit from this methodology regardless of the how or what manufacturer each agency wants to purchase the subscribers. The proposed funding on a monthly basis provides an operational expense to refresh the subscribers on a known calendar basis. This prevents legacy subscribers having issues with WISCOM due to outdated subscriber technology.

WISCOM CURRENT INSOURCED AND OWNED NETWORK SUSTAINMENT WITH A SHARED INFRASTRUCTURE AND SUBSCRIBER FUNDING COST MODEL

The overall cost shared model to include infrastructure and subscribers creates a funding source with sharing the cost of maintaining and sustaining the WISCOM network among all users that utilize the WISCOM network for public safety communications.

Engineering Best Practices	$10,509,920	3 years	State
Infrastructure Software & Manufacture Support	$21,475,652	10 years	Shared
Infrastructure Technology Refresh	$19,892,110	10 years	Shared
WISCOM Future Insource Maintenance Personnel	$36,141,249	10 years	Shared
WISCOM Preventative Maintenance for Sites	$10,083,000	10 years	Shared
Total 10 Year Plan	$98,101,930		

Each individual line item represents a cost for the state. The first line item was defined as the first critical step to stabilize and baseline the WISCOM network and should be funded by the state. The other line items are the respective costs for maintaining and sustaining the network for a ten (10) year period.

In creating a shared model by all WISCOM users, a self-sustaining fund would be generated by this model for technology refreshes and sustainment for an indefinite period of time beyond the 10 years demonstrated.

Infrastructure Sustainment

WISCOM Network Maintenance and Sustainment Cost per Month per Radio	$32.07	10 years	Agency
WISCOM Yearly Maintenance and Sustainment Fund	**$8,759,201.04**		

Subscriber Sustainment

Current WISCOM Subscribers	22,759		
WISCOM Replacement Total Cost	$106,272,996		
Avg. Subscriber Cost Per Radio	$4,669.49		
Avg. Subscriber Cost per Month per Radio	$38.91	10 years	Agency
WISCOM Yearly Subscriber Sustainment Fund	**$10,627,299.56**		

In today's modern technology, this shared cost model is very similar to the cellular phone model. A vendor builds a network with the end user buying a phone (subscriber device) and paying a monthly network fee. Recent cellular providers are now putting the cost of the subscriber device into the monthly network fee to spread the subscriber cost over a period of time. However, the end user can always have the option to buy the subscriber device outright if their budget allows it.

A cellular provider markets their respective network based on reliable communications and subscribers. This is done through good coverage and maintenance of the overall network. The cellular providers also typically demonstrate the coverage of their network with a visual map and also provides different levels of customer service for the end users to include training and operation of the device on the network.

To best demonstrate the impact to each agency on a yearly basis, an agency subscriber summary has been created to show the impact this model would have on each agency according to their current subscriber counts on the WISCOM network.

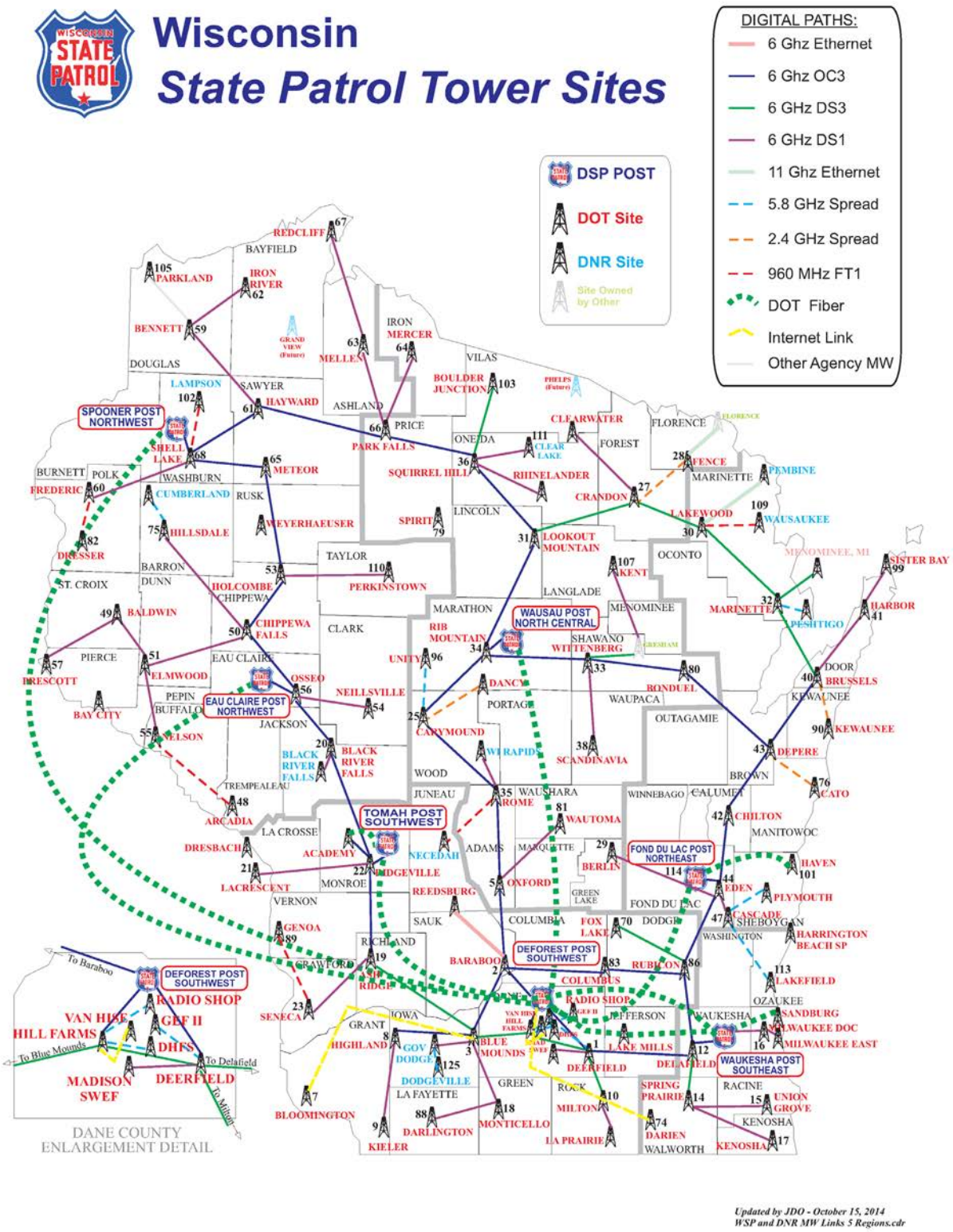
Agency Summary Shared Subscriber and Network Cost

County	Mobile	Portable	Control Station	System Radio	Console	Yearly Cost
Adams	35	17	2	0	0	$18,822
Ashland	7	8	2	0	0	$5,926
Barron	10	33	2	0	0	$15,685
Bayfield	113	153	18	7	4	$101,432
Brown	5	26	21	0	0	$18,125
Buffalo	1	1	2	0	0	$1,394
Burnett	4	0	0	0	0	$1,394
Calumet	3	5	3	0	0	$3,834
Chippewa	9	0	3	0	0	$4,183
Clark	42	40	1	0	0	$28,931
Columbia	14	16	2	0	0	$11,154
Crawford	3	0	1	0	0	$1,394
Dane	1049	1535	39	0	3	$914,284
Dodge	32	59	2	0	1	$32,416
Douglas	394	463	10	0	1	$302,205
Dunn	140	146	4	23	5	$109,101
Eau Claire	12	22	1	0	0	$12,200
Florence	12	16	3	18	2	$17,080
Fond du Lac	394	259	6	0	1	$229,704
Forest	7	1	2	0	0	$3,486
Grant	8	142	1	0	0	$52,633
Green	0	0	1	0	0	$349
Green Lake	3	0	1	0	0	$1,394
Iowa	209	510	18	1	9	$257,241
Iron	4	10	1	0	0	$5,228
Jackson	1	0	1	0	0	$697
Jefferson	30	44	1	0	4	$26,142
Juneau	241	244	23	12	4	$181,253
Kenosha	127	8	2	0	0	$47,753
Kewaunee	148	305	15	30	23	$173,585
La Crosse	28	49	3	0	0	$27,885
Lafayette	11	23	0	0	0	$11,851
Langlade	28	33	4	0	2	$22,657
Lincoln	2	1	2	0	0	$1,743
Manitowoc	97	116	0	0	0	$74,244
Marathon	18	49	7	0	0	$25,794
Marinette	2	8	3	0	0	$4,531
Marquette	3	0	0	0	0	$1,046
Menominee	58	0	12	0	0	$24,400
Milwaukee	502	915	7	14	6	$501,236
Monroe	65	87	1	0	0	$53,330
Oconto	9	2	1	0	0	$4,183
Oneida	101	68	0	0	0	$58,907
Outagamie	3	5	1	0	0	$3,137
Ozaukee	44	31	0	0	0	$26,142
Pepin	1	1	2	0	0	$1,394
Pierce	43	48	3	0	0	$32,765
Polk	5	0	1	0	0	$2,091
Portage	3	0	2	0	0	$1,743
Price	2	0	1	0	0	$1,046
Racine	100	138	1	0	0	$83,307
Richland	18	16	2	0	0	$12,548
Rock	241	537	1	0	0	$271,532
Rusk	0	0	1	0	0	$349
St Croix	15	20	3	0	0	$13,245
Sauk	87	91	5	0	0	$63,787
Sawyer	310	388	17	2	0	$249,921
Shawano	21	31	1	0	0	$18,474
Sheboygan	10	0	0	0	0	$3,486
Taylor	37	93	8	4	15	$49,496
Trempealeau	109	275	9	0	0	$136,986
Vernon	5	2	1	0	0	$2,789
Vilas	41	8	1	0	0	$17,428
Walworth	115	66	0	0	0	$63,090
Washburn	30	27	3	0	0	$20,914
Washington	1031	640	16	0	0	$588,028
Waukesha	118	311	5	0	0	$151,277
Waupaca	4	3	1	0	1	$2,789
Waushara	2	0	0	0	0	$697
Winnebago	20	196	10	0	0	$78,776
Wood	36	56	2	0	0	$32,765
County Totals	6432	8397	325	111	81	$5,320,835

State	Mobile	Portable	Control Station	System Radio	Console	
State Patrol	734	688	8	0	10	$498,447
DOT	0	27	0	0	0	$9,411
DNR	752	730	8	0	1	$519,361
DOJ	141	179	0	0	0	$111,541
DMA	138	389	0	0	1	$183,693
DOA	6	9	0	0	1	$5,228
DHS	478	185	0	5	6	$232,841
DOC	1147	1080	0	6	11	$778,344
UW	52	287	2	0	2	$118,860
State Totals	3448	3574	18	11	32	$2,457,727

	Mobile	Portable	Control Station	System Radio	Console	
Unknown	25	63	0	0	0	$30,674
Non-Government	126	94	2	0	1	$77,381

Federal	Mobile	Portable	Control Station	System Radio	Console	
Federal	212	349	4	0	0	$196,939


Wisconsin
State Patrol Tower Sites
DIGITAL PATHS:
6 Ghz Ethernet
6 Ghz OC3
6 GHz DS3
6 GHz DS1
11 Ghz Ethernet
5.8 GHz Spread
2.4 GHz Spread
960 MHz FT1
DOT Fiber
Internet Link
Other Agency MW
DSP POST
DOT Site
DNR Site
Site Owned by Other
SPOONER POST NORTHWEST
EAU CLAIRE POST NORTHWEST
WAUSAU POST NORTH CENTRAL
TOMAH POST SOUTHWEST
FOND DU LAC POST NORTHEAST
DEFOREST POST SOUTHWEST
WAUKESHA POST SOUTHEAST
DEFOREST POST SOUTHWEST
RADIO SHOP
VAN HISE
HILL FARMS
GEF II
DHFS
MADISON
SWEF
DEERFIELD
To Baraboo
To Blue Mounds
To Delafield
To Milton
DANE COUNTY
ENLARGEMENT DETAIL
REDCLIFF
BAYFIELD
PARKLAND
IRON RIVER
BENNETT
DOUGLAS
LAMPSON
SAWYER
HAYWARD
ASHLAND
IRON
MERCER
MELLEN
VILAS
BOULDER JUNCTION
PHELPS
PRICE
PARK FALLS
ONEIDA
FLORENCE
CLEARWATER
CLEAR LAKE
FOREST
FENCE
MARINETTE
PEMBINE
SHELL LAKE
METEOR
SQUIRREL HILL
RHINELANDER
CRANDON
LAKEWOOD
WAUSAUKEE
BURNETT
POLK
WASHBURN
FREDERIC
CUMBERLAND
RUSK
WEYERHAEUSER
SPIRIT
LINCOLN
LOOKOUT MOUNTAIN
HILLSDALE
DIESSER
TAYLOR
PERKINSTOWN
OCONTO
KENT
MENOMINEE, MI
SISTER BAY
BARRON
DUNN
ST. CROIX
HOLCOMBE
CHIPPEWA
LANGLADE
MARATHON
MENOMINEE
MARINETTE
PESHTIGO
HARBOR
BALDWIN
CHIPPEWA FALLS
CLARK
RIB MOUNTAIN
WAUSAU POST NORTH CENTRAL
SHAWANO
WITTENBERG
GRESHAM
PIERCE
EAU CLAIRE
UNITY
DANCY
BONDUEL
DOOR
BRUSSELS
PRESCOTT
ELMWOOD
OSSEO
NEILLSVILLE
WAUPACA
KEWAUNEE
PEPIN
BUFFALO
EAU CLAIRE POST NORTHWEST
PORTAGE
BAY CITY
JACKSON
CARYMOUND
OUTAGAMIE
NELSON
BLACK RIVER FALLS
WI RAPIDS
SCANDINAVIA
DEPERE
KEWAUNEE
WOOD
BROWN
TREMPEALEAU
JUNEAU
WAUSHARA
ROME
WINNEBAGO
CALUMET
CATO
ARCADIA
TOMAH POST SOUTHWEST
WAUTOMA
CHILTON
LA CROSSE
MANITOWOC
DRESBACH
ACADEMY
NECEDAH
ADAMS
MARQUETTE
FOND DU LAC POST NORTHEAST
BERLIN
HAVEN
LACRESCENT
RIDGEVILLE
REEDSBURG
OXFORD
EDEN
PLYMOUTH
MONROE
VERNON
GREEN LAKE
FOND DU LAC
CASCADE
GENOA
SAUK
COLUMBIA
FOX LAKE
DODGE
SHEBOYGAN
HARRINGTON BEACH SP
RICHLAND
CRAWFORD
DEFOREST POST SOUTHWEST
BARABOO
RUBICON
COLUMBUS
LAKEFIELD
RADIO SHOP
OZAUKEE
SENECA
GRANT
IOWA
JEFFERSON
WAUKESHA
SANDBURG
WAUKEE DOC
HIGHLAND
GOV DODGE
BLUE MOUNDS
LAKE MILLS
MILWAUKEE EAST
DEERFIELD
DELAFIELD
WAUKESHA POST SOUTHEAST
DODGEVILLE
LA FAYETTE
GREEN
ROCK
SPRING PRAIRIE
RACINE
UNION GROVE
BLOOMINGTON
MILTON
KENOSHA
DARLINGTON
MONTICELLO
DARIEN
WALWORTH
KIELER
LA PRAIRIE
Updated by JDO - October 15, 2014
WSP and DNR MW Links 5 Regions.cdr

CONCLUSIONS AND RECOMMENDATIONS

TUSA has analyzed the WISCOM network based on this report and provides the following conclusions and recommendations for the State of Wisconsin to consider. For starters, the WISCOM network was planned and established on a 95% mobile coverage network utilizing many of the existing tower sites being used by the Wisconsin State Patrol and Department of Natural Resources for the legacy conventional VHF network. These tower sites also provided connectivity for the WISDOT microwave network and support of other connectivity for WISDOT. WISCOM was able to utilize this existing infrastructure and connectivity, but it appears to have been done under processes that were not industry best practices. Counties and municipalities have partnered and joined WISCOM, with added sites for coverage enhancements to their respective areas. As these sites followed some industry best practices, some sites were noted as questionable.

Industry best practices have not been taken into consideration, such as tower loading, power loading, HVAC loading, and grounding on the WISDOT sites when they were built, or expanded, to support the WISCOM network. The WISDOT microwave network was also built to support the conventional VHF network and WISDOT connectivity and required EF Johnson engineering assistance to establish an IP type network that better supported the WISCOM network implementation by the state staff. Frequency, antenna, and combiner planning were engineered by state staff, and in some cases industry best practices may not have been followed that would provide an optimal WISCOM network.

WISCOM was the first large scale statewide network for EF Johnson. It was sold as equipment for the WISCOM sites and implemented by state staff. The 3800 series base station was the primary base station implemented by the state, and it have been discovered in this process that the 3800 is end of life. TUSA is concerned the state did not get the anticipated 15+ years of life from the base station for the infrastructure. The newer series of EF Johnson base stations, 4100 and 4200 had technical issues and required stable external frequency sources to lessen the issues.

TUSA recommends the top priority for the WISCOM network is a budget that provides for a plan that outsources engineering and project management to create a detailed plan that analyzes the frequency plan and the overall network to include connectivity based on industry best practices. In parallel with the engineering effort on the technical portion of the network, the sites should be analyzed and upgraded based on engineering best practices.

ESTIMATED COST (3 years) Engineering Best Practices - $10,509,920

The second step and of equal priority is to start the replacement cycle of the EF Johnson infrastructure equipment that is at end of life. This replacement would also include the newer base stations that have presented multiple issues to the state. The EF Johnson proposal shows equipment replacement cycle through 7 years. This should be expedited and completed in 3-5 years.

TUSA also suggests the State explore a competitive procurement for infrastructure and long term maintenance and sustainment plan that includes a detailed specification for a new or upgraded WISCOM network that is completed and tested per established public safety guidelines and best practices. If the

competitive procurement, versus the EF Johnson proposed upgrade, is decided by the state, the outsourced engineering best practices could also be included in the specifications and contracted to the selected vendor for total accountability.

ESTIMATED COST (3-5 years): Infrastructure $60,000,000 to $82,000,000

TUSA also recommends that new subscribers be procured under a state competitive process that allows for all P25 vendors that have completed the CAP process and state certification process. The approved equipment would be under a state plan that includes extended warranty maintenance. This process should be done in parallel with the competitive or negotiated infrastructure process. This cost could be done as a capital expenditure, or a leased model over a period of ten years.

ESTIMATED COST (10 years): Subscribers $106,272,996

In evaluation of funding the entire WISCOM network, TUSA recommends a shared cost model that all WISCOM users would pay a network fee of approximately $349 per subscriber, per year, for a sustained and maintained WISCOM network based on industry best practices. A fund would then need to be created, to support an infrastructure that is procured under a long-term plan. This same cost model could provide a WISCOM user with a subscriber that could be purchased with capital funds, if desired, or pay a yearly subscriber fee of approximately $523 (Subscriber - $467 with extended warranty maintenance fee - $56) for a mid-tier subscriber. These costs could increase or decrease according to the type of subscriber radio chosen by the agency from the state subscriber procurement process.

While establishing the upgraded WISCOM network from this plan and recommendations, TUSA would recommend that WISCOM and WISDOT management and technical staff merge to one organization in the state government with ultimate responsibility to manage, maintain, and sustain the WISCOM network. This plan would require a merger that supports the WISCOM and the WISDOT missions, due to components in the overall network that supports both government departments. This new team should ensure that policies and procedures are created, or refreshed, that support current and future WISCOM users.