4.2.12 **Image:** Images represent a special category of data that is a numeric representation of a picture. Still images include snapshots such as accidents, and crime scenes, mug shots, fingerprints, and a wide variety of other images. Today, there is relatively little use of still image transmission to and from the field in Public Safety. The rapid increase in use of "wire-line" based facsimile transmission and similar image technologies within the Public Safety services has paralleled that within the broader economy. It is expected that such systems will be deployed in ever increasing numbers over the next decade and a half.

4.2.13 Emergency medical providers desire the ability to transmit images of the injured from paramedic units back to trauma centers or hospitals to aid in diagnosis and pre-arrival treatment. Fire agencies desire the ability to transmit building plans and copies of permit and other data for fire prevention and protection. Law enforcement agencies need to quickly transmit fingerprints from field units back to federal, state, and local databases; units need the capability to receive mugshots and drivers license photographs to aid in identifying people in the field.

4.2.14 Key attributes of image communications systems include resolution, B/W vs color, compression, and error control. The subcommittee report outlines existing standards for facsimile and snapshots. Medical services will need high resolution imaging.

4.2.15 The typical passport photo of 2 inch square black and white results in only 1 or 2 kilobytes, while a full-color still from a video camera may exceed a few hundred kilobytes, and a high-definition (several hundred dpi) scan of a color photo can easily reach several megabytes. Image translation can convert higher resolution into a smaller form for transmission, although the reverse is not generally achievable. A notable exception is the emerging technology known as fractal image coding. It promises highly compressed image formats which are rescalable without loss of quality at the destination.

4.2.16 **Video:** Wireless video systems have seen limited use in state and local Public Safety services to date primarily due to a lack of available Public Safety spectrum over which to implement these systems. Video is used in Public Safety today primarily for surveillance of crime scenes and of highways. The fire service uses full motion video extensively in some areas, primarily to monitor wildland fire scenes from airborne platforms, providing real-time video back to emergency command centers. Law enforcement agencies, particularly at the federal level and which have spectrum available for video, have long used video for surveillance purposes. State and local agencies have only recently begun to implement similar systems for monitoring areas of high crime and drug use. State and local transportation agencies have implemented wireless video systems to monitor traffic flow and detect collisions and hazards on roadways in congested metropolitan areas. There is a growing need for full motion video for use with robotic devices in bomb, hostage, hazard avoidance and hazardous materials situations.

4.2.17 Key attributes of video communications systems include frame rate, resolution and color level, error control, and compression. Today, video images are normally transmitted using analog modulation. Wideband channels (several megahertz) are normally used to carry full-motion, high-quality video. However, only very limited spectrum is available to state and local agencies. In the future, we expect that most Public Safety video communications will be digital. Currently, however, compression equipment is still expensive and standards are changing rapidly. The coming of affordable digital video cameras and affordable digital compression can be expected to lead to substantial growth in the requirements for Public Safety video communications.

4.2.18 **System Fundamentals:** Digital Integrated Circuits. The fundamental technology thrust through the year 2010 will be, as it has been in the recent past, that of semiconductor technology. The improvements in semiconductor processing and materials have resulted in roughly an order of magnitude advance every five years. Rapid advancement is also observed in the progress of microprocessor technology over the last two decades.

4.2.19 Batteries. The batteries required to operate portable communications equipment are usually heavy, provide limited hours of operation, and can be expensive. A number of developments in battery technology are alleviating this situation. Some involve new technologies, such as nickel-metal-hydride and lithium-ion batteries. Another development is a zinc-air battery that draws oxygen from the atmosphere to extend its life. Power saving solutions that make more efficient use of battery power by communications equipment hold promise for extending battery life further; more power efficient amplifiers and more efficient sleep modes are examples of ways in which battery life may be increased.

4.2.20 Oscillators. Spectrum efficiency is improved if more communication channels can be placed within a given band of spectrum. In the past, the ability to decrease the channel size has been limited by both the transmission bandwidth and frequency stability concerns. Frequency stability in land mobile radio has also benefitted from improvements in semiconductors. Improvements in frequency stability can be used to enhance spectrum efficiency even when channel spacing is not reduced because the guard bands around the occupied bandwidth of each transmission can be reduced. The information content of the transmitted signal can be increased while maintaining acceptable adjacent channel splatter. This is important because reductions in guard bandwidth are limited by adjacent channel splatter considerations.

4.2.21 Antennas. Smart antennas is a term applied to a family of technologies that generally integrate active antenna elements with microprocessor technology. By changing the current distribution of the array, the shape of the beam can be changed electronically in real-time.

4.2.22 Diversity is a commonly used technique for improving the quality of both digital and analog signals. When the new technique of single sideband is employed the use of

multiple antennas becomes a virtual necessity, as when the vehicle is traveling at high speed, signal will become distorted due to phase shift. The most common form of diversity is space diversity, which is implemented using two appropriately spaced antennas. Another method being researched is a one-piece diversity antenna system that uses two antenna elements that performs the signal combining function in the antenna base. Maximal ratio diversity combining is a third diversity technique which is used to combat fading. The advantages of these techniques must be weighed against the disadvantages.

4.2.23 Source Coding. Using today's systems, additional traffic demands can only be met by increases in the available spectrum. However, the demands can, at least in part, be offset by utilizing semiconductor advances to make more efficient use of the limited spectrum resources. Information compression allows reduction in the amount of information which must be transmitted on the communications channel. Digital speech encoding has received significant attention of late. This means of transmitting speech leads naturally to encryption which is one very important aspect in many Public Safety communications scenarios. Looking to the future, it can be expected that increasingly powerful digital signal processing IC's will facilitate the introduction of more powerful and effective methods for reducing the amount of information that must be transmitted on the communication channel.

4.2.24 As digital processing capability improves, higher complexity compression algorithms will become viable, increasing the compression ratios possible for these services. Thus, by the year 2010, compression schemes more than ten times as complex as those of today should be viable for Public Safety radio. As a result, an assumption of a 3:1 increase in source coding efficiency for fax by 2010 seems reasonable. For full-motion video, a 2:1 improvement over today's compression ratios, or roughly 0.25 bits/pel, should be achievable by the year 2010. For slow video, a 3:1 increase in slow video coding efficiency is indicated when we it is assumed that MPEG-4 will be implemented by 2010.

4.2.25 Modulation. Another method of improving improved spectrum efficiency is to increase the amount of information that the communication channel can support. Nonlinear constant-envelope systems have approached 1.28 bit/sec/Hz, considered to be the limit for those systems. Linear modulation, based on newer SSB-based techniques, is expected to be able to improve this efficiency to approximately 5 bit/sec/Hz by the year 2010; while such linear modulation narrowband techniques have long been used in other applications, the engineering challenges of matching them to mobile communications channels have only recently been overcome in commercially available products.

4.2.26 Multiple Access Techniques. FDMA, TDMA, CDMA, and TDD are different channel access methods. In FDMA (Frequency Division Multiple Access), different conversations are separated onto different frequencies. In TDMA (Time Division Multiple Access), different conversations are separated into different time slots. In CDMA (Code Division Multiple Access), all conversations are separated by code

space. And in TDD (Time Division Duplexing multiple access), a single channel is shared in time to achieve full duplex operation. Each has specific strengths and weaknesses.

4.2.27 Error Correction Coding. In radio systems the primary goal is to reliably deliver communications. In digital communications systems this equates to maximizing the ability to successfully receive digitally coded messages. One method of improving signal reception that is specific to digital communications is to employ error control that add bits to the data stream in a precise fashion. Two types of error control techniques are Forward Error Correction (FEC), which provides the ability to receive a correct message even in the presence of transmission errors, and error detection employed in concert with Automatic Repeat reQuest (ARQ), which uses a return channel to request retransmission of corrupted data. FEC is more commonly used in voice communications or one-way error detection and ARQ are more commonly used in two-way data communications.

4.2.28 Software Radios. Software programmable radios, in which applications are configured under software control, makes it possible to implement multiple military, law enforcement, and commercial air interface standards in a single radio, despite different physical layers (modulation, frequency bands, forward error correction), link layers (link acquisition protocols, link maintenance, frame/slot processing), network layers (network protocols, media access protocols, network time maintenance), upper layers (source coding), timebases and bandwidths. There are many challenges, however, to producing a practical and economical software programmable radio for law enforcement applications; software radios are now much more expensive than hardware-based radios, with the market being largely confined to military applications. It has been projected that, within a few hardware generations, software radios will sufficiently leverage the economics of advancements in microelectronics, and provide seamless communications at a vest-pocket and palmtop level of affordability and miniaturization.

4.2.29 Backbone Systems. Most Public Safety mobile communications systems need a reliable backbone to carry signals to and from the base station sites to the control points. Historically, many of these links have been provided over microwave connections operated by the Public Safety agency. Leased lines obtained from the local telephone companies have also been used. It is expected that the future supply of backbone system elements will look much like the past but with two major exceptions. First, the lowest microwave frequencies (2 GHz) are no longer available for such backbone systems. The second exception is the supply of facilities by the local carriers; historically, only one firm, the local telephone company, provided telecommunications services for hire. However, changes in law and technology have led to the entry of new competitors in many markets and the probability of extensive further entry. Considering all these factors it is reasonable to conclude that these commercial fiber systems could provide valuable backbone alternatives for many Public Safety communication needs. However, the use of any ground-based carrier for Public Safety systems in earthquake-prone areas may be undesirable. In contrast,

in areas affected by hurricanes, such as the southeastern coastal areas, an in-ground fiber network could be preferred.

4.2.30 Performance Modeling. As wireless communications systems evolve, the complexity in determining compatibility among different types of such systems increases. Geography, frequency, modulation method, antenna type, and other such factors impact compatibility. Spectrum managers, system designers and system maintainers have a common interest in utilizing the most accurate and repeatable modeling and simulation capabilities to determine likely wireless communications system performance. The Telecommunications Industries Association TR-8 WG-8.8 Technology Compatibility Committee is working under a charter and mission statement to address these technical challenges.

4.2.31 Many present and future technological capabilities are (or will be) developed for large commercial service providers or government systems. Public Safety agencies often utilize the existing commercial services as an adjunct to the systems which they have developed to provide their essential services. Those essential services (such as voice dispatch) may have unique operational, availability, or security needs, or may be more economically feasible and desirable. In the future, as usage of and dependence on these services increase, Public Safety agencies might elect to "partner" with commercial services (for customized services or features), or develop their own systems utilizing similar technologies.

4.2.32 Mobile Satellite Systems. Satellite systems support thousands of voice channels and in many spot beams are used so that some frequency reuse is possible. Satellite services can be completely digital thereby facilitating encryption systems, as well as commercial voice privacy alternatives. Public Safety agencies and others may lease dedicated channel(s) for their exclusive use. Dispatch, push-to-talk, and "party line" talk group services are available. Priority designations will be lost when communications enter the Public Switched Telephone Network (PSTN) as they are currently configured unless dedicated lines are provided between gateway stations and public service agencies.

4.2.33 Cellular. Current cellular telephone systems have several attributes which limit their appeal to Public Safety users. They are designed to provide adequate capacity during most peak periods, but they are still vulnerable to overload and abuse during large incidents or special activities. In spite of these limitations, cellular telephones are able to meet certain aspects of Public Safety communications needs. They are useful for communications between Public Safety field personnel and the public being served. Cellular telephones are also preferred by many Public Safety agencies as an alternative to carrying telephone interconnect traffic (and consuming large percentages of available capacity) on essential voice channels.

4.2.34 Cellular Digital Packet Data (CDPD). Even with the proliferation of analog cellular systems, circuit switched communications are still not popular for general data applications. Circuit switched usage fees are based on connect time, not data volume.

Short interruptions during hand-offs between cell sites are often imperceptible during voice conversations, but most data communications equipment sends (and expects to receive) a continuous carrier signal. Cellular Digital Packet Data (CDPD) systems were developed to transport data to (or between) cellular users without the need to set up a traditional call. Without some method to provide priority access, CDPD users are subject to the same delays or unavailability of service during peak periods that traditional voice users encounter.

4.2.35 Personal Communications Systems (PCS). PCS are an emerging commercial technology. Due to propagation characteristics of the band, most 2 GHz systems are expected to be developed using a micro-cellular architecture, serving the most populous metropolitan areas using a network of closely spaced stations. Service in lower demand areas will be provided by systems with antenna heights, output power levels, and coverage areas which are more in line with today's cellular systems. Both are intended to provide subscribers with enhanced features and untethered access to the public switched telephone network. Personal Communications Services are under development as of this writing, but indications are that the successful licensees will select and implement differing technologies, even for similar systems in adjacent areas or bands; thus limiting not only competition, but interoperability and mobility as well. The lack of standards is likely to impede the ability of some PCS users to roam nationwide using "local subscriber equipment," or to select between carriers to the extent that current cellular telephones allow.

4.2.36 Specialized Mobile Radio (SMR) services were established by the FCC in the mid-1970's with the allocation of a portion of the 800 MHz band for private land mobile communications system. SMR systems are characterized by a single high-power, high-elevation base station for maximum coverage. The versatility of the SMR industry and its relationship to Public Safety because of the dependence of both on dispatch as a primary service will continue to be attractive as the SMR industry becomes more sophisticated and integrated.

4.2.37 Enhanced SMR. The latest systems, based on digital technology, are known as Enhanced SMR (ESMR) or wide-area SMR systems. ESMR systems are typically characterized by a network of base stations in a cellular-type configuration. They are several times as spectrum efficient as SMR systems and offer enhancements including the consolidation of voice dispatch, telephone interconnect and data services into a single portable/mobile subscriber unit. Regardless of the type of SMR/ESMR service, the Public Safety agency must insure that the coverage, security, priority access and reliability factors associated with each service provider/operator will meet the requirements of the applying agency.

4.2.38 Paging. Today, over 27 million people use commercial paging services. Continued use and increased dependence are expected for many Public Safety functions. New higher speed, multi-level paging protocols have been developed to increase the efficiency of paging networks, while maintaining backward compatibility with existing (lower speed) devices. With increased transmission speeds, higher content messages

(such as facsimiles) can also be delivered to paging receivers with reasonable latency. Advanced paging systems being introduced today allow peer-to-peer communications between pagers, by allowing the initiation of messages from pagers to the network over the reverse channel. Future two-way paging applications are likely to include services like AVL and individual-based GPS services, telemetry services, and interoperable services on dual devices with other wireless providers.

Findings

4.2.39 ▸ New technologies generally produce two important, but counterbalancing effects for the Public Safety community. First, improvements in technology such as digital transmission and advanced modulation techniques permit users to increase the amount of traffic that can be transmitted over any given amount of spectrum. This phenomenon, considered alone, would minimize the requirements for new spectrum. However, the second corresponding effect of technology advances is the creation of a new range of functions and features. These additional capabilities such as high speed data and video transmission require additional spectrum to fully exploit.

4.2.40 ▸ In the year 2010, a great many requirements will be served by some technology which has not yet even emerged from the research labs. However, several aspects of future technology are fairly well agreed upon by examination of technical trends, regardless of whatever specific technology may emerge within the next decade.

4.2.41 ▸ Technology is constantly improving spectrum efficiency. Improvements in semiconductor processing and materials have resulted in roughly an order of magnitude advancement every five years. Rapid advancements in microprocessor technology has also been observed over the last two decades. Although theoretically possible to approach gains of 8:1 based on 25 kHz analog by the year 2010, it is appropriate to set the factor to 4:1 for planning purposes. A 4:1 efficiency recognizes the practical limit of advances over the intervening years; that is, doubling (2:1) in five years, doubling again in another five (4:1), then doubling again in five more years (for a 8:1 improvement in 15 years). Further, within current Public Safety bands, there will be an established base of equipment that will have to be amortized and withdrawn from service before full benefits of any advanced technologies can be realized. Additionally, many of the emerging Public Safety technologies (video and high speed data, for example) will require significantly wider bandwidths than the current 25 kHz channel for analog voice.

4.2.42 ▸ Digital technology will be the key technology for the future. A digital signal format is assumed by most of the bandwidth efficient methods employed today. Digital is essential to data transmission. Digital appears to be superior for secure communications technology. Nevertheless, there is a vast investment in existing analog voice communications technology which meets

communications needs today and which will last for a long time. Analog equipment with 10 to 20 year lifetimes will continue to be installed for several years. Current Public Safety digital equipment offers approximately a 2:1 improvement in spectrum efficiency over 25 kHz analog. Consequently, the Public Safety community will operate with a mix of analog and digital equipment (a mix shifting towards digital) for the foreseeable future.

4.2.43 ▸ Trunking will become increasingly prevalent as the technology for trunking control becomes deployed and copied in what are currently known as conventional systems.

4.2.44 ▸ Improvement in technology unrelated to voice, such as data, will be driven by dramatic technology improvements in computers. It is quite conceivable that computer spectrum efficiency may be more important than voice spectrum efficiency in 2010. Imaging technology will be driven by improvements in digital signal processing (DSP) technology, which should also be dramatic in a decade.

4.2.45 ▸ Spectrum efficient technology includes low bit-rate speech coding. Speech coding trends have already left the concept of "waveform coding" behind, where the ability to reproduce the exact analog speech waveform is lost. This property, employed commonly in land-line telephony where wire bandwidth is less of an issue, permits voice to be converted back and forth from analog to digital at will without loss of quality. Low bit-rate speech coding also produces greater speech delay. Barring currently unexpected innovation in transcoding, this means that interoperability between systems with different speech coding technologies will likely suffer quality loss and increased speech delay, even when patched through infrastructure.

4.2.46 ▸ Direct interoperability over-the-air does not appear possible between systems with different speech coding technologies, bit rates, modulations, formats, access method, or any other attribute associated with the air-interface of a given RF system.

4.2.47 ▸ Without any significant coordination, disparate systems will achieve analog interoperability using a common base-line interoperability technology (analog FM). This can serve both analog speech or data that is converted to a speech bandwidth signal in a fashion similar to using modems over telephone. Data transmitted via analog transmission are subject to no more coordination than generally practiced today requiring compatible modems on both sides of a telephone link. Data speed is significantly less than compared to direct digital transmission.

4.3 INTEROPERABILITY SUBCOMMITTEE SUMMARY

Overview

4.3.1 Interoperability between and among wireless communications systems used by federal, state, and local Public Safety agencies is generally accepted to be not only desirable, but essential for the protection of life and property. Hence, a key activity of the PSWAC was to "advise the NTIA and FCC on options to provide for greater interoperability among federal, state, and local Public Safety entities." Within the PSWAC structure, interoperability issues were addressed by the Interoperability Subcommittee (ISC).

4.3.2 In its deliberations, the Interoperability Subcommittee and ultimately the Steering Committee adopted the following formal definitions of *Public Safety, Public Service, Interoperability, and Mission Critical*:

4.3.2.1 ***Public Safety:*** *The public's right, exercised through Federal, State or Local government as prescribed by law, to protect and preserve life, property, and natural resources and to serve the public welfare.*

4.3.2.1.1 ***Public Safety Services:*** *Those services rendered by or through Federal, State, or Local government entities in support of Public Safety duties.*

4.3.2.1.2 ***Public Safety Services Provider:*** *Governmental and public entities or those non-governmental, private organizations, which are properly authorized by the appropriate governmental authority whose primary mission is providing Public Safety services.*

4.3.2.1.3 ***Public Safety Support Provider:*** *Governmental and public entities or those non-governmental, private organizations which provide essential public services that are properly authorized by the appropriate governmental authority whose mission is to support Public Safety services. This support may be provided either directly to the public or in support of Public Safety services providers.*

4.3.2.2 ***Public Services:*** *Those services provided by non-Public Safety entities that furnish, maintain, and protect the nation's basic infrastructures which are required to promote the public's safety and welfare.*

4.3.2.3 The term *Public Safety*, as defined, extends to all applicable functions of government at the federal, state and local levels, including Public Safety operations on Department of Defense facilities. There are two levels of Public Safety providers. The *Public Safety Services Provider* definition is focused toward entities performing such duties as emergency first response and similar activities. The Interoperability Subcommittee Workgroup recognized that this particular definition did not adequately cover the diverse Public Safety

community and it was necessary to include another level of provider, the *Public Safety Support Provider*. This was in accordance with the question encountered by the Operational Requirements Subcommittee during the process to identify entity-specific needs. The Operational Requirements Subcommittee acknowledged that although a particular organization's primary mission might not fall within the classic Public Safety definition, some aspects of its operations could involve or impact Public Safety. The *Public Safety Support Provider* definition is meant to include entities whose primary mission is other than Public Safety services, but which may provide vital support to the general public and/or the Public Safety Service Provider.

4.3.2.4 The ISC also addressed Public Safety Service Providers that were non-governmental. Properly authorized non-governmental, private organizations performing Public Safety functions on behalf of the government are included in these definitions. The need for this portion of the definition is becoming more evident with the privatization of certain governmental services. For example, a number of local governments contract private organizations for emergency medical and/or ambulance service. Although private, these entities are authorized by the applicable government entity to provide life-saving functions on its behalf. Specific licensing concerns have been surfaced through this mode of operation and will be discussed in a later section of this report.

4.3.2.5 ***Interoperability:*** *An essential communication link within Public Safety and public service wireless communications systems which permits units from two or more different agencies to interact with one another and to exchange information according to a prescribed method in order to achieve predictable results.*

4.3.2.6 *The communications link, whether infrastructure dependent or independent, must satisfy one or both of the following requirements:*

4.3.2.6.1 *Multi-jurisdictional: Wireless communications involving two or more similar agencies having different areas of responsibility. Some examples include a fire agency from one city communicating with a fire agency from another city and the Federal Bureau of Investigation (FBI) communicating with a County Sheriff.*

4.3.2.6.2 *Multi-disciplinary: Wireless communications involving two or more different agencies. Some examples include a police agency communicating with a fire agency and a parks agency communicating with an emergency medical services agency.*

4.3.2.6.3 *The communications link may involve any combination of subscriber units and fixed equipment (e.g., repeaters, dispatch positions, data resources). The points of communication are dependent upon the*

specific needs of the situation and any operational procedures and policies which might exist between the involved agencies.

4.3.2.6.4 *The communications link may be classified as either of the following two types:*

4.3.2.6.5 *Infrastructure independent: The communications link occurs between subscriber units over a direct RF path. An example is portable-to-portable tactical communications at the scene of an incident.*

4.3.2.6.6 *Infrastructure dependent: The communications link requires the use of some items(s) of equipment, other than a subscriber unit, for establishment of the link and for complete subscriber operation. Some examples include a communications link for which a repeater station is required; a communications link which provides full system coverage for a visiting subscriber unit within a host trunked radio system; and a communications link which provides interconnectivity between two or more otherwise incompatible radio systems by cross-connecting the audio signals and/or appropriate signaling functions at some central point.*

4.3.2.7 ***Mission Critical:*** *A mission critical communication is that which must be immediate, ubiquitous, reliable and, in most cases, secure.*

4.3.2.7.1 *EXPLANATION: An "immediate" communication must be capable of being transmitted and received instantaneously, without waiting for a system to be set up, a clear channel or a dial tone. A "ubiquitous" communication is that which can be transmitted and received throughout the area that the mission requires. A "reliable" communication system must be designed, constructed and maintained such that short-term disruptions are minimal. Finally, security, while not currently available in many situations, is increasingly a requirement for law enforcement and other sensitive communications. In this case, "security" is provided with "voice privacy" encryption.*

General Observations and Specific Findings

4.3.3 **Interoperability Needs of Public Safety:** The ISC identified requirements for three different types of interoperability missions in Public Safety communications — day-to-day, mutual aid, and task force. The ISC described the *day-to-day* requirement as the most commonly encountered type of interoperability and one which is typically associated with areas of concurrent jurisdiction where agencies need to monitor each other's routine traffic. For example, the day-to-day requirement might arise when a county sheriff's department wants to monitor the radio traffic on a police system operated by a large city within the county and *vice versa*. Such interoperability

minimizes the need for dispatcher-to-dispatcher interaction in the exchange of information among units in the field.

4.3.4 The ISC described the *mutual aid* requirement as often involving interoperability among multiple agencies under conditions that allow little opportunity for prior planning for the specific event — *e.g.*, riots or wildland fires. In its description of this type of interoperability, the subcommittee noted that there is often a requirement to establish communications among numerous small groups with each group having its own individual talk group or frequency. Such communication is referred to as tactical, and once the responders are on the scene, it typically involves the use of portable radios.

4.3.5 The ISC described the *task force* requirement as often involving communications among agencies representing several layers of government (federal, state, and/or local) under conditions that typically allow for prior planning. In its description of this type of interoperability, the ISC noted that (i) it usually involves the use of portable and/or covert equipment, (ii) it often requires extensive close-range communications, and, (iii) due to the nature of the communications traffic involved, long range transmission is undesirable.

4.3.6 The subcommittee conducted much of its analysis in the context of the Incident Command System (ICS). The ICS is a standardized method of operation for Public Safety agencies during large-scale emergency incidents. It has a hierarchical structure which identifies lines of reporting (communications) throughout the organization. This, in turn, provides a framework for assessing communications needs. The Interoperability Subcommittee concluded that interoperability solutions for large scale events such as wildfires necessarily encompasses solutions for lesser events.

4.3.7 **Obstacles to Interoperability**: As part of its analysis, the ISC studied how interoperability requirements are being met today. As a result of that analysis and taking into account future interoperability needs, the subcommittee identified a number of obstacles to achieving interoperability under current conditions. The obstacles or constraints identified included, among others, (i) the diversity of spectrum resources (bands) utilized by Public Safety agencies, (ii) the sheer scarcity of channels for interoperability, (iii) certain human and institutional factors, (iv) the lack of common communications modes among different types of systems, (v) the lack of congruent coverage among different systems for which interoperability is desired, (vi) the limitations of current commercial systems in terms of their reliability, priority access and command and control characteristics in Public Safety applications, and (vii) the lack of an adequate nationwide mutual aid plan and incident command system to facilitate the interoperability.

4.3.8 ▸ The first obstacle, the diversity of spectrum resources, reflects the fact that Public Safety agencies, federal, state, and local, use a total of ten radio bands that range from a low of 30 MHz to over 800 MHz. No single, commercial grade radio is capable of operating in all of the bands utilized by different

agencies. Thus, individual agencies may be prevented from communicating with another agency simply because their individual radio systems operate in different frequency bands.

4.3.9 ▸ The second obstacle is the general lack of channels available for interoperability. In some cases this may stem from inadequate planning or an overriding need to utilize all available channels to satisfy routine operational demands, but in any event, the subcommittee observed that few channels have been designated and made available to satisfy interoperability requirements.

4.3.10 ▸ The third obstacle involves certain human and institutional limitations or constraints including the ability of a human operator to remember the specific channels assigned for interoperability and the reluctance of some agencies to allow their units to join another system when it jeopardizes their ability to maintain communications with their own personnel.

4.3.11 ▸ The fourth obstacle, the lack of a common communications mode, reflects the fact that, even if the units from different systems operate in the same band, they may not be able to communicate because they use different transmission or signaling techniques. For example, one system may use an analog modulation technique (*e.g.*, FM) while the other may use a digital modulation technique or the two systems may be using proprietary, trunked or digital radio systems provided by different manufacturers.

4.3.12 ▸ The fifth obstacle refers to the fact that, even with infrastructure dependent systems that employ some type of gateway to allow communications between units on their respective systems, they still may not always be able to communicate because the coverage areas of the two systems do not completely overlap.

4.3.13 ▸ The sixth obstacle, limitations of current commercial systems, reflects the fact that while in theory, commercial systems could be used to achieve interoperability, they currently lack certain characteristics that are deemed critical in Public Safety applications.

4.3.14 ▸ The seventh obstacle reflects the fact that, for numerous reasons, there is a lack of an adequate nationwide mutual aid plan and incident command system to facilitate the required degree of interoperability.

4.3.15 **Interoperability Solutions:** The ISC defined multiple levels of technological solutions to interoperability, both short term (defined to be within five years) and long term. These solutions can be categorized into infrastructure independent versus infrastructure dependent, both of which have ranges from simple to complex solutions. These solutions are not mutually exclusive and the optimum solution may use various combinations, especially as the interoperability requirement escalates from day-to-day to mutual aid or task force levels.

4.3.16 *Infrastructure independent methodologies* are communication links directly between radios over a direct RF path. These solutions are typically used for close proximity communications by multiple disciplines and jurisdictions converging on the scene to support the public needs. They are also used when radios are out of range of their infrastructure coverage, such as in rural areas or some in-building communications. Common analog FM technology and mutual aid frequencies allow users to communicate regardless of radio manufacturer. Widespread implementation of infrastructure independent interoperability is hindered by a number of significant issues discussed within the ISC report, including the diversity of radio frequency spectrum in which Public Safety agencies operate, the critical shortage of spectrum available and designated for interoperability, the introduction of new technology creating the risk that a common mode of interfacing over-the-air will hinder interoperability, and other factors discussed in the report.

4.3.17 More complex solutions include development of broad band, dual band and multi-band radios. Commercial viability of these approaches is yet to be proven.

4.3.18 *Infrastructure dependent methodologies* and technologies require the use of some items(s) of equipment, other than a subscriber unit (radio), to establish a communications link and for complete radio operation. These solutions are typically used for wide area communications, where individual users are not within direct range of each other, and for on the scene communications where they may not have a common operating channel. This interconnection can be a temporary or permanent connection and can be accessed through a number of locations using various access methods. Once a permanent solution is in place, it can be idle in standby mode and be activated immediately when required, if all participating systems are operational.

4.3.19 Gateways between two or more system infrastructures can provide viable infrastructure dependent solutions at various degrees of complexity and may be one of the few available solutions in the short term. They can interconnect systems operating in different frequency bands, modes of operation, and manufacturer protocols. Most trunked radio systems require predetermined user or "talk" groups to be identified and programmed into the system. As systems become larger and additional user groups are identified, the problem of interconnecting users from other systems or non-trunked users becomes more complex. Gateways may be one of few viable short term solutions that can be implemented without modifying existing radios to bridge the different Public Safety frequency bands.

4.3.20 Infrastructure dependent methodologies and technologies have several disadvantages. First is that each participating network must have similar geographic coverage because interoperability is limited to the common overlap areas of the participating systems. Interoperability fails if any infrastructure is damaged or otherwise inoperable. Networks must generally be in place prior to an incident requiring their use because most often there is neither time nor opportunity to set up these solutions during emergency incidents. Deployable infrastructures can mitigate this problem, however,

the degree of delay getting this equipment deployed often depends on the destruction severity of a disaster.

4.3.21 *Joint-use and Shared Systems* or consolidated systems covering the same geographic area, either conventional or trunked, readily provide interoperability to those agencies sharing the system. Consolidated systems allow multiple agencies to operate in the same frequency band using compatible equipment on the same infrastructure. These systems improve spectrum efficiency because they allow multiple agencies to interoperate without the need for additional spectrum.

4.3.22 However, unless non-resident radios are fully compatible with the system infrastructure, interoperability with other agencies not sharing this system will require a different methodology for achieving interoperability. Such interoperability is also subject to the same issues and disadvantages as the above solutions.

4.3.23 *New Interoperability Band:* Another solution approached by the ISC involves the creation of a single common Public Safety Interoperability Service (which is abbreviated as "PI") in one central band. The ISC feels this solution is both possible and practical. The band would be dedicated exclusively for interoperation applications but would require the user to have either dual band radios or two radio installations. This approach gives an absolute common technical solution to the common operating requirements of a mutual aid incident. A field unit (or hand-held) with the "PI" capability could interact with any other unit similarly equipped. This approach could offer a short term solution, depending on the frequency band that is selected by the Spectrum Requirements Subcommittee. This solution would likely require most Public Safety agencies to purchase an additional radio for the new "PI" band.

4.3.24 *Current Mutual Aid Channels*: The ISC supports the continued use of current Mutual Aid channels to support interoperability. Additionally, more channels must be designated in current bands to satisfy immediate needs. Moreover, the FCC and NTIA must allow more flexible licensing regulations regarding multi-government use of these channels.

4.3.25 *Commercial Services*: Public Safety agencies use commercial services, including cellular telephone, paging, satellite communications, Personal Communications Systems (PCS), specialized mobile radio (SMR) and enhanced specialized mobile radio (ESMR) systems as an adjunct or supplemental solution for their non-mission critical communications. They anticipate a continued increase in their use of commercial services in the future, particularly for administrative and non-mission critical applications. It has been concluded by the ISC that commercial service providers typically do not provide the required features, priority access and command and control required by Public Safety for mission critical communications and are not likely to meet all requirements within the Public Safety community. As new technologies emerge, objective experiments with and use of these systems will be necessary to determine the portion of Public Safety needs that can be satisfied.

Recommendations

4.3.26 The ISC has concluded that the problems of interoperability cannot be resolved without additional spectrum allocated to Public Safety. Consolidating the number of bands used by federal, state, and local Public Safety agencies into fewer bands will enhance the opportunity for interagency interoperability but it must be offset by increases in the total amount of spectrum allocated to Public Safety use. To promote interoperability, such additional spectrum should be provided immediately adjacent to existing channels, and lend itself to possible consolidation in the Public Safety bands.

4.3.27 Specifically, the ISC recommends:

4.3.27.1▸ the establishment of a new Interoperability band. This solution may be a short term (less than five years) solution, depending on the availability of spectrum. This would require that a relatively free band of frequencies be identified, preferably central to existing Public Safety bands. Although the responsibility to identify spectrum rests with the Spectrum Requirements Subcommittee, the ISC suggests the UHF band below 512 MHz. Define specific frequencies and pairs of frequencies using developed Incident Command System (ICS) guidelines.

4.3.27.2▸ that the FCC and the NTIA freely license these frequencies to all eligible Public Safety/service providers under operational as well as technical regulations and they restrict use to mutual aid interoperation.

4.3.27.3▸ that the following interoperability links be established: 21 paired voice links and 20 simplex voice links within current bands. It is believed that existing designated interoperability frequencies can be used for 13.5 of the repeatered and 13 of the simplex voice links (i.e. an additional 7.5 paired and 7 simplex need to be designated in existing bands). Additionally, 31 repeatered voice, 70 simplex voice, 2 independent high speed data and 2 independent full motion video links must be provided in the new Public Safety Spectrum.

4.3.27.4▸ that a national planning process be established as soon as possible to address a nationwide mutual aid plan, define operational policies and procedures, provide guidance and procedures for regional planning processes, and define incident command system requirements with all levels of government involved.

4.3.27.5▸ that the minimum baseline technology for interoperability, for unit to unit voice communication, be 16K0F3E (analog FM), unless FCC and/or NTIA regulations stipulate a different emission in a specific operational band. This recommendation is applicable to Public Safety spectrum between 30 MHz and 869 MHz, and should be adopted as soon as possible by the FCC and NTIA. Effective January 1, 2005, the minimum baseline technology for interoperability, for unit to unit voice communication, should be mandated as 11K25F3E (analog FM) in Public Safety spectrum between 30 MHz and 512 MHz, unless

FCC and/or NTIA regulations stipulate a different emission in a specific operational band. The maximum allowable interoperability bandwidth in any new spectrum allocation should not be allowed to exceed the bandwidth established for operational communications within that new spectrum. It further recommends that a group comprising experts representing government, industry and users be organized to further address baseline technology for interoperability. This effort should be managed by a neutral third party with no vested interest in the outcome of the effort.

4.3.27.6▸ that any digital baseline standards for interoperability be open standards, developed/adopted in an open and fair process.

4.3.27.7▸ that, to allow multi-level government interoperability, FCC and NTIA regulations provide for equal access by both federal and non-federal Public Safety agencies.

4.3.27.8▸ that the regulatory aspects of the licensing by the FCC and NTIA of shared/consolidated systems by agencies covering the same geographic area be relaxed to allow for flexibility to encourage systems of this type.

4.4 SPECTRUM REQUIREMENTS SUBCOMMITTEE SUMMARY

Overview

4.4.1 The mission of the Spectrum Requirements Subcommittee (SRSC) is to examine the overall spectrum requirements of both federal and non-federal Public Safety agencies through the year 2010. In order to accomplish this, the SRSC quantified a broad range of factors to develop a realistic model for spectrum needs in the year 2010 and tested its assumptions against other empirical data and models to ensure consistency and reliability. The results of the SRSC's efforts conclude that 129.3 MHz of mobile spectrum overall — including 95.3 MHz of *new* spectrum — will be required for Public Safety officials to continue to protect life and property efficiently and effectively in the year 2010. Of this spectrum, at least 25 MHz should be allocated immediately to satisfy existing demands. The SRSC also determined that at least 161 MHz of new point-to-point spectrum will be required to support Public Safety services in the year 2010, as well as additional 2.5 MHz of spectrum to support nationwide interoperation among federal, state, and local Public Safety agencies. Specific details on spectrum requirements for interoperability are contained in the Report of the Interoperability Subcommittee.

General Observations

4.4.2 **Factors Affecting Demand for Public Safety Spectrum:** To develop quantitative inputs for its spectrum demand model, the SRSC identified the general trends and factors affecting future Public Safety spectrum needs. As discussed below, the SRSC determined that demand for additional spectrum is driven by predicted increases in the population of Public Safety officials utilizing spectrum, changes in the services available to Public Safety personnel to allow them to effectively discharge their duties, advances in radio technologies, and, to a certain degree, the ability to utilize non-dedicated Public Safety services provided by commercial entities. By coordinating with the other subcommittees of the PSWAC, the Spectrum Requirements Subcommittee quantified each of these factors to arrive at a model of spectrum usage that comprehensively estimates the needs of Public Safety in 2010.

4.4.3 The SRSC first calculated the number of Public Safety personnel that will be using spectrum resources in the year 2010. As a result of growth in the overall U.S. population and demographic changes, additional Public Safety resources will be needed to combat increases in crimes, fires, and other threats to the safety of life and property. The SRSC utilized the Census Bureau's population growth figures for key metropolitan areas and historical trend data on the number of Public Safety officials, and other supporting personnel, required *per capita*. The SRSC also adjusted this data based upon identified trends relating to increases and decreases in particular Public Safety activities (*e.g.*, increases in violent crimes, decreases in robberies), to arrive at an estimate of the total size of the Public Safety user base in 2010.

4.4.4 Next, in coordination with the Operational Requirements and Interoperability Subcommittees, the SRSC identified the total wireless channel capacity needed to support the population of Public Safety personnel that will exist in 2010. The SRSC considered the number of wireless channels necessary to serve the voice, data, and other communications needs of types of Public Safety officials and their associated command structures. The SRSC also adjusted these requirements to reflect the demand for day-to-day, mutual aid, and task force interoperability channels required to coordinate the productive joint use of Public Safety resources. In identifying services to support Public Safety officials, the SRSC also considered emerging services that will play a critical role in future Public Safety activities, including remote transmission of fingerprint and photographic identification information, mobile access to building structural information to assist in fire and hazardous materials emergencies, realtime color video transmission of potentially hazardous situations, and automatic vehicle location systems to allow more efficient deployment of Public Safety personnel.

4.4.5 The SRSC then considered potential advances in radio technologies to determine how much spectrum would be required to support the identified channel capacity needed for Public Safety activities. In other words, the SRSC compensated for future efficiencies in the transmission of information, including greater cell re-use, smaller channel sizes, and information compression schemes. The SRSC model of efficiency also considered the cyclic replacement of equipment, which results in an embedded base of equipment at any particular time that must be depreciated before newer, more efficient equipment can be deployed. Included in this factor is also implicit recognition of future spectrum management policies that will dictate or encourage the rapid introduction and adoption of more efficient technologies, such as the FCC's private radio refarming initiative and comparable federal efforts.

4.4.6 As a final matter, the SRSC considered the proportion of future spectrum needs that could reasonably be satisfied by commercial services using spectrum not specifically allocated for Public Safety. As discussed previously, though the SRSC determined that commercial systems can, and presently do, serve as complementary adjuncts to dedicated Public Safety systems, the minimum baseline requirements for *mission critical* applications are not met by any existing or planned offerings. However, the SRSC found that a range of *non-mission critical* communications can be satisfied by commercial systems. The SRSC therefore considered on a case-by-case basis how and where commercial systems may serve as replacement options for Public Safety needs and concluded that approximately 10 percent of future Public Safety demand could be served through commercial systems.

4.4.7 **The SRSC's Model of Spectrum Demand:** Spectrum demand is modeled by relating the predicted user population, service penetration, offered load (*i.e.*, demand), transmission content requirements, coding efficiencies, transmission rate, error control and overhead requirements, channel loading limitations, and geographic re-use factors. Because different types of spectrum use have different characteristics in this model (*e.g.*, the compression factor and offered load for video are different than voice), the

SRSC essentially modeled spectrum demand for five "classes" of services, including voice (*e.g.* dispatch, one-to-many communications, and monitoring), narrowband data (*e.g.*, remote database access), status/messaging (*e.g.*, paging, status messaging, location updates), wideband data (*e.g.*, complex images, slow scan video, fingerprint and identification information), and special data (*e.g.*, full scan color video). The total demand is thus the sum of the demands for individual classes of services, as shown in the table below. It must be stressed however that the aggregate spectrum requirement is more important than its constituent parts. The following table is shown mainly for illustrative purposes:

Table 4-4-1

SPECTRUM NEEDS	
SERVICE	**SPECTRUM (MHz)**
Voice	32.3
Narrowband Data	5.3
Status/Message	0.2
Wideband Data	40.8
Special Data	50.7
TOTAL NEED IN 2010	**129.3**

4.4.8 After compensating for the 23.4 MHz of spectrum that will be in use by Public Safety in 2010, and subtracting 10 percent (10.6 MHz) to be served by commercial providers, the SRSC estimates a total of 95.3 MHz of new spectrum will be needed in 2010 (not including interoperability channels). The SRSC also determined that at least 25 MHz of spectrum should be allocated *immediately* to alleviate capacity shortfalls for critical voice and data needs and to promote development of equipment for new services.

4.4.9 Federal government users indicated that future federal requirements could be satisfied in the currently allocated bands providing that: (1) no more federal allocations are lost through transfer to the FCC for commercial use; (2) the assumed spectrum-efficient technologies become available as needed; (3) funds are provided by appropriations to implement the spectrum-efficient technologies into federal radio systems.

4.4.10 The SRSC notes that its estimates of the expected technology level for the average installed system in 2010 are quite aggressive. Because these estimates are part of the basis for the modeling of spectrum usage, the SRSC's spectrum estimates are correspondingly conservative. For example, the technology forecast, based on the PSWAC Technology Subcommittee's input, estimated that the *average* Public Safety voice radio system in use in the year 2010 would require only 4 kHz of spectrum per

active conversation.[19] Realistically, this high level of efficiency could only be achieved by universal replacement of existing equipment with more spectrum efficient equipment and the widespread deployment of Public Safety systems more spectrum efficient than any on the market today or required by the FCC's *Refarming* docket. To put this requirement in perspective, assuming that the older one fourth of installed equipment in 2010 operates with a spectrum efficiency of 12.5 kHz per active conversation (the level required for new type acceptances today under the FCC's *Refarming* rules, but not yet in significant use in Public Safety), if the SRSC's forecasts are to be met, the other three-quarters of equipment must operate with a spectrum efficiency of 1.17 kHz per active conversation -- roughly *twenty* times more efficient than today's typical practice. Other forecasts were similarly aggressive in other areas such as data modulation, video coding improvement, *etc.* Notably however, the SRSC's model predictions are consistent with the FCC's 1985 staff study on Public Safety spectrum needs and other, more recent, studies by the NTIA, the Coalition of Private Users of Emerging Multimedia Technologies, and the Association of Public Safety Communications Officers, in that all agree that additional spectrum for Public Safety services is necessary.[20]

Specific Findings

4.4.11 Recognizing that Public Safety telecommunications infrastructure (e.g., fixed microwave systems) are vital to the operation of area-wide systems, the SRSC recommends that 161 MHz of additional allocations be made for this use. This figure was derived through analysis, recognizing that although landline technology, including fiber optics, offers increasing 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 those systems often fail during severe earth movements. The SRSC expects that the future supply of backbone system elements will look much like the past, but with two major exceptions. First, the lowest microwave frequencies (2 GHz) are no longer available for backbone systems.[21] Second, the supply of facilities by local carriers historically has been limited to only one firm, the local telephone company. Changes in law and technology, however, have led to the entry of new competitors in many markets and the probability of extensive further entry.

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19 The value of 4 kHz per voice channel is based on an offered load of 6 kb/s for digitized voice today, and by the year 2010, an improvement in coding of 2:1, the use of error correcting code and overhead that requires double the offered load, and a transmitted rate (or modulation efficiency) of 1.5 b/s/Hz.

20 *Report on Future Public Safety Telecommunications Requirements*, Notice of Inquiry in P.R. Docket No. 84-232, 49 Fed. Reg. 9754 (March 15, 1984); *NTIA Spectrum Requirements Study*, Land Mobile Spectrum Planning Options, (October 19, 1995); *Petition for Rulemaking of the Coalition of Private Users of Emerging Multimedia Technologies* (filed December 23, 1993); *Public Safety Spectrum Needs Analysis and Recommendation* (Assoc. of Public Safety Comm. Officers 1994).

21 This spectrum was reallocated for Personal Communications Systems.

4.4.12 **Frequency Band Selection:** In order to insure that Public Safety users have sufficient spectrum to perform efficiently and effectively their duty to protect life and property, the SRSC has identified, in the following table, a range of potential new spectrum bands that could potentially be allocated for Public Safety use between now and 2010. Due to a variety of factors, summarized below, not all of these bands are suitable for all classes of services. In addition, all of the identified bands are currently occupied by existing users, and thus in Section 10 of the subcommittee report, the SRSC has examined how existing users could be relocated or transitioned out of specific bands.

Table 4-4-2

Band	Current Use	Proposed Use	Comments
30-50 MHz	Private radio services (Part 90). Includes 315 PS channels.	Preserve current allocations for voice and narrowband data. Technical constraints impair further use.	Useful for wide area mobile coverage, but not technically suitable for urban areas. Limited amount of equipment available.
138-144 MHZ	Gov't (DoD).	Potential for PS sharing for voice and narrowband data on a case-by-case basis.	Useful for wide area mobile coverage. Proper system design can compensate for building penetration difficulties in urban areas.
148-174 MHZ	Gov't/non-gov't shared. Includes 242 PS channels between 150-174 MHz.	Retain current allocations for voice and narrowband data. PS should retain new channels created through refarming.	
174-216 MHz	VHF TV Channels 7-13	Potential for immediate PS sharing for additional voice and narrowband data. Parts of this band should be reserved for exclusive PS use.	
380-399.9 MHZ	Gov't (DoD fixed, mobile and MSS).	Initiate discussions with DoD and U.S. Coast Guard to determine feasibility of reallocation or sharing with PS for voice and narrowband data.	Good technical characteristics. DoD states reallocating present users will be costly.

Table 4-4-2

Band	Current Use	Proposed Use	Comments
450-470 MHz	Private radio services (Part 90). Includes 74 PS channels.	Preserve current allocations for voice and narrowband data. PS should be allocated additional channels created through refarming.	Good technical characteristics. Reallocation of narrowband channels through refarming. Other channels difficult to reallocate.
470-512 MHz	UHF TV channels 14-20. This band is shared by private land mobile users in 13 metro areas.	Potential for new allocations in present areas by relocating non-PS users to PCS or ESMR systems. Additional PS allocations should be made in all areas.	This band can provide the quickest spectrum relief for frequency impacted areas.
746-806 MHz	UHF TV channels 60-69.	24 MHz should be reallocated to PS for all uses.	Channels 60-69 have relatively light use, and four channels should be reallocated for PS use.
806-902 MHZ	Non-gov't mobile (Part 90, Part 22). Includes 300 PS channels.	Retain current allocations for voice and narrowband data.	Good urban propagation properties. No new allocations are feasible because of ongoing SMR regulatory changes.
1710-1755 MHz	To be reallocated for mixed gov't/non-gov't use on 1/1/04.	Primary band for future wideband data and video.	Early access (sooner than 2004) should be pursued.
1990-2110 MHz	Has been reallocated for emerging technologies	Could be used for Microwave or wideband data/video requirements.	Not yet designated for specific use
4635-4660 MHz	To be reallocated for non-gov't use on 1/1/97	Point-to-point systems or short range mobile video systems	

Table 4-4-2

Band	Current Use	Proposed Use	Comments
4660-4685 MHz	Tentatively allocated for GWCS.		4660-4685 MHz has already been allocated for a "General Wireless Communications Service."
5850-5925 MHz		Intelligent Transportation Systems	Spectrum already reserved for ITS.

4.4.13 The selection of particular new spectrum bands for Public Safety involves a complex balancing of many technical and economic factors. As a technical matter, spectrum band selection is constrained by the propagation limitations of various parts of the radio spectrum, because factors like the transmitter power to coverage distance ratio and building penetration characteristics may be more favorable in one band than another. Moreover, as the need for interoperability increases, the separation between existing bands and new bands becomes relevant because a single radio may be technically incapable of tuning between widely separated bands, which would necessitate the use of expensive, multiple transmitter elements in multi-band radios or the establishment of additional interoperability channels in each band, above and beyond the requirements already identified by the SRSC.

4.4.14 Spectrum allocation policies could also increase spectrum needs and affect radio costs by, for example, limiting economies of scale or scope critical to equipment manufacturing. By locating new spectrum bands for Public Safety near or adjacent to existing Public Safety bands or other comparable private uses, the development investment to produce radio equipment is lowered and volume production benefits can be gained. Similarly, allocation policies that create a large number of Public Safety bands scattered across the spectrum, as opposed to a few larger allocations, can result in inefficiencies by requiring additional interoperability channels. In addition, the more efficient management of existing spectrum has been presumed, including such measures as improvements in federal spectrum use, initiatives like the Commission's private radio refarming proceeding, and increased federal/non-federal sharing.

Recommendations

4.4.15 As there are many competing interests for spectrum, many options are presented in this section. There is approximately 315 MHz of spectrum, not including new channels from refarming, identified to fully meet the Public Safety needs. The subcommittee offers these options to the FCC and NTIA so the needs of Public Safety for spectrum are fully met. To assist the FCC and NTIA in the regulatory changes required, the subcommittee recommends the following priority listing for each type of use.

4.4.16 **Voice, Data, and Video Requirements**

1. Immediate further sharing of TV channels in the 470-512 MHz band in all areas.

2. Reallocate all or part of 746-806 (broadcast channels 60-69) MHz band.

3. Immediate allocation of the VHF and UHF channels in other services created by the FCC's Refarming Proceeding (including TV sharing bands).

4. Eventual reallocation of all TV sharing channels in the 470 to 512 MHz band.

5. Immediate new sharing of the 174-216 MHz VHF TV band primarily outside of urban areas and for statewide systems.

6. Reallocation of the 380-399.9 MHz band.

7. Sharing of the 380-399.98 MHz band with DOD on a mutually agreeable basis to minimize interference to Public Safety operations.

8. Hold a portion of the 174-216 MHz band in reserve to meet future Public Safety needs, or needs not met by this effort.

4.4.17 **Wide Band Data and Video Requirements**

1. Allocations in the 1710-1755 MHz band.

4.4.18 **Short-Range Video Requirements**

1. Allocations in the 4635-4685 MHz band.

4.4.19 **Fixed Service Requirements**

1. Allocations in the 4635-4685 MHz band.

2. Allocations in the 1990-2110 MHz band.

3. Allocations in the 3700-4200 MHz band.

4.4.20 **Intelligent Transportation Systems**

1. Allocations in the 5850-5925 MHz band.

4.4.21 Only if these measures are undertaken promptly will Public Safety officials have access to wireless capabilities that are critical to their safety as well as their ability to effectively discharge their sworn duty to protect the life and property of our citizens.