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Interoperability White Paper

First Responder Communications

Purpose

This White Paper will provide insight to the possible methods of providing effective and interoperable first responder communications in a resource-constrained environment. This paper is designed to provide a framework for understanding the issues involved in Interoperability and an overview of potential solutions.

This paper is written as much as possible in "plain English", without many of the High-Tech buzzwords and detailed technical discussions. This way, non-technical decision makers and researchers can review the paper with excellent understanding.

The Paper is organized to:

- Describe the current Interoperability Environment
- Discuss potential Interoperability Solutions
- Provide specific examples
- Develop Conclusions

Each First Responder Agency and each emergency scenario is unique. The set of possible solutions continues to change in rapid response to the demands and advances in technologies.

Upon reviewing this White Paper, the reader should have a better understanding of the concept of Interoperability, the issues involved, and some solutions for enhancing First Responder Communications Interoperability at multiple levels.

Introduction

Public Safety in its most elegant and critical implementation is the act of deploying emergency personnel and equipment to the right place at the right time with the ability to understand what has happened and how to effectively and efficiently deal with the situation. There are *two absolute keys* to success in First Responder Operations – Communications and Training.

First Responders generally have a very high level of training that allows them to observe and assess any emergency situation, to react properly to those assessments, and to be prepared for the unexpected. Communications enables the decisions of the First Responders to be implemented effectively, efficiently, and safely.

Few First Responder scenarios are simple. Most require multiple responses. Even a simple single vehicle accident in the suburbs can require multiple responders:

- Local Police
- Sheriff (depending upon the location)
- Ambulance (Emergency Medical Services – EMS)
- Fire

Large incidents such as an airplane crash, a large fire, or a terrorist incident can require a major commitment of multiple First Responders over a large operational area:

- Local Police (multiple jurisdictions)
- Sheriff (multiple jurisdictions)
- Ambulance (multiple jurisdictions)
- Fire (multiple companies and multiple jurisdictions)
- State Police
- State Emergency Management Agency
- Federal Emergency Management Agency
- National Guard

At best, training for each of the various First Responder Agencies at the local, state, and Federal levels will be different. Terminology will be different. SOP's will be different.

Communications is the enabling tool to allow First Responders and First Response Management Teams to pass information, formulate plans, and implement those plans.

The ability for First Responders to communicate together is most often referred to as Communications Interoperability.

The Public Safety Wireless Network Consortium (PSWN) describes Interoperability:

> **What Is Interoperability?** "Interoperability" simply refers to the ability of public safety personnel to communicate by radio with staff from other agencies, on demand and in real time. Public safety agencies require three distinct types of interoperability — day-to-day, mutual aid, and task force.
>
> *Day-to-day interoperability* involves coordination during routine public safety operations. Interoperability is required, for example, when firefighters from around a county join forces to battle a structural fire or when neighboring law enforcement agencies must work together during a vehicular chase.
>
> *Mutual aid interoperability* involves a joint and immediate response to catastrophic accidents or natural disasters and requires tactical communications among numerous groups of public safety personnel. Airplane crashes, bombings, forest fires, earthquakes and hurricanes are all examples of mutual aid events.

Task force interoperability involves local, state and federal agencies coming together for an extended period of time to address a public safety problem. Task forces lead the extended recovery operations for major disasters, provide security for major events and conduct operations in response to prolonged criminal activity.

The Requirement

We will use the mythical City of Midland as a classic description of the issues, problems, and potential solutions for interoperability.

The City of Midland has a population of approximately 500,000 taxpayers, with a reasonable mix of industrial, commercial, and residential regions. Midland is also host to an Air Force Base and a US Army Post. A large State Forest joins the boundary of Midland.

City of Midland is a forward-looking community that has been awakened by the events in New York City, Washington DC, and Pennsylvania on September 11, 2001. While Midland is certainly not anywhere near the size or strategic importance of NYC or Washington DC, Midland's leadership knows that they must still be able react to emergency situations when they occur. To try to ensure that proper governmental emergency services are provided to the population, Midland is conducting a review of three emergency scenarios that are entirely feasible:

1. A fire in the downtown corridor
2. A commercial plane crash at the municipal airport located just outside the City limits
3. A terrorist strike at one of the military bases in the Midland region

In each of these scenarios, Midland has a requirement to respond with emergency services and support.

The Environment

Agreements:

- Mutual Aid Agreements exist between Midland and the Military Bases for Fire, Police, and ambulance services
- Mutual Aid Agreements exist between Midland, the County, and the State for Police support (Sheriff and State Police)
- Emergency Agreements and Activation Policies exist between Midland and the State Emergency Management Agency (which includes all state response elements)

Communications:

- The City of Midland has a 5 year old Public Safety Radio Network providing voice communications for Police. This radio network is a Motorola Digital Trunked Radio Network in the 800 MHz band. This Trunked Radio network is a very feature rich network that provides solid radio communications within the City limits of Midland and extends out to the Airport. It also provides some coverage to the Military Bases.
- Midland's Fire Department and EMS does not have the funding to join the 800MHz Radio network, so it still uses its conventional VHF Radio System. This radio system provides adequate radio communications within Midland and in some areas outside the Midland City Limits.
- County uses the Sheriff's VHF conventional VHF Radio System which provides reasonable coverage throughout the County.
- State is building a brand new "state of the art" 800 MHz P25 radio network that provides reasonable coverage throughout the state. Coverage for that network is spotty or non-existent in several places in Midland. One or more additional radio network sites is required to provide good coverage and communications for that State network in Midland.
- While the State is building the new 800 MHZ network, the state has emergency first responders and management teams on the 800 MHz network and the old State VHF conventional repeater System.
- The military bases share a UHF trunked radio system that provides adequate coverage for the military bases, but minimal useful coverage and capability off-base.

In matrix format, the communications capabilities situation looks like this:

Entity/Agency	800 MHZ P25	800 MHz non-P25	VHF	UHF	Other
Midland Police		**X**			
Midland Fire / EMS			**X**		
State Police	**X**		**X**		
State EMA	**X**		**X**		
State National Guard					**X**
US Military				**X**	**X**
FBI			**X**		**X**
FEMA			**X**		**X**
Federal BLM			**X**		

Photos Courtesy Motorola

In the 3 emergency scenarios, communications requirements look like this:

Entity/Agency	Fire in Downtown	Commercial Plane Crash	Terrorist Emergency at Military Base
Midland Police	**X**	**X**	**X**
Midland Fire / EMS	**X**	**X**	**X**
State Police		**X**	**X**
State EMA			**X**
State National Guard			**X**
US Military			**X**
FBI		**X**	**X**
FEMA		**X**	**X**
Federal BLM			

Comparing the requirements matrix with the capabilities matrix, there are some obvious issues.

- Communications Systems in the different Frequency Bands (800 MHz, UHF, VHF, Other) do not “talk” to each other.
- Even the two trunked systems in the 800 MHz Band do not talk to each other because one is a P25 technology and one is a non-P25 technology. Simply put, they use different and non-compatible means to take the users voice and send it from radio to radio and person to person.
- There are many many different people and organizations involved!

The City of Midland must develop polices, procedures and techniques to allow it to provide maximum First Responder capability for each of these scenarios.

The State must also look at these two matrices from a larger scale. The scenario played out in Midland is similar to Municipalities and Counties all over the State. The State also has fiscal and political resources that far surpass that of any Municipality in the State.

Solutions

There are three generic solutions to interoperability:

Solution 1: Everyone has the same radio system

Solution 2: Provide First Responders with additional communications to talk to everyone they need to talk to

Solution 3: Link Radio Systems together

These solutions each have advantages and disadvantages that are worthwhile discussing.

Solution1: Everyone has the same radio system

The ideal solution is for all First Responders to be using the same communications equipment. However, this is not at all feasible.

First, for everyone to be on the same communications infrastructure, every radio system in the Local, State and Federal Governments would have to be replaced with a "standard infrastructure". The cost for doing this is estimated at between $15 Billion and $ 20 Billion.

Second, the time to complete such a replacement would be 20 years or more. Several States are currently implementing state-wide systems to try to provide such a common First Responder Communications Infrastructure. Michigan and Florida have been working this issue for over 10 years each. Nationwide, the time for deployment will be longer.

Third, local municipalities simply cannot fund such a large-scale change of infrastructure. As with most Cities, Midland purchased their 800 MHz Radio Network expecting a life cycle of 10-15 years. It cost approximately $10M to purchase and implement. It would be a major fiscal blow to Midland to have to replace their 5 year-old Trunked Radio Network with a new network identical to the State's. Even if Midland decided to immediately join the State's effort in building the State-wide network, additional sites will be needed and a whole new fleet of radios will need to be purchased – not only for Police, but for Fire and EMS.

Fourth, there are a number of spectrum issues involved. Spectrum – or the radio frequencies that First Responder Communications Systems use – is a precious resource that is scarce and highly controlled. Only so many users can effectively use a frequency (or a channel) allocation. There are only so many frequencies available. As more users join a common network, the requirement for more frequencies to service the added capacity becomes a major issue and constraint. Further, Federal Agencies as a general rule are authorized only certain frequencies (Department of Defense is authorized UHF). Both of these spectrum related issues are major impediments to building and using a totally ubiquitous common infrastructure.

As frequencies become scarce and crowded, the search for additional spectrum continues. Recently, Congress and FCC have allocated 24MHz in the 700MHz band for inter-operations frequencies. This is probably the most aggressive attempt, to date, to bring wide-scale interoperations spectrum, as well as additional general spectrum, on line.

The FCC intends for a portion of this new spectrum allocation to be used for interoperations frequencies, and part of it for general use by public safety entities. State and local governments will be highly motivated to explore the possibilities that this new spectrum allocation offers. The FCC's vision is that the new spectrum will be enabled with new Technology Standards and Capabilities. Because of its characteristics and the way it will be allocated to using agencies, there is the possibility that new technologies such as enhanced AVL, GPS, imagery, and mapping can be added to wireless First Responder communications systems.

A comment about P25 is relevant at this point. P25 is a Technology Standard that was proposed and established to provide a common Interoperability Infrastructure for Public Safety Radio Communications and to provide competition among the various radio manufacturers. While the vision is entirely noble, the implementation is quite different.

- The concept for using P25 as a common interoperability infrastructure requires that every user has a P25 radio. This is only achievable with a complete replacement of all non-P25 compliant radios systems with P25 radio systems and user units.

- P25 does nothing to eliminate the interoperability problems inherent with differing frequency bands. One major example is in Alaska and Hawaii, where the Department of Defense implemented a P25 compliant infrastructure to support DOD operations in both states. The intent was that Radio users in Hawaii could take their radios to Alaska and use them there, and vice versa – a highly worthy vision. The only issue is that Hawaii DOD Radios work in the UHF band and the Radios in Alaska work in the VHF Band. While all those DOD radios are totally P25 compatible, there is absolutely no interoperability because of the frequency incompatibility issue.

- The entire P25 solution suite is a technology solution that is over a decade old. As technology changes, improvements such as integration of wireless data and voice communications, are creating more value for investment than pure P25 solutions. Even as early as 1999, the validity of P25 as a long tem solution was challenged:

  > *However, the APCO <P25> digital standard was developed during the early days of digital development, and recent advancements in digital technology offer better solutions for "all digital" systems than what is contained in the Phase I standard. Perhaps this is why the FCC chose to require a new standard for the 700MHz frequencies. That is one of the pitfalls of fast-paced developing technologies. Ernest Worthman, contributing editor,* ***Mobile Radio Technology, Apr 1, 1999***

The dominant manufacturer of P25 equipment, Motorola, is currently marketing a Voice Over IP technology for implementation in the new 700 MHz bands rather than its current offering of P25 conventional and trunked radio systems.

- Market Surveys and competitive bid processes have shown that the cost of P25 compliant radios and radio systems remains high – higher than non-P25 complaint radios and systems. There are a number of reasons for this, but the hope that competition would reduce the costs of P25 systems has not come to pass. P25 is a premium cost solution.

P25 is neither good, nor bad. Often it is often simply irrelevant when it comes to short and mid-term interoperability solutions. Many Municipalities and other agencies have recently chosen not to implement a P25 based solution. It is instructive that the Washington DC CAPWIN Team evaluated P25 as a potential solution and chose not to implement a P25 based technology for the regional interoperability solution (see discussion on page 11).

Solution 2: Provide First Responders with additional communications to talk to everyone they need to talk to

Most Municipalities and Counties have recipricol agreements to provide Police Radios to each other to facilitate inter agency communications. The Midland Police and the County Sheriff are no different. These agreements are generally implemented with all County Sheriff Patrol Cars equipped with two or more radios – one for County Sheriff radio system, one for the Midland 800 MHZ Police Radio system and, often, one more radio for the State Police.

This multiple radio installation is useful in the local area, but is not feasible State-wide. The number of different radio systems is simply too large. Further, addition of more than two or three radio systems becomes extremely cumbersome – and sometimes dangerous through distraction or missing information - to the radio users/First Responders.

ACU-1000 Intelligent Interconnect

There are several manufactures that are marketing these smaller, more localized solutions today. One example is the Raytheon/JPS ACU-1000. JPS Communications, Inc. designs, manufactures, and sells electronic hardware and software products that enhance the effectiveness of communications systems. The company's focus is on Radio Interconnect Products, which facilitate communications between HF, VHF/UHF, 800 trunked, and various other media such as cellular, NEXTEL, landline telephone and SATCOM. The ACU-1000 is a local solution, applicable to providing connectivity between disparate radio systems in a tactical scenario such as a fire or plane crash.

ACU 1000's are used in several high profile projects including:

- **NYPD Tunnel Communications** The ACU-1000 is used to provide communication at a simulated train tunnel accident between rescuers in the train and coordinators above ground.

- **City of Chicago** uses TRP-1000 (ACU-1000 Version) to address some of the interoperability problems within the City.

- **NYC** uses JPS PortaLink along with the ACU-1000 to facilitate the NYPD to communicate between officers on the ground and in a high rise building.

Solution 3: Link Radio Systems together

Midland currently has several existing radio systems that provide First Responder Communications. Each of these systems has proven to be fairly useful and functional in most cases. There is tremendous value in linking these existing networks together.

The first method of linking systems together is through the use of mobile or stationary "cross-band repeaters". Cross-band repeaters connect, for example, an 800 MHz radio site with a VHF and/of UHF radio site. In such a configuration, a radio on the 800MHz network would be heard on the UHF or VHF repeater and vice versa. This is most often accomplished Between dispatch facilities to allow dispatchers to communicate via radio between Police, Fire, and Ambulance services, or between local police and sheriff departments.

This solution is enhanced when a vehicular or mobile repeater is used in order to to provide local communications between dissimilar radio systems for First Responders. If configured properly, such a solution can provide a method of bringing together radio communications from Fire Fighters, Police, Ambulance, County and Military into one integrated local network. This sort of connectivity is highly useful in a smaller scale or confined location, such as a localized fire or other emergency incident.

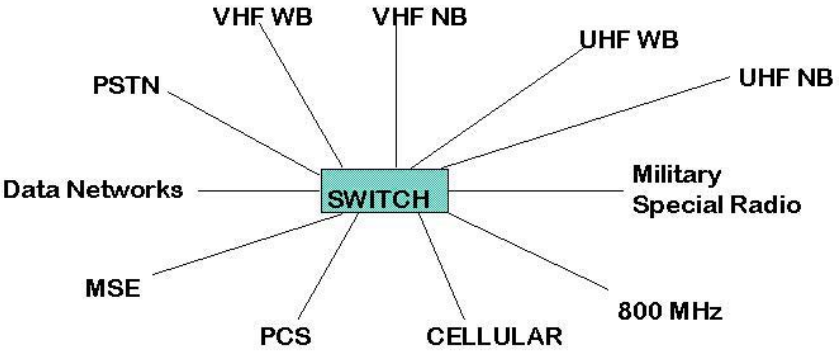
The second method of linking networks is to use some sort of direct patching between dispatchers or Emergency Management Operations Centers. Information is passed between Dispatch or Command Centers and then disseminated via each agencies own wireless networks. This process is cumbersome and slow, but is in use in many jurisdictions nationwide.

The third method of linking networks is through the use of a switching capability – such as a telephone or data switch. A switch is a mechanism that connects communications paths together so that people can talk together without being permanently connected.

A good example of a switch, is the current Public Switched Telephone Network (PSTN). If one desired to talk on their telephone to 100 people, there needs to be – somehow – 100 different talk paths. Without a switch, your phone would have 100 lines running to it – one to each phone you wanted to talk to. Obviously, this is not a functional solution. A switch is used as a central connection point for a large number of phones. That way, there is only one line to and from each phone. The switch is used to connect different phones together, either one to one, one to many, or many to many. In the early days of the telephone, there were manned switchboard operators to physically make the connection between talk paths.

Radio systems can likewise be connected together via a switching capability. In the past, normal telephone switches/PSTNs were used. Today, Internet Protocol (IP) data switches are used to provide enhanced rapid connectivity between radio systems. This allows virtually limitless expansion of the network as needed, without costly upgrades. This concept is best understood in the context of today's public Internet. Regardless of the type of end-user device -- an IBM PC, PalmPilot or iMac -- each is capable of connecting to the Internet. With an IP-based solution, it isn't necessary to invest in new equipment because it is "technology neutral."

One IP switch installed in the City of Midland can provide connections between all the major first responders (Police, Fire, EMS, Military, County, FBI) on a pre-planned or ad-hoc (on the fly) process. As long as police radios, fire radios, EMS radios, Military radios, etc were able to operated on their own networks as normal, the IP switch can connect those radios to each other quickly and efficiently.



Switching connectivity can be implemented for several orders of magnitude cheaper than replacing an entire radio system. It provides an immediate interoperability solution during the transition period between current architectures and the implementation of new architectures. IP switching provides interoperability until new spectrum or infrastructure is authorized and implemented. IP switching connectivity provides immediate interoperability and can provide interoperability well into the future - even if Midland changes wireless systems in the near or distant future!

From the State perspective, IP switching offers an immediate solution to linking the developing statewide networks to all other networks in the state without having to wait for the complete buildout of the new network, and without having to force municipalities to spend large amounts of money to join the State network. This network solution can be implemented on a State-wide scale for a fraction of the cost of any other state-wide Interoperability Solution. It also allows for dynamic linking of networks on a case-by-case or emergency-by-emergency basis. Switching – especially IP switching – offers an interoperability solution that will also be viable in the future as new networks and technologies are developed and come on line.

Switching solutions are offered by multiple vendors including M/A Com Wireless (Network First IP Switch and Integrated Multi-site Controller Analog switch), Harris (Digital Network Management System – DNMS), DynCorp (Software Adaptive Advanced Computing (SAAC), and CISCO (IP Routers).

An interesting versions of Network Connectivity is implemented in Washington DC as part of the CAPWIN Project. The Capital Wireless Integration Network — CapWIN — project provides for interoperable communications between Public Safety First Responders in Washington DC and the neighboring Counties and States(Montgomery County, MD, Fairfax, VA, etc.), providing a “virtual” regional network. CAPWIN however focused on providing data interoperability instead of voice interoperability. Each of the regional Public Safety First Responders that had the capability to conduct wireless data operations are connect via a “communications bridge” provided by the CAPWIN central authority.

Each mobile data system operates a message gateway process that communicates between it and the centralized CapWIN server. This server knows every data system within the extended network. CapWIN processes messages into a compatible format and forwards them along to the appropriate place, either to a CapWIN user or onto another gateway to another system. The message gateways enable existing mobile data systems in the region to communicate among all agencies, as well as allowing car-to-car direct messaging between CapWIN mobile computers and mobile computers using a different vendor's message switching system. The CAPWIN switching function also provides both connectivity and required text-based interfaces to area law enforcement databases, and if desired, access to internet based e-mail systems.

Data was chosen to facilitate interoperability because:

- Data is easier to integrate than voice in a dynamic environment
- Technology is fairly mature (it is the same technology that is used in the Internet)
- Data is more efficient that voice in the wireless environment

While CAPWIN uses data connectivity, it still is a very good example of how network connectivity provides interoperable communications.

Another similar use of data overlay to tie networks together is found in Vancouver, BC. Vancouver's Interoperability Project is called ECOMM. ECOMM uses the Northrop Grumman ALTARIS CAD suite of products to provide a common means of transferring and displaying emergency information in real time across multiple networks.

Conclusions:

According to the Public Safety Wireless Network (PSWN) Consortium:

> Improving interoperability, and thus public safety communications as a whole, is a multi-dimensional challenge. The Congress, regulatory agencies, state and local governments and the entire public safety community need to maintain a long-term focus on interoperability as decisions are made and as planning takes place for communications systems. Decision makers must be educated about the need for additional and appropriate public safety spectrum, particularly for interoperability purposes. A continued push at all levels of government for funding is necessary to provide for upgrades to interoperable technology and to enable shared systems development. Active participation in standard setting initiatives is needed to ensure an open and competitive market that meets public safety operational needs. Improved systems planning and the coordinated planning of shared systems is essential for realizing potential cost and spectrum efficiencies and resolving technical, operational and organizational issues related to interoperability. And perhaps most importantly, active and constant coordination among public safety officials and politicians from all levels of government is needed to share information and build on effective solutions for fostering interoperability.

There are a number of suitable interoperability solutions for Local, State, and Federal agencies to consider and implement. Each has its advantages and disadvantages. The key is to decide the level of interoperability desired, the value of that interoperability, and counterbalance that with the cost and time to implement.

Interoperability Solution	Functionality Provided	Relative Ease to Implement	Cost to Implement	Time To Implement	Impact Potential
Total System / Network Replacement	Highest	Hardest	Highest Possible Cost	Longest (if ever)	High – regional or statewide
Cross Band – Localized Repeaters	Low	Easy	Low	Short	Low – local only
Direct Connecting of Dispatch Centers	Low	Easy	Low	Short	Medium
Network Connectivity via IP Switching	Medium	Medium	Medium	Medium	High – regional or statewide

Given all the information available, it is apparent that Network Connectivity via IP switching provides the greatest value and the most effective interoperability solution available today. Using network connectivity, Interoperability can be provided:

Entity/Agency	800 MHZ P25	800 MHz non-P25	VHF	UHF	Other
Midland Police	X	X	X	X	X
Midland Fire / EMS	X	X	X	X	X
State Police	X	X	X	X	X
State EMA	X	X	X	X	X
State National Guard	X	X	X	X	X
US Military	X	X	X	X	X
FBI	X	X	X	X	X
FEMA	X	X	X	X	X
Federal BLM	X	X	X	X	X

Of course, there are limitations to any solution. In the case of network connectivity, radios are only useful in their normal areas of radio coverage. For example, Midland Police are able to use their radios only in the Midland area. If they wander too far form their radio network, their radios will not work no matter what the level of network connectivity is applied. Care must be taken in the design of the solution, and great effort must be given to train the radio users as to the best and most effective use of the solution. Training can never be overemphasized. It is essential to the implementation of any new technology and solution.

The most difficult aspect in the quest for interoperability is the political element – the will to be open to new ideas and new concepts. The technology is available today to implement any or all of these solutions. The real key to interoperability is the understanding, leadership, and managerial capability at the Local, State, and Federal Levels.

ACRONYMS

EMS	Emergency Medical Services
FBI	Federal Bureau of Investigation
FCC	Federal Communications Commission
INS	Immigration and Naturalization Service
KHz	Kilohertz
LMR	Land Mobile Radio
MHz	Megahertz
MOU	Memorandum of Understanding
NTIA	National Telecommunications and Information Administration
P25	Project 25 (standards suite)
PSWN	Public Safety Wireless Network
RF	Radio Frequency
UHF	Ultra High Frequency
VHF	Very High Frequency
VoIP	Voice-Over Internet Protocol

References:

PSWN Booklet - PUBLIC SAFETY and Wireless Communications Interoperability

Cap WIN connects crossed wires, Doug Mohney, Mobile Radio Technology, Mar 1, 2003

Public safety interoperability: Where are we now?, Ernest Worthman, contributing editor, Mobile Radio Technology, Apr 1, 1999

On-Scene Interoperability (NYC), Stewart Goldstein, Public Safety Report, October 2002

The interoperability quandary, By Jay Herther, Mobile Radio Technology, Aug 1, 2002

Local and Regional Interoperability Solutions Map Informational Material, PSWN, Feb 2003

Post-Symposium Support Report— PSWN Program and NTIA Conference. Final, PSWN July 2002

http://www.capwinproject.com/index.html

http://www.publicsafetywins.gov/

http://www.pswn.gov/news.cfm

http://www.jps.com/NEWScaseTUNNEL.html

http://www.wirelessfuturemagazine.com/publicsafety.html, October 200

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Frontier Systems Integrators, LLC is an Alaskan Based company, providing Telecommunications Consulting, Security Systems Integration, and Specialized Project Management. Frontier's core expertise is in wireless communications and emergency communications.

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