restored to analog, patched, vocoded again, restored to analog again, and presented to the listener. This patch also requires system coverage overlap, and uses a channel resource on both systems to complete a single transaction.

B. Complex Solutions:

- Cross band connectivity: Uses base stations or repeaters that are cross-connected allowing transmissions from one band or protocol to be retransmitted on another band or protocol. They can be fixed, transportable or mobile. If fixed, communications are limited to site coverage overlap. If transportable or mobile, they could be moved to a disaster scene, which does not have to be within infrastructure coverage. This interoperability solution also requires the use of two radio channels, one in each band, for each transmission.

- Gateways: Provides sophisticated system level interconnects which decodes one system's protocol and recodes the communication into another system's frequencies and protocol. Depending on the number of channels interconnected (in a trunked system, for example), the result can be full feature interoperability, including multi-talk groups, trunking and signaling features, and encryption. Gateways require system coverage overlap, and use a dedicated channel on both systems to complete a single transaction.

2. Direct Solution Range:

A. Simple Solutions:

- Analog radios on mutual aid channels: Uses standard analog carrier squelch radios for over-the-air interoperability on common channels, which multiple agencies agree to use under a mutual aid agreement. For agencies that have systems in different frequency bands or protocols, this solution still requires public safety officers to carry a second emergency radio, either mobile or portable.

B. Complex Solutions

- Broad band radios: Requires development of next generation radios that will be capable of communicating across a wider range of the frequency band, such as 380 MHz to 520 MHz, or 746 MHz to 824 MHz. Reallocating public safety spectrum in bands adjacent to existing UHF bands or 800 MHz bands will provide interoperability to a greater number of agencies having systems within such new frequency range. These radios will most likely be larger, heavier, have shorter battery operating time and other reduced performance characteristics, which may also require incremental system infrastructure. They will not provide interoperability with agencies that have systems in different frequency bands or protocols.

- Dual band / Multi-band radios: Requires development of next generation radios that will be capable of communicating across a two or more frequency bands. Each additional frequency band interoperability will require an additional receive module to be built into every multi-band radio. If these radios are to interoperate across bands with current radios, they will require an additional transmit/receive module for each additional band. These radios will most likely be larger, heavier, require more battery power and have other reduced performance characteristics, which may also require incremental system infrastructure. The above challenges will be even greater than those for broad band radios. They will, however, allow public safety agencies to communicate on one radio across two or more frequency bands with other radios having the same protocol.

Land Mobile Radio Standards:

Spanning the above "simple" and "complex" interoperability solutions is the need for common communication modes defined as standards. Successful interoperability in all ranges of technical complexity will be promoted through such standards. However, existing communication system life cycles mean that interoperability will take years to achieve, even after such standards are resolved by the public safety users.

Also. multi-agency systems continue to emerge in the public safety market, providing individual agency autonomy via software partitioning, while providing interoperability to all agencies on that system. Standards for such system architecture will promote additional interoperability with incoming disaster response resources.

Low and Non-Technical Solutions:

The public safety community has also devised a variety of "low technical" and "non-technical" solutions to overcome interoperability issues of insufficient spectrum, different frequency bands, incompatible system protocols, and lack of inter-agency operating standards. These include the following:

1. Multiple radios:

   Police and federal law enforcement vehicles often have multiple mobiles, while multiple portables are somewhat common in the fire service. This allows interoperability across bands or system protocols, but causes vehicle space problems or burdens public safety officials with additional weight to carry.

2. Emergency radio supply ;

   Larger agencies, such as New York City Police Department, have a supply of additional radios poised for emergency use, to provide interoperable communications coverage whenever incidents occur. Federal agencies, such as FEMA and the FBI, also often bring a supply of radios and distribute them to supporting public safety agencies to provide interoperability at declared emergencies.

3. Emergency Operations Centers / Mobile Command Centers ;

Major city, county and Federal agencies often establish fixed or mobile command centers to coordinate multi-agency responses at declared emergencies. Interoperability is achieved by operators relaying messages, often via wireline, from one agency's dispatch center to another agency's dispatch center for rebroadcast. Such relay operations not only require additional personnel, they also delay the communication process and introduce a greater possibility of human error in the message.

Standard Operating Procedures and Training;

Public safety agencies should develop and apply standard methods, practices, procedures, protocols and operations in such a manner that optimizes the use of inter-agency interoperability solutions. An optimal solution may use various combinations of direct radio to radio interoperability and infrastructure to infrastructure interoperability features. As missions progress from day-to-day load levels to disaster load levels, the needs for interoperability communication links escalate, usually well beyond the non-disaster, peak load level demand. Established procedures or protocols for the escalation process and the associated communications required, such as Incident Command System plans, are essential to minimize additional spectrum needs. These contingency plans are currently in place with many agencies and have proven successful in multiple incidents.

Agencies should also evaluate, update and expand radio communications training specific to interoperability modes and methods for their officials who use radios. Radio systems are becoming ever more sophisticated, incorporating software in the radios and computers in the infrastructure. Training all line personnel in the capabilities of this newer equipment is essential not only to proper use, but also effective interoperability with other radios and efficient use of spectrum resources.

COST AND BENEFITS:

Motorola's approach to evaluating the various costs and benefits associated with interoperability is to assess it in terms of relative comparisons and known relationships. There are far too many combinations of possible solutions and unknown factors (spectrum, engineering, market sizing, etc.) that would make it difficult to assign a believable dollar estimate to any one universal approach or approaches. In addition, evaluating intangible benefits such as lives, resources and property must be considered in any cost/benefit equation. We would offer the following as a means of making a comparable cost/benefit evaluation for these solutions.

Spectrum Dispersion Impact

The degree to which public safety spectrum is dispersed across the radio spectrum has a direct impact on both the cost of the radio system and interoperability. The cost of introducing new radios increases as the spectrum for public safety users becomes more diverse and segregated

from other land mobile radio users. Public safety spectrum allocations that are both unscattered and adjacent to other commercial LMR bands enable manufacturers to take advantage of economies of scale, resulting in a lower radio price for the user. We estimate that the cost for non-adjacent bands could be greater than a factor of two. In addition, public safety spectrum dispersion directly affects an agency's ability to use existing infrastructure, with possible modifications.

Infrastructure Solution Costs

Costs are dependent on their level of sophistication, and can be a very economic and effective use of existing system assets. The more automated the connectivity, the steeper the cost curve for implementing this solution. As a curve implies, the increase is projected to be non-linear, with cost increasing more rapidly to achieve the most sophisticated solutions. For example, a simple console patch may require the cost of a console and telephone circuit plus some dispatcher time. The cost of a gateway system depends on the number of communications paths to be interconnected, and the number of systems to be interconnected. A protocol translator is needed for each channel on each trunked system, and at least one channel on each conventional system, which are to be interconnected in a given geographic area to achieve full featured interoperability among multiple agencies. Because infrastructure connectivity is dependent on the presence of infrastructure, its interoperability value is limited to the system coverage overlap area and the survivability of such infrastructure in a disaster.

Direct Solution Costs

These costs are dependent on the percent of interoperability required. To achieve interoperability, some federal, state and local public safety agencies have two mobile radios, plus one (or even two) portable radios for each vehicle and official. The incremental cost of this level of interoperability is roughly between 25% and 50% of their total system cost.

To provide dual band radios to agencies could mean a per unit cost which is greater than two single band radios. This is due to engineering developmental costs and manufacturing costs of scale. Depending on how close production volume approaches current levels, we estimate the cost of dual band radios will significantly exceed the cost of single band radios, and could be greater than a factor of two.

The cost of multi-band radios (more than two bands) will most likely be a multiple of the number of bands on which the radio is communicating. We do not currently foresee these radios becoming a commercial solution, thereby precluding economies of scale from being applicable.

Broad band radios could provide the lowest cost solution for direct interoperability within an expanded spectrum band, assuming that public safety spectrum is allocated adjacent to an existing band, such as the UHF band. Depending on how close production volume approaches current levels, we estimate the cost of broad band radios could be between one and a half and two times the cost of non-broad band radios.

The above radio cost factors should be multiplied by the percent of unit to unit interoperability needed by the agency. We anticipate that broad band and dual band radios will have reduced radio performance characteristics, given current technology limitations. These performance reductions, such as talk-in range, would require incremental system infrastructure cost to maintain existing performance levels. Such additional infrastructure costs need to be considered with the above calculated radio cost to approximate the cost of interoperability for a given agency.

Benefits

The need for immediate, effective communications across agencies is evidenced by the fact that public safety response time is directly proportional to the ability to save both lives and property. As a result, interoperability solutions decisions should not only consider costs, but also take into account the benefits attained through interoperability. Some of these are obvious, such as savings in suffering, lives and property, but often intangible. While it may be difficult to project potential dollar savings, quantifiable resource benefits for agencies can include:

- Spectrum resource efficiencies of using direct (unit to unit) interoperability solutions. Infrastructure solutions normally require use of two channels, one in each band, to complete a single transaction.
- Manpower resources are not used efficiently if public safety officials have to be "teamed" across agencies, have to act as runners, or have to repeat messages to provide interagency interoperability. This also applies to dispatcher time required to repeat messages.
- Tangible dollar savings are realized whenever property damages or losses are avoided as a result of greater communications interoperability.

CONCLUSION:

Motorola believes that there is no one universal solution to achieving inter-agency interoperability for the public safety community. There are multiple levels of interoperability solutions which we have outlined in this white paper. These include both infrastructure and direct radio to radio solutions, which can be categorized on a range from simple solutions to complex solutions. We noted that these solutions are not mutually exclusive and the optimal solution may use various combinations as interoperability needs escalate from day-to-day, to peak load, to disaster load levels. What is universal is the essential need for interoperability between wireless communications systems of the public safety community.

The common and most significant challenge facing public safety toward achieving interoperability is the need for more frequency spectrum. Adequate spectrum is the most essential element of a wireless communications system and technical interoperability solutions are dependent on availability of adequate spectrum to permit implementation. To promote the development of radios needed for over-the-air interoperability, we encourage allocation of additional spectrum to a band adjacent to existing public safety authorizations. Consideration should be given to expanding LMR allocations to 380 MHz - 520 MHz range or to the 746

MHz - 806 MHz range. Such adjacent reallocation would also promote rapid availability of equipment using existing technology, and provide economies of scale to manufacturers, resulting in lower priced communications equipment for the user.

ATTACHMENT 6

PSWAC/ISC 96-05-051

The Role Of Commercial Wireless Services And Their Impact On Spectrum Requirements

Submitted by Motorola Inc. to the Public Safety Wireless Advisory Committee

Wednesday, May 29, 1996

In an appearance before the US Senate Committee on Commerce, Science and Transportation, PSWAC Chair Phil Verveer stated that "Commercial mobile radio services can absorb some of public safety's demands." We agree with this general statement and believe it is consistent with the sentiment of the majority of the PSWAC committee. To help clarify the salient issues on this topic, this paper will expand upon this statement and offer a clear opinion of the extent to which public safety demands that "can" be absorbed by commercial mobile radio service *would* be absorbed and identified and size "some of public safety's demands" that would be absorbed.

Commercial wireless services cannot be widely used to replace an entire public safety private system, or even a significant portion of one, because most public safety communications cannot be adequately served by commercial mobile radio services today or in the foreseeable future. Public safety requires a level of customized service that significantly exceeds, or is at least distinctly different than, that which is demanded by the principal users of commercial wireless services -- business/industrial users and individual consumers. Since commercial mobile radio services are fundamentally designed to meet the more modest needs of private sector customers and individual consumers they do not offer the type or level of service demanded by public safety. Also, it is unknown whether the providers of commercial wireless services would make the significant investment in improvements that would be required to adequately serve public safety.

For the public safety user, the major deficiencies of commercial wireless services center around their general inability to provide instant push-to-talk group dispatch, guaranteed access, priority access, security and remote location coverage. A public safety user operating over a wide area may have a communications footprint that would require piecing together service from multiple providers to form a commercial wireless "system" that meets their coverage requirements. Additionally, the multiple commercial wireless service providers may be using different technologies that are not interoperable with each other.

Public safety organizations engage in a wide variety of activities in their mission to protect life, property, and provide for the public safety. Like any other public or private sector organization, their activities range from those that are mission-critical and primary to the core activities of the organization to those that are of a more subordinate nature and therefore of a lower priority. The communications needed to support these activities are similarly wide ranging and carry differing operational requirements. The gap between what is required by public safety and what can be delivered by commercial wireless services is widest among mission-critical communications and narrowest among lower priority communications.

Public safety private systems are primarily designed to handle the higher priority mission-critical communications. A properly designed private system is designed to accommodate all mission-critical communications during peak load time periods. Any system designed for peak load capacity will, by definition, have excess capacity during off peak time periods.

Since the gap between what is required by public safety and what can be delivered by commercial wireless services is narrowest for lower priority communications, these applications are the strongest candidates for placement on commercial wireless services.

However, if lower priority communications are retained on the private system the users can leverage their infrastructure investment and fill available system capacity. Lower priority communications can coexist on a private system designed for peak load mission-critical communications because the system manager has the ability to manage radio traffic to ensure that mission-critical communications get through during peak load periods while lower priority communications are postponed until capacity is available.

The protocol for managing communications traffic can be either technology-based or policy-based. Trunked systems provide a technology-based solution whereas conventional systems must rely on policy-based solutions. Trunked system priority access capabilities that can be used to assign priority to members of the system. These priority assignments can be used to queue channel requests and even displace low priority communications that are in process with high priority mission critical communications. Conventional systems cannot assign priority but can incorporate unit identification to allow monitoring of channel usage to ensure that priority based policies and procedures are followed by all users during peak load periods.

CONCLUSIONS

Mission-critical communications can not be adequately served by commercial wireless services. Therefore, it is in the public interest for the FCC to allocate sufficient spectrum to allow public safety to design and build private systems that can handle all mission-critical communications during peak load time periods.

Many lower priority communications can be served by commercial wireless services. Therefore, the FCC should weigh the macro economic factor of alternative spectrum use when considering the prospect of allocating private spectrum for these types of communications by public safety agencies. The FCC should not allocate additional private spectrum to public safety for low priority communications that can be adequately provided for by commercial wireless services.

Public safety should be allowed to choose whether low priority communications should be placed on commercial wireless services or remain on their private system. The budget pressures felt by public safety agencies are expected to continue through the time period under consideration here. Any opportunity to save money with a solution, private or commercial, that meets their requirements would be eagerly embraced. Decision makers at the state or local level are in the best position to weigh the economic and market factors affecting their situation and decide where to place their lower priority communications.

In public safety today, commercial wireless telephone interconnect and paging are widely used, primarily for connectivity with individuals or organizations outside the private system. This usage will continue into the future and it is widely believed to increase significantly. However, this wide spread supplemental or complementary usage is actually irrelevant to the determination of spectrum needs for public safety. It represents a usage that the planners of public safety systems have already identified as being outside the scope of their private system

and was never intended to be included in PSWAC's quantification of incremental spectrum needs for public safety.

As we've discussed, the communications requirements of mission critical and lower priority communications are primarily differentiated by the extent to which guaranteed priority system access and security are required. One way to forecast the amount of public safety spectrum that would be absorbed by commercial wireless services would be to estimate the amount of lower priority communications and then estimate the amount of that which public safety private system planners would choose to have coexist , on a secondary basis, with mission-critical communications on the private system instead of moving them to commercial wireless services.

We believe that mission critical communications represent the majority of communications on a private system. We also believe that a majority of the lower priority communications can be retained, if desired, on a private system which is designed for mission critical peak loads by employing priority protocols that allow unrestricted lower priority communications during off peak periods but limits or eliminates them during peak periods. If we assume that mission critical communications represent two-thirds to three-fourths of all communications and that private systems can retain two-thirds to three fourths of lower priority communications, the percentage of all public safety communication that would move to commercial wireless service would be on the order of 6-11%.

It is difficult to accurately forecast commercial wireless service usage because it is difficult predict the extent to which the providers of commercial wireless service will make the necessary and significant investments to further serve public safety. Even if long range strategic plans for public safety were being developed by some commercial wireless service providers, it would be unrealistic to expect them to jeopardize their business position by prematurely revealing their plans in order to aid PSWAC. Nevertheless, we believe the 6-11% percent range is of the right order of magnitude.

In his appearance before the US Senate Committee on Commerce, Science and Transportation, Mr. Verveer also stated that "...the advisory committee will attempt to factor the CMRS alternatives into its conclusion about the amount of additional spectrum public safety requires". Motorola recommends that after the advisory committee has concluded the amount of additional spectrum required by public safety it use a factor of 10% to reduce that amount to reflect the impact of commercial wireless services.

ATTACHMENT 7

PSWAC/ISC 96-07-073

PUBLIC SAFETY INTEROPERABILITY SERVICE

A NEW APPROACH TO MUTUAL AID AND INCIDENT COMMUNICATIONS

WHITE PAPER

SUBMITTED TO THE INTEROPERABILITY SUBCOMMITTEE OF THE PUBLIC SAFETY WIRELESS COMMUNICATIONS ADVISORY COMMITTEE

By
Ron Haraseth
State of Montana
July 1, 1996

PUBLIC SAFETY INTEROPERABILITY SERVICE

A NEW APPROACH TO MUTUAL AID AND INCIDENT COMMUNICATIONS

Interoperability has been identified as one of the critical elements of public safety communications and only follows basic dispatch service coverage and frequency congestion in importance. Long range planning that considered inter-disciplinary and inter-jurisdictional communications has thus far only existed in localized situations and at a national level only in a cursor manner with the creation of mutual aid channels in the 800 MHZ NPSPAC channels.

Growth of the land mobile radio industry has progressed over a 60 year period. Original operations occurred at relatively low frequencies and progressed to the higher frequencies as technology and manufacturing procedures progressed. Public safety communications expanded into newer frequency bands as both capacity and feature requirements increased with passing time. The end result of this growth process has resulted in public safety operating in more than 5 discrete bands of frequencies such as the 30-50 MHZ, 120-174 MHZ, 380-500 MHZ, portions of UHF TV (shared), and above 800 MHZ. Along with this dispersion across multiple bands, both non-compatible operational and technical standards further complicated the situation with-in individual bands. The result is a chaotic mix of operations which often make interoperability at best, extremely difficult and expensive or in many instances impossible.

Much discussion has arisen during the Public Safety Wireless Advisory committee (PSWAC) meeting on solutions for interoperability. Discussion often revolves around technical solutions. These solutions have included moving all of public safety to a single band, using cross-band gateways and repeaters and others. Technical compatibility discussions have ranged from wide band analog to future use of digital narrow band techniques. None of these solutions can fully address the requirements of interoperability.

Common discrete frequencies are a must. A partial solution is linking frequencies in different bands. This solution is somewhat usable if and only if discrete frequencies in each and every identifiable band are reserved, named, and set aside exclusively for this purpose.

There is no interoperability in this scenario if direct infrastructure independent operation is required. It only serves the purpose of interoperability in a very limited and narrow operational area. Fully implementing such a scenario on a wide area basis is unworkable. There are too many bands and combinations of frequencies to even consider such a solution acceptable.

Another major solution consisting of migrating all of public safety to a common band has been discussed. While definitely being utopian, it is flawed and not practical. There is good technical reasoning behind use of particular bands based on the differing specific characteristics for each of these bands and their suitability depending on the area of operation.

An Operational View

All participants in any joint endeavor must speak the same language to be fully functional. In this case, we must speak the language of emergency response. This fits in with the operational aspects which have been discussed centering around using the Incident Command System (ICS) architecture to identify channels of operation along the same levels of function and command within ICS. ICS attempts to address the problem from an operational stand as opposed to a strictly technical approach.

At the very least, a strictly technical approach is doomed to failure no matter how many channels or gateways are provided if they do not conform to the manner in which they are used. It has often been repeated in the Department of Defense discussions that the military must train as they fight. The same is no less true for public safety responders.

Any incident includes the functions explained by ICS. Identifying functionality using the ICS structure standardizes operations allowing an understanding of the procedures by all involved. By operating under the assumptions in ICS, all parties are aware of their role and responsibilities within the overall event. Designating common names for common functions is the basic precept that makes ICS work. The same situation must take place in the communications structure of any incident. Channels must have designated names and associated usages so that all involved will understand where and in what manner they are to be used.

The basic command level and subsequent lower command levels must have pre-designated (and named) channels associated with those levels. Lower levels can be more flexible and dynamic. Understanding the operational characteristics does not complete the solution, but once they are defined, the correct technical solutions can then be applied.

A technical solution must be practical, relatively inexpensive, ubiquitous, and above all, attainable. A solution must be available both on the near term as well as the long term. It must work with existing systems without causing interference with standard dispatch systems or creating an undue hardship to implement.

PI Service Category

The move of the entire public safety operating environment to a single band is not practical, and cross banding existing bands is far less than fully effective. The former being unworkable financially and later being extremely inefficient in terms of spectrum use. However, creating a single common Public Safety Interoperability service (which I will abbreviate as "PI") in one central band is very possible and very practical. This band would be dedicated exclusively for interoperation applications. This will not eliminate the need for dual band radios or two radio installations, but having a universal declared service gives an absolute common technical solution to the common operating requirements of a mutual aid incident. A field tactical vehicle (or hand-held) with the "PI" capability could interact with any other unit similarly equipped. This capability need not be linked in any way to the user's home system operation.

As an example, one unit's basic internal system dispatch operation could be in an 800 trunked environment while another unit could be operating in low band. If these field units' second band or second radio in each case were the common "PI" radio, they would technically be capable of true interoperability. Bringing a third unit into the picture more than clarifies the practicality of a common PI service band.

Operational Requirements - Unplanned/Planned Incidents

We can learn much from the communications problems of historical incidents. Those that indicate failures in the communications link may not point directly to solutions. While some failures point to technical deficiencies, many have resulted from operational deficiencies. We also must review the aspects of these incidents that worked correctly and expand on those aspects. Similarly, we must avoid the known points of failure.

Planned incidents fall under the category of preplanned tactical events or locally restricted common action situations that can be anticipated accurately. These events are rarely a problem technically regardless of what systems are involved. By their very nature and description they exist with pre-knowledge and the participants are prepared for the forthcoming actions. Planned incidents are not fully detailed here other than to indicate that they could be handled very easily under the following operational description for unplanned incidents.

By their very nature, unplanned incidents may happen any time and any place. These situations are difficult to plan for in any situation ad even the best and thorough plans can not prepare for all of the possible unknowns.

"PI" System Operation

Mutual aid operations that are unplanned are unique and go through several definable phases. The first phase is always the "first response" or "initial attack." Some incidents may never escalate beyond this point. As a typical example, a public safety responder of any service traveling outside of their home coverage area often may be the first contact at a typical accident. Their conventional home dispatch system may be totally unusable. Under the PI scenario, a call on the PI radio to a monitoring station or another mobile in the area may be the one and only response required of the incident.

Other incidents may escalate requiring the same first responder to communicate to more units of various types. As long as the terminology and operating aspects of the PI capable radios are standardized, all units would be compatible. More developed incidents requiring the declaration of a planned operation under ICS would see the command shifted from the first responder to a more appropriate Incident Commander (IC). From this point on, any units entering the operation and conforming to the PI radio standard would be automatically capable of inclusion into the ICS command structure. Local units working as strike teams or individual resources lower in the ICS structure could use their own internal radio system for their level of operation or if mixed with dissimilar units, they could use

assigned PI channels. In either case, communicating up the ICS chain of command would occur on the PI radio channel assigned for that purpose.

It is generally accepted that isolating a unique incident from routine daily radio traffic is to be preferred. A unique PI service would easily allow such an action.

Again this scenario is dependent upon standardized common assigned names associated with standardized associated channels used under standard operating procedures. This requirement, although it may seem extreme, is absolutely required for any successful multi-disciplinary incident. All aspects of a successful incident (not just radio operation), require the same standard procedure.

It is important for full universal utilization that a national standardized plan be devised and tied very closely to operating restrictions and requirements, This should be a basic requirement of any interoperability solution.

The PI Solution

The above descriptions include the following basic requirements:

* Find a relatively free band of frequencies, preferably central to existing public safety bands. (220 MHZ?)

* Define specific frequencies and pairs of frequencies using developed ICS guidelines.

* Freely license these frequencies to all eligible public safety/service providers under operational as well as technical regulations.

* Restrict use to mutual aid interoperation.

The preceding requirements may seem somewhat simplistic, however there is a flexibility to the operational aspects of the PI solution that could allow for much higher levels of robust capabilities. **This would be a fresh and new service which could be implemented without regard to any backward compatibility requirements.** It need not be tied to existing technology and modulation schemes. This leads to a plethora of possibilities:

* Narrow channel bandwidth (or equivalent) should be specified for maximum spectrum efficiency.

* Digital modulation could be required for the same reason.

* Digital modulation leads to the fact that data transfer would be a natural possibility.

* Bandwidth on demand applications (or the equivalent) could also be implemented for the very same reason.

* Encryption could also be very easily adapted considering the possible digital nature of the service. Over the air rekeying (OTAR) should be a requirement.

* Although conventional mode infrastructure independent operation is basic and mandatory to support first response capabilities, trunking should be encouraged for escalated incidents. Trunking would have several advantages for implementation of escalated incidents or for systems embedded in local or regional systems. Caches could be developed that include base/controller equipment that would allow dynamic over the air reconfiguration of all units involved in the incident. This could be enhanced by requiring every radio manufactured to have an internal unique ID similar to the NAM in cellular radios. The ID should be easily read by units entering the incident either by physical connection, optical, or wireless. While such advanced types of operations would require knowledgeable and available communications unit leaders, this activity already takes place on large ICS incidents with existing programmable equipment.

Migration to this interoperability solution could take place as soon as rules and regulations were put into place. There are of course stumbling blocks such as adopting standards for a new operation, but these could also be looked upon as building stones. This solution would not require scrapping any existing system or worry about compatibility with existing systems and the associated costs.

6.4 APPENDIX D - Spectrum Requirements Subcommittee Report

FINAL REPORT

SPECTRUM REQUIREMENTS SUBCOMMITTEE

PRESENTED TO

PUBLIC SAFETY WIRELESS ADVISORY COMMITTEE

NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

FEDERAL COMMUNICATIONS COMMISSION

FINAL REPORT
SPECTRUM REQUIREMENTS SUBCOMMITTEE
PUBLIC SAFETY WIRELESS ADVISORY COMMITTEE

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Spectrum Requirements Subcommittee

1.0 Executive Summary.

Charter

The mission of the Spectrum Requirements Subcommittee (SRS) is to examine the overall spectrum requirements of both Federal and non-Federal public safety agencies through the year 2010. To determine these spectrum requirements, the SRS has considered trends in demographics, crime, previous public safety spectrum studies, technology, and coupled these with the recommendations set forth in the Reports of the Operational Requirements, Technology, and Interoperability Subcommittees.

The SRS has attempted to develop a long-term spectrum plan for both the Federal and non-Federal public safety entities through the year 2010. This plan can be used by the FCC, National Telecommunications and Information Administration (NTIA), and others when addressing the spectrum requirements of the public safety community.

Background

Telecommunications constitutes one of today's prime "leverage technologies." Throughout business, industry, and government, the United States has increasingly relied on this technology to boost productivity, create new jobs and investment opportunities, and deliver more and better choices and services to the American public.

Radio-based communications are critical to the effective and efficient delivery of a wide range of important police, fire safety, emergency medical, and other public safety and related services. Although serious crime reported in 1994 and 1995 has declined, the demands for services continue to increase. Similarly, although the number of fires reported has declined slightly in recent years, the cost of fire losses has risen nearly 10 percent annually. Public concern regarding overall effectiveness of Federal, state, and local law enforcement and fire safety efforts is steadily increasing. Responding to these concerns, and ensuring that trends seen in recent years continue to show improvement, will require additional commitments by public safety professionals to improve their efforts. In most, if not all instances, this has entailed greater investment in, and reliance on, radio-based telecommunications.

Public safety entities have requirements for spectrum to support their many and varied missions. These include immediate communications access to satisfy critical response times in the case of emergencies; the need for security, both in the physical integrity of the infrastructure and to ensure the privacy of the communications; control of the system to ensure priority access over the other non-emergency users; and custom coverage for the communications system. Leading the demand for additional spectrum to meet the requirements for enhanced public safety systems are high-technology mobile radio systems capable of transmitting, among other things, mugshots, fingerprints, building diagrams, and medical data.

For many years, mobile radio in general and public safety communications specifically, ranked relatively low in terms of the FCC priorities. The centrality of broadcasting, especially broadcast television, overwhelmed the radio frequency process and the regulatory environment. Consequently, less than 100 MHz of radio spectrum was allocated to all mobile radio applications. The non-Federal public safety community occupies slightly less than 30 MHz in the New York and Los Angeles areas, and slightly less than 24 MHz in the rest of the nation. Bands occupied by users are scattered across a wide range of frequencies.

In recent years, public safety communications groups have successfully urged that their requirements be seriously studied. Section 6002 of the Omnibus Budget Reconciliation Act of 1993 directed the FCC submit to Congress in February 1995 a review of the current and future state and local government public safety communications needs through the year 2010. The FCC was also directed to develop a plan to ensure adequate frequency spectrum would be available to meet those requirements. Subsequent actions by the Commerce Department's NTIA and the FCC led to the establishment of the Public Safety Wireless Advisory Committee (PSWAC).

Additional spectrum alone, however, is inadequate to meet the ever-increasing demands on public safety agencies. Long-term spectrum planning is also critical for the effective management of public safety spectrum allocations. The SRS notes that increased spectrum efficiency, increased interoperability, and the use of commercial services, where practicable, will play a major role in the satisfaction of future public safety radio communications requirements.

Demographics

The subcommittee used projections for population, trends in crime, types of services provided by public safety agencies, and the usage rates of the services in the projections of spectrum requirements. To provide a better estimate of population density in the year 2010, the Rand McNally metric called Ranally Metropolitan Area (RMA) was used to estimate population changes. RMA's that approximate Metropolitan Statistical Areas (MSA's) comprise about 92 percent of the MSA population, while including only about 28 percent of the MSA area.

Current Spectrum Allocations and Usage

Spectrum management authority in the United States is shared between the FCC and NTIA. The FCC allocates frequencies to be used by the private sector (including state and local governments) for public safety operations. NTIA authorizes frequencies to be used by Federal agencies that are, by definition, public safety agencies. The FCC has generally allocated approximately 23.2 MHz for public safety land mobile use, plus specific amounts of spectrum ranging from 6 to 18 MHz on a local basis in major metropolitan areas.

The Federal Government operates non-tactical land mobile systems generally in 7 frequency bands, but these operations are often shared with Federal fixed, hydrologic, and airborne operations.

Spectrum Management Options for Increased Efficiency

There is a growing trend to consider public safety a synergy between Federal and non-Federal agencies. Federal law enforcement often must work with state and local police; the National Guard is called out by the controlling state to supplement the police when emergencies are declared. Several states are either considering or actually using shared Federal/state land mobile radio systems. The Subcommittee has found that shared Federal/state systems may offer advantages to both parties, and should be encouraged.

Federal use of the spectrum is authorized by NTIA via an entry in the Government Master File (GMF). These authorizations may be for a local area, for state-wide use, or even for the United States and Possessions (US&P). Private licensing for public safety by the FCC is more local, but may include state-wide systems. The Subcommittee recommends that the FCC and NTIA establish a joint study group to further discuss and evaluate how their separate spectrum management processes can be improved to the benefit of the public safety community and the general public. This effort should be completed within 12 months of the completion of the PSWAC Report.

The Subcommittee further recommends the FCC and NTIA study and evaluate methods to improve the coordination between the national-level spectrum managers and the user communities. A short-term solution could be to have FCC and NTIA participation in the Public Safety Communications Council.

Impact of New Technology and Commercial Services on Spectrum Requirements

The Technology Subcommittee provided technology estimates for the state-of-the-art of the average installed radio system in the year 2010. The Technology Subcommittee indicated that these estimates were aggressive. This implies that spectrum estimates based solely on new technology may be understated. This is balanced, however, by using one of the largest metropolitan areas in the public safety spectrum requirements example.

Privately-owned public safety systems are designed to handle high-priority, mission-critical radio communications. A properly designed system should be able to accommodate all mission-critical radio traffic during peak load periods, and have excess capacity during off-peak periods to service subordinate radio communications as well.

When subordinate communications are routinely postponed due to mission-critical operations, then outsourcing to commercial wireless providers becomes an alternative. Based on feedback from individual agencies to the Interoperability Subcommittee, and estimates by private network manufacturers, approximately 10 percent of the current applications running on private systems are candidates for outsourcing.

Review of Previous Spectrum Management Studies

Within the last 12 years, several studies have been published that investigated the need for additional public safety spectrum. In 1985 the FCC released a staff report entitled *Report on Future Public Safety Telecommunications Requirements*. This report indicated that at least 12.5 MHz to 44.6 MHz of spectrum would be needed for public safety use in 21 major metropolitan areas by the year 2000. Eight years later, in 1993, the Coalition of Private Users of Emerging Multimedia Technologies (COPE) petitioned the FCC for 75 MHz to be used for developing advanced private land mobile radio systems, including public safety operations.

In 1994, the Association of Public Safety Communications Officials International, Inc. (APCO) filed a study with the FCC entitled *Public Safety Spectrum Needs Analysis and Recommendation*. This study concluded that an additional 18 MHz of spectrum was immediately needed "just to keep pace with the demand for basic voice and data communications." APCO also concluded that an additional 25 MHz would be needed by 2000, and still another 50 MHz by 2010 to permit public safety agencies to implement a vast array of new telecommunications technologies.

In 1995, NTIA released a comprehensive study of future spectrum needs in the *NTIA Spectrum Requirements Study*. NTIA concluded, based on inputs from the private and Federal Government sectors, that 204 MHz of spectrum was needed for land mobile services in the next 10 years, which included 50 MHz for private land mobile radio services such as public safety.

The conclusion drawn from these various studies was that there is general agreement that additional spectrum for public safety services is needed, but the exact amount of spectrum and the specific frequency bands for operation was still unsettled.

Spectrum Need Projections

The major output of the PSWAC process is the forecast of spectrum needs of the public safety community to the year 2010. The Spectrum Requirements Subcommittee intensely focused on the problem of spectrum requirements forecasting and to this end developed an equation, based in part on previous attempts to forecast spectrum needs by a mathematical method. Working Group 8 was chartered to evaluate a spectrum requirements model proposed to the Subcommittee by Motorola, Inc. This model was refined by the Working Group and used to define the future spectrum requirements.

The model uses as input parameters the basic building blocks of telecommunications system design, but is independent of any specific manufacturer's product. Certain technologies are assumed, based on inputs from the Technology Subcommittee.

Two major urban areas, the New York City and the Los Angeles metropolitan areas were chosen to represent high spectrum-use areas. It was reasoned that if these areas could be satisfied, all other areas in the nation would also have sufficient spectrum. Data corresponding to the NPSPAC Region 8 was used to approximate the New York City area.

Five general types of telecommunication services were analyzed for public safety use: voice, data, status/message, wide band data, and video. These services included advanced communications services such as slow scan and full motion video, data access and transfer, and image transmission (e.g., snapshot, mugshot, or fingerprint).

Erlang theory was incorporated into the model to assure effective channel usage at a design grade-of-service level of one per cent. The Erlang-C equation was used with a one per cent probability of queuing with a 19-channel server. Other significant parameters, such as future improvements in error correcting code rates and modulation efficiencies were used as agreed to by the Technology Subcommittee.

Table 1 summarizes the results of the spectrum needs modeling. The use of commercial services as an adjunct to privately-owned systems was considered. Commercial services are presently being used by public safety agencies. It was estimated that commercial services would be used to a degree that represented 10 per cent of allocated spectrum. As a consequence, the required spectrum as derived from the model is reduced by that 10 per cent. The final result is that 95 MHz will be needed for mobile public safety telecommunications by the year 2010. That is, voice requirements on a per-officer basis will increase until wide band data and video services are fully implemented. Long-term estimates show only a modest increase in the per-officer voice requirement. This implies that there will be an accelerated short-term need for voice operations, but this spectrum could be used for data or video at a later date as voice requirements track only the growth in user population. Further, it is stressed that the aggregate spectrum requirement is more important than its constituent parts. Table 1 below is shown mainly for illustrative purposes.

TABLE 1
Expected Land Mobile Spectrum Requirements for 2010

SERVICE	SPECTRUM (MHz)
Voice	32.3
Data	5.3
Status/Message	0.2
Wide Band Data	40.8
Video	50.7
SUBTOTAL	129.3
Present Allocation	(- 23.4)
Commercial Services	(- 10.6)
Net Need in 2010	95.3

Spectrum Band Options

National population growth has increased the demand for public safety services across the country. Modern public safety agencies, both Federal and non-Federal, depend heavily upon wireless telecommunications to accomplish their missions. However, radio spectrum allocated for public safety services has been fully assigned in many metropolitan areas of the United States. Generally, spectrum allocation to public safety services has not kept up with the demand in urban areas. Public safety agencies view this spectrum shortfall with alarm, since if not corrected, this shortfall may lead to a degradation of the quality of service rendered to the public.

Since there are no spectrum reserves from which to draw for public safety use, consideration must be given to selection of bands that may be made available in the future. Several parameters are important in considering which spectrum bands are suitable for public safety use. First, the spectrum used to support public safety must satisfy the requirements for land mobile voice, data, image, and video transmission and reception. Second, spectrum enhancing voice and data requirements should be near current public safety frequency bands, while applications using new or emerging technology may be in bands significantly removed from current bands.

Generally, frequency bands considered for new public safety requirements were (1) unused television channels, either in the VHF or UHF regions; (2) those frequency bands transferred from Federal use to the FCC; (3) increased allocation in present VHF/UHF land mobile bands; and (4) other Federal bands not currently under consideration for transfer.

Conclusions and Recommendations

Additional Spectrum

The Spectrum Requirements Subcommittee concluded that immediate relief was needed for land mobile voice and data operations in major cities. In the short-term, voice and data operations require 25 MHz of new public safety allocations. By the year 2010, an additional 70 MHz will be needed for these applications, plus image and video requirements, for a total of 95 MHz.

Recognizing that the public safety telecommunications infrastructure (e.g., fixed microwave systems) are vital to the operation of area-wide systems, the Subcommittee recommends that 161 MHz of additional allocations be made for this use, as shown below.

It was noted that although landline technology, including fiber optics, offers increased telecommunications capacity and can be used to off-load communications from spectrum-dependent systems, certain areas of the country that are susceptible to earthquakes cannot rely on ground-dependent systems since these systems often fail during severe earth movements.

Federal Government users indicated that future Federal requirements could be satisfied in the currently allocated bands, provided that: (1) no more Federal allocations are