PALLANS ASSOCIATES

COMMUNICATION CONSULTANTS

Bermuda Radio System Assessment and Recommendations

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EXECUTIVE SUMMARY

Pallans Associates is pleased to present this Radio Systems Assessment and Recommendations to the Bermuda Ministry of National Security.

The purpose of this assessment is to provide an analysis of the current communication systems utilized by Bermuda and to provide recommendations for future growth and improvement to the existing government and public safety communication systems. The recommendations presented are based upon the advances in technology for radio communication and the "best practices" of local government public safety entities. The intent of this report is to identify the technical solutions and to provide logical steps to take to resolve them.

Pallans Associates, through site inspections, user interviews and surveys, and data research has evaluated the radio systems of the Government of Bermuda.

The challenges associated with radio communications in the future are quite different from what they were in the past. Bermuda has been using technology that is obsolete but still operating. The participating agencies recognize the importance of having properly functioning communications networks that enable the appropriate first responder disciplines to respond to any threat or challenge that may present itself, be it cross agency, cross discipline or cross jurisdiction.

Radio systems provide the critical wireless communication link between 911 dispatchers, fire/rescue, law enforcement, emergency medical responders, public works and general government personnel. The next generation of radio technology will have the capability to enhance all of the performance needs for these agencies. Then, with advances in information technology and high speed data, there will be another advance in technology. With a change in technology today Bermuda will be on the path to the technologies that follow.

Primary concerns of the Government are radio coverage, current levels of performance, and the possible migration paths to future technology. This report addresses all of these aspects.

The initial step of this project was familiarization with Bermuda, the communications capabilities and the radio sites themselves. Meetings with government and industry representatives helped to provide a picture that gave direction for our research.

Through analysis of licensing documentation and our own mathematical modeling of the theoretical system performance we were able to develop a course of action to take. This led to determining all of the factors that have impacted the radio system over its years of operation.

Radio equipment, also known as subscriber units, is performing relatively well considering that the some of the units are as almost old as the radio system which was built in the 1980's and 1990's. Statistically, the life span of a portable radio is 7 years and a mobile is 10 years. Virtually all of the subscriber units have exceeded these ages. Since the infrastructure is privately owned, maintenance has not been a problem. Any subscriber problems related to age will disappear upon implementation of a new system.

A significant amount of time for this project was spent analyzing the coverage of the system and several specific areas that affect performance.

- The terrain is a challenge on parts of the island due to areas of cliffs blocking beach areas and some inland areas where high ground blocks signals.
- The actual radiation patterns from the infrastructure antennas, in some cases does not penetrate to the target areas but rather flies over them due to the line of sight nature of 800 MHz (Megahertz) signals
- The multiple radio systems in use limit interoperability between users.

System operation is good. All of the agencies commented on how well the dispatch centers operates. There are some operational issues between Fire and Police relating to 911 transfers but the operations are effective.

Our coverage models and the user surveys agree that coverage in the populated areas is good with a few exceptions. The system operators have added sites over the years to accommodate coverage issues.

Spectrum availability for a new radio system is not clear. The Regulatory Authority has stated that 800 MHz is not available. Operation in the 800 MHz band is common for public safety systems and not having it available in Bermuda may limit the procurement process. Future broadband systems can operate in the 700 MHz spectrum so future migration will not be impacted.

Pallans Associates' primary recommendation for Bermuda is to replace the current leased radio system with its own radio system utilizing TETRA technology.

TETRA is a mature digital technology that operates on an IP(Internet Protocol) platform, the migratable path to broadband technology. It has proven its values as a primary digital voice technology all over the world. It offers features that are looked for by end users and performs as a voice radio system suitable for public safety applications. There are applications that can have cell phones operate as two way radios when interfacing the TETRA system through the public wireless networks. It can support moderate speed data for graphics and video transmissions. It is migratable to broadband when that technology matures for public safety. In a few years broadband technology will have matured to the point that it will have viable voice and high speed data capabilities for public safety which can bring all of the advantages of smart phones and computers directly to the public safety user in the field.

INTRODUCTION

The Bermuda Ministry of National Security (MoNS) contracted with Pallans Associates, Communication Consultants, to perform an assessment of all radio systems and communication networks utilized by The Government. This assessment consisted of an analysis of the existing systems from both technical and operational aspects. It also provides an evaluation of the current interoperability between agencies and communities. The goal was to provide recommendations for the future improvements of the existing radio systems and a migration strategy to implement the recommended changes. The goal of these recommendations is to ultimately provide a migration path to utilizing broadband technology as the primary communications platform when such technology has matured.

METHODOLOGY

Analysis of Support Documentation

Prior to attending the kickoff meeting Pallans Associates compiled available data regarding the communication systems of the MoNS by researching available databases and analyzing the prior Requests for Proposals. Additionally the local geography was studied by viewing topographic maps of the area and considering the types of terrain, forestation and vegetation that is common to the area. Preliminary contact was made with Mr. Vernon Wears the representative of the MoNS for this project.

On site meetings

During the week of April 17th through April 21st, 2017 meetings were held with all of the stakeholders, service providers and Government staff responsible for technology and resources such as radio sites.

An initial kickoff meeting was held at the Bermuda Regiment headquarters with representative of many of the Government's departments. The purpose of the meeting was to introduce Pallans Associates to the radio system users of the MoNS. The topics discussed included how Pallans Associates would approach the goals of the MoNS with respect to assessing all of communications capabilities, assure that technical and regulatory requirements are met with respect to equipment and licensing and making recommendations as to what should be done to improve communications to assure that future growth and performance requirements are met. The questions asked by the Pallans representatives were designed to stimulate their involvement with the project.

Over the next three days visits to individual user locations Pallans Associates had the opportunity to observe how many of the users operated and received input from the individual users about their concerns regarding the performance of the communication systems. Site visits took place when traveling between user agencies.

Pallans Associates confirmed that the desired deliverables for this project includes;

- ❑ An analysis of current capabilities
- ❑ A needs assessment for future communications
- ❑ A recommendation for future communications improvements and technology.

In order to accomplish this project Pallans Associates has undertaken the following tasks.

User Discussions

During the kickoff meeting Pallans Associates discussed the current status of the communication systems with the participants. This was done in order to get their ideas and to assure that they had completely responded to the user surveys that had been previously distributed. An open discussion between users was encouraged in order to allow the participants to come to consensus regarding any issues that were raised.

Organizations visited were;

- ❑ Bermuda Police Department
- ❑ Fire and Rescue Service
- ❑ Bermuda Regiment
- ❑ Parks and Lifeguards
- ❑ Department of Corrections
- ❑ Department of Health
- ❑ Marine Unit
- ❑ LINK Bermuda
- ❑ ECL
- ❑ East End Telecom
- ❑ CCS

The discussion topics were designed to identify key operational and performance needs of the user community and to determine how well the current system meets these needs. The users in attendance provided insightful and valuable feedback for use in developing recommendations for the future.

Site Visits

Pallans Associates visited the radio sites that support the existing SmartNet and SmartZone radio systems as well as other tower locations on the Island. Several sites are government owned and are potential radio sites for future use.

The Sites listed in **Table 1** are those sites that house primary communications equipment for the radio system providers as well as government owned sites that will be available for use in a new radio system.

TABLE 1 – PRIMARY RADIO SITES

Site	Comments
Warwick Camp	Bermuda Regiment location
Gibbs Hill	Lighthouse - observed to consider terrain
Sentinel Hill	No tower - equipment shelter and direction finding site
Central Tower	Police HQ
Somerset Police Station	Tower in Police site
Alton Hill	Southwest site
Prospect	Two sites nearby
Barker's Hill	Golf Course site
Quarry	East central location
Ft. George	Northern tower site
Wilderness Lane	Unused site
Link Bermuda	Secure Telecom site with facilities for backup
St. David's Lighthouse	Elevated site - not visited
Link Bermuda	Hardened Commercial Complex
Ft. Scaur	Not visited

Site visits are an integral part of the assessment process. Radio equipment is inspected as are towers, antenna, cabling, grounding and emergency power. These inspections assist in determining which equipment must be upgraded or replaced. Several sites not currently used for radio system have been visited for purposes of determining their suitability for future use.

If system expansions are recommended the inspections provide data on how much space is available in the facilities and how additional antennas may be installed.

User Surveys

Pallans Associates utilizes a proprietary user/system survey that is customized to meet the requirements of each client. It addresses current system performance and technology. It then considers the existing infrastructure and the radio and networking capabilities of the client. The final aspect is the input from the radio system users regarding their opinions about the current system, their needs, their minimum requirements and then their “wish list” requirements for a future system. If applicable there are additional sections related to service providers and other operating partners.

This survey is distributed prior to our kickoff meeting with the client. Ideally the completed surveys are returned prior to the meeting in order for the Pallans staff to develop a first impression of the radio system.

Analysis of User Surveys.

The user survey is the most important tool that Pallans Associates uses. Not only does it provide information describing the actual equipment in use but it also gets the opinions of the users relevant to the existing systems and where they would like to focus future implementations or upgrades. Analysis of the surveys takes an in-depth look at such issues as;

- System coverage
- System capacity
- Interference
- Interoperability needs and capabilities
- Existing user hardware

Users were asked to describe any specific issues or deficiencies they found with the existing radio system. These included topics relating to;

- Poor coverage areas
- Interference
- Insufficient frequencies
- Lack of interoperability

The analysis provides significant insight when making recommendations for the future especially relating to technology, frequencies and standards. A summary of the key results of the user surveys is included as **Attachment D** to this report.

Initial Propagation Study

Utilizing data available from radio sites and the Regulatory Authority mathematical models were developed to depict the probable radio wave propagation that Pallans Associates could expect from the existing radio systems. These models take into consideration the transmitter locations, antenna elevations, power and frequency of the transmitters. Factors are estimated for the type of terrain, the density of the forestation, as well as estimates of local building densities.

FINDINGS

General

Bermuda is a British Overseas Territory with a population is approximately 61,300 and located in the Atlantic Ocean approximately 650 miles east of the United States. It has a temperate climate that is supported by the Gulf Stream ocean current. It has a total land area of approximately 20 square miles. The islands that make up Bermuda are volcanic in nature and the terrain is relatively rugged in many areas.

Existing systems

There are two primary government radio system on Bermuda. Both are well beyond their life expectancy. The SmartNet system is a Motorola 800 MHz trunked radio system originally installed in 1988. The SmartZone radio system is a Motorola 800 MHz trunked radio system implemented in 1998. Although these are both analog systems the SmartZone system is capable of supporting digital subscriber units (user radios). Both of these systems are no longer supported by Motorola nor does Motorola support the technologies of SmartNet and SmartZone.

These radio systems are leased to the government. The company that own these systems also support other radio systems used by Island businesses. These systems operate on Digital Mobile Radio (DMR) technology and TETRA technology. Both of these are current forms of digital radio systems. In order to have some enhanced performance some government agencies such as the Corrections Department and Customs utilize these systems and have no connectivity to the primary systems.

The SmartNet radio system operates from a single site at Prospect. The Smartzone system operates Island wide from five sites. The original three site system at Prospect. Warwick and St. George was expanded by the owners by adding sites at Ft. Scaur and the Quarry.

Dispatch Centers

Bermuda has two primary dispatch centers. The Police department ComOps operates with five Motorola consoles and hosts the 911 center. The police utilize a New World Systems CAD (computer Assisted Dispatch) system). 911 calls for fire service are routed to the Fire Department dispatch center where they are dispatched. **Figures 1 and 2** show views of both centers.

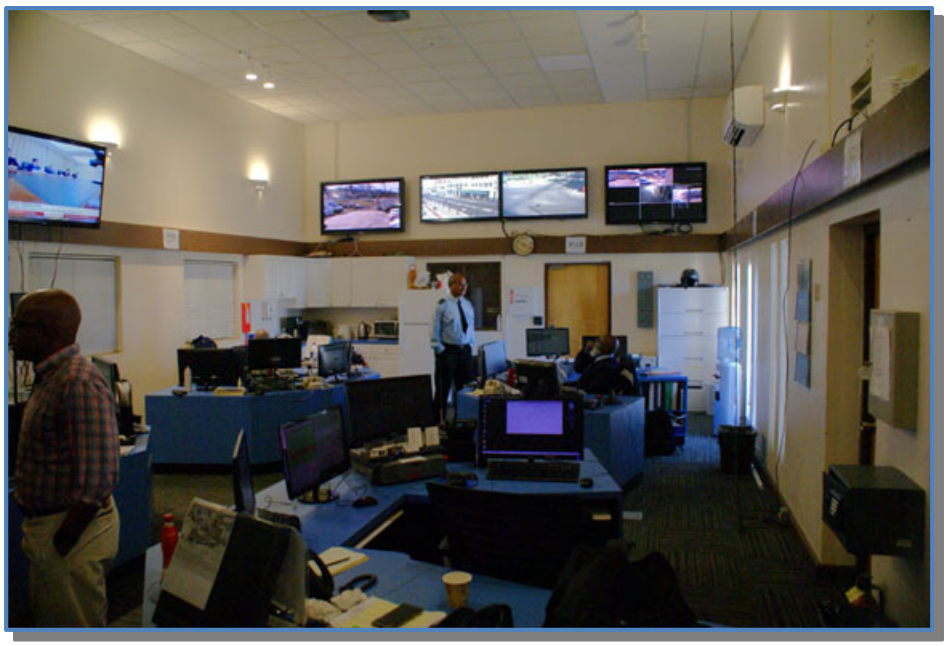
Police ComOps has an extensive video system that provides images from all over the Island. This network operates over a mesh networked Wi-Fi system.

Located in the same building as ComOps is an emergency operations center that is set up when the need presents itself (hurricanes for example)

The Fire Dispatch center contains backup radios for dispatch and may communicate direct to units if there is a system failure. Fire dispatch has connectivity with the Emergency Medical Service, ambulances and the Island hospitals.

The ambulance service utilizes GPS location for its vehicles. The Fire services utilizes the Police Department CAD system. The Fire Department paging system operates over the commercial cellular network.

FIGURE 1 - Police ComOps

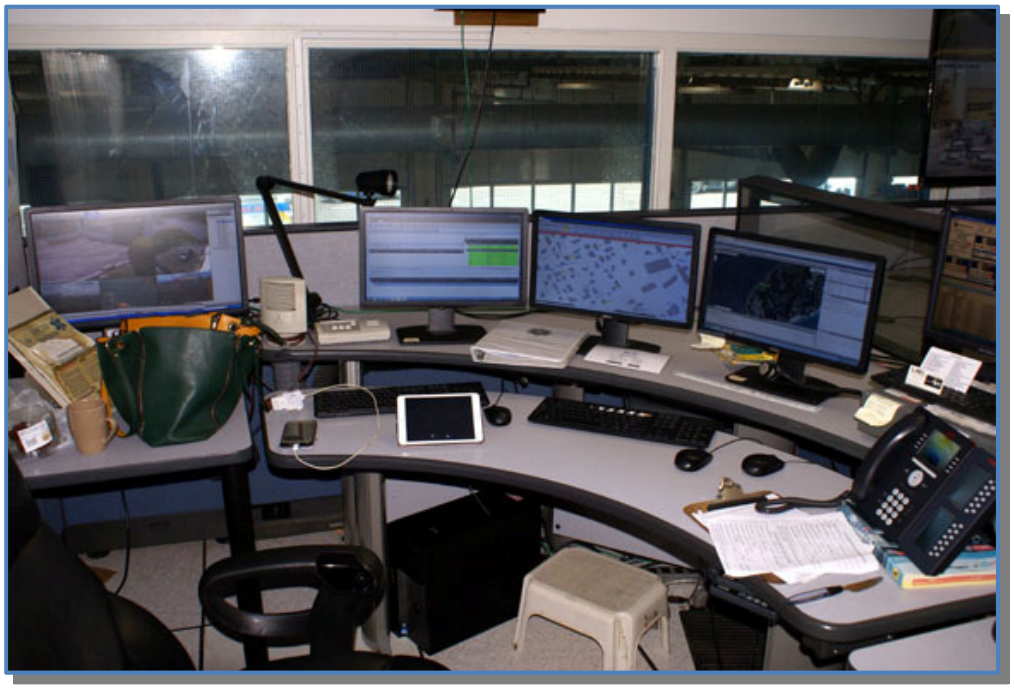


Microwave Network

The radio sites are linked together via microwave "hops" connecting all of them to the radio system cores sites. These, like the radio systems are owned and operated by private companies.

CCS Limited, which operates the video network, maintains Island wide broadband circuits which may be used for a future network backbone between radio sites.

FIGURE 2 - Fire Dispatch



Voice Radio Systems

The primary radio systems used by Bermuda government agencies are two 800 MHz trunked radio systems produced by Motorola more than eighteen years ago. At that time they were the "state of the art" technology available. Today they are well past their life expectancy and are no longer supported by Motorola, the manufacturer. Replacement parts are no longer available from Motorola. When needed, replacement components are procured by scavenging existing unused network components or purchased used from surplus dealers or on line from such sites as E-Bay.

Some radio users such as Customs and the Department of Corrections also use radios with other technologies provided by the radio system owners. Digital mobile radio (DMR) technology and TETRA technology are used at specific locations to meet the coverage and performance requirements of these agencies.

Spectrum

The primary public safety radio systems operate in the 800 MHz frequency range. The frequencies in use are dedicated to the government's public safety users. Other 800 MHz users on the Island also utilize the 800 MHz spectrum but with different technologies. There have been no reports of interference to government radios from the other users.

The government users of the TETRA radio system have reported hearing other users occasionally when they are on the fringes of their coverage areas.

The Bermuda Regulatory Authority (RA) is the government agency responsible for all telecommunications authorization and licensing for the Island. they assign spectrum segments and frequencies to all wireless system users. These include regular businesses utilizing radio communications, the cellular radio carriers, the television providers and the Telephone Company.

The spectrum allocation process follows, in general, the frequency plans of the United States Federal Communications Commission (FCC). The RA has informed Pallans Associates that the virtually the entire 800 MHz spectrum has been assigned for commercial use and that government has been assigned the 700 MHz spectrum. This has yet to be clarified. Without the availability of the 800 MHz spectrum procurement of a new radio system may not be competitive.

ANALYSIS

Radio System Coverage

Radio system coverage is affected by many variables. System range is of paramount importance and therefore the transmit power of a radio is a major issue, as is the sensitivity of the radio’s receiver. Mobile radios transmit a much higher signal level

than portable radios. A typical mobile is from 25 to 50 watts while a portable transmits in the order of four to five watts. Repeaters and satellite receivers are used to enhance the range of these radios.

When operating indoors the next consideration is the density of buildings. For effective public safety communications it is necessary to have radio equipment that performs inside of structures, especially for fire communications. When operating in rural environments radios are greatly affected by terrain and foliage.

The evaluation of coverage is considered for both mobile unit range and portable operations both indoors and outdoors. Developing predictions for radio coverage includes the factors described above as well as the radio specifications, the antenna location on a vehicle for mobiles and where a portable is operating from (e.g.: belt or handheld). Mobile radios typically perform better than portable radios because their antennas are higher, there is less loss due to nearby obstructions and their receivers are designed for higher sensitivity. Portable radio suffers from losses due to their short antennas, closeness to the body and lower power in the transmitters. If a portable radio is worn on the belt it's transmissions and reception are affected by the shielding effects of the user's body.

When operating a portable radio inside a building the signals are severely compromised by the structure. Wood, brick and metal all cause reductions in signal levels, both transmitting and receiving. As would be imagined a metal structure creates much more signal reduction than does a wooden building. When calculating radio system performance it is typical to estimate the losses created by buildings. The densities of structures are considered as part of the mathematical modeling of radio coverage.

The typical considerations for buildings are described in **Table 2**.

TABLE 2 – Building Densities

Building Density	Type of Structure	Typical Loss
Light	Single story wood residential	6-9 db
Medium	Multistory wood or brick, metal studs, Strip type commercial centers	12-15 db
Heavy	Commercial CBS buildings, metal warehouse structures, large shopping centers	> 15 db

The actual losses created by buildings are difficult to quantify because of the many factors that degrade radio signals. Even glass windows can inhibit signals if they are made with internal tinting which can be metallic in nature.

When comparing the quality of radio transmissions radio specialists use a value developed as part of a radio performance standard known as TSB-88. The measurement is called Delivered Audio Quality or DAQ. This is a subjective measurement made by actually listening to a voice transmission and rating it. The

values of DAQ are shown in **Table 3**. A DAQ level of 3.4 is considered as the minimum level for a public safety radio system.

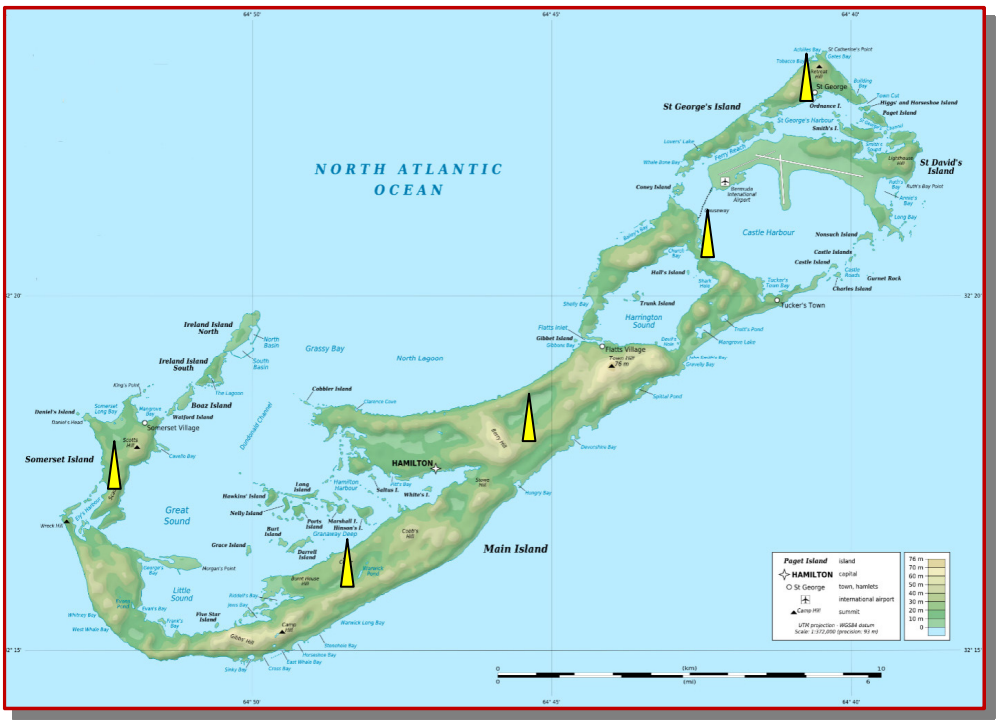
TABLE 3 - Delivered Audio Quality

DAQ	Description
1	Unusable; speech present but unreadable
2	Understandable with considerable effort. Frequent repetition needed due to noise or distortion
3	Speech understandable with slight effort. Occasional repetition needed due to noise or distortion
3.4	Speech understandable with repetition only rarely required. Some noise or distortion
4	Speech easily understood. Occasional noise or distortion
4.5	Speech easily understood. Infrequent noise or distortion
5	Speech easily understood

Coverage in Bermuda

Radio system performance over the Island and surrounding waters is primarily provided by three radio sites operating the 800 MHz SmartNet and SmartZone systems. The radio sites are located at Warwick, Prospect and St. George as shown in **Figure 3**.

Figure 3 - Primary Radio Site Locations



Coverage for each site is designed to maximize performance by accounting for the local terrain in each site's local area.

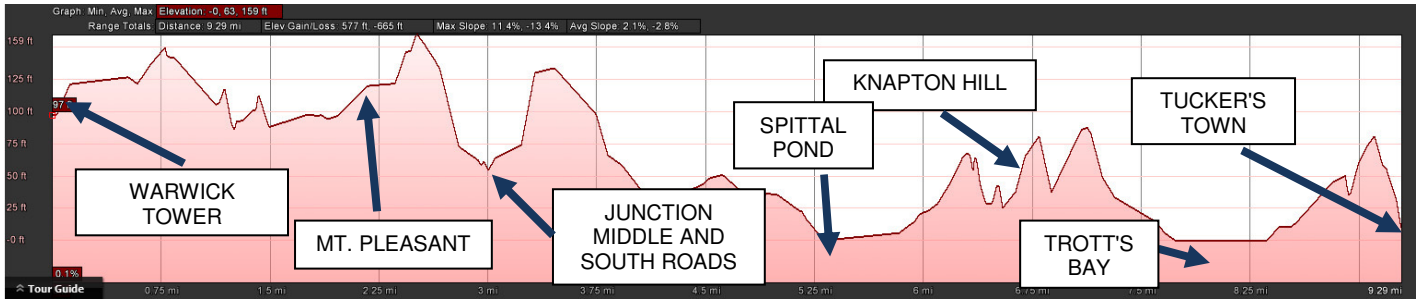
Even though the elevations of the terrain in Bermuda is relatively low it does vary significantly and plays a role in radio system coverage. The coverage of the radio systems radio systems is primarily limited by distance from the transmitters and steepness of the terrain. Coverage issues should be expected on the fringes of the coverage area of each radio site.

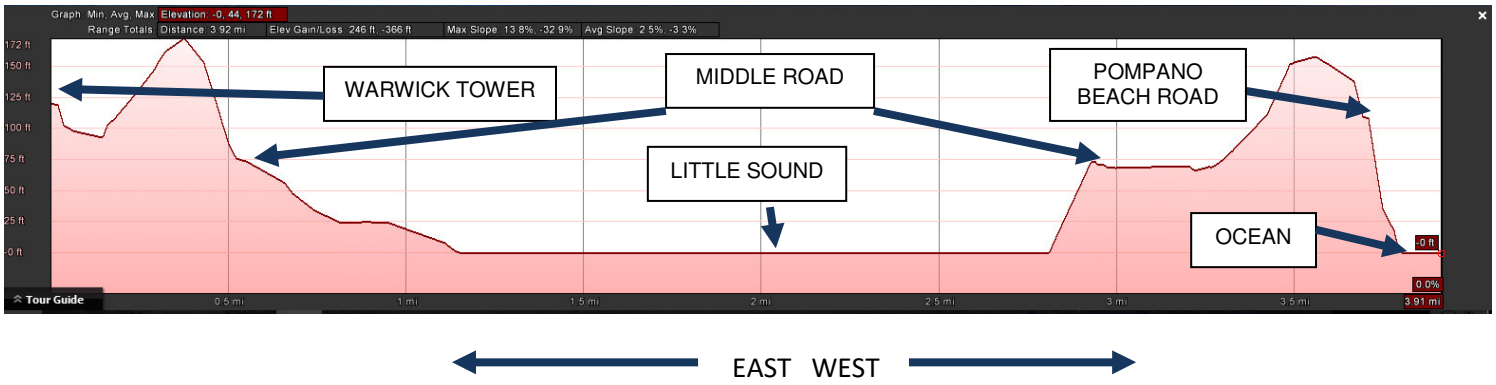
Users have reported that many of the beach areas and perimeter roadways have coverage issues. The is generally due to the steepness of the terrain as it approaches the surrounding waters.

Terrain Issues

To analyze the effects of Bermuda's terrain, Pallans Associates has studied the terrain variations across the Island. To visualize the problems we have taken profiles of the terrain across two sample terrain paths.. **Figure 4** illustrates the terrain along the south shore from Warwick to the area of Flatt's Village. The second profile runs from Warwick to offshore of Hog's Bay.

FIGURE 4 - Terrain Profile Warwick to Tucker's Town





Key landmarks have been added to the maps in order to identify locations.

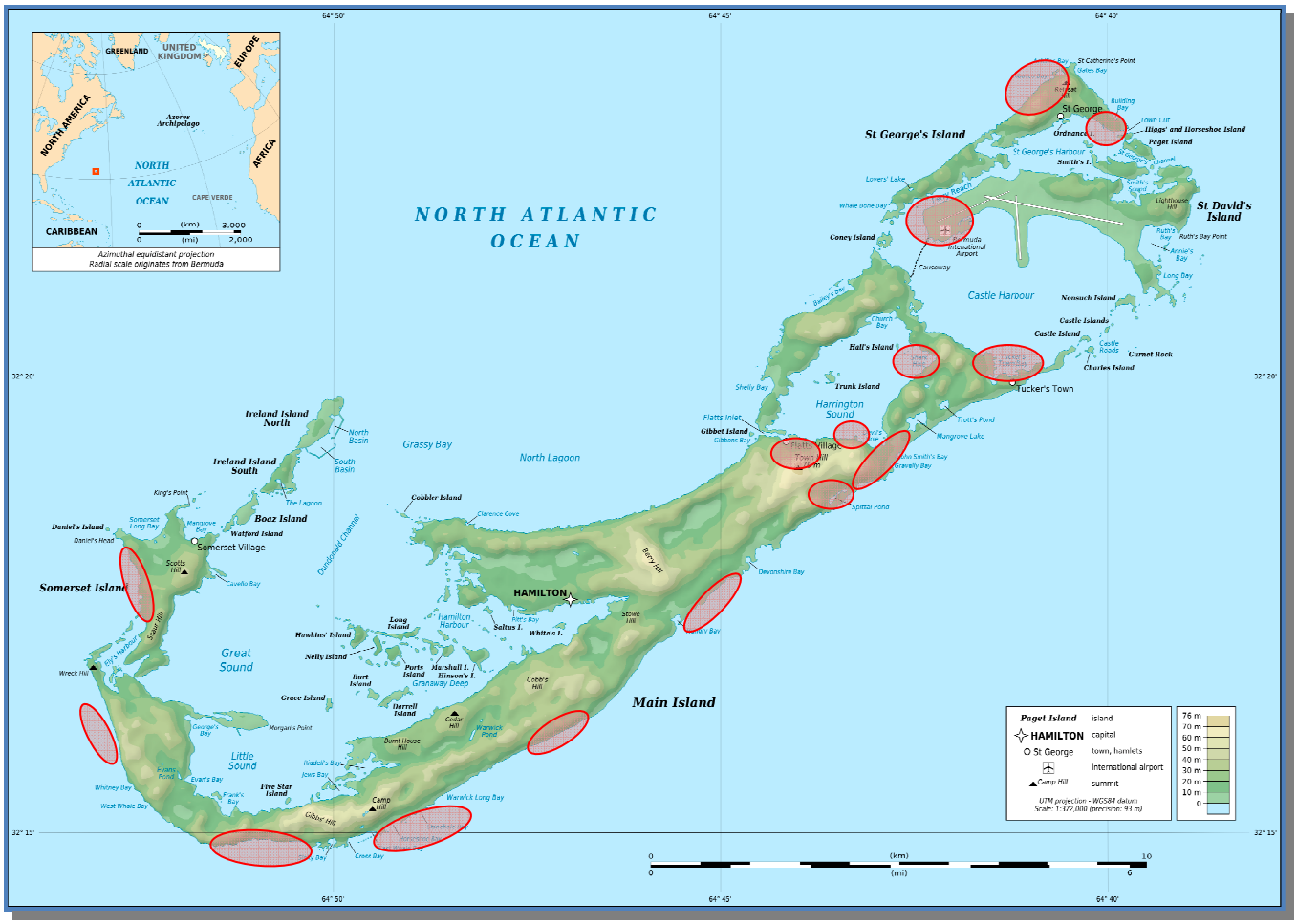
Figure 5 illustrates the areas and roadways that the users reported as providing less than reliable radio coverage. The highlighted areas and the highlighted roadways are

the reported locations. It can be reasonably assumed that nearby roadways and areas will have similar coverage issues.

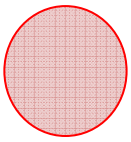
While not specifically indicated, it is clear that, from the terrain studies coverage in interior rural areas will have similar weak sections.

All of the populated areas of the County had some degree of poor or reduced coverage reported when considering the necessity for first responders to enter buildings.

FIGURE 5 - Poor Coverage Areas



Shaded areas represent poor coverage areas reported by users. --



Propagation Mapping

In order to visualize how the radio system is performing a mathematical study of the coverage was undertaken by using modeling software. Several different propagation

mapping programs were utilized in order to validate the data. One program, Comstudy 2.2, performs a more detailed analysis, The other program, RAPTR provides a better graphical interface for viewing results. A third program provides an overview of presumed coverage.

By viewing the coverage of individual sites and the entire system Pallans Associates can accurately assess the current system operation and make recommendations for improvement.

All data entries consist of the actual location, antenna types, heights, cable types, losses due to combining, losses due to cable lengths and other factors that affect performance such as terrain, normal weather conditions, etc. The results are based upon a standard public safety radio system reliability factor of 95%. This factor can be stated as; the system performs acceptably 95% of the time at 95 % of locations within the defined coverage area.

The following figure are generalized representations of the talk out performance of each site. The Green color indicates good readable signals. The yellow indicates weak and noisy signals.

Figure 6 is the site at Warwick. **Figure 7** is the site at Prospect and **Figure 8** is the site at St. George

Propagation map analysis

While the initial propagation maps for Bermuda are estimates based upon observations of the sites and equipment specifications they can still be used to identify various aspects of the coverage. An analysis of the radio system propagation mapping has indicated several important aspects of the existing radio system. In the maps, green represents good coverage and yellow marginal coverage. The blue(water) and gray (shadows) are no coverage areas.

1. The maps concur with the user survey comments
2. Coverage in interior, rural areas of the Island is fair to poor
3. The talk out performance of the system is approximately equal to the talk back performance. This shows that the system design is balanced.
4. There are some anomalies. **Table 4** addresses the performance and important factors relevant to each site.

FIGURE 6 - Warwick Site Talkout

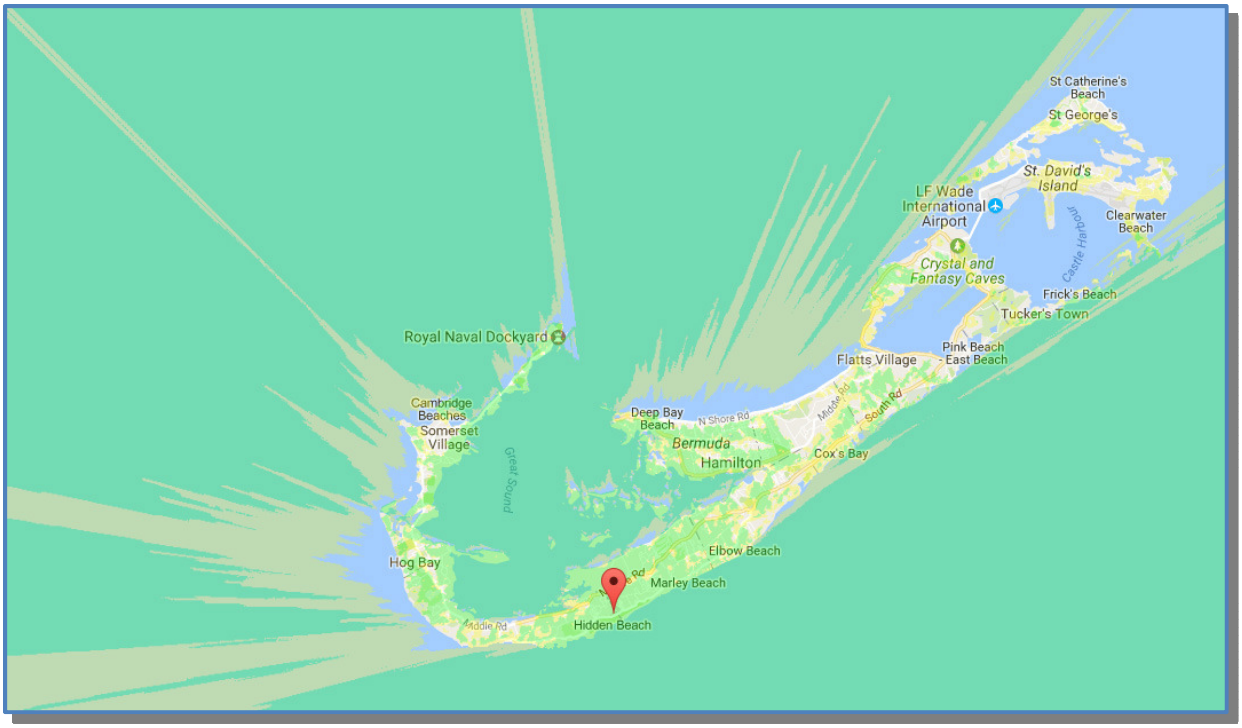


FIGURE 7 - Prospect Site Talkout

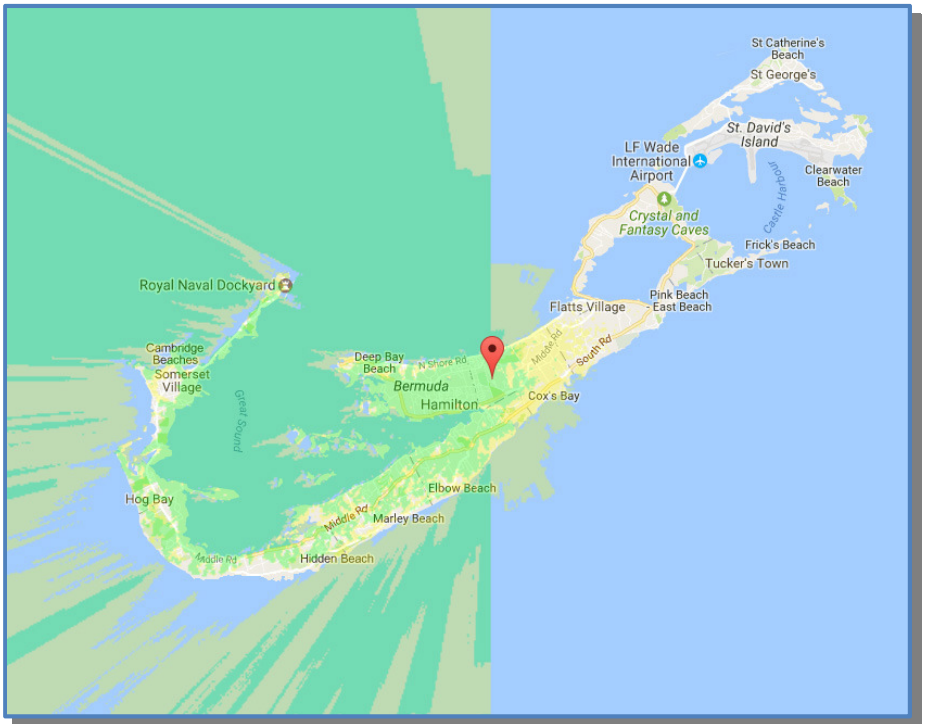


FIGURE 8 - St. George Site Talkout

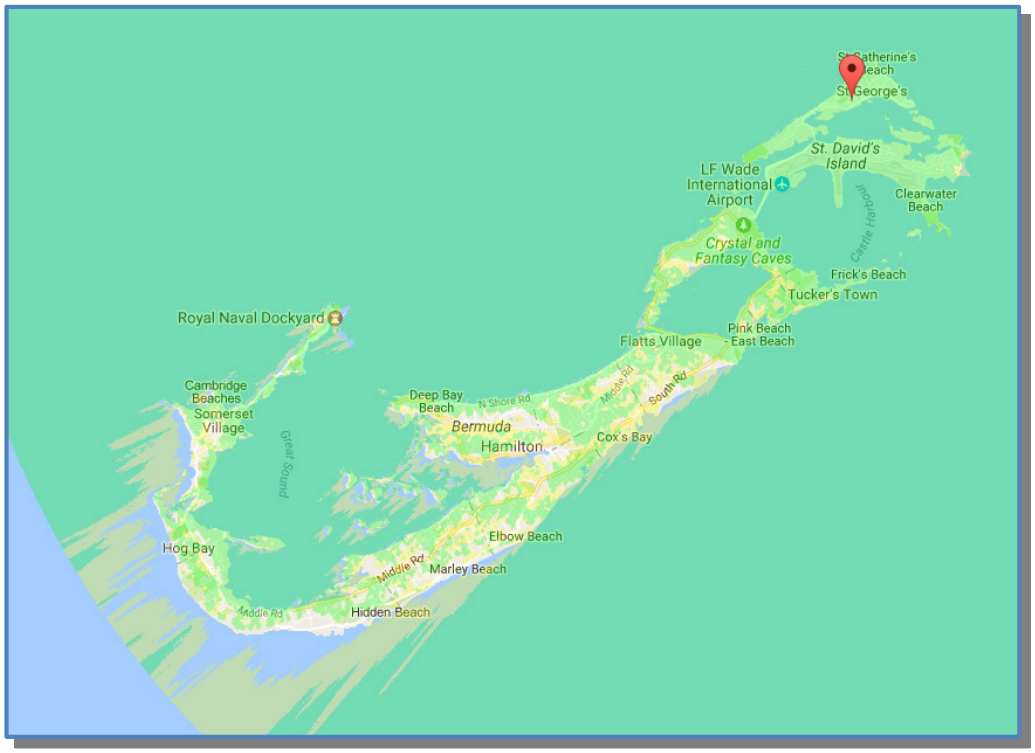


TABLE 4 - Propagation Map Analysis

Site	Performance	Significant Impacts
Warwick	Warwick provides south shore coverage from Elbow Beach to west of Hidden Beach. It also improves coverage in Hamilton to support the performance of Prospect.	This site does not enhance any existing coverage east of Hog Bay except for Royal Navy Dock area and Great Sound.
Prospect	Prospect site covers the central area of the Island and includes Hamilton. Terrain limits coverage to the south shore areas as well as the western shore areas. This site covers the Great Sound area.	Much of South Road west of Elbow Beach has reduced coverage due to the high terrain north of the road and between the road and the radio site. Somerset Village has reduced signals due to terrain obstructions
St. George	St. George provides coverage for the eastern third of the Island as well as offshore in all directions except southwest where land features block signals.	Coverage also extends to the area around the Royal Naval Dockyard but its value is limited due to the weak signals due to distance. Land features limit performance south of Flatt's Village
Ft. Scaur	Covers Great Sound and limited areas in Somerset	The coverage of Great Sound duplicates coverage provided by Prospect and Warwick

The Quarry	Provides radio coverage from Flatt's Village to St. David's Island and the airport.	Airport coverage, indoors, could be improved.

The user surveys requested the locations of known poor coverage areas. It also requested the users to describe their opinions regarding the level of radio coverage within the County. **Table 5** lists the average reported countywide coverage provided by the user surveys.

TABLE 5 - User Reported Radio Coverage

Radio System Coverage	
Mobile Coverage	87.2%
Portable Coverage	89.9%
In-building Coverage	74.8%

It must be noted that these values are based upon the individual user agencies requirements. For example, the majority of calls for fire and rescue services are in the populated areas where radio coverage is superior to that of the rural areas of the Island.

There seems to be some anomalies in portable and indoor coverage. The majority of portable coverage on the Island is outdoors and the high level of reliability stated by the users appears to support that since the radio sites prove good coverage from each of the primary sites and most of the activity is in these areas. In building coverage on average usually is much lower as is shown in the chart.

Pallans Associates believe that in Hamilton, with its urban structures the in building performance is actually lower than reported but still acceptable.

Predicted Current Radio System Coverage

Using the technical information provided by the system providers Pallans Associates has developed the radio system coverage maps in figures 9 through 11. The data includes the transmitter power, receiver sensitivity, antenna gain, cable losses and terrain features and other overall technical characteristics and technical assumptions for each site. These maps represent a consolidated coverage of all of the radio sites used in the system.

The colors in each figure represent approximate signal strength.

- Yellow represents strong, easily readable signals
- Blue indicates signal that are weaker but readily readable
- Orange indicates weak and noisy signals that may fade out
- Red represents almost unreadable signals and dead spots
- Gray indicates no signal areas or areas beyond the boundary of the coverage model.

Figure 9 indicates that "talkout" (signals from the towers to mobiles) mobile coverage is good over the entire Island except where signals are blocked by terrain which is primarily along the beachfronts where cliffs block the signals. Coverage in Hamilton is

good. Talkout to portable radios (handheld units) is almost as good as mobile coverage as shown in **Figure 10**.

Mobile talkback (the signals from the mobile radios to the towers) is almost identical to the talkout patterns.

FIGURE 9 -Talkout from system to mobile

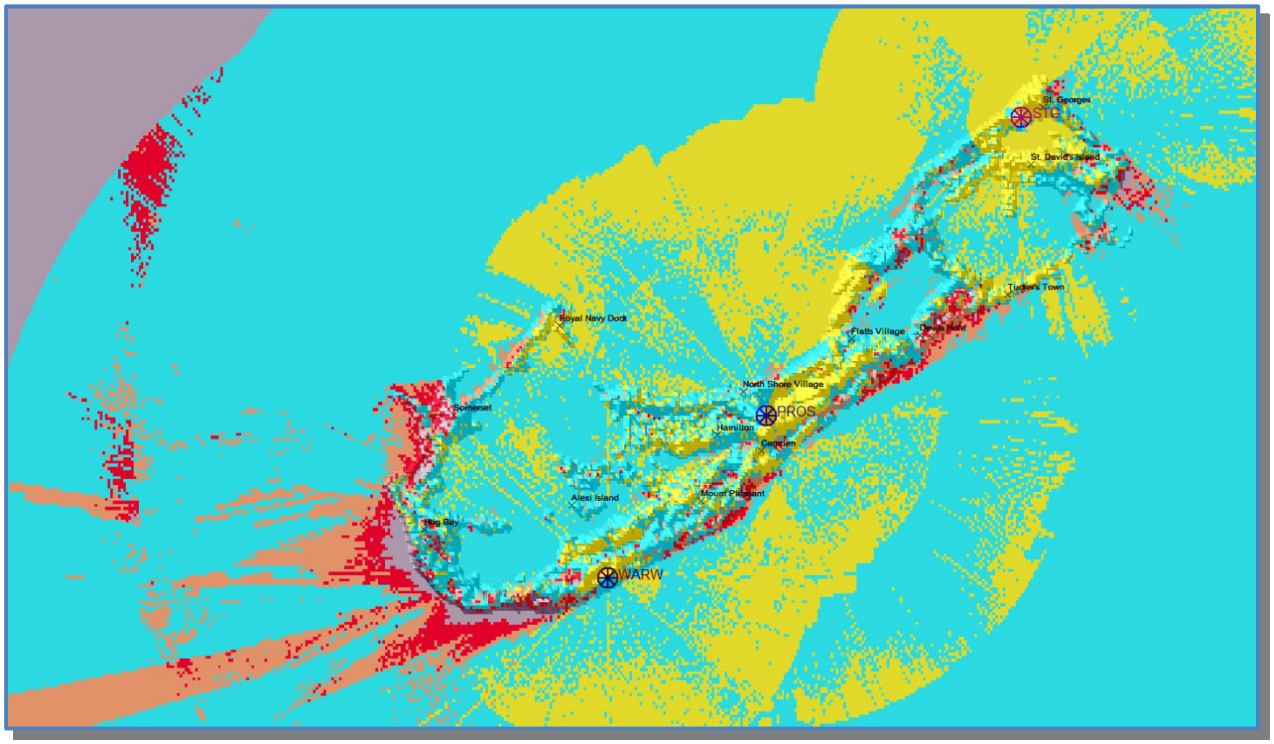


FIGURE 10 -Talkout from system to portable

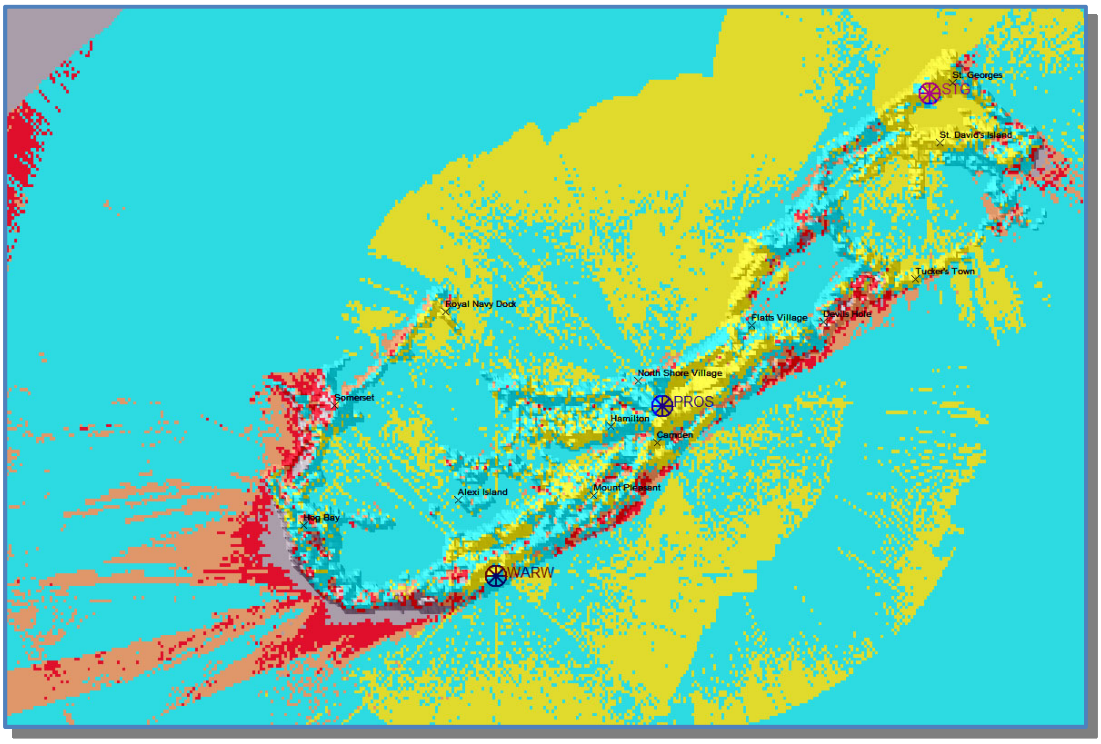


FIGURE 11 -Talkback from portable to system

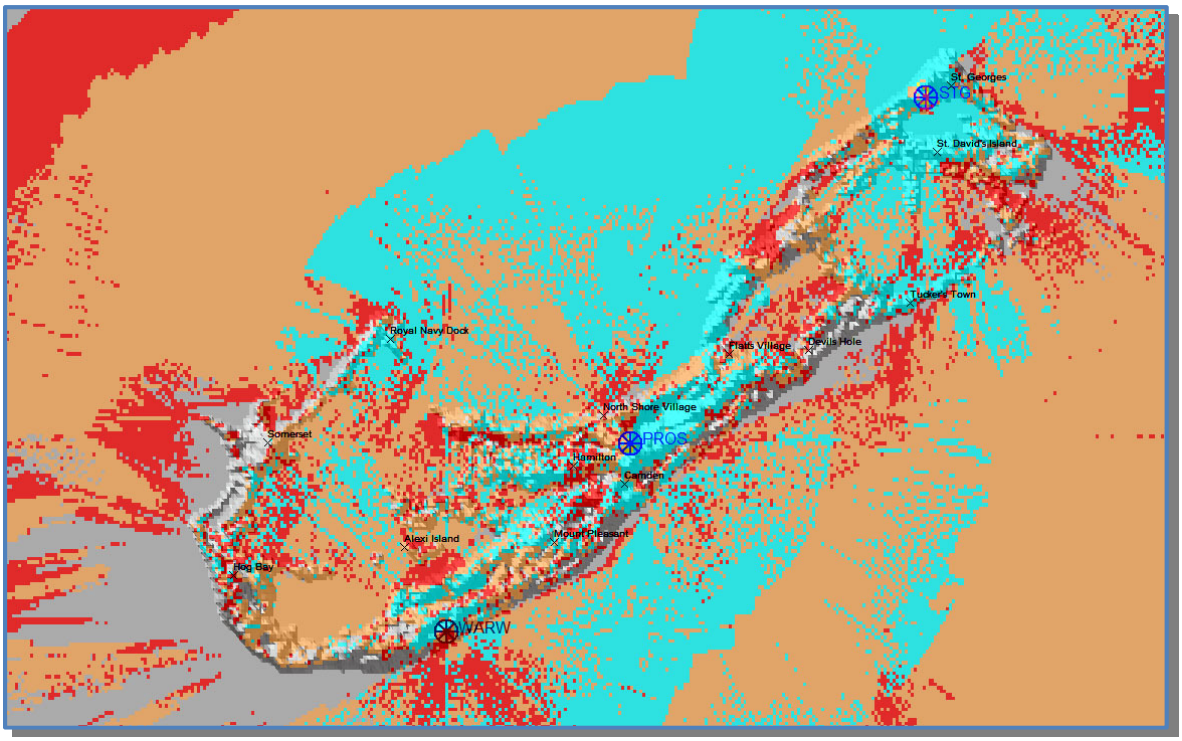


Figure 11 shows that talkback coverage for portable radios is significantly different. The only good coverage from a portable to a tower is right in the area of the tower. The yellow coloring is hidden by the tower symbol. Most other coverage is weaker. Coverage is acceptable when in the line of sight from the nearest tower.

Unit to unit coverage is good for portable radios when the users are in the same vicinity, such as on the scene of and event. On these occasions the users can speak directly to each other without being relayed by the towers.

CAPACITY

The capacity of a radio system references the system's ability to accommodate all users. A system reaches its capacity limits when users frequently cannot get into the system (talk to dispatchers or other users) due to too many other users actively transmitting.

In a trunked radio system typically 100 users per RF (radio frequency) channel is considered the normal loading as the determining factor for the number of channels than an agency needs. That figure is based normal radio traffic and normal transmit and receive intervals. During an emergency or other event creating a need for many users to access the radio system the 100 users per channel guideline is of no value. In any radio system only one person can speak at a time on any one channel. The other

limiting factor is the number of discrete functions assigned to the radio system. For example, a fire department typically has a dispatch channel, a tactical channel and one or more “fire ground” channels. Fire ground channels are those channels dedicated for use at the scene of a fire.

When designing a radio system there are several scenarios that should be considered as they affect the effective operation of the system. These factors are described in **Table 5.**

TABLE 5 - Types of Radio Traffic

Type of Traffic	Description
Daily normal traffic	The routine daily operation of the system
Busy hour traffic	Operations during those times when traffic can be expected to be higher such as evenings and weekends for police activities
Special events	Where extra communications are anticipated due to the nature of the event
Emergencies or disasters	The occasions require an increase in capacity in order to assure communications between agencies and between outside responders who arrive to assist.

While fire-ground operations are considered as normal traffic, multiple fires become communication emergencies if there are not enough channels for the extra communications required by the multiple events. A wildfire scenario, where multiple agencies have responded, likewise causes a communications emergency if not enough channels are available.

Ideally, a system should be designed to be capable of carrying the traffic that occurs in the worst case scenario. Unfortunately this is not always possible.

If emergency situations were the prime consideration when designing for the capacity of a radio system, many more channels would be needed. Alternatively, more advanced technologies such as trunking could be employed. Reality suggests that design considerations take into account the economic impact of the radio system design on the community as well as the operational needs.

Capacity is not an issue on the District's radio system. The FCC guidelines for conventional VHF and UHF radio systems is 70 users per channel for public safety and 90 users per channel for other users. These levels are not approached by The District radio users.

Interoperability

Agencies generally consider interoperability to be a requirement when considering the response to emergencies or disasters. Assistance from outside organizations is not the highest priority in Bermuda except when considering natural disasters such as hurricanes. Internal to the Island is the requirement for all government entities having

the ability to communicate with each other when considering multiagency responses and for cooperation when supporting each other on a regular basis.

For the most part interagency cooperation is ongoing in Bermuda and most of the government entities already can communicate on the primary radio systems. In some cases though agencies do not operate on the primary government SmartNet and SmartZone radio systems. Agencies that are not using these primary systems are required to have additional radios that can be activated when working with other organizations. One example is the Department of Corrections which uses both SmartNet and DMR radios in its operations.

Within the prison the DMR system works well for the Correction Officers. When outside of the Prison Corrections users operate on the SmartNet system when traveling on the Island.

The Customs Department operates Tetra radios around the airport and harbor and has no direct interoperability with public safety. This could be a potential problem area if as police type of event occurred with the Customs personnel.

The Bermuda Regiment operates multiple radio systems while at home and has a separate, transportable radio system, when offshore supporting other nations or territories.

Interoperability can be enhanced to the highest level by having all local government entities operating on the same communications platforms. The first level of this capability is to share a voice radio communications system. This should be followed by using a common high speed data network

AVAILABLE TECHNOLOGIES

P25 Digital Technology

P25 is the first standard developed by the communications industry addressing the technology used by a radio system. For many years in the United States, the FCC hesitated on creating technical standards and only applied operational standards to their rules.

APCO (the Association of Public Safety Communications Officials) urged the communications industry to develop a standard that could be utilized by public safety agencies in order to uniform standard for all public safety equipment. The result was the establishment of the Telecommunication Industry Association's P25 standard. The primary feature of P25 radios is that they operate using digital voice and signaling rather than analog mode. This allows the radios to be more versatile and provide improved audio. All P25 radios are also capable of operating in analog mode in order to assure backwards compatibility with existing analog systems.

The P25 standard incorporates eight specific standards which allow all vendors to manufacture compatible and interoperable communication systems. These standards are shown in **Table 6**.

The primary goals of P25 are to create interoperability between all users and create a competitive environment for the procurement of public safety communications equipment. Internet Protocol (IP) is the basic digital platform used with the standard. It is the same standard used for internet communications with computers.

TABLE 6 - P25 Standard Interfaces

Interface Name	Description
Common air interface (CAI)	Creates radio to radio compatibility that is independent of vendor
Fixed/base station subsystem interface (FSSI)	Allows connectivity between base stations and consoles independent of vendor
Inter radio frequency subsystem interface (ISSI)	Allows connectivity between radio systems of different vendors
Console subsystem interface (CSSI)	Allows consoles from different vendors to be compatible
Data network interface	Creates a standard for data peripheral equipment to be compatible (using IP protocol)
Network management interface	Allows radio system network management tools to work with multiple vendors
Telephone interconnect interface	Creates a standardized telephone interconnect standard between system manufacturers
Subscriber data peripheral interface	Creates host network compatibility between data systems and radio systems

P25 offers many features that were previously only available in high tier trunked radio systems. **Table 7** describes the primary features of P25 radios.

TABLE 7 - P25 Radio Features

Feature	Description
Priority calling	Radios can be assigned priorities that can guarantee system access over other users
High level encryption	Digital encryption of voice for secure operations
Call Alert	Radio will alert user to incoming call
User ID	Each radio has a unique ID which can include an alias to identify the user
Group calling	Radio can be programmed to call all system users
Emergency Call	By pressing the "emergency" button a user can notify dispatch and other users that he has a problem
Affiliation	Radio system access is controlled
OTAR – Over the air rekeying	Allows encrypted radios to have encryption codes programmed over the air

Some of the benefits of P25 can only be realized in a trunked radio system environment. Multi-vendor compatibility has created a competitive environment in, what for years, was a sole source environment. The proprietary nature of radio system trunking allowed only for the system vendor's brand of radios. Now any P25 radio can be used with any vendor's P25 trunked system. There are some caveats because some vendors have created features that go beyond the defined standards. If a customer wants those specific features, they must buy that vendor's system and radios.

In conventional systems using the P25 standard it is possible to link them into P25 trunking systems that have what is called ISSI capability. The conventional site then can readily pass talkgroup traffic directly from the trunked system. P25 radios are also inherently backwards compatible and can communicate with older analog radios, without the benefits of the P25 features.

Radio coverage from a P25 radio system will not be significantly different than the existing analog radio systems. Since the P25 is a digital technology, the received signal performs differently than in an analog system. With analog radios, the signal gets weaker and background noise gets louder as the user moves further away from the transmitter site or enters a building which shields the signal. Digital radios maintain the same quality of signal until the signal bit error rate gets too high and then it stops receiving. The user may notice some slight echoes or "fish bowl" effect just before the signals get weak enough to shut off the audio.

This effect can be frustrating to a person who is used to the analog affect of increasing noise before the signal is lost. With analog, the radio could be moved around for a better signal. With digital, the signal is either on or off with no hint of signal failure. While the analog radio operated down to a DAQ level of 2.5 to 3 at the fringe areas of performance, this same location is now operating at a DAQ of 3 to 3.5 at the same location, but gives no indication of pending loss of signal. Therefore it is actually performing better but the initial perception of a new user makes it appear worse.

TETRA

Tetra is a digital radio technology used worldwide. It was originally developed in 1995 and has become an accepted public safety grade of technology. It was first Used in the United Kingdom where London Metropolitan Police implemented it in the late 1990's. It is currently in use as a nationwide radio system in several countries.

TETRA uses Time Division Multiple Access (TDMA) which allows four separate conversations on the same 25 kHz radio channel at the same time. It also allows low speed data called short data service , similar to SMS used on cellular systems. The messaging is transported over the radio system's control channel so it does not interfere with voice communications.

The fact that it TETRA is in use for government and public safety on every continent attests to its robust capabilities **Table 8** describes the advantage and disadvantages of Tetra when compared with other technologies

TABLE 8 - TETRA Advantages and Disadvantages

TETRA Advantages	TETRA Disadvantages
Communications are not lost when moving out of the coverage area of a radio site. Like cellular radio it will be picked up by the next nearest site	Data rates are slow but users can interface to modern LTE networks to facilitate high data rates. Networks can be designed to increase data bandwidth by combining multiple time slots but then voice traffic is limited.
Subscriber units still can communicate with each other when off the network (direct radio to radio)	With only one exception, Tetra is only available in 800 MHz and 400 MHz versions. One manufacturer also makes a 700 MHz version and Motorola has been engineering a 700 MHz version
Network connected radios can act as relays for each other into the system infrastructure	Requires many more sites than a dedicated LMR system to provide a public safety user level of performance
Operates in the "one-to many users mode" as is common in LMR (Land Mobile Radio) systems as well as "one to one" (private call)	
System is digital from end to end and can contain high level encryption for security	
Infrastructure options allow rapid deployment in emergency situations. A transportable Tetra system can be deployed at a remote location for temporary use.	
TETRA radios can act as a mesh network allowing multiple radios to relay traffic without a backbone system.	
Can operate as a one to one unit similar to calling using a cell phone	
Since IP protocol is used Tetra systems can interface readily with other digital systems	

Digital Mobile Radio (DMR)

Digital Mobile Radio is a family of new technologies that has developed over the past few years. Like the P25 technology, the radios operate in a digital mode but there is no industry standard and there are several different and incompatible technologies available. Some of the technologies under the umbrella of DMR include; P25, DMR, NXDN, C4FM and D-Star.

C4FM and D-Star are limited to amateur radio operations. DMR and NXDN are available in commercial radios and systems. None of these technologies have been developed for use by public safety agencies. Even the manufacturers state that DMR products are for business and industrial users rather than public safety.

Each vendor has its own trade name for its DMR product. Motorola uses DMR technology for its Mototrbo brand. Harris is the United States marketer for Tait, a New

Zealand DMR line of DMR radios. Respectively, Kenwood and Icom use the NXDN technology under the Nexedge and IDAS trade names. Other vendors also have their own trade names.

Each manufacturer has chosen its own technology with the goal in mind to meet FCC requirements for narrower bandwidth communications. In addition, the use of digital modulation allows vendors to provide data features the products. DMR radios are capable of sending and receiving GPS data to show their locations; adding data streams to identify the user and priorities; adding limited messaging capabilities.

The manufacturers state that DMR was not developed for public safety and that using these products will not allow for any interoperability with agencies that comply with the interoperability requirements of the Department of Homeland Security's Interoperability Continuum.

There is one feature of DMR radios that P25 Phase 1 does not have. DMR can have "two slot" or TDMA(Time Division Multiple Access) performance. This allows two separate conversations to take place on the same frequency without interfering with each other. This essentially doubles the number of channels available to the user. P25 Phase 2 is a two slot technology. However, it requires an entire trunking infrastructure to operate while a DMR two-slot system has all of the technology built into the radios.

Broadband LTE Technology

In 2012,The United States Congress gave public safety a large piece of the 700 MHz spectrum for the development of LTE (Long Term Evolution) technology. FirstNet, as it is called, will present a quantum leap for public safety communications when implemented. Like cellular technology, this will allow public safety to effectively have its own nationwide cellular system with complete interoperability between public safety agencies. Using smart phone like devices, public safety will be able to send high speed data to users in the field. This will allow fingerprinting in the field, downloading of building plans for firefighters, full motion video to allow headquarters and management to be “on-scene” with their forces and even simple data requests such as license plate checks. It can be considered almost the same as placing a personal computer in every public safety officer’s hand.

Since Bermuda follows the guidelines of the United States Federal Communication Commission the Island has adapted the same segment of the 700 MHz frequency band for public safety and LTE implementation.

LTE is the next step in the development of cellular technology. Like 4G cellular followed "3G", it offered more than the existing cellular devices. 4G uses LTE technology, however, it is significantly different than the current form of radio communications that public safety and local government is accustomed to. One of the most important aspects is that current LTE does not offer what is called “one too many” communications. A regular radio user can key a radio (push to talk) and speak to

everyone on the channel (or talk group in a trunked system). Current cellular and LTE technology offers only "one to one" communication. That is communications from one user directly to one other user (dialing the phone number of another person). That may be good for messaging but not for dispatching. Only the person called hears the message. Public safety personnel must hear all of the calls in order to maintain situational awareness. If you consider the way cellular phones are used by public safety today, it is clear that it is good for only non-mission critical communications such as administrative functions.

The devices used for LTE, like cellular phones, operate at very low power of a few tenths of a watt. Public safety handheld radios transmit up to 5 watts and the radio sites that they communicate with are usually high power at high locations. Therefore, the range of an LTE device will be very limited. In-building use will not be up to public safety standards. The network infrastructure for an LTE system will require many more sites at relatively low locations just as the cellular networks require.

Table 9 compares the capabilities and features of current land mobile radio and LTE technology.

TABLE 9 - LMR LTE Comparison

Land Mobile Radio (LMR) Technology	LTE Technology
One to many communications – a user calls on a channel where anybody else on the channel can hear	One to one communications – call is directed to a single user like dialing a telephone call
High powered radio sites-few site required depending upon terrain	Low power means many more sites are required to cover the same area
Radio sites at high locations	Sites can be on rooftops or other low convenient locations (i.e. light poles)
High power radios – allow signal penetration into buildings and provide greater range	Low powered units good for short range only-in-building use requires in-building antenna systems
Direct unit to unit communications- simplex or talk around	Requires calls go through infrastructure- must be in range of at least one site of the system
In-building performance- higher power allows penetration	Low power means in-building use is limited
Transmit only with Push to talk –battery lasts a full shift	Continuously transmitting like a cell phone reduces battery life
Omni-directional antennas	Sectorized antennas
External antennas	Handhelds have built in antennas like cell phones limiting range
Range 10 to 15 miles per site	Typically less than a mile
Limited number of sites required	Multiple sites needed, usually spaced a half mile or less apart
External speaker/mic	Built in microphone and speaker
Simple channel changing	Network changes functions so user must key in address
Simple backhaul- low speed data and voice only require phone line connections to sites	Digital signaling requires high speed microwave or fiber optic links
Volume control- higher power audio output	Limited volume control-limited audio level

Since the United States Congress approved public safety LTE, the industry has taken great leaps in subscriber units. Even though there is no FirstNet network in place, currently, at least two vendors have come up with public safety LTE units in smart phone style. One has a tablet unit available. These can interface to the current 3G and 4G cellular networks and link into existing P25 radio systems using each vendor's proprietary interfaces.

LTE is not meant as a replacement for traditional land mobile radio. The technology is still in its infancy and will not be able to replace the functionality of dispatch type radio systems for several years. The important characteristic that makes it of concern to governments is that there is the possibility to design current voice systems that can gracefully migrate to LTE when the technology matures.

The industry agrees that LTE will not replace current land mobile radio systems for many years to come. The key issues are the lack of a reliable, mission critical push to talk technology and the lack of a proven dispatch methodology to replace the existing LMR known performance.

Connecting the Radio System to the Telephone System (Radio over Cell phones)

Since both P25 technology and Tetra uses IP protocol, like most data systems and networks, an IP based telephone system can be connected to a P25 radio system. All that is required is a radio to PSTN (Public Switched Telephone Network) adapter on the P25 system radio infrastructure. Any IP based telephone system can then simply be plugged in. Several P25 radio manufacturers have recently developed interfaces that will allow connectivity between a Smartphone and a P25 system controller. They provide an "app" for the phone that will emulate the operation of a radio on the system.

The user connectivity is obtained through the existing cellular network by "dialing up" the interface to the radio system. The user 's cell phone then acts like a portable radio unit on the radio system.

OBSERVATIONS

New Radio System Funding

The current radio system is owned and operated by private businesses. The Government pays and annual fee for the services and the maintenance of the systems. The subscriber units (user radios) are paid for by the users. With the procurement of a new radio system both the cost of the system and its maintenance will be part of the annual budgeting process for the Ministry of National Security. The funding now allocated to pay the annual "lease" costs will have to be allocated for both procurement and maintenance over the life of the future radio system.

Plans will be required to establish maintenance plans whether through the Government or through contracts with the private sector. Since radio system operation is a high

priority public safety function, if maintenance is done internally then an internal section will have to be established that can react to system issues within short time frames on a 24-7 basis.

Microwave System Operation and Performance

The microwave system used for interconnecting the sites of a new radio system will require high reliability and redundancy. The microwave system for the current radio system has both since in addition to supporting the government radio system it also supports the business networks of the owners.

Radio Sites

Radio sites available to the Government are numerous and well located. Some are government owned.

The Government has available a hardened site owned by Link Bermuda, the Island's data and internet provider

Bermuda Mission Critical Communication System

System Components

For the Bermuda's Government Mission Critical Communication System (MCCS) there are two sets of components that must be put together in order to effectively deploy the MCCS. These are the Operational/Administrational component and the Technological component. Both are described below:

Operational/Administrational Component

This consists of the structured arrangement of the duties, responsibilities and activities related and required to preserve the good operation and administration of the MCCS. Many of these elements will require organizational reviews or process management that will alter the current work practices. The Bermuda Government will maximize the benefits of the technological components, control cost and achieve the goal of operational independence.

The Operational/Administrational components are represented here as a stack of elements. Each element is described; its scope defined and suggested responsible organization in **Table 10**.

- User Operation
- User Administration
- Technology Administration
- Facilities and Infrastructure
- Business Model

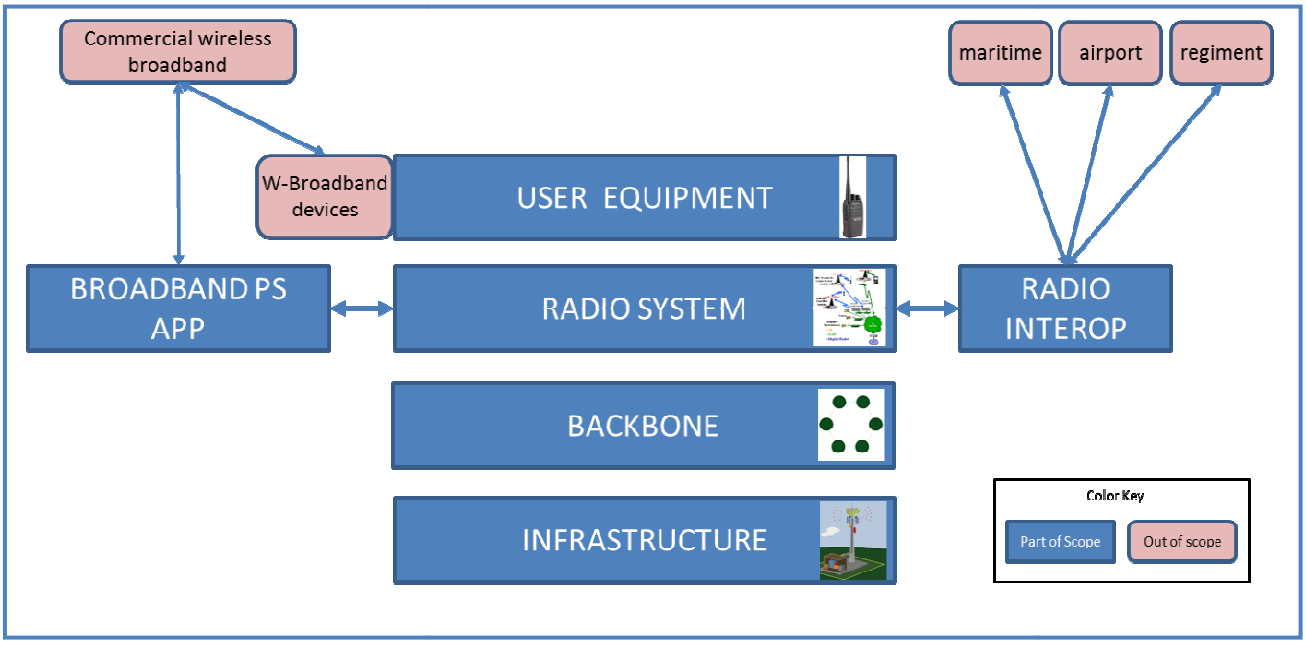
Table 10 - Operational/Administrational components description

COMPONENT	DESCRIPTION	SCOPE	RESPONSIBLE
User Operation	Operation of the field equipment to perform emergency and critical communications related to Public Safety.	Uses cases like one-to-one, one-to-many, dispatch, and others as defined by the user agency policies.	All Public Safety related agencies like Police, Fire, EMS, Regiment, Corrections, etc.
User Administration	Control of the MCCS operation in order to enable user operations.	Access control, use case definitions in the MCCS, security policies, field devices management.	IT as Master Admin, Independent Admin for Police or agencies with that requirement.
Technology Administration	Maintenance and support of the technological components including user equipment.	1st level support, vendor 2nd and 3rd level support. Monitoring of system's operation. Patches and preventive maintenance.	Primarily Vendors. Some tasks may be fulfilled by IT, Police or Regiment if they have capabilities.
Facilities & Infrastructure	Keeping physical facilities suitable to host equipment.	Access, security, civil engineering, janitorial, electrical power.	Department
Business Model	Administrative and financial considerations.	Financial and Legal model with vendor (lease, own, etc). Internal financial model like inter-agency budgeting.	Information Technology

Technological Components

These components consist of all of the technological elements required for the MCCS to exist and function. They are shown in **FIGURE 12** as a stack of components in the architecture, arranged from the basic components to the User's. Some other elements that interact with the MCCS are described for completeness but are not part of the MCCS project scope.

FIGURE 12: Technological Components



These components are described in a vertical stack because it is easier to match technology with Operational/Administrational components this format. It also helps in defining procurement and sourcing for the MCCS. The following is a general description of each Technological Component:

- Infrastructure: includes physical towers, antennas and cabling required for radio frequency transmission, shelters in the transmission sites; uninterrupted power systems and security. Other important considerations are required for the Data Center hosting the computer and network equipment that runs the Core System protocols. Following Motorola's R56 standard is recommended as the facilities maintenance guidelines. R56 is accepted universally as an installation and implementation standard worldwide.

- Backbone: consists of a private transport network (IP based) that interconnects the re-transmitting equipment of the Radio System. It requires mission critical level of availability. It may be shared with other mission critical services but preserving QoS (Quality of Service), which is critical since any extra delay produced can compromised the “Mission Critical” grade of the Radio Network.

- Radio System: This key element consists of the RF distribution systems, radio transmitters and/or repeaters, all the hardware and software for the LMR control protocol, for the required functionalities and for the network management system.

- User equipment: All the devices that are going to be operated by the Public Safety users, will include radios carried by officers and staff (portables), radios installed in vehicles and vessels (Mobiles), Equipment stationary at Stations or offices (Radio base), workstations with more sophisticated functionality for dispatching and creating communication groups (Dispatch Consoles) and even devices like alarms, switches and remote sensors that deliver communication functionality. It is important to mention that quality of voice, RF characteristics, robustness and ergonomics are among the main qualities required in these devices.

- Radio Interoperability: In a National Emergency System like the Bermuda MCCS, interoperability must be designed to completely fulfill its purpose, hence it is highlighted it as a separate module that includes all hardware and software required to connect all other radio networks voice functionality with the Radio System. It should provide dispatch functionalities, so emergency interagency communication can be achieved seamlessly between disparate networks.

- Broadband Apps: Public Safety Broadband applications are becoming main stream and will be, in the near future, the primary means of communication. The overall conceptual design of the Bermuda’s MCCS incorporates a Next Generation communication element consisting of a mobile application portal for

Public Safety users including applications like PTT over LTE, PTT over IP integrated with the Radio System and other important applications like presence, active video, etc. In a first phase, the MCCS will rely in the commercial Wireless Broadband services to connect wireless broadband devices like smart phones or tablets to the radio system. This initial low cost deployment strategy will allow Bermuda's Public Safety agencies to start piloting the services and start the process of evaluation and incorporation of this technology in a 3-5 years horizon.

RECOMMENDATIONS

The following recommendations are based upon the observations made and noted in this report as well as the conversations with various representatives of the departments visited. Some recommendations go beyond the basic concept of selecting a new radio communications system. They go to possible future improvements under the concept of an overall mission critical communications system.

Technology

The radio systems in use by the Government of Bermuda are made up of hardware that is in excess of 25 years old and, even though it still works, is truly obsolete by all measurable standards. Technology today has advanced from just providing a platform for voice transmission to platforms that support voice, data, video and technologies that allow the real time ability to monitor and evaluate public safety events by all levels of service providers.

Today radio communications is capable of meeting much of the demand for these platforms but it is not quite there. The advances being brought by broadband technology are not quite up to public safety standards so any new systems must be capable of bridging the gap when broadband matures. **For that reason Pallans Associates recommends that Bermuda look to TETRA technology today.**

TETRA is a mature digital technology that operates on an IP platform, the migratable path to broadband technology. It has proven its values as a primary digital voice technology all over the world. It offers features that are looked for by end users and performs as a voice radio system suitable for public safety applications. There are applications that can have cell phones operate as two way radios when interfacing the TETRA system through the public wireless networks. It can support moderate speed data for graphics and video transmissions. It is migratable to broadband when that technology matures for public safety.

The only other viable technology for public safety use is P25, the technology used primarily in the United States. P25 is more practical over large jurisdictions since its infrastructure is designed for high sites covering large areas. TETRA is more suitable for low sites. TETRA costs are , in general lower, especially when coverage is over a smaller area such as the Island of Bermuda.

The basic logic for not selecting P25 is that the cost of P25 systems is considerably higher than the other technologies. For example, a high tier P25 handheld radio can cost in the range of $3,500 to $5,000 Some multiband models cost over $6,000. A high Tier Tetra radio will cost less than $1,500 and a DMR radio slightly less.

DMR, while a viable and effective technology was not developed for public safety. Its targeted market has been in utilities and other services that do not look towards long

term reliability. Several of the manufacturers have actually included comments in their literature that DMR is an industrial radio. DMR also lacks some of the features and performance levels that most public safety entities request.

Tetra technology was specifically developed to service the public safety market. It is used worldwide (except for the US) as the primary communications system for public safety agencies. It is fully IP based end to end and is similar to cellular system in that it uses low radio sites and users shift seamlessly between them as the user traverses an area. The UK has been using Tetra since it was first developed and the original system is currently being replaced with the latest version.

Why Should the Government Buy a New System When One Already Exists?

This question arose during discussions with staff and management. What are the differences between the existing commercial Tetra radio system and a public safety grade system. The existing system used by ECL is designed to provide businesses with radio communications so they do not need to have a subscription to the cellular network. One advantage of "radio" over "cell service" is that radio units communicate between authorized users. Businesses only want to talk to their own people so they just want to be able to push a button and be in communications without having to dial up anyone and pay for each call made.

Similarly public safety uses this same concept but expands it so that any authorized user can hear what is happening. For example, a 911 call is handed over to a radio dispatcher who then broadcasts it to a police officer in the district where the caller located. At the same time all other officers in that district also hear the all so they can be aware of what is taking place and assist if appropriate. The only users of the system are public safety agencies which carefully control access and operational procedures. A business Tetra system is, essentially, a free for all where many users can try to access the system for any purpose. This frequently creates situations where users are denied access if the system is busy.

There is little control over users of a commercial system. Historically, worldwide, the first communication systems to fail during major emergencies are the cellular network followed by the commercial radio systems. They do not fail due to "breaking" but rather to being unable to meet the demand for use by a frantic population.

Public safety systems are immune to this problem up to the point that system capacity is exceeded and even then the technology is such that user radios are assigned priorities so the most important calls go to the head of the queue.

Dedicated radio systems are the norm for public safety users. Even the two systems currently in use by the Government are dedicated strictly to the government use even though they are privately owned.

Radio System Coverage

Radio coverage in Bermuda today is fairly good. The terrain causes some issues as does coverage in larger or denser buildings. TETRA can improve these issues. The primary concept of TETRA is that it relies and many low sites rather than a few high sites. The existing SmartNet system uses a single site and the SmartZone system uses five sites. Depending upon the vendors final design for a TETRA system more sites may be needed. There are an adequate number of tower sites on the Island for this to be accomplished. The technology is adaptable for placing additional sites into limited coverage areas without high cost. When designing the radio system it is easy to add additional "cells" to provide coverage at much lower costs that adding large P25 sites.

Radio Spectrum

All of the technologies work in the 800 MHz range and UHF (450 MHz) range. The RA (Regulatory Authority) has stated that 800 MHz is not available because it has been given to the commercial radio services. He recommended 700 MHz for the government system. At the present time only one company makes Tetra for use at 700 MHz (and 800 MHz and UHF). The other potential TETRA vendors operate in the UHF and 800 MHz ranges. DMR is available in VHF, UHF and 800 MHz.

The recommended spectrum for this system is in the 700 and 800 MHz range. This spectrum provides the most effective range and coverage.

Dispatch Systems

There are two primary dispatch locations in Bermuda, one for Police and one for Fire. Both of these will require replacement to be compatible with the IP technology being implemented

Today there are some operational inefficiencies in the dispatch operations and with the 911 system. While this report does not address operations or 911 it must be noted that during conversations with users it was understood that the existing 911 is operated by the Police Department and the versatility of the 911 (caller location and name) is not available to Fire when a call is transferred. As part of our section on developing a Mission Critical Communication System the topics of available information should be considered in the future.

Connectivity

All of the radio sites in the system required connectivity between each other. Currently the system provider uses microwave systems to provide this connectivity. There is an existing island wide microwave system being used for the video system which is available to the Government. It can be used to provide the radio system connectivity.

This system will require being measured to determine its data capacity prior to being implemented as part of the radio system.

Site Improvements

There are many existing radio sites on the Island. Since no new system design has been developed it is not known how many sites will be needed for the radio system. The final vendor design will determine the number of sites required.

Pallans Associates visited multiple radio sites which on the Island. There are an adequate number of sites available for use and the variety of locations will assure that coverage on Bermuda can be designed to be good enough for a public safety grade system both indoors and outdoors.

The availability of the Link Bermuda facility provides the Government with an ideal location for backup and redundancy. It is self contained with power. It has multiple towers that are build to withstand hurricanes. The facility can sustain an operations crew for an extended period of time.

System Oversight and Maintenance

Over the years the Government has not had to worry about oversight of the facilities or of the system hardware since the owners have treated maintenance of the infrastructure as part of their "turnkey" operation. When a new system is procured it will be owned and operated by the Government. All of the system oversight, operation and maintenance will become a Government responsibility. There are two clear options when it comes to maintenance. The Government can perform the maintenance or the government can contract with outside companies to perform maintenance.

Pallans Associates' recommendations are based on the vast majority of Public safety systems we have procured and implemented. Maintenance is an issue that varies among the governments that own and operate these systems. Modern communications systems are combinations of radio technology and data technology so a maintenance provider must have both sets of skills. A pure data technician will have to be trained in radio technology and a radio technician will require data training. If the Government wishes to be self maintained it will have to take on the training responsibilities for the technical staff to become proficient. A frequently used alternative is to contract with local representative companies that are contracted to the system vendor to provide the maintenance services similar to what is currently being done with the two private systems in use.

If the government were to do its own maintenance it will be necessary to train technicians on the specific technology being implemented. If there are no existing skilled radio technicians the best course of action is to establish maintenance agreements with companies already in the industry.

Pallans Associates actually envisions that the system vendors offering responses to the RFP would have have already contacted local technology companies and developed working agreements to service the equipment if they get the contract for the system. Maintenance agreements could then be worked out through the system vendor to provide long term maintenance through the local companies

SURVEY RESULTS SUMMARY

	Bermuda Regiment	Customs	Department of Corrections	Fire Rescue EMS	Health Department	Parks	Post Office	Public Transportation	Lifeguards	Police
Radio Inventory										
Portable	135	12	93	23	0	30	7*	0	17	578
Mobile	0	0	0	35	18	5	0	8	1	0
Base Unit	3	0	7	3	0	3	0	3	0	10
System								none		
Smartzone	n	n	n	y			n		y	y
Smartnet	n	n	n	n		?	n		y	n
Tetra	y	y	n	n			y		n	n
DMR	n	n	y	n		?	n		n	n
Dispatch	y	n	n	y	y	y	n	y	y	y
Changes Anticipated		n	y	y	y	n	y	n	n	n
Paging	n	n	y	y	n	n	n	n	n	n
Fire Station Alerting	n	n	n	y	n	n	n	n	n	n
Interop Needs		y	n	n	n	y	n	n	y	
Interoperability needs	Special needs	ATC, Skyport customs, Harbor radio	y	n			n	n	Police, Marine Operations	
Encryption	y	Desired	n	Desired	Desired	Desired	n	n	n	Desired
Shift Duration	10	10	12	16	7.5	8	7.5	7	8	10
Battery life	y	y	n	y	y	y	ok	y	y	y*
Coverage Problems		n	y	y	n	n	y	n	n	y
Capacity problems		n	n	n	n	n	n	n	n	n
Mobile Coverage		*	*	98	98	90		75	75	

	Bermuda Regiment	Customs	Department of Corrections	Fire Rescue EMS	Health Department	Parks	Post Office	Public Transportation	Lifeguards	Police
Portable Coverage	85	100	*	98		90	98	75	75	98
In Building Coverage	95	100	*	85-90		65	*	99	*	90
Key Coverage requirements	In emergencies- Government House, Belco,Link Bermuda, Fuel farms, etc	airport terminal	inside all correction facilities. Island wide for escorts, mass arrest events	King Edward Hospital,Tynes Bay Incinerator, Dame Lois Brown Courthouse					Cooper's Island (Beaches/Park), Turtle Beach (Beach/Park), Clearwater Beach (Beach/Park), John Smith's Bay (Beach/Park), Shelly Bay Park (Beach/Park), Admiralty House Park (Beach/Park), Warwick Long Bay through to Horseshoe Bay otherwise known as "South Shore Park"- all areas.	Courts, Police Stations, Government House, Comops
Critical Shortcomings	St. Georges area			Pompano Beach, Paynters Road		Flatts Village, Devil's Hole, John Smith's Bay, Tucker's Bay	Airport area - weak area for system. Pick up other users		1) Tobacco Bay, St.George's through to (including Achilles Bay, Fort St. Catherine Beach, Drew's Bay St. George's 2) John Smith's Bay, Smith's Parish 3) All along South Road from John Smith's Bay, Smith's Parish through to Spittal Pond (west parking lot), Smith's Parish 4) Various locations along the South Shore Park, Warwick/Southampton specially in the beach/cove areas	West Side Road, Devils Hole

Features	Bermuda Regiment	Customs	Departent of Corrections	Fire Rescue EMS	Health Department	Parks	Post Office	Public Transportation	Lifeguards	Police
Must have	external speaker/mic ,Bluetooth, GPS, water resistant	Display, caller ID, push button functions, encryption, scanning, home group	Display name,unit ID,man-down button,external speaker mic, GPS, encryption	Display, caller ID,large knobs, pb feature,man-down,external speaker/mic,GPS,encryption,scanning, call alert, channel busy alert, water resistant	Push button fiunctions, man down button, water resistant	Display, Caller ID, large knobs, external speaker/ mic, scanning , call alert, channel busy alert, private call, dat, water resistant	Built in GPS	Current features adequate	Water Resistant	Caller ID, Push button functions,man down button,external speaker/mic,encryption scanning
Desireable	Display, large knobs, push button functions,encryption,private call,data, texting	man down button, external speaker mic, GPS, call alert, channel busy, private call, water resistant	Scanning home group,private call	Home group button, channel busy, private call			Display name, man-down feature,scanning, call alert,channel busy signal, private call, texting, water resist		Display name,external speaker/mic,scanning ,private call, vehicle data	Talkgroup displan, GPS, private call
Additional features		Intrinsically safe	Cell phone jamming							ability to change radio IDs and assignments, Ability to assign secure channel on the fly