PUBLIC SAFETY WIRELESS NETWORK PSWN PROGRAM

Saving Lives and Property Through Improved Interoperability

Land Mobile Equipment Market Analysis Report

FINAL

July 2001

FOREWORD

Land mobile radio (LMR) equipment is a critical component for adequate public safety wireless communications. In response to various inquiries from the public safety community, the Public Safety Wireless Network (PSWN) Program analyzed various vendor offerings of public safety grade mobile and portable radio equipment and subsequently compiled the *Land Mobile Equipment Market Analysis Report*. This report provides analysis and background information to public safety system administrators and communications systems planners on the different types and capabilities of LMR subscriber units (mobile and portable radios). The report does not contain an analysis of radio system infrastructure components, e.g., base stations, console components, antenna systems, or switches.

This *Land Mobile Equipment Market Analysis Report* considers mobile and portable radio products and matches the specifications of these products to applicable public safety physical, functional, and interoperability criteria. The report is intended to serve local, state, federal, and tribal public safety agencies managing or considering the procurement of LMR subscriber units. In addition to providing a detailed analysis of mobile and portable radios, the report supplies a wealth of background discussion and supporting materials examining LMR equipment features, system characteristics, and technical standards.

The report begins with a road map indicating the location and type of content in each section of the report. In place of a table of contents, this report map is intended to help readers navigate through the substance of the report based on their technical knowledge of LMR equipment and systems. Brief explanations of the various components of the report follow the report map.

Pricing information for mobile and portable equipment discussed within this report has not been provided as it may vary greatly depending upon the vendor, system involved, procurement structure, and contract vehicles. This report does not reflect a government position or endorse a particular type of LMR network, equipment, standard, or architecture.

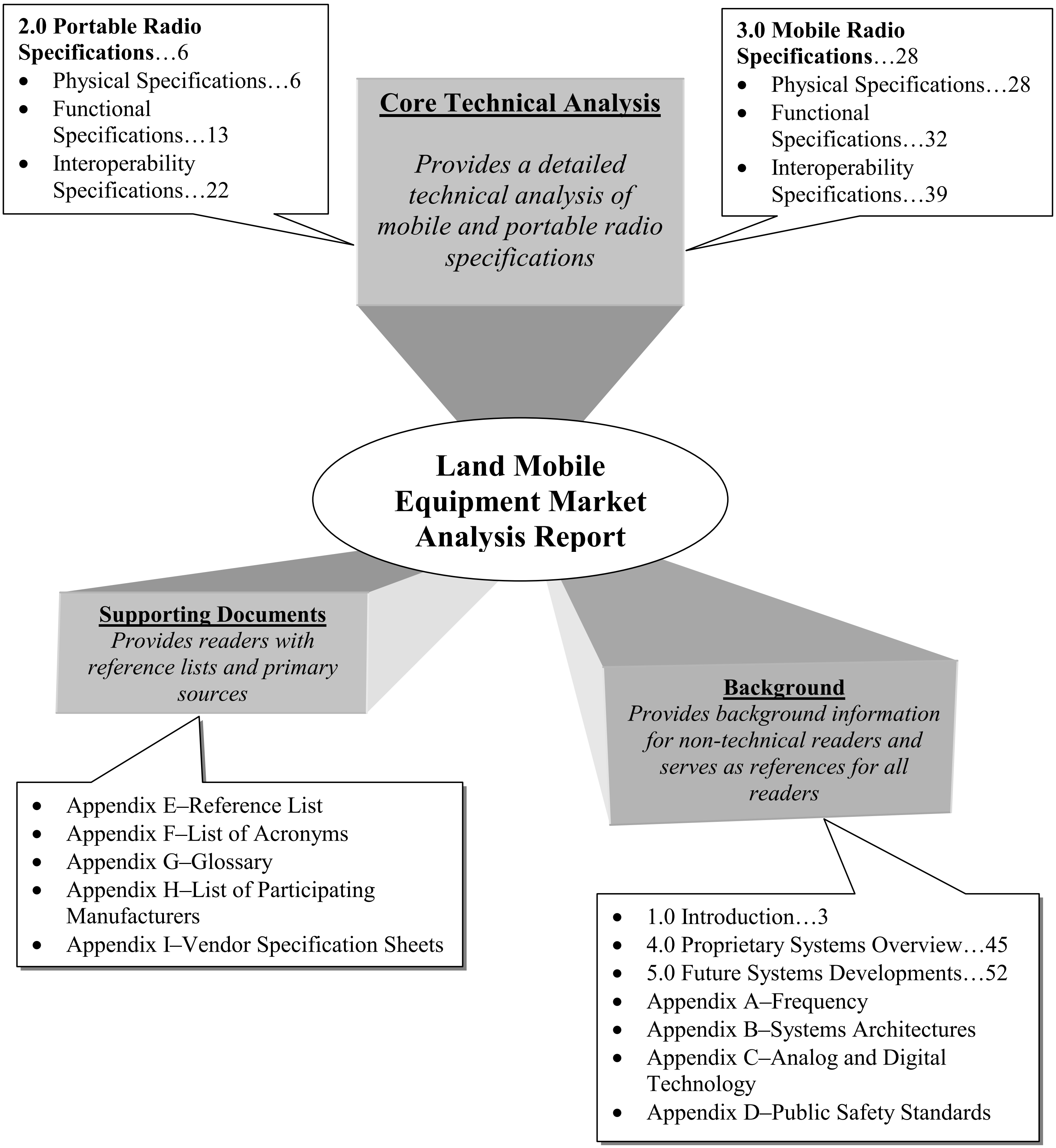

Figure 1
Report Map

Core Technical Analysis
• Provides a detailed technical analysis of mobile and portable radio specifications • Intended for readers with a high level of technical knowledge of LMR systems and equipment • Contains an analysis of the physical, functional, and interoperability specifications of both mobile and portable radios • Includes Sections 2.0 and 3.0
Background
• Intended to provide readers with minimal technical knowledge of LMR systems and equipment with a baseline of information needed to interpret Sections 2.0 and 3.0 effectively • Serves as an overview and background discussion of the technology and standards considered in Sections 2.0 and 3.0 • Provides a reference explaining LMR system features and key standards relevant to public safety agencies • Includes Sections 1.0, 4.0, and 5.0, as well as Appendices A, B, C, and D
Supporting Documents
• Identifies and provides copies of primary sources used to develop the analysis included in Sections 2.0 and 3.0 • Provides readers with quick reference lists defining technical terms and acronyms used throughout the report • Includes Appendices E, F, G, H, and I

Figure 2
Report Map Explanations

1.0 INTRODUCTION

Technological developments in the LMR marketplace have substantially impacted public safety communications over the past 80 years. Within the last 20 years, technological developments have led to the deployment of public safety systems with unique features, such as trunking protocols and encryption technologies, which in turn have lead to proprietary systems. Evolving technological issues affecting public safety today include the introduction of narrowband-capable digital LMR systems, the deployment of 220 megahertz (MHz) systems, the impending deployment of 700 MHz systems, the convergence of voice and data communications, and the incorporation of advanced user function and feature sets within mobile and portable radio equipment.

In addition, LMR standards developed by and for the public safety community have affected vendors' LMR offerings over the past 20 years. Such standards have been primarily focused on removing the communications barriers caused by proprietary system features. Figure 1 notes the key technological developments and events for public safety agencies that have occurred throughout the history of the LMR marketplace.

History of Public Safety Land Mobile Radio
1928—City of Detroit, Michigan, initiates operation of first one-way amplitude modulation (AM) broadcast radio system for the police department.
1940—Connecticut State Police begin operating a two-way analog frequency modulation (FM) radio system. The first AM handheld two-way radio was developed for the U.S. Army Signal Corps and was used worldwide during World War II.
1960s—Solid-state circuits are incorporated into LMR equipment replacing vacuum tubes.
1969—Manufacturers introduce "tone coded squelch" that makes signaling unique and channel reuse possible. Signaling protocols are shared among various manufacturers.
1970s—Very Large Scale Integrated (VLSI) circuits are incorporated into LMR equipment and also facilitate further development of microprocessor technologies.
1970—The first commercial 4-bit microprocessors are introduced and incorporated into LMR equipment.
1976—Advanced 8-bit microprocessors with five times the execution speed are introduced and used in LMR equipment.
1977—Association of Public-Safety Communications Officials (APCO) begins Project 16 with funding from a Law Enforcement Assistance Administration (LEAA) grant.
1978—The first 16-bit microprocessors are introduced by computer chip manufacturers.
1979—The Project 16 standards are completed. This effort specified features specifically for the public safety industry to be added to existing standards for commercial systems and specialized mobile radio (SMR) systems.
1980—Commercial 16-bit microprocessors are incorporated into LMR equipment.

History of Public Safety Land Mobile Radio
1982/1983—Data Encryption Standard (DES) is introduced. DES further distinguishes system features but does not ensure interoperability and compatibility. **1984—**Thirty-two bit microprocessors and other VLSI chips are incorporated in LMR equipment, providing new and enhanced features and functions. **Early to mid 1980s—**LMR manufacturers continue to develop unique, proprietary trunking protocols and produce LMR equipment that is not interchangeable. **Mid 1980s—**The Open Architecture Radios for Public Safety (OARPS) committee was formed and attempted to standardize analog trunked radio systems. However, after much research and discussion, it was concluded it was too late to standardize analog trunked systems. **1987—**Additional manufacturers introduce APCO 16-compliant LMR trunk systems. **1989—**APCO Project 25 is initiated to develop commonality between disparate trunking systems technologies as the manufacturers continued to move toward digital technologies. **1990s—**New digital technologies including integrated Dispatch Enhanced Network (iDEN) and Enhanced Digital Access Communication System (EDACS) are developed and incorporated into commercial and public safety systems. **1993—**First voice coder ("vocoder") Telecommunications Systems Bulletin (TSB) released. **1993—**First transmission of digital trunked 800 MHz radio communication occurred at Florida Highway Patrol, Troop E Headquarters in Miami on March 26, 1993. **1994—**First common air interface TSB released. **1994—**Terrestrial Trunked Radio (TETRA) standards are finalized for trunking systems for LMR system deployments except in North America. **1996—**The Public Safety Wireless Network (PSWN) Program is established as a joint initiative sponsored by the U.S. Department of Justice and the Department of the Treasury in an effort to address public safety radio interoperability. **1997—**Improved multiband excitation (IMBE) vocoder selected in an extremely competitive process, based on tests and voice quality measurements. The selected technology was consistent with APCO 25 standards. **1998—**American National Standards Institute (ANSI) approves vocoder and common air interface (CAI) as American National Standards. **1999—**The State of Pennsylvania announces its plan to build the first statewide Voice-over-IP wireless network servicing numerous local, state, and federal public safety agencies. **2001—**The State of Michigan completes the third phase of a multiyear effort to deploy a statewide all-digital trunking system to support various public safety agencies.

Figure 3
History of Public Safety Land Mobile Radio

In light of these developments, it is important for public safety agency administrators, communications system planners, and procurement officials to consider the range of LMR features and standards when replacing systems and/or equipment. Comparative analyses of vendors' offerings can help determine the most fitting mobile and portable radios for public safety agencies' existing or new systems environment. Law enforcement, fire and rescue services, and emergency medical services (EMS) must consider the special and unique operational requirements imposed by activities within their service delivery area.

An essential decision for local, state, federal, and tribal LMR system planners is determining which mobile and portable equipment should be procured to meet the stringent physical, technical, and operational requirements of the public safety communications environment. Generally, portable and mobile equipment must be compatible with the agency's system infrastructure, and consideration should be given to achieving sufficient interoperability with neighboring LMR systems. Appropriate research and understanding of the communication system infrastructure and its capabilities, features, and functions must be undertaken prior to the procurement of mobile and portable equipment.

This *Land Mobile Equipment Market Analysis Report* is intended for members of the public safety community responsible for the procurement, management, and operation of mobile and portable radios. The report serves these members of the public safety community as a reference tool providing analysis, insight, and information about mobile and portable radios. Specifically, the report—

- Provides a detailed analysis of the physical, functional, and interoperability features of mobile and portable radios in the public safety marketplace today. These analyses are based on criteria incorporating the user needs of public safety personnel and the public safety operating environment.

- Provides background information regarding the characteristics of the different frequency bands employed by public safety agencies, system infrastructure technologies, system signaling protocols, relevant standards, and the various proprietary systems currently available and used by public safety agencies.

- Provides public safety administrators, procurement officials, and communications system planners with descriptive information, comparisons, and operational considerations to foster appropriate decision-making and procurement processes for new or replacement mobile and portable radio equipment.

Finally, the report discusses the communications trends in the public safety environment and opportunities that may present themselves with continuing technical advances and the application of emerging standards.

2.0 PORTABLE RADIO EQUIPMENT SPECIFICATIONS

Portable radios commonly accompany public safety personnel deployed in the field. In essence, the portable radio is an extension of the mobile radio environment in most cases. More and more agencies are issuing portables to personnel as standard equipment regardless of assignment. To examine a radio's practical use for such personnel, it is important to examine the unique specifications relating to the physical, functional, and interoperability features of the portable radio.

The following three sections include analytical charts relating to the physical, functional, and interoperability features of portable radios on the market today. Each chart matches criteria to portable radio specifications. Criteria are explained after each analytical chart.

The specifications listed for each radio product were extracted from specification sheets supplied by the respective vendor. It is important to note that, in accordance with the PSWN Program's requests, *the vendors* have identified portable radio products listed in the charts as those commonly sold to the public safety LMR community. In cases where the criteria data was not available or apparent from the product's specification sheet, "N/A" (not applicable) is recorded. Copies of the specification sheets provided by the vendors are included in Appendix I.

2.1 Portable Radio Physical Specifications

A radio's physical features determine its practical use for public safety agencies. The public safety operating environment calls for unique radio features that can prove crucial for public safety personnel when responding to incidents. For example, features such as liquid crystal displays (LCD) or oversized knobs that are operable with gloved hands can help public safety personnel react without losing valuable time and critical information. The following charts provide an analysis of the physical features for portable radios most applicable to the public safety operating environment and user needs.

Table 2.1 Physical Specifications for Portable Radio and Battery Products

Vendor	Product	Analysis Considerations								
		Dimensions (W" x H" x D")	Weight	DTMF Keyboard	LCD/LED Indicator	Oversized Knobs/ Switches	Battery Specifications		Casing Material	Relevant Features & Accessories
							Acceptable Battery Type – Rated Capacity – Duty Cycle (90 Stdby./5Tx/5Rx)	Intrinsically Safe		
Com-Net Ericsson	Cougar 400P	6.1 x 2.4 x 1.7 (with 1100 MAH NiCd battery)	17.5 oz (with 1100 MAH NiCd battery)	No	No	No	Three Options: 1. NiCd – 1100 MAH – 7.5 hrs. 2. NiCd – 1500 MAH – 10 hrs. 3. NiMH – 2000 MAH – 12.5 hrs.	N/A	N/A	• External speaker jack • Accessories connector • Vehicular charger
Com-Net Ericsson	EDACS Jaguar 700P	6.75 x 2.58 x 1.79 (with battery)	26.0 oz. (with battery)	Optional	LCD	Yes	Two Options: 1. NiCd – N/A – 9 hrs. 2. NiMH – N/A – 11 hrs.	Pending	N/A	• External speaker jack • Accessories connector
Com-Net Ericsson	ProVoice Jaguar 700P	6.75 x 2.58 x 1.79 (with battery)	26.0 oz. (with battery)	Optional	LCD	Yes	Two Options: 1. NiCd – N/A – 9 hrs. 2. NiMH – N/A – 11 hrs.	Pending	N/A	• External speaker jack • Accessories connector
Com-Net Ericsson	Panther 300P	5.67 x 2.5 x 1.65 (with battery)	16 oz. (with battery)	No	No	No	Standard: High capacity N/A – N/A – N/A	No	Black Poly-carbonate	• External speaker jack • Accessories connector
Com-Net Ericsson	Panther 400P	6.1 x 2.6 x 1.8 (with 1100 MAH NiCd battery)	18.1 oz. (with battery)	No	No	No	Three Options: 1. NiCd – 1100 MAH – 8 hrs. 2. NiCd – 1500 MAH – 10.5 hrs. 3. NiMH – 2000 MAH – 13 hrs.	No	N/A	• External speaker jack • Accessories connector • Vehicular charger
Com-Net Ericsson	Panther 500P	5.4 x 2.6 x 1.7 (with high capacity battery)	15.9 oz. (with high capacity battery)	Optional	LCD	No	Two Options: 1. High capacity N/A – N/A – N/A 2. Extra high capacity N/A – N/A – N/A	No	N/A	• External speaker jack • Accessories connector
Com-Net Ericsson	Panther 600P	6.1 x 2.6 x 1.8 (with 1100 MAH NiCd battery)	18.1 oz. (with battery)	Yes	LCD	No	Three Options: 1. NiCd – 1100 MAH – 8 hrs. 2. NiCd – 1500 MAH – 10.5 hrs. 3. NiMH – 2000 MAH – 13 hrs.	No	N/A	• External speaker jack • Accessories connector • Vehicular charger
Com-Net Ericsson	Panther 625P	6.1 x 2.6 x 1.8 (with 1100 MAH NiCd battery)	18.1 oz. (with battery)	Yes	LCD	No	Three Options: 1. NiCd – 1100 MAH – 8 hrs. 2. NiCd – 1500 MAH – 10.5 hrs. 3. NiMH – 2000 MAH – 13 hrs.	No	N/A	• External speaker jack • Accessories connector • Vehicular charger
Datron	Guardian G25 RPV100	7.75 x 2.35 x 1.7 (without antenna)	14.5 oz. (with standard battery)	Yes	LCD	Yes	Five Options: 1. NiCd – 1800 MAH – 10+ hrs. 2. NiMH – 2000 MAH – 10+ hrs. 3. NiMH – 2700 MAH – 10+ hrs. 4. NiMH – 4000 MAH – 10+ hrs. 5. AA clamshell – N/A – N/A	N/A	Black Poly-carbonate	• External speaker jack • Accessories connector

Vendor	Product	Analysis Considerations								
		Dimensions (W" x H" x D")	Weight	DTMF Keyboard	LCD/LED Indicator	Oversized Knobs/ Switches	Battery Specifications		Casing Material	Relevant Features & Accessories
							Acceptable Battery Type – Rated Capacity – Duty Cycle (90 Stdby./5Tx/5Rx)	Intrinsically Safe		
EF Johnson	501X	2.4 x 8.8 x 1.9 (without antenna)	29 oz. (with standard battery)	Optional	LCD	No	Standard: NiMH – 3000 MAH – 13 hrs. Optional: NiMH – N/A – N/A	N/A	Black Poly-carbonate	• External speaker jack
EF Johnson	504X	2.4 x 8.8 x 1.9 (without antenna)	29 oz. (with standard battery)	Optional	LCD	No	Standard: NiMH – 3000 MAH – 13 hrs. Optional: NiMH Med. Capacity – NA – NA	N/A	Black Poly-carbonate	• External speaker jack
EF Johnson	508X	2.4 x 8.8 x 1.9 (without antenna)	29 oz. (with standard battery)	Optional	LCD	No	Standard: NiMH – 3000 MAH – 13 hrs. Optional: NiMH Med. Capacity – N/A – N/A	N/A	Black Poly-carbonate	• External speaker jack
EF Johnson	7780/7781	6.5 x 2.2 x 1.2 (with battery)	18 oz. (with battery)	7781 model only	LCD	No	Standard: N/A – 1300 MAH – N/A	Intrinsically safe battery included	N/A	• External speaker jack • Accessories connector
EF Johnson	Avenger SK-HM83 8160	6.5 x 2.2 x 1.2 (with battery)	18 oz. (with battery)	Optional	LCD/3 LED indicators	No	Standard: N/A – 1300 MAH – NA	Optional	N/A	• External speaker jack • Accessories connector
EF Johnson	Avenger SK-HM93 8162	6.5 x 2.2 x 1.2 (with battery)	18 oz. (with battery)	Optional	LCD/3 LED indicators	No	Standard: N/A – 1300 MAH – N/A	Optional	N/A	• External speaker jack • Accessories Connector
EF Johnson	Viking CM-HM/83 8585, 8586, 8587, 8588	8.65 x 2.76 x 1.7 (with battery)	24.7 oz. (with battery)	Optional	LCD display	No	Standard: N/A – N/A – 9 hrs.	8586 & 8588 models only	N/A	• External speaker jack • Accessories connector • Vehicular charger
Kenwood	TK-290	2.31 x 6.09 x 1.5	1.25 lbs. (with antenna and belt hook)	Optional	User-Defined LED	No	Two Options: 1. N/A – 10 hrs. at 5/5/90 duty cycle 2. NiCd Recharge. – 1500 MAH – N/A	N/A	Die-Cast Aluminum	• External speaker jack • Accessories connector
Kenwood	TK-390	2.31 x 6.09 x 1.5	1.25 lbs. (with antenna and belt hook)	Optional	User-Defined LED	No	Two Options: 1. N/A – 10 hrs. at 4W – 5/5/90 2. NiCd Recharge. – 1500 MAH – N/A	N/A	Die-Cast Aluminum	• External speaker jack • Accessories connector
M/A-COM	Polaris P-801T	2.3 x 6.1 x 1.5 (without battery)	14 oz. (without battery)	Yes	LCD/1 LED indicator	No	Two Options: 1. NiMH – 2000 MAH – 8+ hrs. 2. NiCd – 2000 MAH – 8+ hrs.	N/A	Poly-carbonate	• External speaker jack • Accessories connector • Vehicular charger

Vendor	Product	Analysis Considerations					Battery Specifications			
		Dimensions (W” x H” x D”)	Weight	DTMF Keyboard	LCD/LED Indicator	Oversized Knobs/ Switches	Acceptable Battery Type – Rated Capacity – Duty Cycle (90 Stdby./5Tx/5Rx)	Intrinsically Safe	Casing Material	Relevant Features & Accessories
Motorola	JT 1000	2.34 x 6.3 x 2.15 (with Alkaline battery)	24.2.oz (with Alkaline battery)	Yes	LCD/1 LED indicator	No	Three Options: 1. Alkaline – N/A – 16 hrs.* 2. High Capacity NiCd – N/A – 11 hrs. * 3. Ultra High Capacity NiCd – N/A – 12 hrs.* *at 1 W RF power output	Optional	N/A	• External speaker jack • Accessories connector
Motorola	HT 1000	2.34 x 6.3 x 1.49 (with High Capacity NiCd battery)	18.3 oz. (with High Capacity NiCd battery)	No	1 LED indicator	No	Two Options: 1. High Capacity NiCd – N/A – 8 hrs.* 2. Ultra High Capacity NiCd – N/A – 9 hrs.* *rated at maximum RF output power per each frequency band	Optional	N/A	• External speaker jack • Accessories connector
Motorola	HT 1250	2.26 x 5.4 x 1.6 (with NiCd battery)	15.8 oz. (with NiCd battery)	Optional	LCD display only	No	Four Options: 1. NiCd – N/A – 9 hrs.* 2. Lithium Ion – N/A – 8 hrs.# 3. High Capacity NiMH – N/A – 8 hrs. 4. Ultra High Capacity NiMH – N/A – 11 hrs. * 8 hrs. for low band VHF # 7 hrs. for low band VHF	Optional	N/A	• External speaker jack • Accessories connector
Motorola	HT 1250·LS	2.26 x 5.4 x 1.6 (with NiCd battery)	15.8 oz. (with NiCd battery)	Yes	LCD/LED	No	Four Options: 1. NiCd – N/A – 9 hrs. 2. Lithium Ion – N/A – 8 hrs. 3. High Capacity NiMH – N/A – 8 hrs. 4. Ultra High Capacity NiMH – N/A – 11 hrs.	Optional	N/A	• External speaker jack • Accessories connector
Motorola	Digital Saber I	2.94 x 8.34 x 1.18 (with High Capacity NiMH battery)	26.2 oz. (with High Capacity NiMH battery)	No	No	No	Five Options: 1. Med. Capacity NiCd – 1100 MAH – N/A 2. Ultra High Cpcty. NiCd – 1800 MAH –N/A 3. High Capacity NiMH – 1650 MAH – N/A 4. High Capacity FM – 1050 MAH – N/A 5. Ultra High Cpcty. FM – 1750 MAH – N/A	Optional & Pending	N/A	• External speaker jack • Accessories connector
Motorola	Digital Saber II	2.94 x 8.34 x 1.18 (with High Capacity NiMH battery)	26.2 oz. (with High Capacity NiMH battery)	No	LCD	No	Five Options: 1. Med. Capacity NiCd – 1100 MAH – N/A 2. Ultra High Cpcty. NiCd – 1800 MAH –N/A 3. High Capacity NiMH – 1650 MAH – N/A 4. High Capacity FM – 1050 MAH – N/A 5. Ultra High Cpcty. FM – 1750 MAH – N/A	Optional & Pending	N/A	• External speaker jack • Accessories connector

Vendor	Product	Analysis Considerations								
		Dimensions (W" x H" x D")	Weight	DTMF Keyboard	LCD/LED Indicator	Oversized Knobs/ Switches	Battery Specifications		Casing Material	Relevant Features & Accessories
							Acceptable Battery Type – Rated Capacity – Duty Cycle (90 Stdby./5Tx/5Rx)	Intrinsically Safe		
Motorola	Digital Saber III	2.94 x 8.34 x 1.18 (with High Capacity NiMH battery)	26.2 oz. (with High Capacity NiMH battery)	Yes	LCD	No	Five Options: 1. Med. Capacity NiCd – 1100 MAH – N/A 2. Ultra High Cpcty. NiCd – 1800 MAH –N/A 3. High Capacity NiMH – 1650 MAH – N/A 4. High Capacity FM – 1050 MAH – N/A 5. Ultra High Cpcty. FM – 1750 MAH – N/A	Optional & Pending	N/A	• External speaker jack • Accessories connector
Motorola	ASTRO XTS 3000 Model I	2.44 x 6.58 x 1.65 (without battery)	704 g (with Ultra High Capacity NiCd)	No	1 LED indicator	Yes	Two Options: 1. Ultra High Capacity NiCd – N/A – 8 hrs. 2. Ultra High Capacity NiMH – N/A – 8 hrs.	N/A	N/A	• External speaker jack • Accessories connector
Motorola	ASTRO XTS 3000 Model II	2.44 x 6.58 x 1.65 (without battery)	704 g (with Ultra High Capacity NiCd)	No	LCD/1 LED indicator	Yes	Two Options: 1. Ultra High Capacity NiCd – N/A – 8 hrs. 2. Ultra High Capacity NiMH – N/A – 8 hrs.	N/A	N/A	• External speaker jack • Accessories connector
Motorola	ASTRO XTS 3000 Model III	2.44 x 6.58 x 1.65 (without battery)	704 g (with Ultra High Capacity NiCd)	Yes	LCD/1 LED indicator	Yes	Two Options: 1. Ultra High Capacity NiCd – N/A – 8 hrs. 2. Ultra High Capacity NiMH – N/A – 8 hrs.	N/A	N/A	• External speaker jack • Accessories connector
Motorola	ASTRO XTS 3500 Model I	2.44 x 6.58 x 1.65 (without battery)	704 g (with Ultra High Capacity NiCd)	No	1 LED indicator	Yes	Four Options: 1. Ultra High Capacity NiCd – N/A – 8 hrs. 2. Ultra High Capacity NiMH – N/A – 8 hrs. 3. Lithium Ion – N/A – 8 hrs. 4. FM Ultra High Cpty. NiCd – N/A – 8 hrs.	N/A	N/A	• External speaker jack • Accessories connector
Motorola	ASTRO XTS 3500 Model II	2.44 x 6.58 x 1.65 (without battery)	704 g (with Ultra High Capacity NiCd)	No	LCD/1 LED indicator	Yes	Four Options: 1. Ultra High Capacity NiCd – N/A – 8 hrs. 2. Ultra High Capacity NiMH – N/A – 8 hrs. 3. Lithium Ion – N/A – 8 hrs. 4. FM Ultra High Cpty. NiCd – N/A – 8 hrs.	N/A	N/A	• External speaker jack • Accessories connector
Motorola	ASTRO XTS 3500 Model III	2.44 x 6.58 x 1.65 (without battery)	704 g (with Ultra High Capacity NiCd)	Yes	LCD/1 LED indicator	Yes	Four Options: 1. Ultra High Capacity NiCd – N/A – 8 hrs. 2. Ultra High Capacity NiMH – N/A – 8 hrs. 3. Lithium Ion – N/A – 8 hrs. 4. FM Ultra High Cpty. NiCd – N/A – 8 hrs.	N/A	N/A	• External speaker jack • Accessories connector

Vendor	Product	Analysis Considerations								
		Dimensions (W" x H" x D")	Weight	DTMF Keyboard	LCD/LED Indicator	Oversized Knobs/ Switches	Battery Specifications		Casing Material	Relevant Features & Accessories
							Acceptable Battery Type – Rated Capacity – Duty Cycle (90 Stdby./5Tx/5Rx)	Intrinsically Safe		
Thales	Racal 25	2.6 x 7.8 x 1.05 (with Lithium Ion battery)	16.7 oz. (with Lithium Ion battery)	Yes	LCD/1 LED indicator	No	Standard: Lithium Ion – 1500 MAH – 10+ hrs.	N/A	Metal	• External speaker jack • Accessories connector
Vertex	VX-400	2.28 x 4.0 x 1.0 (with standard NiCd battery)	11.3 oz. (with NiCd battery)	No	No	No	Standard: NiCd – 1100 MAH – 8.2/7.1 hrs. (VHF/UHF)	Optional	N/A	• External speaker jack • Accessories connector
Vertex	VX-510	2.3 x 5.9 x 1.5 (with standard NiCd battery)	20.1 oz. (with standard NiCd battery)	Optional accessory	LCD	No	Standard: NiCd – 1700 MAH – 11 hrs.	Optional	Metal	• External speaker jack • Accessories connector • Vehicular charger
Vertex	VX-800	2.3 x 4.3 x 1.1 (with Lithium Ion battery)	.7 lbs. (with Lithium Ion battery)	Optional accessory	LCD	No	Two Options: 1. NiCd – 1100 MAH – N/A 2. Lithium Ion – 1600 MAH – 12 hrs.	Optional	N/A	• External speaker jack • Accessories connector
Vertex	VX-900	2.3 x 6.1 x 1.3 (with Lithium Ion battery)	.93 lbs. (with Lithium Ion battery)	Optional	LCD	No	Two Options: 1. Lithium Ion – 1800 MAH – 13 hrs. 2. Lithium Ion – 2400 MAH – 16 hrs.	Optional	N/A	• External speaker jack • Accessories connector

2.1.1 Explanation of Physical Specifications Criteria for Portable Radios

Dimensions—The dimensions of the portable radio are very important to public safety personnel who carry the equipment either on utility belts or within protective clothing. Dimensions are important when specifying carrying cases or clips to secure the radio. The length and flexibility of the antenna supported by the unit are also important for personnel comfort and usability. Dimensions may also be important if vehicular chargers are used because the dimensions could influence the placement and mounting of the charging units.

Weight—The weight of the portable radio and the applicable battery is important to personnel who must carry the devices throughout a tour of duty. The different battery types also affect the overall weight of the entire unit, and choices must be made consistent with the intended operation of the radio.

DTMF Keyboard—The inclusion of a DTMF keypad provides the portable radio with the ability to generate audible tones for signaling applications and telephone interconnection to the PSTN. The system infrastructure must support interconnect features to allow telephone calls to be completed. Some models of portable radios include this feature as part of a speaker/microphone assembly that attaches through the accessory connector.

LCD/LED Indicators—The radio may use both types of indicators for certain functions and displays incorporated in the device. LCDs usually have a user-activated "backlight" source to illuminate the display in darkness. LED displays usually have controls to limit the amount of light produced. Agencies should understand how these displays operate and be aware that the light output can be restricted when required for personnel safety.

Oversized Knobs/Switches—There should be sufficient separation between the controls on the device to allow for easy manipulation and operation. In addition, the controls should be oversized so that they may be easily and effectively manipulated by personnel wearing gloves or other protective gear.

Battery Specifications—Battery specifications to consider include the following:

> *Type*—The type of battery available for the portable radio is important to overall operation of the unit. The battery technology used by the manufacturer correlates directly with the length of time the battery lasts on a full charge. The type of battery technology also impacts the total life cycle (charge to discharge) available in the unit. Several manufacturers, as well as after-market suppliers, offer different capacity batteries that may provide extended operational cycles. Agencies should consider their specific needs and activities when selecting portable radio batteries.
>
> *Rated Capacity and Duty Cycle*—Manufacturers who provide batteries for portable radios usually present rated capacity and duty cycle information. Most batteries are rated on a duty cycle of 90/5/5, which means that the battery will be in standby mode 90 percent, transmitting 5 percent, and receiving 5 percent of the time. Higher transmit and receive percentages reflect higher capacity batteries. Batteries may also indicate the number of

cycles. A full cycle correlates to the life of the battery and is measured as full charge to discharge. If a battery states a rating of 1,100 cycles, it can be fully charged and discharged 1,100 times before the battery is considered depleted.

Intrinsically Safe—Some portable radio manufacturers who supply units to the public safety market provide radios and batteries that have been certified to work in dangerous, hazardous, or explosive environments. The ability to acquire intrinsically safe portable units is an important consideration for most fire and rescue-oriented departments, which may conduct operations in these extreme environments. A radio and battery that have been rated as intrinsically safe are specifically configured to limit the production of sparks or other electrical discharges.

Casing Materials—The materials used to construct the case of the battery are important to the overall life cycle of the unit. The more durable the material, the longer service life the unit may provide.

Relevant Features and Accessories—Relevant features and accessories to consider include the following:

External Speaker Jack—The portable radio should support an external speaker jack to allow connection of an ear bud speaker for alternative audio output. This is useful in covert operations or when broadcast of radio audio needs to be limited to the receiver only.

Accessories Connector—The provision of an accessories connector allows after-market products such as speaker/microphones, headsets, and self-contained breathing apparatus (SCBA) interfaces to be easily connected to the equipment. The lack of an accessories connector would require technicians or agencies to request manufacturers to create special interfaces for connections of these devices.

Vehicular Charger/Converter/Booster—These accessories for portable radio equipment can provide additional usability and flexibility for public safety agencies. A vehicular charger, coupled with proper battery types that do not generate memory, can keep portable radios charged and ready for service. Agencies can use rack-mounted chargers to maintain fully charged batteries for use during long incidents. Some manufacturers provide converter/booster units that accept the portable radio unit, provide input power, as well as boost the RF output power to a level similar to that of a mobile radio. Some agencies find that this arrangement works well for administrative personnel where there is no need for both a mobile and portable unit and the use of the radio is limited. This type of arrangement is not recommended for first-line or front-line equipment or personnel because of the harsh operational environment and the continual need to insert and remove the radio from the device.

2.2 Portable Radio Functional Specifications

Reliable wireless communications is essential for public safety agencies. The operating needs of public safety portable radio users necessitate equipment that performs consistently despite the extreme and varying conditions of the public safety operating environment. Functional radio features distinguish a portable radio's reliability and durability. Features such as channel capacity or RF output power can help users gauge the radio's capacity for reliable intra-agency wireless communications under public safety operating conditions. The criteria included in the following charts help identify the functional features for portable radios that correlate most to the demands of public safety agencies.

Table 2.2 Functional Specifications for Portable Radio Products

Vendor	Product	Analysis Considerations								
		Frequency Ranges (MHz)	Channel Capacity	Wide/Narrow Band Support (kHz)	MIL-STD 810 Test Procedures	Programming Support	RF Output Power (W)	Audio Output Power (mW)	Software Upgrade Support	User Defined Buttons/Knobs
Com-Net Ericsson	Cougar 400P	136-174; 400-530	10 Conventional channels	Wide – 20/25 Narrow – 12.5	High Temp; Low Temp; Blowing Rain; Humidity; Salt Fog; Blowing Dust; Blowing Sand; Shock	Yes (PC)	1-5 (VHF); 1-4 (UHF)	500	Yes	Yes (2 keys)
Com-Net Ericsson	EDACS Jaguar 700P	806-870	200+ Conventional channels	Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Blowing Rain; Humidity; Salt Fog; Blowing Dust; Vibration; Shock	Yes (PC)	.5-3	500	Yes	No
Com-Net Ericsson	ProVoice Jaguar 700P	806-870	200+ Conventional channels	Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Blowing Rain; Humidity; Salt Fog; Blowing Dust; Vibration; Shock	Yes (PC)	.5-3	500	Yes	No
Com-Net Ericsson	Panther 300P	450-488	6 Channels	Wide – 25 Narrow – 12.5	Dripping Rain; Humidity; Salt Fog; Blowing Dust; Shock	Yes (PC)	1-4	500	Yes	No
Com-Net Ericsson	Panther 400P	136-174; 400-470; 450-530	16 Channels	Wide – 25/30 Narrow – 12.5/15	High Temp; Low Temp; Blowing Rain; Humidity; Salt Fog; Blowing Dust; Blowing Sand; Shock	Yes (PC)	1-5 (VHF); 1-4 (UHF)	500	Yes	Yes (2 keys)
Com-Net Ericsson	Panther 500P	136-174; 403-512	16 Channels	Wide – 25/30 Narrow – 12.5/20	Low Pressure; High Temp (storage & op.); Low Temp (storage & op.); Solar Radiation; Temp Shock; Blowing Rain; Humidity; Salt Fog; Blowing Dust; Vibration; Shock; Transit Drop;	Yes (PC)	1-5 (VHF); 1-4 (UHF)	500	Yes	No
Com-Net Ericsson	Panther 600P	136-174; 400-530	100 Channels	Wide – 25/30 Narrow – 12.5/15	High Temp; Low Temp; Blowing Rain; Humidity; Salt Fog; Blowing Dust; Blowing Sand; Shock	Yes (PC)	1-5 (VHF); 1-4 (UHF)	500	Yes	Yes (2 keys)
Com-Net Ericsson	Panther 625P	136-174; 400-530	350 Channels	Wide – 25/30 Narrow – 12.5/15	High Temp; Low Temp; Blowing Rain; Humidity; Salt Fog; Blowing Dust; Blowing Sand; Shock	Yes (PC)	1-5 (VHF); 1-4 (UHF)	500	Yes	No
Datron	Guardian G25 RPV100	136-174	256 Channels	Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain/Blowing Rain; Humidity; Salt Fog; Dust and Sand; Vibration; Shock	NA	.1-5	500	NA	Yes (3 keys, toggle switch)

Vendor	Product	Analysis Considerations								
		Frequency Ranges (MHz)	Channel Capacity	Wide/Narrow Band Support (kHz)	MIL-STD 810 Test Procedures	Programming Support	RF Output Power (W)	Audio Output Power (mW)	Software Upgrade Support	User Defined Buttons/Knobs
EF Johnson	501x	136-174	256 Channels	Wide – 25/30 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain/Blowing Rain; Humidity; Salt Fog; Dust and Sand; Vibration; Shock	NA	1-5	500+	Yes	No
EF Johnson	504x	403-470; 450-512	256 Channels	Wide – 25/30 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain/Blowing Rain; Humidity; Salt Fog; Dust and Sand; Vibration; Shock	NA	1-5	500+	Yes	No
EF Johnson	508x	806-870	256 Channels	Wide – 25/30 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain/Blowing Rain; Humidity; Salt Fog; Dust and Sand; Vibration; Shock	NA	1-5	500+	Yes	No
EF Johnson	7780/7781	806-869	256 Channels	Wide only – 25	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain; Humidity; Salt Fog;; Vibration; Shock	Yes (type NA)	1-3	500+	Yes	Yes (6 buttons)
EF Johnson	Avenger SK-HM83 8160	806-869	16 Channels	Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain; Humidity; Salt Fog;; Vibration; Shock	Yes (PC)	1-3	500+	Yes	Yes (1 button)
EF Johnson	Avenger SK-HM93 8162	896-941	16 Channels	Narrow only – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain; Humidity; Salt Fog; Vibration; Shock	Yes (PC)	1-2.5	500+	Yes	Yes (1 button)
EF Johnson	Viking CM-HM/83 8585, 8586, 8587, 8588	806-869	154 Channels	Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	1.5-3	500	Yes	Yes (1 button)
Kenwood	TK-290	136-174	160 Channels	Wide – 25/30 Narrow – 12.5/15	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	1-5	500	Yes (Flash)	Yes (5 keys, toggle switch)

Vendor	Product	Analysis Considerations								
		Frequency Ranges (MHz)	Channel Capacity	Wide/Narrow Band Support (kHz)	MIL-STD 810 Test Procedures	Programming Support	RF Output Power (W)	Audio Output Power (mW)	Software Upgrade Support	User Defined Buttons/Knobs
Kenwood	TK-390	450-490	160 Channels	Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	1-5	500	Yes (Flash)	Yes (5 keys, toggle switch)
M/A-COM	Polaris P-801T	806-870	N/A	Wide – 25 Narrow – 12.5	N/A	Yes (PC)	.1-3	500	Yes	Yes (toggle switch)
Motorola	JT 1000	136-174; 403-470; 450-512	16 Channels	Wide – 25/30 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (User-defined)	1-5 (VHF); 1-4 (UHF)	500	Yes	Yes (# of keys N/A)
Motorola	HT 1000	136-174; 403-470; 450-512; 806-825; 851-870	16 Channels	VHF & UHF Wide – 25/30 Narrow – 12.5 800 MHz: Wide only – 25	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	1-5 (VHF); 1-4 (UHF); 3 (800 MHz)	500	Yes	Yes (3 side buttons, toggle switch)
Motorola	HT 1250	29.7-42; 35-50; 136-174; 403-470; 450-527;	128 Channels	Low Band VHF: Wide only – 20/25 VHF & UHF: Wide – 20/25/30 Narrow – 12.5/15	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	N/A	1-6 (VHF Low) 1-5 (VHF) 1-4 (UHF)	500	N/A	Yes (6 buttons)
Motorola	HT 1250·LS	403-470; 450-527	16 Conventional Channels	Wide – 20/25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	1-4	500	N/A	Yes (6 buttons)
Motorola	Digital Saber I	136-174; 403-470; 450-520; 806-870	32 Channels	VHF: Wide – 20/25/30 Narrow – 12.5 UHF & 800 MHz: Wide – 20/25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain & Blowing Rain; Humidity; Salt Fog; Dust; Vibration; Shock	N/A	1-5 (VHF) 1-4 (UHF) 1-3 (800 MHz)	500	Yes (FLASHport memory)	Yes (# N/A)
Motorola	Digital Saber II	136-174; 403-470; 450-520; 806-870	255 Channels	VHF: Wide – 20/25/30 Narrow – 12.5 UHF & 800 MHz: Wide – 20/25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain & Blowing Rain; Humidity; Salt Fog; Dust; Vibration; Shock	N/A	1-5 (VHF) 1-4 (UHF) 1-3 (800 MHz)	500	Yes (FLASHport memory)	Yes (# N/A)

Vendor	Product	Analysis Considerations								
		Frequency Ranges (MHz)	Channel Capacity	Wide/Narrow Band Support (kHz)	MIL-STD 810 Test Procedures	Programming Support	RF Output Power (W)	Audio Output Power (mW)	Software Upgrade Support	User Defined Buttons/Knobs
Motorola	Digital Saber III	136-174; 403-470; 450-520; 806-870	255 Channels	VHF: Wide – 20/25/30 Narrow – 12.5 UHF & 800 MHz: Wide – 20/25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain & Blowing Rain; Humidity; Salt Fog; Dust; Vibration; Shock	N/A	1-5 (VHF) 1-4 (UHF) 1-3 (800 MHz)	500	Yes (FLASHport memory)	Yes (# N/A)
Motorola	ASTRO XTS 3000 Model I	136-174; 403-470; 450-520; 806-870	48 Channels	VHF: Wide – 20/25/30 Narrow – 12.5 UHF & 800 MHz: Wide – 20/25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain & Blowing Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	1-5 (VHF) 1-4 (UHF) 3 (800 MHz)	500	Yes (FLASHport)	Yes (2 side buttons)
Motorola	ASTRO XTS 3000 Model II	136-174; 403-470; 450-520; 806-870	255 Channels	VHF: Wide – 20/25/30 Narrow – 12.5 UHF & 800 MHz: Wide – 20/25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain & Blowing Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	1-5 (VHF) 1-4 (UHF) 3 (800 MHz)	500	Yes (FLASHport)	Yes (2 side buttons, soft keys)
Motorola	ASTRO XTS 3000 Model III	136-174; 403-470; 450-520; 806-870	255 Channels	VHF: Wide – 20/25/30 Narrow – 12.5 UHF & 800 MHz: Wide – 20/25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Temp Shock; Rain & Blowing Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	1-5 (VHF) 1-4 (UHF) 3 (800 MHz)	500	Yes (FLASHport)	Yes (2 side buttons, soft keys)
Motorola	ASTRO XTS 3500 Model I	136-174; 450-520	48 Channels	VHF: Wide – 25/30 Narrow – 12.5 UHF: Wide – 25 Narrow – 12.5	Low Pressure; High Temp (storage); High Temp (operational); Low Temp (storage & operational); Solar Radiation; Temp Shock; Rain & Blowing Rain; Humidity; Salt Fog; Dust; Vibration; Shock; Leakage (immersion)	Yes (PC)	1-6 (VHF) 1-5 (UHF)	500	Yes (FLASHport)	Yes (2 side buttons, monitor button)

Vendor	Product	Analysis Considerations								
		Frequency Ranges (MHz)	Channel Capacity	Wide/Narrow Band Support (kHz)	MIL-STD 810 Test Procedures	Programming Support	RF Output Power (W)	Audio Output Power (mW)	Software Upgrade Support	User Defined Buttons/Knobs
Motorola	ASTRO XTS 3500 Model II	136-174; 450-520	255 Channels	VHF: Wide – 25/30 Narrow – 12.5 UHF: Wide – 25 Narrow – 12.5	Low Pressure; High Temp (storage); High Temp (operational); Low Temp (storage & operational); Solar Radiation; Temp Shock; Rain & Blowing Rain; Humidity; Salt Fog; Dust; Vibration; Shock; Leakage (immersion)	Yes (PC)	1-6 (VHF) 1-5 (UHF)	500	Yes (FLASHport)	Yes (2 side buttons, soft keys, monitor button)
Motorola	ASTRO XTS 3500 Model III	136-174; 450-520	255 Channels	VHF: Wide – 25/30 Narrow – 12.5 UHF: Wide – 25 Narrow – 12.5	Low Pressure; High Temp (storage); High Temp (operational); Low Temp (storage & operational); Solar Radiation; Temp Shock; Rain & Blowing Rain; Humidity; Salt Fog; Dust; Vibration; Shock; Leakage (immersion)	Yes (PC)	1-6 (VHF) 1-5 (UHF)	500	Yes (FLASHport)	Yes (2 side buttons, soft keys, monitor button)
Thales	Racal 25	136-174; 380-520; 800 band	256 Channels	Wide – 20/25/30 Narrow – 12.5	Shock; Vibration; Salt Fog; Humidity; Altitude; Sand & Dust; Blowing Rain	Yes (PC)	.1-5	500	Yes	Yes (3 side keys, toggle switch)
Vertex	VX-400	134-160; 148-174; 400-430; 450-485; 485-512	16 Channels	VHF: Wide – 30 Narrow – 15 UHF: Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	.1-5	500	Yes	No
Vertex	VX-510	29.7-38; 38-50; 148-174; 450-488	32 Channels	Low VHF: Wide only – 20 VHF: Wide – 30 Narrow – 15 UHF: Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	1-5	500	Yes	No
Vertex	VX-800	148-174; 450-485	200 Channels	Wide – 25/30 Narrow – 12.5/15	Low Pressure; High Temp; Low Temp; Solar Radiation; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	.25-5 W	500	Yes	Yes (2 soft keys, toggle switch)

Vendor	Product	Analysis Considerations								
		Frequency Ranges (MHz)	**Channel Capacity**	**Wide/Narrow Band Support (kHz)**	**MIL-STD 810 Test Procedures**	**Programming Support**	**RF Output Power (W)**	**Audio Output Power (mW)**	**Software Upgrade Support**	**User Defined Buttons/Knobs**
Vertex	VX-900	134-160; 148-174; 400-430; 450-485; 485-512	512 Channels	VHF: Wide – 25/30 Narrow – 12.5 UHF: Wide only – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	.25-5	700	Yes	Yes (8 soft keys, toggle switch)

2.2.1 Explanation of Functional Specifications Criteria for Portable Radios

Frequency Ranges—This criterion defines frequency ranges/bands supported by the equipment. When selecting products it is important to ensure that the device operates on the frequency band used within a system.

Channel Capacity—This criterion identifies the maximum number of channels hosted by the portable radio. The capacity of a unit is an important consideration to ensure that the equipment can effectively communicate on all of a jurisdiction's talk paths, as well as mutual-aid channels or surrounding agency's systems.

Wideband and/or Narrowband Capable—The radio equipment's ability to support future channel separation minimizes premature replacement requirements. Presently, most units should support wideband channel spacing (25 kHz) and narrowband requirements (12.5 kHz).

MIL-STD 810 Test Procedures—The radio's compliance to certain tests included in MIL-STD 810 standard suite ensures basic environmental and physical durability. Compliance is imperative for public safety two-way radio users whose operating environments often involve extreme conditions. The particular MIL-STD 810 tests applied to the radio vary by vendor.

Programming Support—The method and manner in which the radio feature/functions are established within the radio device influences how easily agency personnel can program their radios. PC software and hardware is usually more accessible to public safety agencies than other proprietary methods of radio programming.

RF Output Power—Sufficient RF power output of the device is essential to successful communications. If the device does not generate sufficient RF output, the radio will not communicate with the system infrastructure and the communication will be lost. Agencies should always consider the operational environments of the radio equipment when making decisions regarding power output to ensure that sufficient output is achieved within licensed limits.

Audio Output Power—The amount of audio output produced by the radio equipment is extremely important to the public safety community. Public safety personnel operate in a variety of environments, some of which produce high ambient noise. The ability of the radio device to produce high levels of audio output with limited distortion may enhance operations.

Software Upgrade Support—The software/firmware within the radio that define the capabilities of the radio should be upgradeable. This capability helps to minimize premature replacement when new versions are developed. In addition, synthesized equipment does not require the replacement of crystals or other firmware components in order to change the features of the device.

User-Defined Buttons/Knobs—The ability for agencies to program certain radio control buttons/knobs and switches to their requirements enhances usability of the equipment. This capability provides additional flexibility so that agencies themselves can decide what features/functions are assigned to buttons, switches, knobs, and other controls on the radio.

2.3 Portable Radio Interoperability Specifications

Interagency communications remains a critical issue for public safety agencies. Proprietary and non-proprietary LMR system features often obstruct seamless interagency communications and impede interagency coordination. Certain portable radio features, however, can help improve interagency wireless communications regardless of the proprietary and system features at hand. Development of some of these features continues, as demonstrated by the ongoing TIA/EIA 102 standards development process, while others, such as user-defined scanning or encryption, are widely employed by the public safety LMR community. The following charts provide an analysis of portable radios features most relevant to achieving interoperable wireless communications in the public safety LMR marketplace.

Table 2.3 Interoperability Specifications for Portable Radio Products

Vendor	Product	Analysis Considerations											
		Analog/ Digital Capable	Cross/Multi-Band Support	Conventional/ Trunking Support	Encryption Specifications		Over-the-Air Programming	Radio-to-Radio Cloning Support	Scanning Specifications		TIA 102 Standards		
					Encryption Capable	OTAR Support			User Defined	Between Systems/Modes	CAI	IMBE	DES Encryption
Com-Net Ericsson	Cougar 400P	Analog only	No	Conventional & Trunked (MP1327 trunking)	No	No	Yes (Dynamic regroup)	N/A	N/A	N/A	No	No	No
Com-Net Ericsson	EDACS Jaguar 700P	Analog & Digital	No	Conventional & Trunked (EDACS)	Yes (Aegis DES, Aegis VGE)	No	Yes	Yes	Yes	N/A	No	No	No
Com-Net Ericsson	ProVoice Jaguar 700P	Analog & Digital (ProVoice Digital)	No	Conventional & Trunked (EDACS)	Yes (ProVoice DES, Aegis DES, Aegis VGE)	No	Yes	N/A	Yes	Yes	No	Yes	No
Com-Net Ericsson	Panther 300P	Analog only	No	Conventional only	No	No	No	Yes	No	No	No	No	No
Com-Net Ericsson	Panther 400P	Analog only	No	Conventional only	No	No	No	Yes	No	No	No	No	No
Com-Net Ericsson	Panther 500P	Analog only	No	Conventional only	No	No	No	Yes	Yes	No	No	No	No
Com-Net Ericsson	Panther 600P	Analog only	No	Conventional only	No	No	No	Yes	N/A	N/A	No	No	No
Com-Net Ericsson	Panther 625P	Analog only	No	Conventional only	No	No	No	Yes	N/A	N/A	No	No	No
Datron	Guardian G25 MPV100	Analog & Digital	No	Conventional only	Yes (wide-band analog SBCF DES)	Optional	N/A	Yes	Yes	N/A	Yes	Yes	Optional
EF Johnson	501X	Analog & Digital	No	Conventional & Trunking (SMARTNET II and SmartZone)	Yes (SecureNet DES, DES-XL)	Yes	N/A	N/A	Yes	Yes	Yes	Yes	Optional
EF Johnson	504X	Analog & Digital	No	Conventional & Trunking (SMARTNET II and SmartZone)	Yes (SecureNet DES, DES-XL)	Yes	N/A	N/A	Yes	Yes	Yes	Yes	Optional
EF Johnson	508X	Analog & Digital	No	Conventional & Trunking (SMARTNET II and SmartZone)	Yes (SecureNet DES, DES-XL)	Yes	N/A	N/A	Yes	Yes	Yes	Yes	Optional

Vendor	Product	Analysis Considerations											
		Analog/ Digital Capable	Cross/Multi-Band Support	Conventional/ Trunking Support	Encryption Specifications		Over-the-Air Programming	Radio-to-Radio Cloning Support	Scanning Specifications		TIA 102 Standards		
					Encryption Capable	OTAR Support			User Defined	Between Systems/Modes	CAI	IMBE	DES Encryption
EF Johnson	7780/7781	Analog only	No	Conventional & Trunking (SMARTNET II and SmartZone)	No	No	No	No	Yes	Yes	No	No	No
EF Johnson	Avenger SK-HM83 8160	Analog only	No	Conventional & Trunking (MultiNet II and LTR)	No	No	No	Yes	Yes	Yes	No	No	No
EF Johnson	Avenger SK-HM93 8162	Analog only	No	Conventional & Trunking (MultiNet II and LTR)	No	No	No	Yes	Yes	Yes	No	No	No
EF Johnson	Viking CM-HM/83 8585, 8586, 8587, 8588	Analog only	No	Conventional & Trunking (MultiNet II, MultiNet, and LTR)	No	No	No	NA	Yes	Yes (Between systems only)	No	No	No
Kenwood	TK-290	Analog only	No	Conventional only	Yes (types N/A)	No	N/A	Yes	Yes	Yes (Between systems only)	No	No	No
Kenwood	TK-390	Analog only	No	Conventional only	Yes (types N/A)	No	N/A	Yes	Yes	Yes (Between systems only)	No	No	No
M/A-COM	Polaris P-801T	Analog & Digital (OpenSky)	No	Conventional and Trunking	Yes (types N/A)	N/A	Yes	N/A	Yes	N/A	No	No	No
Motorola	JT 1000	Analog only	No	Conventional only	N/A	N/A	No	Yes	Yes	Yes (Between systems only)	No	No	No
Motorola	HT 1000	Analog only	No	Conventional only	N/A	N/A	No	Yes	Yes	Yes (Between systems only)	No	No	No
Motorola	HT 1250	Analog only	No	Conventional only	N/A	N/A	No	N/A	Yes	Yes	No	No	No
Motorola	HT 1250·LS	Analog only	No	Conventional and Trunking (LTR)	No	No	No	N/A	Yes	Yes	No	No	No
Motorola	Digital Saber I	Analog & Digital (ASTRO)	No	Conventional only	Yes (ASTRO and SECURNET)	Yes	Yes	N/A	N/A	N/A	Yes	Yes	No
Motorola	Digital Saber II	Analog & Digital (ASTRO)	No	Conventional only	Yes (ASTRO and SECURNET)	Yes	Yes	N/A	N/A	N/A	Yes	Yes	No
Motorola	Digital Saber III	Analog & Digital (ASTRO)	No	Conventional only	Yes (ASTRO and SECURNET)	Yes	Yes	N/A	N/A	N/A	Yes	Yes	No

Vendor	Product	Analysis Considerations											
		Analog/ Digital Capable	Cross/Multi-Band Support	Conventional/ Trunking Support	Encryption Specifications		Over-the-Air Programming	Radio-to-Radio Cloning Support	Scanning Specifications		TIA 102 Standards		
					Encryption Capable	OTAR Support			User Defined	Between Systems/Modes	CAI	IMBE	DES Encryption
Motorola	ASTRO XTS 3000 Model I	Analog & Digital (ASTRO)	No	Conventional & Trunking	Yes (ASTRO and SECURNET)	Yes	Yes	N/A	N/A	N/A	Yes	Yes	No
Motorola	ASTRO XTS 3000 Model II	Analog & Digital (ASTRO)	No	Conventional & Trunking	Yes (ASTRO and SECURNET)	Yes	Yes	N/A	N/A	N/A	Yes	Yes	No
Motorola	ASTRO XTS 3000 Model III	Analog & Digital (ASTRO)	No	Conventional & Trunking	Yes (ASTRO and SECURNET)	Yes	Yes	N/A	N/A	N/A	Yes	Yes	No
Motorola	ASTRO XTS 3500 Model I	Analog & Digital (ASTRO)	No	Conventional & Trunking	Yes (ASTRO and SECURNET)	Yes	Yes	N/A	N/A	N/A	Yes	Yes	No
Motorola	ASTRO XTS 3500 Model II	Analog & Digital (ASTRO)	No	Conventional & Trunking	Yes (ASTRO and SECURNET)	Yes	Yes	N/A	N/A	N/A	Yes	Yes	No
Motorola	ASTRO XTS 3500 Model III	Analog & Digital (ASTRO)	No	Conventional & Trunking	Yes (ASTRO and SECURNET)	Yes	Yes	N/A	N/A	N/A	Yes	Yes	No
Thales	Racal 25	Analog & Digital (P25 CAI digital)	No	Yes (trunking support with software upgrade)	Yes (analog & digital DES)	Yes	No	Yes	Yes	Yes (Between systems only)	Yes	No	Yes
Vertex	VX-400	Analog only	No	Yes (trunking support with software upgrade)	Yes (Voice inversion)	No	No	Yes	Yes	N/A	No	No	No
Vertex	VX-510	Analog only	No	Yes (trunking support with software upgrade)	Yes (Voice inversion)	No	No	Yes	Yes	N/A	No	No	No
Vertex	VX-800	Analog only	No	Yes (trunking support with software upgrade)	Yes (Voice inversion)	No	No	Yes	Yes	Yes	No	No	No
Vertex	VX-900	Analog only	No	Yes (trunking support with software upgrade)	Yes (Encryption pager unit accessory)	No	No	Yes	Yes	Yes	No	No	No

2.3.1 Explanation of Interoperability Specifications Criteria for Portable Radios

Analog/Digital Capable—The radio equipment's ability to support multiple protocols enhances its potential for interoperability as well as backward capability to older legacy systems. Digital support is of paramount importance moving forward because most manufacturers are moving toward support of digital standards to enhance spectrum efficiency.

Crossband/Multiband Support—The ability of a radio to operate on multiple bands, such as VHF/UHF or 700/800 MHz, enhances opportunities to communicate across systems with one radio device. Support for multiple bands or crossband communications increases opportunities for interoperability.

Conventional/Trunking Support—This criterion usually applies to trunking-type radio equipment. The ability of the radio equipment to operate in a conventional mode is important so that the unit can communicate with conventional radio systems and on established national mutual-aid channels. Dual support provides the ability to communicate in trunking modes and conventional modes and may enhance interoperability of the radio device.

Encryption Specifications—Encryption specifications to consider include the following:

> *Encryption Capable*—Many public safety agencies need to restrict access to voice communications over RF. To accomplish this, radio vendors have incorporated different encryption capabilities within the equipment. In order to operate, encryption capabilities must also be present within the system's infrastructure. Agencies should assess their encryption requirements and select equipment compatible with the standard supported. Interoperability can be affected by the use of encryption. If an agency decides against the incorporation of encryption and neighboring agencies use encryption, interoperability may not be possible.
>
> *OTAR Support*—The use of encryption also requires a degree of administration of radio equipment in order to maintain the status of encryption keys. The ability to update or modify keys assigned to a device over radio frequency substantially reduces the administrative effort. Agencies deploying a large number of encryption-capable radios should consider incorporating OTAR support. The OTAR capability can also benefit interoperability between agencies because keys could be reprogrammed "over the air" quickly to allow interagency communications.

Over-the-Air Programming Support—This capability allows for wireless manipulation of the radio's programming. This ability substantially reduces the administration time required to reprogram equipment when changes to features or functions occur. (This capability would not include dynamic regrouping of the radio through a system management console.)

Radio-to-Radio Cloning—This equipment feature allows a unit's programming to be copied to another same-type unit through a data cable attachment between the two units. This capability can reduce administration time required to program units.

Channel Scanning Support—Channel scanning support to consider includes the following:

User Defined—This capability allows users to program certain characteristics and personal preferences for scanning of channels/modes.

Between Systems/Modes—Usually found in trunking technologies, this capability allows scanning of talk paths between different systems that are defined in a radio. Therefore, a scan list is not limited to only the user's agency or department but may include other agencies and departments. This capability can have a positive impact on interoperability.

TIA/EIA 102 Standards—TIA/EIA 102 standards to consider include the following:

CAI—The presence of the CAI standard, as specified by the TIA/EIA 102 suite of standards, ensures basic interoperability among all TIA/EIA 102-compliant digital subscriber units.

IMBE—The IMBE vocoder technology is recognized as the TIA/EIA 102 vocoder standard for voice-to-digital conversion. Similar to CAI, IMBE is a TIA/EIA 102 system standard providing a basic level of interoperability among all TIA/EIA 102-compliant radios.

DES Encryption—The Data Encryption Standard (DES) is the service standard for encrypted voice and data communications in accordance with the TIA/EIA 102 suite of standards. Uniform encryption technology can play a critical role in achieving interoperable communications among neighboring systems. Both Triple DES and Advanced Encryption Standard (AES) are now being considered as part of Phase II of the TIA/EIA 102 standards development process, which is discussed in Appendix D.[1]

[1] Triple DES serves as an advanced form of DES and has been endorsed by the National Institute of Standards and Technology (NIST). AES continues to be developed under NIST guidance and is intended to serve as a solution to the shortfalls of DES and Triple DES.

3.0 MOBILE RADIO EQUIPMENT SPECIFICATIONS

Criteria sets similar to those applied to portable radios can also be effectively applied to mobile radio products. For public safety personnel, mobile radios are mounted in vehicles, such as police cruisers or fire engines, and serve as a high-powered communications link for personnel arriving at the scene of an incident or reporting critical information. To examine a mobile radio's practical use for public safety agencies, it is important to first identify the unique physical, functional, and interoperability criteria reflecting the needs of public safety mobile radio users and then match these criteria with vendor offerings. Similar in structure to the previous section, this section provides analytical charts relating to the physical, functional, and interoperability features of mobile radios followed by criteria explanations. Each chart matches criteria with specifications of mobile radio products available in the public safety LMR marketplace today.

The information included for each mobile radio product was extracted from specification sheets supplied by the respective vendor. It is important to note that, in accordance with the PSWN Program's requests, *the vendors* have identified mobile radio products listed in the tables as those commonly sold to the public safety LMR community. In cases where the criteria data was not available or apparent from the product's specification sheet, "N/A" (not applicable) is recorded. Copies of the specification sheets provided by the vendors are included in Appendix I.

3.1 Mobile Radio Physical Specifications

A mobile radio's physical features determine its feasible use for public safety agencies. Features such as the radio's weight or ability to support a remote control head can help public safety personnel use the mobile radio effectively and efficiently while in a vehicle. The criteria listed in the following charts correlate to the physical features of mobile radios most applicable to the public safety operating environment and user needs.

Table 3.1 Physical Specifications for Mobile Radio Products

Vendor	Product	Analysis Considerations								
		Dimensions (W" x H" x D")	Weight	DTMF Keyboard	External Speaker Jack	Accessories Connector	LCD Display/LED Indicator	Oversized Knobs/ Switches	Remote Control Head Support	Dual Control Head Support
Com-Net Ericsson	Panther 200M	5.9 x 1.97 x 7.28 (minus knobs)	2.65 lbs.	Microphone (optional)	Yes	Yes	LED	No	No	No
Com-Net Ericsson	Panther 300M	7.05 x 2.2 x 4.45 (minus knobs)	2.45 lbs.	Microphone (optional)	Yes	Yes	LED	No	No	No
Com-Net Ericsson	Panther 400M	5.9 x 1.97 x 7.28 (minus knobs)	2.65 lbs.	Microphone (optional)	Yes	Yes	LED	No	No	No
Com-Net Ericsson	Panther 600M	5.9 x 1.97 x 7.28 (minus knobs)	2.65 lbs.	Yes	Yes	Yes	LCD/LED	No	Yes	No
Com-Net Ericsson	Conventional Orion (Low Band)	6.9 x 2.0 x 11.1 (minus knobs)	N/A	Yes	Yes	Yes	LED	Yes	Yes	Yes
Com-Net Ericsson	Conventional Orion (VHF, UHF, 800)	6.9 x 2.0 x 9.3 (minus knobs)	N/A	Yes	Yes	Yes	LED	Yes	Yes	Yes
Com-Net Ericsson	EDACS Orion (900)	6.9 x 2.0 x 9.3 (minus knobs)	N/A	Yes	Yes	Yes	LED	Yes	Yes	Yes
Com-Net Ericsson	EDACS Orion (VHF, UHF, 800)	6.9 x 2.0 x 9.3 (minus knobs)	N/A	Yes	Yes	Yes	LED	Yes	Yes	Yes
Com-Net Ericsson	ProVoice Orion (800)	6.9 x 2.0 x 9.3 (minus knobs)	N/A	Yes	Yes	Yes	LED	Yes	Yes	No
Datron	Guardian G25RMV100	7.1 x 2.75 x 5.5	5 lbs.	Microphone (optional)	Yes	N/A	LCD/LED	Yes	No	No
EF Johnson	531X	7.15 x 2.1 x 8.3	5.25 lbs.	Microphone (optional)	Yes	Yes	LCD	Yes	Yes	No
EF Johnson	531X (P25)	7.15 x 2.1 x 8.3	5.25 lbs.	Microphone (optional)	Yes	Yes	LCD	Yes	Yes	No
EF Johnson	532X	7.15 x 2.1 x 13.75	8.38 lbs.	Microphone (optional)	Yes	Yes	LCD	Yes	Yes	No
EF Johnson	538X	7.15 x 2.1 x 8.3	5.25 lbs.	Microphone (optional)	Yes	Yes	LCD	Yes	Yes	No
EF Johnson	538X (P25)	7.15 x 2.1 x 8.3	5.25 lbs.	Microphone (optional)	Yes	Yes	LCD	Yes	Yes	No
EF Johnson	9883	6.0 x 2.1 x 7.5	3.5 lbs.	Microphone	Yes	Yes	LCD	Yes	Yes	No
Kenwood	TK-690H	7 x 2.25 x 12.75	7.9 lbs.	Microphone (optional)	Yes	Yes	LCD/LED	No	Yes	Yes
Kenwood	TK-790H	7 x 2.25 x 12.75	7.9 lbs.	Microphone (optional)	Yes	Yes	LCD/LED	No	Yes	Yes

Vendor	Product	Analysis Considerations								
		Dimensions (W" x H" x D")	Weight	DTMF Keyboard	External Speaker Jack	Accessories Connector	LCD Display/LED Indicator	Oversized Knobs/ Switches	Remote Control Head Support	Dual Control Head Support
Kenwood	TK-790	7 x 2.25 x 7.75	5 lbs.	Microphone (optional)	Yes	Yes	LCD/LED	No	Yes	Yes
Kenwood	TK-890H	7 x 2.25 x 12.75	7.9 lbs.	Microphone (optional)	Yes	Yes	LCD/LED	No	Yes	Yes
Kenwood	TK-890	7 x 2.25 x 7.75	5 lbs.	Microphone (optional)	Yes	Yes	LCD/LED	No	Yes	Yes
M/A-COM	Gemini M-803	7.125 x 2.375 x 9.25	6 lbs.	No	No	Yes	LCD	Yes	Yes	Yes (up to 6)
M/A-COM	Mercury M-801	7 x 2 x 8.5	6 lbs.	No	No	Yes	LCD	Yes	No	No
Motorola	ASTRO Spectra W3	2.4 x 5.4 x 1.2 (remote)	6.1 lbs.	Yes	Yes	Yes	LCD	No	Yes	No
Motorola	ASTRO Spectra W4	7.1 x 2.0 x 8.6	6.1 lbs.	No	Yes	Yes	LCD	Yes	Yes	No
Motorola	ASTRO Spectra W5	7.1 x 2.0 x 8.6	6.1 lbs.	No	Yes	Yes	LCD	No	Yes	No
Motorola	ASTRO Spectra W7	7.1 x 2.0 x 8.6	6.1 lbs.	Yes	Yes	Yes	LCD	No	Yes	No
Motorola	ASTRO Spectra W9	6.5 x 3.4 x 1.7 (remote)	6.1 lbs.	Yes	Yes	Yes	LCD	No	Yes	No
Motorola	LCS 2000	6.61 x 1.73 x 5.67	2.67 lbs.	No	Yes	Yes	LCD/LED	No	No	No
Motorola	Spectra A5	7.1 x 2.0 x 8.6	5.5 lbs.	No	Yes	Yes	LCD/LED	No	Yes	No
Motorola	Spectra A7	7.1 x 2.0 x 8.6	5.5 lbs.	Yes	Yes	Yes	LCD/LED	No	Yes	No
Motorola	Spectra A9	7.1 x 2.0 x 8.6	5.5 lbs.	Yes	Yes	Yes	LCD/LED	No	Yes	No
Vertex	VX-2000	6.25 x 1.5 x 4.25	1.9 lbs.	Microphone (optional)	Yes	Yes	LED	No	No	No
Vertex	VX-3000	6.3 x 1.6 x 6.3	3 lbs.	Microphone (optional)	Yes	Yes	LCD/LED	No	No	No
Vertex	VX-4000	7 x 2.4 x 7.7	4.9 lbs.	Microphone (optional)	Yes	Yes	LCD	No	Yes	Yes

3.1.1 Explanation of Physical Specifications Criteria for Mobile Radios

Dimensions—The dimensions of the mobile radio dictates the available locations where the radio can be placed within a vehicle.

Weight—The weight of the radio is important, especially when considering alternative mounting systems or locations such as overhead consoles. The mounting location must be able to support the radio weight securely, taking into account both routine and emergency operations of the vehicle.

DTMF Keyboard**—**The inclusion of a dual-tone multi-frequency (DTMF) keypad provides the mobile radio the ability to generate audible tones for signaling applications and telephone interconnection to the PSTN. The system infrastructure must support interconnect features to allow telephone calls to be completed.

External Speaker Jack—The mobile radio should support an external speaker jack to allow connection of a larger, more capable speaker to provide better, non-distorted audio output. The speaker jack provides additional flexibility when choosing mounting locations for the radio equipment.

Accessories Connector**—**The provision of an accessories connector allows after-market products such as intercom systems, headsets, and data terminals to be easily connected to the equipment. The lack of an accessories connector would require technicians to create special interfaces for connections of these devices.

LCD/LED Indicators**—**The radio may use both types of indicators for certain functions and displays incorporated in the device. LCDs usually have a user-activated "backlight" source to illuminate the display in darkness. A light emitting diode (LED) display usually has controls to limit the amount of light produced. Agencies should understand how these displays operate and be aware that the light output can be restricted when required for personnel safety.

Oversized Knobs/Switches**—**There should be sufficient separation between the controls on the device to allow for easy manipulation and operation. In addition, the controls should be oversized so that they may be easily and effectively manipulated by personnel wearing gloves or other protective gear.

Remote Control Head—A control head assembly that can be placed away from the actual radio can be beneficial for installation. This type of device provides more flexibility for the installers as well as potentially enhancing safety by not requiring the radio to be mounted within the passenger compartment.

Dual Control Head**—**For some public safety agencies, there is a need to have two or more control head assemblies for a mobile radio. This capability allows the radio to be controlled from different points in the public safety vehicle. Dual control heads are common on fire trucks and EMS vehicles.

3.2 Mobile Radio Functional Specifications

Reliable mobile radios are essential for public safety agencies. Functional radio features distinguish the reliability and durability of mobile radios. Features such as channel capacity or primary input power can help users gauge the mobile radio's capacity for reliable intra-agency wireless communications among personnel deployed in an agency's fleet of vehicles. The criteria included in the following charts analyze the functional features of mobile radios that most closely correspond to the demands of public safety agencies.

Table 3.2 Functional Specifications for Mobile Radio Products

Vendor	Product	Analysis Considerations									
		Frequency Ranges (MHz)	Channel Capacity	Wide/Narrow Band Support (kHz)	MIL-STD 810 Test Procedures	Programming Support	Primary Input Power	RF Output Power (W)	Audio Output Power (W)	Software Upgrade Support	User Defined Button/ Knobs
Com-Net Ericsson	Panther 200M	136-174; 400-470; 450-520	4 Channels	Wide – 25/30 Narrow – 12.5/15	Humidity; Vibration; Shock	Yes (PC)	13.6 VDC	5 - 25	4 (internal) 4 (external)	No	No
Com-Net Ericsson	Panther 300M	450-488	6 Channels	Wide – 25/30 Narrow – 12.5/15	Salt Fog; Blowing Dust; Vibration; Shock	Yes (PC)	13.6 VDC	20 – 40	5 (internal) 10 (external)	No	No
Com-Net Ericsson	Panther 400M	136-174; 400-470; 450-520	24 Channels	Wide – 25/30 Narrow – 12.5/15	Humidity; Vibration; Shock	Yes (PC)	13.6 VDC	5 - 25	4 (internal) 4 (external)	No	Yes (2 keys)
Com-Net Ericsson	Panther 600M	136-174; 400-470; 450-520	100 Channels	Wide – 25/30 Narrow – 12.5/15	Humidity; Vibration; Shock	Yes (PC)	13.6 VDC	5 - 25	4 (external)	No	No
Com-Net Ericsson	Conventional Orion (Low Band)	29-42; 35-50	192 Channels	Wide only – 25/30	High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	12 VDC	60, 110	15 (external) 12 (with remote cable)	Yes	Yes
Com-Net Ericsson	Conventional Orion (VHF, UHF, 800)	136-153; 150-174; 403-440; 440-470; 470-512; 806-825; 851-870	192 Channels 800 Groups	Wide – 25/30 Narrow – 12.5 (UHF, VHF only)	High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	12 VDC	50, 110 (VHF); 40, 100 (UHF); 12, 35 (800)	15 (external)	Yes	Yes
Com-Net Ericsson	EDACS Orion (900)	896-902; 935-941	192 Channels 800 Groups	Wide – 25/30 Narrow – 12.5/15	High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	12 VDC	12, 30	15 (external)	Yes	Yes
Com-Net Ericsson	EDACS Orion (VHF, UHF, 800)	136-153; 150-174; 403-440; 440-470; 470-512; 806-825; 851-870	192 Channels 800 Groups	Wide – 25/30 (in VHF and UHF) Narrow – 12.5	High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	12 VDC	50, 110 (VHF); 40-100 (UHF); 12, 35 (800)	15 (external)	Yes	Yes
Com-Net Ericsson	ProVoice Orion (800)	800-825; 851-870	192 Channels 800 Groups	Wide – 25/30 Narrow – 12.5/15	High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	12 VDC	12, 35	15 (external)	Yes	Yes

Vendor	Product	Analysis Considerations									
		Frequency Ranges (MHz)	Channel Capacity	Wide/Narrow Band Support (kHz)	MIL-STD 810 Test Procedures	Programming Support	Primary Input Power	RF Output Power (W)	Audio Output Power (W)	Software Upgrade Support	User Defined Button/ Knobs
Datron	Guardian G25RMV100	136-174	256 Channels	Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Solar Radiation	Yes (PC)	13.6 VDC	20 – 50	5 (internal) 10 (external)	Yes	Yes (3 keys. 1 toggle switch)
EF Johnson	531X	136-174	256 Channels	Wide – 25/30 Narrow – 12.5/15	Low Pressure; High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	13.6 VDC	10 – 50	12	Yes	No
EF Johnson	531X (P25)	136-174	256 Channels	Wide – 25/30 Narrow – 12.5/15	Low Pressure; High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	13.6 VDC	10 – 50	12	Yes	No
EF Johnson	532X	136-162; 146-174	256 Channels	Wide – 25/30 Narrow – 12.5/15	Low Pressure; High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	13.6 VDC	50 – 100	12	Yes	No
EF Johnson	538X	806-870	256 Channels	Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	13.6 VDC	10 – 35	12	Yes	No
EF Johnson	538X (P25)	806-870	256 Channels	Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	13.6 VDC	10 – 35	12	Yes	No
EF Johnson	9883	806-824 (Tx); 851-869 (Tx/Rx)	256 Channels	Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Solar Radiation	Yes (PC)	13.6 VDC	2-15/10-30	3 (internal) 5 (external)	Yes	No
Kenwood	TK-690H	29.7-37; 35-43; 40-50	160 Channels	Wide – 20	Low Pressure; High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	13.4 VDC	45 - 110	13	Yes	Yes (7-13 keys)

Vendor	Product	Analysis Considerations									
		Frequency Ranges (MHz)	Channel Capacity	Wide/Narrow Band Support (kHz)	MIL-STD 810 Test Procedures	Programming Support	Primary Input Power	RF Output Power (W)	Audio Output Power (W)	Software Upgrade Support	User Defined Button/ Knobs
Kenwood	TK-790H	148-174	160 Channels	Wide – 25/30 Narrow – 12.5/15	Low Pressure; High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	13.4 VDC	45 - 110	13	Yes	Yes (7-13 keys)
Kenwood	TK-790	148-174; 136-156	160 Channels	Wide – 25/30 Narrow – 12.5/15	Low Pressure; High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	13.6 VDC	5 - 45	13	Yes	Yes (7-13 keys)
Kenwood	TK-890H	450-480	160 Channels	Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	13.4 VDC	40 - 100 40 – 75 (in 470-480 MHz)	13	Yes	Yes (7-13 keys)
Kenwood	TK-890	450-490; 480-512; 403-430	160 Channels	Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	13.6 VDC	5 – 40	13	Yes	Yes (7-13 keys)
M/A-COM	Gemini M-803	SMR 806-821, 851-866; NPSPAC 821-824, 866-869	256 Channels	Narrow – 12.5	Low Pressure; High Temp; Low Temp; Temp Shock; Vibration; Shock; Humidity; Dust; Salt Fog; Driven Rain; Solar Radiation	Yes (PC)	12-17 VDC	15	10	Yes	No
M/A-COM	Mercury M-801	SMR 806-821, 851-866; NPSPAC 821-824, 866-869	256 Channels	Wide – 25 Narrow – 12.5	N/A	Yes (PC)	12 – 16 VDC	100 mW – 15 W	5	Yes	No
Motorola	ASTRO Spectra W3	136-162; 146-174; 403-433; 438-470; 450-482; 482-512; 806-824; 851-870	255 Channels	Wide – 25/30 Narrow – 12.5	Vibration; Shock; Dust; Salt Fog; Driven Rain	Yes (PC)	13.8 VDC	10 – 110	5 – 10	Yes	Yes

Vendor	Product	Analysis Considerations									
		Frequency Ranges (MHz)	Channel Capacity	Wide/Narrow Band Support (kHz)	MIL-STD 810 Test Procedures	Programming Support	Primary Input Power	RF Output Power (W)	Audio Output Power (W)	Software Upgrade Support	User Defined Button/ Knobs
Motorola	ASTRO Spectra W4	136-162; 146-174; 403-433; 438-470; 450-482; 482-512; 806-824; 851-870	128 Channels	Wide – 25/30 Narrow – 12.5	Vibration; Shock; Dust; Salt Fog; Driven Rain	Yes (PC)	13.8 VDC	10 – 110	5 – 10	Yes	Yes
Motorola	ASTRO Spectra W5	136-162; 146-174; 403-433; 438-470; 450-482; 482-512; 806-824; 851-870	128 Channels	Wide – 25/30 Narrow – 12.5	Vibration; Shock; Dust; Salt Fog; Driven Rain	Yes (PC)	13.8 VDC	10 – 110	5 – 10	Yes	Yes
Motorola	ASTRO Spectra W7	136-162; 146-174; 403-433; 438-470; 450-482; 482-512; 806-824; 851-870	255 Channels	Wide – 25/30 Narrow – 12.5	Vibration; Shock; Dust; Salt Fog; Driven Rain	Yes (PC)	13.8 VDC	10 – 110	5 – 10	Yes	Yes
Motorola	ASTRO Spectra W9	136-162; 146-174; 403-433; 438-470; 450-482; 482-512; 806-824; 851-870	255 Channels	Wide – 25/30 Narrow – 12.5	Vibration; Shock; Dust; Salt Fog; Driven Rain	Yes (PC)	13.8 VDC	10 – 110	5 – 10	Yes	Yes
Motorola	LCS 2000	806-821; 821-824; 896-902; 935-941	90 Channels	Wide – 25 (800 MHz) Narrow – 12.5 (900 MHz)	Low Pressure; High Temp; Low Temp; Temp Shock; Shock; Dust	Yes (PC)	13.8 VDC	10 – 15	4, 7.5 (optional)	Yes	No
Motorola	Spectra A5	806, 824, 851-869, 896-902 (Tx); 851-869, 935-941 (Rx)	128 Channels	Wide – 25 (800 MHz) Narrow – 12.5 (900 MHz)	Vibration; Shock; Dust; Salt Fog; Driven Rain	Yes (PC)	13.8 VDC	4 - 35	5 – 10	No	Yes
Motorola	Spectra A7	806, 824, 851-869, 896-902 (Tx); 851-869, 935-941 (Rx)	128 Channels	Wide – 25 (800 MHz) Narrow – 12.5 (900 MHz)	Vibration; Shock; Dust; Salt Fog; Driven Rain	Yes (PC)	13.8 VDC	4 - 35	5 – 10	No	Yes

Vendor	Product	Analysis Considerations									
		Frequency Ranges (MHz)	Channel Capacity	Wide/Narrow Band Support (kHz)	MIL-STD 810 Test Procedures	Programming Support	Primary Input Power	RF Output Power (W)	Audio Output Power (W)	Software Upgrade Support	User Defined Button/ Knobs
Motorola	Spectra A9	806, 824, 851-869, 896-902 (Tx); 851-869, 935-941 (Rx)	128 Channels	Wide – 25 (800 MHz) Narrow – 12.5 (900 MHz)	Vibration; Shock; Dust; Salt Fog; Driven Rain	Yes (PC)	13.8 VDC	4 - 35	5 – 10	No	Yes
Vertex	VX-2000	134-160; 148-174; 400-430; 450-480; 480-512	4, 40 Channels	Wide – 25 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	10.8 – 15.6 VDC	2 - 25	5	Yes	No
Vertex	VX-3000	29.7-37; 37-50; 134-150; 146-174; 400-460; 450-490; 480-512	4, 40, 120 Channels	Wide – 25/30 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	13.8 VDC	10 – 70 (VHF Low) 5 – 50 (VHF High) 5 – 40 (UHF)	5 (internal) 10 (external)	Yes	No
Vertex	VX-4000	134-160; 148-174; 400-430; 450-480; 480-512	250 Channels	Wide – 25/30 Narrow – 12.5	Low Pressure; High Temp; Low Temp; Solar Radiation; Rain; Humidity; Salt Fog; Dust; Vibration; Shock	Yes (PC)	13.8 VDC	25 – 50 (VHF) 25 – 40 (UHF)	5 (internal) 10 (external)	Yes	No

3.2.1 Explanation of Functional Specifications Criteria

Frequency Range(s)—This criterion defines the frequency ranges/bands supported by the equipment. When selecting products it is important to ensure that the device operates on the frequency band used within a system.

Channel/Mode/System Capacity—This criterion defines the possible capacity of the equipment to support either channels (conventional) or mode/systems/talk groups (trunking). The capacity of a unit is an important consideration to ensure that the equipment can effectively communicate on all of a jurisdiction's talk paths, as well as on mutual-aid channels or surrounding agency systems.

Wideband and/or Narrowband Capable—The radio equipment's ability to support future channel separation minimizes premature replacement requirements. Presently, most units should support wideband channel spacing (25 kHz) and narrowband requirements (12.5 kHz).

MIL-STD 810 Test Procedures—The radio's compliance to certain tests included in MIL-STD 810 standard suite ensures a basic environmental and physical durability. Compliance is imperative for public safety two-way radio users whose operating environments often involve extreme conditions. The particular MIL-STD 810 tests applied to the radio vary by vendor.

Programming Support—The method and manner in which the radios features/functions are established within the radio device influences how easily agency personnel can program their radios. PC software and hardware is usually more accessible to public safety agencies than other proprietary methods of radio programming.

Primary Input Power Voltage Required—The power requirements of the radio equipment are important when considering the environment and location where the radio will be installed and operated. The installation location must provide sufficient power to support proper operation of the radio.

RF Output Power—Sufficient RF power output of the device is essential to successful communications. If the device does not generate sufficient RF output, the radio will not communicate with the system infrastructure and communication will be lost. Agencies should always consider the operational environments of the radio equipment when making decisions regarding power output to ensure that sufficient output is achieved within licensed limits.

Audio Output Power—Public safety personnel operate in a variety of environments, some of which produce high ambient noise. The ability of the radio device to produce high levels of audio output with limited distortion can be critical for public safety operations.

Software Upgrade Support—The software/firmware within the radio that define the capabilities of the radio should be upgradeable. This capability helps to minimize premature replacement when new versions are developed. Also, synthesized equipment does not require the replacement of crystals or other firmware components in order to change the features of the device.

User-Defined Buttons/Knobs—The ability for agencies to program certain radio control buttons, knobs, and switches to their requirements enhances usability of the equipment. This capability provides additional flexibility so that agencies themselves can decide what features/functions are assigned to buttons, switches, knobs, and other controls on the radio.

3.3 Mobile Radio Interoperability Specifications

Interagency communications remains a critical issue for public safety agencies. Proprietary and non-proprietary LMR system features often obstruct seamless interagency communications and impede interagency coordination. Certain mobile radio features, however, can help improve interagency wireless communications regardless of the proprietary and system features at hand. Development of some of these features continues, as demonstrated by the ongoing TIA/EIA 102 standards development process, while others, such as user-defined scanning or encryption, are widely employed by the public safety LMR community. The following charts provide an analysis of the features of mobile radios most relevant for achieving interoperable wireless communications in the public safety LMR marketplace.

Table 3.3 Interoperability Specifications for Mobile Radio Products

Vendor	Product	Analysis Considerations											
		Analog/ Digital Capable	Cross/Multi-Band Support	Conventional/ Trunking Support	Encryption Specifications		Over-the-Air Programming	Radio-to-Radio Cloning	Scanning Specifications		TIA 102 Standards		
					Encryption Capable	OTAR Support			User Defined	Between Systems/Modes	CAI	IMBE	DES Encryption
Com-Net Ericsson	Panther 200M	Analog	No	Conventional	Scrambler (optional)	No	No	No	No	N/A	No	No	No
Com-Net Ericsson	Panther 300M	Analog	No	Conventional	N/A	No	No	Yes	No	N/A	No	No	No
Com-Net Ericsson	Panther 400M	Analog	No	Conventional	Scrambler (optional)	No	No	No	Yes	N/A	No	No	No
Com-Net Ericsson	Panther 600M	Analog	No	Conventional	Scrambler (optional)	No	No	No	Yes	N/A	No	No	No
Com-Net Ericsson	Convent. Orion (Low Band)	Analog	No	Conventional	N/A	No	No	No	Yes	N/A	No	No	No
Com-Net Ericsson	Convent. Orion (VHF, UHF, 800)	Analog/Digital (Optional)	No	Conventional	DES; Aegis encryption (optional on wideband mode only)	No	No	No	No	N/A	No	No	Yes
Com-Net Ericsson	EDACS Orion (900)	Analog	No	Conventional/ Trunked (EDACS)	N/A	No	No	No	Yes	Yes	No	No	No
Com-Net Ericsson	EDACS Orion (VHF, UHF, 800)	Analog	No	Conventional/ Trunked (EDACS)	Aegis encryption (optional on wideband mode only)	No	No	No	Yes	Yes	No	No	No
Com-Net Ericsson	ProVoice Orion (800)	Digital	No	Conventional/ Trunked	DES	No	No	No	Yes	Yes	No	Yes	Yes
Datron	Guardian G25RMV100	Analog/Digital	No	Conventional	DES; P25 OFB DES (optional)	Yes	No	Yes	N/A	N/A	Yes	Yes	Yes
EF Johnson	531X	Analog/Digital	No	Conventional/ Trunked (SmartZone, SmartNet)	P25 OFB; SecureNet encryption (both optional); Scrambler	No	No	No	Yes	Yes	Yes	Yes	Yes
EF Johnson	531X (P25)	Analog/Digital	No	Conventional/ Trunked (P25 Trunking)	P25 OFB DES (optional)	No	No	No	Yes	Yes	Yes	Yes	Yes

Vendor	Product	Analysis Considerations											
		Analog/ Digital Capable	Cross/Multi-Band Support	Conventional/ Trunking Support	Encryption Specifications		Over-the-Air Programming	Radio-to-Radio Cloning	Scanning Specifications		TIA 102 Standards		
					Encryption Capable	OTAR Support			User Defined	Between Systems/Modes	CAI	IMBE	DES Encryption
EF Johnson	532X (P25)	Analog/Digital	No	Conventional/ Trunked (P25 Trunking)	P25 OFB DES (optional)	No	No	No	Yes	Yes	Yes	Yes	Yes
EF Johnson	538X	Analog/Digital	No	Conventional/ Trunked (SmartZone, SmartNet)	P25 OFB; SecureNet encryption (both optional); scrambler	No	No	No	Yes	Yes	Yes	Yes	Yes
EF Johnson	538X (P25)	Analog/Digital	No	Conventional/ Trunked (P25 Trunking)	P25 OFB DES (optional)	No	No	No	Yes	Yes	Yes	Yes	Yes
EF Johnson	9883	Analog	No	Conventional/ Trunking (SmartZone, SmartNet)	N/A	No	No	No	Yes	Yes	No	No	No
Kenwood	TK-690H	Analog	No	Conventional	Scrambler (optional)	No	No	No	Yes	N/A	No	No	No
Kenwood	TK-790H	Analog	No	Conventional	Scrambler (optional)	No	No	No	Yes	N/A	No	No	No
Kenwood	TK-790	Analog	No	Conventional	Scrambler (optional)	No	No	No	Yes	N/A	No	No	No
Kenwood	TK-890H	Analog	No	Conventional	Scrambler (optional)	No	No	No	Yes	N/A	No	No	No
Kenwood	TK-890	Analog	No	Conventional	Scrambler (optional)	No	No	No	Yes	N/A	No	No	No
M/A-COM	Gemini M-803[2]	Analog/Digital	No	Conventional/ Trunked (OpenSky, VoIP)	Optional	Yes	Yes	Not required	Yes	N/A	Yes	No	No
M/A-COM	Mercury M-801	Analog/Digital	No	Conventional/ Trunked (OpenSky, VoIP)	Optional	Yes	Yes	Not required	Yes	N/A	No	No	No
Motorola	ASTRO Spectra W3	Analog/Digital	No	Conventional/ Trunked (ASTRO)	DES, ASTRO and SecureNet encryption	Yes	No	No	Yes	Yes	Yes	Yes	Yes

[2] Not yet type-accepted by the FCC. May not be offered for sale or lease until FCC approval has been obtained.

Vendor	Product	Analysis Considerations											
		Analog/ Digital Capable	Cross/Multi-Band Support	Conventional/ Trunking Support	Encryption Specifications		Over-the-Air Programming	Radio-to-Radio Cloning	Scanning Specifications		TIA 102 Standards		
					Encryption Capable	OTAR Support			User Defined	Between Systems/Modes	CAI	IMBE	DES Encryption
Motorola	ASTRO Spectra W4	Analog/Digital	No	Conventional/ Trunked (ASTRO)	DES, ASTRO and SecureNet encryption	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Motorola	ASTRO Spectra W5	Analog/Digital	No	Conventional/ Trunked (ASTRO)	DES, ASTRO and SecureNet encryption	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Motorola	ASTRO Spectra W7	Analog/Digital	No	Conventional/ Trunked (ASTRO)	DES, ASTRO and SecureNet encryption	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Motorola	ASTRO Spectra W9	Analog/Digital	No	Conventional/ Trunked (ASTRO)	DES, ASTRO and SecureNet encryption	Yes	No	No	Yes	Yes	Yes	Yes	Yes
Motorola	LCS 2000	Analog	No	Conventional/ Trunking (SmartZone, SmartNet)	N/A	No	No	No	Yes	Yes	No	No	No
Motorola	Spectra A5	Analog	No	Conventional	N/A	No	No	No	Yes	N/A	No	No	No
Motorola	Spectra A7	Analog	No	Conventional	N/A	No	No	No	Yes	N/A	No	No	No
Motorola	Spectra A9	Analog	No	Conventional	N/A	No	No	No	Yes	N/A	No	No	No
Vertex	VX-2000	Analog	No	Conventional/ Trunked (optional hardware/software)	N/A	No	No	Yes	No	N/A	No	No	No
Vertex	VX-3000	Analog	No	Conventional/ Trunked (optional hardware/software)	N/A	No	No	No	No	N/A	No	No	No
Vertex	VX-4000	Analog	No	Conventional/ Trunked (optional hardware/software	N/A	No	No	Yes	No	N/A	No	No	No

3.3.1 Explanation of Interoperability Specifications Criteria for Mobile Radios

Analog/Digital Capable—The radio equipment's ability to support multiple protocols enhances its potential for interoperability as well as backward capability to older legacy systems. Digital support is of paramount importance moving forward because most manufacturers are moving toward support of digital standards to enhance spectrum efficiency.

Crossband/Multiband Support—The ability of a radio to operate on multiple bands, such as VHF/UHF or 700/800 MHz, enhances opportunities to communicate across systems with one radio device. Support for multiple bands or crossband communications increases opportunities for interoperability.

Conventional/Trunking Support—This criterion usually applies to trunking-type radio equipment. The ability of the radio equipment to operate in a conventional mode is important so that the unit can communicate with conventional radio systems and on established national mutual-aid channels. Dual support provides the ability to communicate in trunking modes and conventional modes and may enhance interoperability of the radio device.

Encryption Specifications—Encryption specifications to consider include the following:

> *Encryption Capable*—Many public safety agencies need to restrict access to voice communications over RF. To accomplish this, radio vendors have incorporated different encryption capabilities within the equipment. In order to operate, encryption capabilities must also be present within the system's infrastructure. Agencies should assess their encryption requirements and select equipment compatible with the standard supported. Interoperability can be affected by the use of encryption. If an agency decides against the incorporation of encryption and neighboring agencies use encryption, interoperability may not be possible.
>
> *OTAR Support*—The use of encryption also requires a degree of administration of radio equipment in order to maintain the status of encryption keys. The ability to update or modify keys assigned to a device over radio frequency substantially reduces the administrative effort. Agencies deploying a large number of encryption-capable radios should consider incorporating OTAR support. The OTAR capability can also benefit interoperability between agencies because keys could be reprogrammed "over the air" quickly to allow interagency communications.

Over-the-Air Programming Support—This capability allows for wireless manipulation of the radio's programming. This ability substantially reduces the administration time required to reprogram equipment when changes to features or functions occur. (This capability would not include dynamic regrouping of the radio through a system management console.)

Radio-to-Radio Cloning—This equipment feature allows a unit's programming to be copied to another same-type unit through a data cable attachment between the two units. This capability can reduce administration time required to program units.

Channel Scanning Support—Channel scanning support to consider includes the following:

User Defined—This capability allows users to program certain characteristics and personal preferences for scanning of channels/modes.

Between Systems/Modes—Usually found in trunking technologies, this capability allows scanning of talk paths between different systems that are defined in a radio. Therefore, a scan list is not limited to only the user's agency or department but may include other agencies and departments. This capability can have a positive impact on interoperability.

TIA/EIA 102 Standards—TIA/EIA 102 standards to consider include the following:

CAI—The presence of the CAI standard, as specified by the TIA/EIA 102 suite of standards, ensures basic interoperability among all TIA/EIA 102-compliant digital subscriber units.

IMBE—The IMBE vocoder technology is recognized as the TIA/EIA 102 vocoder standard for voice-to-digital conversion. Similar to CAI, IMBE is a TIA/EIA 102 system standard providing a basic level of interoperability among all TIA/EIA 102-compliant radios.

DES Encryption—The Data Encryption Standard (DES) is the service standard for encrypted voice and data communications in accordance with the TIA/EIA 102 suite of standards. Uniform encryption technology can play a critical role in achieving interoperable communications among neighboring systems. Both Triple DES and Advanced Encryption Standard (AES) are now being considered as part of Phase II of the TIA/EIA 102 standards development process, which is discussed in Appendix D.[3]

[3] Triple DES serves as an advanced form of DES and has been endorsed by the National Institute of Standards and Technology (NIST). AES continues to be developed under NIST guidance and is intended to serve as a solution to the shortfalls of DES and Triple DES.

4.0 PROPRIETARY SYSTEMS OVERVIEW

In addition to the specifications of LMR subscriber units, a public safety agency's ability to maintain seamless, reliable intra- and interagency communications is determined by certain aspects of the proprietary LMR system architectures in place. The development of proprietary system protocols has, in large part, limited the number of compatible subscriber units for each proprietary system. As previously exhibited in the analytical charts for mobile and portable radio products, a number of factors determine if a subscriber unit is compatible with certain systems, let alone those of other agencies. The purpose of this section is to provide an overview of the proprietary LMR systems prevalent in the public safety marketplace today. Specifically, this section traces the development of proprietary system architectures, provides a brief description of proprietary trunking protocols commonly used by public safety agencies, and considers the potential impact of emerging new system protocols on the public safety LMR marketplace.

4.1 Proprietary System Development

In 1974, the FCC allocated an additional 30 MHz of the 800/900 MHz spectrum for public safety land mobile radio users in response to calls from law enforcement officials for more spectrum to relieve congestion. Two hundred of these newly allocated channels were reserved for trunked radio systems.

In 1977, APCO began Project 16 to establish standards for public safety trunking systems with a funding grant from the LEAA. Project 16 concentrated on features and functionality specifically for public safety agencies to be added to existing standards of commercial and specialized mobile radio (SMR) systems.[4] This effort was completed in 1979 and provided direction to both the vendor community and public safety agencies regarding functional system requirements for trunking systems.

During the next 10 years, a number of manufacturers introduced APCO Project 16-compliant solutions to the public safety community. These manufacturers included Coded Communications, ComNet/Ericsson/GE, EF Johnson/Transcrypt, and Motorola. As the new system products were introduced, a significant communications dilemma surfaced. Each of the systems was proprietary in system operations and user equipment, which prohibited users from directly communicating using dissimilar vendor systems. While public safety agencies enjoyed the enhanced features and functionality of the APCO Project 16 environment, they found they were restricted from taking advantage of previous opportunities for interoperability and competitive procurements of additional equipment and services. Some relief was available using the five National Public Safety Planning Advisory Committee (NPSPAC) 800 MHz conventional channels established for interagency communications, but no comprehensive solutions were available.

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[4] SMR is a dispatch radio and interconnect service for businesses. SMRs also can provide additional services, such as two-way acknowledgment paging and inventory tracking, credit card authorization, automatic vehicle location, fleet management, remote database access, voicemail, and facsimile services. SMRs commonly operate in the 220 MHz, 800 MHz, and 900 MHz frequency bands.

Presently, with the exception of Coded Communications, the previously listed manufacturers continue to provide trunking systems technology to commercial and public safety entities, most of which continue to operate on proprietary technology. All are working to meet the new requirements of Project 25 and the impending deployment of systems within the 700 MHz band. The M/A-COM Division of Tyco Electronics, Nokia, and IPMobileNet have also been identified as providers of new emerging technology radio systems.

4.2 Major Trunking Systems Available to Public Safety Agencies

The following is a brief description of the major trunked LMR systems available in the marketplace today.

ComNet–Ericsson/GE Trunking—EDACS®. ComNet-Ericsson offers a trunking system known as Enhanced Digital Access Communications System (EDACS). EDACS can accommodate up to 24 channels per site and uses a dedicated control channel signaling approach for channel assignment. Control channel signaling occurs at 9,600 bits per second. Mobile data may also be accommodated within the trunking system infrastructure using any of the working channels operating at a 9,600 bit per second rate. EDACS is presently offered in four different feature/function levels designated by system features and coverage ability. EDACSs have been deployed as enhanced special mobile radio (ESMR)[5] by commercial entities and by public safety agencies serving single or multiple jurisdictions across the United States.

A few entities using the trunking EDACS include—

- Lower Colorado River Authority (LCRA)—Multi-county water conservation district that provides fee-for-service support to various public safety and general government agencies

- City of San Antonio and Bexar County, Texas—Implementing a multi-site, multi-agency system

- State of Florida—Intends to complete a statewide trunking system

- RACOM Inc.—Commercial business ESMR that covers Iowa, Minnesota, Nebraska, South Dakota, Wisconsin, and Illinois and provides fee-for-services to various governmental entities, including local, state, and federal public safety agencies.

EF Johnson/Transcrypt Trunking—LTR® and MultiNet® II. EF Johnson's original trunking system signaling protocol, called Logic Trunked Radio (LTR), provides a unique method of system control and signaling between base stations and mobile and portable radios. The LTR system does not use a dedicated control channel protocol for system control; instead, all control signaling is transmitted on any of the available frequencies. This method of channel

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[5] ESMR is a dispatch radio and interconnect service for businesses. ESMRs also can provide additional services, such as two-way acknowledgment paging and inventory tracking, credit card authorization, automatic vehicle location, fleet management, remote database access, voicemail, and facsimile services. ESMRs commonly operate in the 220 MHz, 800 MHz, and 900 MHz frequency bands.

management gives all system users automatic access to all channels, resulting in a minimum wait to make a call and the most efficient use of the available channels. Trunking is controlled by logic circuitry in the mobile and portable radios and the base station repeaters. This circuitry continually monitors the system and generates data messages, which update the mobiles and repeaters regarding which repeaters are free. Several other manufacturers of LMR systems and equipment have licensed the LTR technology for incorporation within their trunking system offerings. These systems are primarily used for commercial radio services.

The LTR system was the basis for the development of EF Johnson's advanced trunking system referred to as "MultiNet II." The MultiNet architecture can accommodate up to 30 radio channels per site, which is 10 channels greater than its predecessor. The central hub of the MultiNet II system is the Radio Network Terminal (RNT). The RNT provides capabilities for dispatcher console connections, multiple site interfaces, public switch telephone system (PSTN) interconnects, and conventional network interfaces. The RNT also supports Johnson's "Auto-Trak" system for the control of multiple sites. The EF Johnson MultiNet II trunking system design differs from several of the other systems and adheres to the original topology of the LTR systems, since it does not require a dedicated control channel but employs sub-audible signaling on each of the system's working channels.

A few entities using EF Johnson MultiNet II include—

- State of Washington Department of Transportation (statewide system)
- State of Connecticut Department of Corrections (statewide system)
- City of Dothan, Alabama
- City of Yuma, Arizona
- Oswego County, New York—Available to local, county, and state public safety and general government agencies.

M/A-COM Trunking—Open Sky®. M/A-COM, a relatively new system provider in the U.S. domestic market, incorporates an entirely different approach in the development of its radio system offering. The M/A-COM system, known as Open Sky, uses digital radio equipment in time division multiplex (TDM) architecture and can be deployed in single or multiple site configurations to support local, state, or regional communications requirements. Presently, the TDM architecture allows M/A-COM repeaters to operate in a 25 kHz channel and divides each channel into three time slots, one of which is used to support control channel signaling. The other two time slots are used to provide two different voice channels for conversations.

The Open Sky system is based on voice-over-Internet Protocol (VoIP) technology, allowing the system to transmit voice and mobile data communications simultaneously using a single radio device for both applications. Each mobile and portable radio unit is addressed by the network as an IP network node, providing for increased flexibility and scalability. M/A-

COM formed an agreement with Kenwood Communications to manufacture software-based, digital portable radios for the Open Sky network.

A few agencies using MA-COM Open Sky include—

- Commonwealth of Pennsylvania—May support a variety of public safety and non-public-safety users in local, state, federal, and tribal agencies. The initial network has been designed to support approximately 25,000 users, and may be expanded to 50,000 in future years (statewide system).

- Lancaster County, Pennsylvania.

Motorola Trunking—SmartNet™, SmartZone®. Motorola was the first manufacturer to provide an APCO Project 16-compliant system with the introduction of SmartNet systems in 1984. The most recent version is referred to as "SmartNet II." SmartNet II/SmartZone systems are capable of supporting up to 28 radio channels per site. The Motorola SmartNet system is designed to incorporate a dedicated control channel on which the signaling for channel assignments is transmitted and received between the system infrastructure and the mobile and portable radio units.

Motorola offers its trunking system technology in several different levels that correspond to the feature sets available within the provide systems. These levels are—

- StartSite Express
- StartSite
- SmartNet
- SmartZone
- SmartZone OmniLink.

The SmartZone and SmartZone OmniLink systems are deployed to meet the requirements of wide-area coverage for multiple cities, counties, states, or regions, while the StartSite Express, StartSite, and SmartNet systems are deployed for smaller coverage areas. The SmartNet II and SmartZone offerings also provide analog and digital voice capability.

Motorola offers a variety of mobile and portable radio equipment for conventional trunking system solutions. As with the systems technology, the user radio equipment is offered in levels based on incorporated features and functionality. ASTRO is Motorola's TIA/EIA 102-compliant digital technology. It is important to note that EF Johnson has licensed Motorola's core trunking technology and recently began manufacturing and offering mobile and portable radio equipment compatible with Motorola's trunking systems.

A few entities using Motorola ASTRO Trunking Systems include—

- State of Michigan's Public Safety Communications System (MPSCS).

- City and County of San Francisco, California—Available to public safety and general government agencies.

- Hamilton County, Ohio—Available to public safety and general government agencies.

- Connecticut Highway Patrol (statewide system).

- South Carolina—Motorola-owned statewide system (formerly owned by SCANA Communications, a subsidiary of the South Carolina-based power company, SCANA Corporation) that is used, on a fee-for-service basis, by the South Carolina Highway Patrol and various local public safety agencies.

- The 9-1-1 Radio, Dispatch, Mobile Data, Transportation Coalition (9-1-1 RDMT Coalition) in and around Austin and Travis County, Texas—Intends to deploy a regional 800 MHz ASTRO SmartZone trunked radio system to serve both public and non-public-safety entities. This new system will support a Project 25 CAI.

4.3 Emerging Systems Technologies

The following is a brief description of some of the emerging LMR systems being developed in the marketplace. It should be noted that these systems have not yet been fully tested or marketed for the U.S. public safety market.

IPMobileNet—INVADR. IPMobileNet recently announced the release of its new IP-based wireless voice and data communications system known as INVADR. The INVADR is marketed as an open architecture plug-and-play system that allows up to four paths of voice communications, or three voice communication paths and a single data communications path, to be transmitted simultaneously over a single radio channel. This is achieved by using a combination of FDMA and TDMA technology. Channel separation is supported at 12.5 kHz and 25 kHz.

The system incorporates 19.2 kilobytes per second (KBps) IP data radios with voice interface units and IP base stations. These units are controlled by the IP network server, which enables radio users to rapidly transmit and receive voice and data messages over traditional radio frequencies in a standard IP format. The system is configurable in both trunked and conventional modes and can support single-site or multi-site wide area communications requirements in both the UHF and 800 MHz bands. This solution appears to be primarily offered as a mobile data solution with the opportunity to support VoIP infrastructure as an adjunct. It should be noted that no portable radio devices are presently available for this technology solution.

At the time of this report, no INVADR systems had been deployed in North America; however, the core technology component of the INVADR has been deployed by the Winston-Salem, North Carolina, fire department to support mobile data capabilities.

Securicor Wireless Technology Linear Modulation. Linear modulation (LM) is a proprietary modulation technique originally developed by Bristol University in England in 1991 and commercially marketed by Securicor Wireless Technology (SWT).[6] LM technology allows for the transmission of voice and data over radio channels that are only 5 kHz wide. LM is an analog FDMA system that provides one voice channel in a 5 kHz spectrum division. This spectrum division meets the FCC's efficiency standards for an operating radio system. LM is available in the 150, 220, 450, and 800 MHz bands. LM channel characteristics allow for voice, data, and video transmissions in either a digital or analog format—a remarkable feature for LMR systems. This technology was not specifically developed with the feature/function requirements that are usually sought by public safety agencies but may be beneficial as the convergence of voice and data technologies continues.

Several system networks using LM are currently in use or under construction. These include a 220 MHz system being developed by the National Rural Telecommunications Cooperative (NRTC) to support rural utilities operations and potentially fee-for-service commercial entities within the Co-op's operating areas.

Motorola—iDEN™. Motorola developed a digital technology known as iDEN. This technology, primarily used in ESMR systems, allows commercial businesses to use a single, palm-size handset to make digital cellular phone calls, send text messages, and instantly communicate with one or hundreds of individuals. The system also supports a dispatch type environment for use with the two-way radio feature, an Internet connection via a notebook or handheld computer, and the capability to send and receive e-mail.

In North America, iDEN carriers include Nextel Communications and Nextel Partners, Southern LINC, and Pacific Wireless. There are 13 iDEN carriers outside of North America operating systems in Asia, Latin America, and the Middle East. It is estimated that there are more than 5 million subscribers worldwide.

The iDEN technology is remarkably spectrally efficient. iDEN's digital technology uses TDMA digital signaling technology. The technology divides a 25 kHz channel six times, providing system features in a seamless communications package. iDEN is not currently sold to public safety agencies as a primary communications system in the U.S. market because it lacks the features/functionality normally found in APCO Project 16/25-compliant systems. Many public safety agencies, however, use iDEN systems on a fee-for-service basis.

A few entities using iDEN include—

- Southern LINC 800 MHz system—Statewide system in Alabama used by Highway Patrol and other state-level public safety agencies
- Federal Bureau of Investigation (FBI)—Using NEXTEL iDEN in and around San Francisco, California
- NEXTEL—Nationwide commercial ESMR.

[6] http://www.linearmod.com/tech/index-tech-ie.htm

Nokia Trunking—ACTIONNET/TETRA. Nokia, a major handset provider in the wireless telecommunications marketplace, is planning to introduce a Terrestrial Trunked Radio Access (TETRA)-based trunked radio system in the United States.[7] Nokia manufactures and markets its TETRA-based public safety trunked radio systems throughout the world with the exception of North America. Nokia also provides TETRA- and MPT1327[8]-based technology systems for commercial business radio applications throughout the world.

A four-slot TDMA technology, European TETRA, is the only technology in use today that meets the FCC efficiency standard for the 700 MHz band. Major differences from the North American proposed standard include European TETRA's inability to interoperate at the Project 25 Phase I level. TETRA was developed as an LMR system standard with extensions for public safety operations. Many industry leaders, such as Nokia, Marconi, and Motorola, manufacture universal European TETRA radio equipment. The European TETRA standard is not supported in North America, and existing legal issues prohibit the sale of TETRA equipment here.

The TETRA protocol provides four time slots in each 25 kHz slice of the spectrum. One slot must be used as a control channel, leaving three available for voice or data transmissions. TETRA-based systems are configured like a cellular system design and currently do not facilitate simulcast capabilities although this is proposed in the standard. Numerous SMR and public safety TETRA-based systems are installed or under construction throughout the world.

North American TETRA is another technology standard proposed under Project 25 Phase II. North American TETRA proposes to operate on channels spaced 25 kHz with 20 kHz bandwidth. Four time slots are produced that provide for four voice or data communications paths. One path is required for system control, leaving three for voice or data channels. As currently proposed, the technology permits combining slots for higher speed data when they are not being used for voice. This scheme meets the Project 25 Phase II and FCC requirements of one voice channel in 6.25 kHz. North American TETRA is currently proposed for use within the 700 MHz band and may be portable to the other public safety bands.

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[7] http://www.nokia.com/networks/pmr/index.html

[8] MPT 1327 is the first open trunking signaling standard for analog trunked private LMR systems prepared by the British Department of Trade and Industry Radiocommunications Division. This standard applies to systems other than those in North America. Other specifications in this context include MPT1343 (System Interface Specification) and MPT1347 (Radio Interface Specification).

5.0 FUTURE DEVELOPMENTS

Over the last few years, the LMR marketplace has evolved significantly. Manufacturers have merged, and technologies have rapidly advanced. Landmark mergers, such as the buyout of EF Johnson by Transcrypt International and the acquisition of Com-Net Ericsson by Tyco International, have dramatically altered the LMR vendor landscape. At the same time, continuing advancements in the technology sector are driving the development of many new products and services in the communications industry. LMR systems and equipment, in particular, have benefited greatly from advances in computer component technologies over the past 50 years. In fact, the majority of the mobile and portable radios manufactured today incorporate sophisticated computer technologies that expand radio features and capabilities unthinkable only a decade ago.

The vendor community continues to respond to public safety's requirements by producing mobile and portable equipment that incorporates the extended features and functionality required for public safety operations. Spurred by their involvement in various standards development organizations (SDOs), the vendors are incorporating standards-compliant features and capabilities into their system and equipment offerings. The resulting market competition helps lower product prices and increases the chances for interoperable communications for public safety agencies. Emerging technologies promise to provide a new generation of features and functions for LMR systems and equipment. Therefore, it is imperative that public safety agencies and the vendor community continue to work together and engage in the development of open standards for public safety communications systems.

The migration to digital technologies, coupled with new standards and regulatory requirements, is benefiting all LMR users, commercial and public safety alike. However, as they make wireless equipment more accessible to the public, it is critical that vendors maximize the efficiency of available spectrum. In response to this need, vendors are achieving more efficient spectrum utilization through the deployment of digital multiplexing techniques such as FDMA, CDMA, and TDMA, which decrease nominal bandwidths from 25 kHz to 12.5 kHz. Future developments and expansions of current technology may allow for the further reduction in bandwidth requirements by allowing for the transition to bandwidths of 6.25 kHz, or possibly 5 kHz. The incorporation of digital signal processors (DSP) has helped facilitate digitized voice over narrowband radio frequency.

Vendors are also beginning to consider the development of radio equipment that will support communications between multiple bands within one radio (i.e., able to operate in the 700 MHz and 800 MHz band without requiring reprogramming). Emerging equipment also supports over-the-air programming, which allows for the manipulation of the radio's configuration programming via RF. As with most technical advances, new equipment will continue to become smaller, lighter, and more feature-rich than its predecessors. Battery technologies also continue to develop that will allow the production of smaller, lighter, and more powerful cells that should extend operational and life cycles.

Wireless data transmission is also emerging as a new advantage for public safety agencies. Manufacturers are developing new equipment that will embrace opportunities to incorporate wireless data capabilities into mobile and portable radio equipment. These capabilities include short messaging services (SMS), enhanced telephony support, video and imagery transmission, and support for wireless local area network (LAN) and wide area network (WAN) communications. This development is being driven by the pursuit of third-generation wireless initiatives that will incorporate many new features and functions for commercial applications. Ultimately, these initiatives will benefit public safety by providing new capabilities and opportunities to move larger amounts of data at faster transmission speeds.

Although the technological advances are promising, public safety agencies and officials must continue to be cognizant of the importance of maintaining the interactive relationship between the development and application of standards and the development of manufacturers' equipment offerings. Public safety must continue to ensure that the merging of these activities will meet and enhance the ability of public safety agencies to achieve their mission of protecting lives and property. In the interest of financial and spectral efficiencies, local, state, federal, and tribal public safety agencies must continue to be active participants in multi-agency, countywide, regional, or statewide communications system initiatives. In the long term, this participation will enhance interagency coordination, information sharing, and the interoperability necessary for public safety agencies.

APPENDIX A. FREQUENCY

To date, the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA) have allocated several bands of spectrum for public safety's use. These allocations have been made in several areas across the radio spectrum including[9]—

- Low Band Very High Frequency (VHF) (25–50 MHz)
- High Band VHF (138–144/148–174/220–222 MHz)
- Ultra High Frequency (UHF) (406.1–420/450–470/470–512 MHz)[10]
- 800 MHz (806–824/851–869 MHz)
- 700 MHz (764–776/794–806 MHz).[11]

When procuring a new wireless communications system, public safety agencies are confronted with deciding which frequency band best suits their needs. The answer is not always clear because each band offers different advantages and disadvantages.

The suitability of a frequency band may depend on a variety of factors including the size of the coverage area needed, the terrain characteristics of the area, or the number and size of the buildings in the area. Ideally, an agency would prefer a frequency band that best matches their coverage needs and interoperates with the frequencies used by neighboring agencies.

Frequently, however, the selection of an operating frequency band is dictated by the availability of the spectrum in the area and the funds available to procure a new system. Because spectrum is a scarce commodity, public safety agencies must often take what spectrum is available rather than choose what they feel best suits their needs. Because a large number of public safety legacy systems operate in lower frequency VHF bands, many agencies may be pushed to operate in less congested higher frequency bands. An analysis of combined data on public safety interoperability collected by the PSWN Program indicates that more than half of the responding public safety agencies planning to procure a new system in the next 10 years intend to operate in the 800 MHz frequency band—doubling the number of systems operating in that band.[12] From a funding standpoint, moving to higher frequency systems may be more expensive depending on the coverage area needed and the infrastructure required. Public safety agencies must ensure that the appropriate funding mechanisms are available to procure their desired system.

Despite the limitations imposed on public safety agencies' frequency selection, it is important that agencies understand the benefits and limitations inherent in each frequency band. Propagation characteristics, defined as the behavior of a frequency in different environments,

[9] The frequencies listed are for local, state, federal, and tribal public safety use.
[10] The frequency band of 470–512 is commonly referred to as the UHF-T band.
[11] The additional spectrum in the 700 MHz band was allocated for public safety use as part of the Balanced Budget Act of 1997. Scheduled availability for this spectrum is 2006.
[12] Combined data extracted from survey questionnaires used in the development of the *PSWN Program Analysis of Fire and EMS Communications Interoperability* and *State and Local Law Enforcement Wireless Communications and Interoperability: A Quantitative Analysis* developed by the National Institute of Justice.

vary across the spectrum band. Perhaps the most important of these characteristics to be aware of is the inverse relationship that exists between frequency and range. As a general rule, all other things being equal (e.g., power of the transmitter, atmospheric conditions, gain of the antenna), as frequency increases, the range decreases. For example, a 100 MHz frequency, which has a long wavelength, can travel farther than an 800 MHz frequency, which has a shorter wavelength. An agency whose jurisdiction covers a large area of land will likely be better served with a system based on lower frequency ranges.

As wavelengths get shorter, they can be more easily affected by their natural and manmade surroundings. Generally, longer wavelengths are more capable of bending around objects along a path while shorter waves are more likely to be reflected or absorbed by their surroundings. For example, at 3 kilohertz (kHz), the radio wavelength is greater than 60 miles. Few objects are large enough to obstruct the path of such a low frequency. Alternatively, at 3 gigahertz (GHz), the wavelength is slightly less than 4 inches. Given the relatively small size of this frequency, it is easy for the signal to be absorbed and reflected by other objects in its environment.

There are advantages and disadvantages to differing wavelengths. The physics of radio frequency dictates that the size of the antenna needed to capture a radio frequency is directly proportional to the length of the wavelength. As the wavelength gets shorter, the antenna needed becomes shorter. For example, a 100 MHz frequency requires a larger antenna than an 800 MHz signal. For public safety agencies, this characteristic can translate into smaller portable radios. Higher frequency radios require a significantly shorter antenna, thus reducing the bulkiness of a portable radio on a public safety officer's belt.

The drawbacks to the limited frequency range inherent in higher frequencies can be overcome through an enhanced infrastructure. To compensate for shorter ranges, antennas and repeater radio towers can be added to retransmit signals, extending the reach of the system. The downside is the increased cost of the infrastructure. Many agencies cannot afford the necessary backbone equipment to build and maintain an extensive infrastructure.

Urban Environment

Common features of an urban working environment for public safety include a high density of tall buildings, a large population density, smaller coverage areas, and many field-deployed resources. The need for a signal that has a high level of building penetration may take precedence over the need for a signal that can travel a long distance. In this case, an agency may consider an 800 MHz system because of the increased availability of spectrum and the frequency's increased building penetration.

When considering building penetration, it should be noted that all public safety frequencies are capable of achieving some level of in-building penetration. On any frequency band, signal loss within buildings can be affected by numerous factors, such as building composition (e.g., concrete and steel), exterior and interior wall construction, orientation of the building to the antenna site, height of the building, aperture of windows and other openings, window coatings and treatments, and density within the building. Some buildings require additional antenna systems to provide in-building coverage to adequately support portable radio communications. Public safety agencies have found, however, that the shorter antennas featured on 800 MHz portable radios and the ability of the 800 MHz band signal to travel within a building are more suited for the mobile communications needs of public safety personnel.[13]

Additionally, many urban public safety agencies have achieved better coverage with 800 MHz systems than with older VHF systems. This improvement may be due in part to the addition of new antenna tower sites throughout the metropolitan area. Additional tower sites contribute to fewer "dead spots" or areas lacking adequate system coverage and better frequency reuse. Advanced trunking technology available on an 800 MHz system allows the systems to accommodate more users than conventional systems.[14]

Suburban Environment

A greater density of smaller buildings and a large number of users often characterize suburban environments. The suburban environment varies in topographical features and size. Given the diversity of this operating environment, agencies can have a great degree of flexibility in choosing the frequency band in which they operate. To accommodate a large number of users, agencies may choose to operate in the frequency ranges that allow for trunked radio systems. A low-band VHF system may not be as suitable given the high degree of congestion in the lower frequencies. On the other hand, if the coverage area is large, a high-band VHF system may be the best choice.

As with other operating environments, frequency band selection in the suburban environment may also be contingent on the amount of funds available for a new system. The additional towers and other infrastructure costs associated with higher frequency systems may not be feasible for many agencies. It may be necessary for these towers to be placed in areas that impose on residential areas, which may be objectionable to many residents. Success in suburban environments often depends on how well public safety agencies are able to balance radio system coverage, financial, and residential concerns.

Given the interaction frequently necessary between agencies in suburban environments and their urban neighbors, agencies should also carefully weigh how well their frequency selection will interoperate with adjoining agencies. Although there is technology that allows dissimilar operating frequency systems to interoperate with one another, these solutions can be costly. Proper planning can save agencies a significant amount of money in the long term and enhance the ability of agencies to achieve their mission.

[13] Portable radios are engineered with antennas designed to maximize RF output power. In some instances, agencies have decided to replace antennas in the interest of user comfort. Shorter replacement antennas, however, can limit the output power of the radio, thereby reducing its operational range. Furthermore, agencies requiring additional attenuation for their radios have opted to supplement their radios with gain antennas. Given the variety of public safety personnel and system needs, it is important for agencies to consider the relevant service effects prior to any antenna replacements.

[14] Trunked systems allow for improvements in system capacity. Trunking technology, which is employed by many new 800 MHz systems, allows the use of talk groups as well as the efficient distribution of conversations. It is the trunking technology, not the frequency itself, that allows for the accommodation of additional users. Trunking is also available in high-band VHF and UHF systems. See Appendix B for additional details.

Rural Environment

A large coverage area, fewer clusters of buildings, and fewer system users typify the rural operating environment. Geographical features vary widely, ranging from mountainous terrain to flat plains to dense forests. Although all of the public safety frequency bands can be used, it is typically most economical and efficient for agencies in rural environments to choose lower frequency systems. Because of the inverse relationship of frequency to range, these systems offer a lower cost and wider coverage area than higher frequency systems.

While higher frequencies have usually demonstrated better building penetration characteristics, certain environmental elements can adversely affect higher frequency transmissions. It has been reported that, in some regions, higher frequencies do not propagate well in areas with dense forests, vegetation, below ground requirements, or extreme weather conditions. The signal loss tends to be particularly pronounced in areas with coniferous forests. This reported effect may be because pine needles are similar in size to quarter-wave whip antennas, thus scattering radio signals and causing signal fading. The same principle also applies in adverse weather conditions. In some cases, rain and snow may distort higher frequency signals more than lower frequency signals. Public safety agencies that must operate in extreme weather conditions or dense forests may be better served with lower frequency systems (i.e., VHF).

As previously noted, lower frequency ranges are better able to "bend" around large objects because of their longer wavelength. This propagation characteristic makes lower frequency bands more suitable for mountainous terrains. Because VHF systems are less affected by changes in elevations and topography, in addition to their increased coverage, they are often an appropriate choice in rugged terrain.

Maritime Environment

Maritime environments present unique frequency and interoperability challenges. Confronted with the need for radio signals that can travel a long distance across the water while also communicating across diverse mainland geography, maritime public safety agencies may require multiple frequencies. It has been observed that mainland agencies often use 800 MHz systems to accommodate multiple users. However, maritime agencies typically use VHF frequencies because the lower frequencies carry better over long distances over water.[15] The use of different frequencies and dissimilar systems can create significant interoperability issues between land-based public safety agencies and maritime agencies. The range of missions (e.g., law enforcement, hazardous material clean-up, national fisheries management, marine environmental response, and commercial and recreational boating safety enforcement) and multiple operating environments (e.g., navigable waterways, large bodies of water, and land-based activities) also make interoperability with mainland agencies more challenging. Maritime public safety agencies must carefully consider their geographic terrain, surrounding agency frequencies, and funding situations before selecting an operating frequency.

[15] Public Safety Wireless Network Program. *Maritime Public Safety Case Study: Results and Recommendations Report*. January 2001.

Summary

In short, while all frequencies are not created equal, there is no *best* frequency for public safety. Operating frequency decisions may be dictated by spectrum availability; however, because spectrum will likely remain in short supply as public safety competes with other wireless users, public safety personnel can still play an active role in the decision-making process. Political decision makers must monitor FCC licensing and frequency coordination activities because these decisions will substantially impact available frequencies and subsequent infrastructure decisions. Agencies should consider participation in regional initiatives for the deployment of multi-agency communication systems. Radio engineers must assess what frequency works best in their operating environment. System planners must thoroughly measure the pros and cons of each frequency band against their unique communications needs. By carefully balancing spectrum availability, coverage areas, interoperability needs, and costs, public safety agencies can select the frequency bands that work best for them.

APPENDIX B. SYSTEMS ARCHITECTURES

There are three basic options to choose from when selecting a system architecture—conventional, trunked, and hybrid systems.[16] Determining which architecture is right for a specific public safety agency requires assessing that agency's technical, operational, and environmental requirements, as well as financial constraints. While conventional systems have long been the architecture of choice for public safety agencies, advancing technology and increasing spectrum needs have led many agencies to choose trunked radio systems when replacing their legacy systems. When identifying which architecture best suits an agency's needs, it is important to understand the basics of the two primary architectures (i.e., conventional and trunked) and how they compare with one another.

Conventional Radio Systems

Traditionally, conventional systems have been the most popular form of two-way radio with public safety agencies. Until the 1970s, conventional radio systems were the only option when selecting a LMR communications system. A conventional radio system offers public safety agencies proven, reliable technology that is available at a lower cost than newer radio technologies. For agencies not pressed for spectrum but facing limited budgets, a conventional system will typically satisfy their communications needs at a lower cost.

While the capabilities of conventional systems vary from system to system, all conventional radio systems operate on the premise that users are assigned specific frequencies or channels (each frequency equals one usable channel). While a channel is in use, other assigned users must wait their turn to access the channel. As an example, consider a town where police officers operate from Channel 1, fire and EMS officials operate from Channel 2, and public works personnel operate from Channel 3. If a law enforcement emergency occurs, responding officers communicate via Channel 1. If Officer A is on Channel 1, Officer B cannot speak until that channel is free. However, Officer B must compete with other officers who may be waiting to speak once the channel is available. This competition for frequency will occur whether Channels 2 and 3 are available or not. Although it is possible that the other channels may be available, because of the configuration of the conventional system, the police officers cannot take advantage of the available spectrum.

Figure 4 demonstrates a potential configuration of a conventional trunked system's channel allocation. The example demonstrates the most significant disadvantage of conventional systems. The inability to use available spectrum results in the less efficient use of frequencies. It is the responsibility of the users to wait for idle time and make manual channel selections, which may result in an unbalanced channel load. In an emergency situation with a large response, a conventional system may experience significant levels of lost calls. Additionally, in an emergency situation, mutual aid coordination across agencies can be difficult because of the difficulty of channel sharing inherent in a conventional system.

[16] This report examines only conventional and trunked systems.

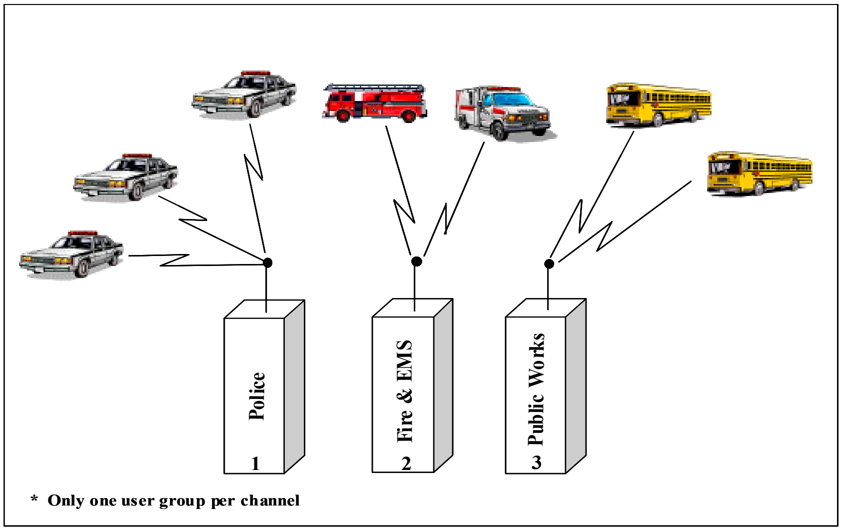

Figure 4
Example of Channel Allocation in a Conventional Radio System

Aside from conventional LMR channel allocation techniques, it is important to note that public safety agencies can enhance the reception and transmission capacities of a conventional system through the use of tailored system architectures. These architectures include voting, simulcast, multicast, and transmitter steering system configurations. Voting helps strengthen a system's reception, or "talk-in," capability by adding receiver sites to the system's infrastructure. This configuration improves the system's ability to receive radio signals in areas of less than optimal coverage and transmissions of low-powered portable radios used by personnel in the field. Simulcast, multicast, and transmitter steering, in turn, help increase a conventional system's transmission, or "talk-out," capability. Upon receiving a signal from a radio user, simulcast and multicast systems retransmit the signal throughout the system infrastructure over one (simulcast) or several (multicast) frequencies, essentially expanding the strength and reach of the signal. Transmitter steering redirects a received radio communication signal to a particular transmitter site. The transmitter steering unit chooses this specified transmitter site based on the site's proximity to the receiver identified by the voting receiver system as having the strongest audio reception power. Transmitter steering units usually serve as a less expensive alternative to simulcast and multicast system configurations.

Trunked Radio Systems

Trunked radio systems bring the basics of wireline telephone trunking to the wireless LMR market. In either system, a "trunk" generally refers to a voice or data path that is shared between two points. Controlled by a computer, trunked systems use control schemes to share channel capacity among users. In contrast to a conventional system, a trunked system takes advantage of the fact that some available channels are idle at a particular time while other channels are busy. By allocating radio calls across channels, a trunked system ensures a more balanced channel load. Figure 5 illustrates how a typical trunked radio system may operate.

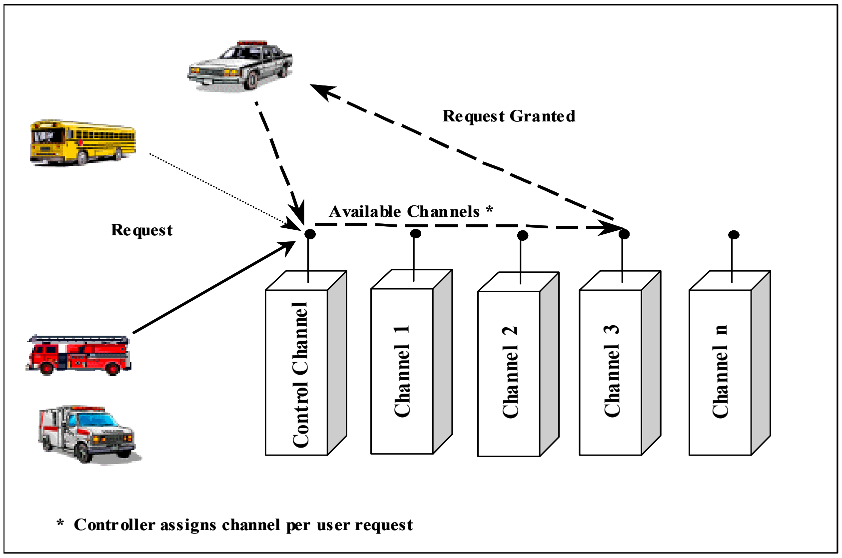

Figure 5
Example of Channel Allocation in a Trunked Radio System

In a trunked system, each radio has a unique identifying address that corresponds to a talk group. Users may switch between talk groups, just as they would switch between channels on a conventional system, by physically turning the knob on their radio to a different number. When a user radio needs to communicate, the radio sends out a channel request on the control channel. The system controller checks the ID of the talk group with which the radio wants to communicate, checks for a vacant channel, and sends channel assignment instructions on the control channel to the all of the radio units presently selected to this talk group. Unlike a conventional system, if no channels are available, the controller places the call in a queue to wait for the first available channel, minimizing the number of lost calls. Because radio channels are shared among all users, the wait time for an available channel is typically minimal compared with conventional systems. The assignment and use of channels in a trunked system is completely transparent to the user. Figure 6 illustrates how a typical talk group may be configured.[17]

[17] Public Safety Wireless Network Program. *Comparisons of Conventional and Trunked Systems*. May 1999.

SYSTEM LEVEL	COUNTY GOVERNMENT		
Announcement Group/Fleet Level	**Police**	**Fire & Rescue**	**Public Works**
Talk Group/Subfleet Level	Police Dispatch	Fire Dispatch	Water & Sewer
	Operation	Fire Ground Command 1	Parks &Recreation
	Vice Squad	Fire Ground Command 2	Roads & Transportation
	Traffic	Arson	

Figure 6
Example of a Trunked System Talk Group

By improving spectral efficiency, trunked radio systems are ideal for large regional systems serving multiple users from different agencies. Trunked systems offer faster access times, increased user privacy, and easier system expansion. Additionally, most trunked systems offer state-of-the-art features, such as automatic unit ID, emergency alerting, talk group scanning, over-the-air dynamic regrouping, call prioritization, and telephone interconnect. Many public safety agencies commonly request these types of features and functionality within their LMR systems as well as their mobile and portable radio equipment.

Trunked radio systems are not suited for all public safety agencies, however. A trunked system is significantly more expensive to purchase, install, and maintain than a conventional system. It requires more advanced training to handle systems operation and maintenance. Currently, trunked systems operate on proprietary technologies and, as a result, achieving interoperability between different manufacturers' trunked systems can be a challenge. Until recently, trunking was not allowed in spectrum bands below 800 MHz.[18] Although trunking is now allowed in the VHF band, few systems are presently deployed. Ultimately, the decision whether to procure a trunked system requires weighing an agency's spectrum needs and financial situation.

Comparison of Conventional and Trunked Radio Systems

Figure 7 compares many of the key characteristics of conventional and trunked system architectures.[19]

Analysis Considerations	Conventional	Trunked
Spectrum Efficiency	– Used in areas with smaller user bases and few frequencies where spectral efficiency in not a necessity	– Used in areas with larger user bases where frequency pooling can improve system performance
Grade of Service (GOS)	– Call blocking at peak user periods – Manual call delay	– Call queuing during peak periods prevents call retries and message collision – Call delay occurs during queuing

[18] The *FCC Second Report and Order FCC 97-61*, which became effective October 17, 1997, allowed for trunking in bands below 800 MHz if certain requirements were met.
[19] Public Safety Wireless Network Program. *Comparisons of Conventional and Trunked Systems*. May 1999.

Analysis Considerations	Conventional	Trunked
System Capacity	– Lower throughput and capacity at high usage	– Call queuing provides higher throughput and capacity at peak usage periods
Call Setup Time	– 15 milliseconds (ms) typical for legacy systems – 250 ms typical for advanced digital systems with user authentication features. Increases if encryption is used	– 250 ms typically for both analog and digital technologies. Increases if encryption is used
System Architecture	– Simple design	– More complex than conventional architecture
System Scalability	– Capacity expansion requires obtaining additional channels or frequencies and equipment	– Capacity expansion can occur through enhanced talk group management or by obtaining additional frequencies
System Security	– Fewer architecture elements allows for fewer opportunities for intrusion – Fixed frequency allows for easy eavesdropping on one channel	– User IDs and authentication prevents unauthorized access – Frequency hopping between conversations or messages makes eavesdropping more difficult
System Redundancy/ Reliability	– Sites capable of functioning independently in the event of outage at another site	– Backup system typically converts system into conventional mode
Multi-organizational Interoperability	– Non-proprietary nature of systems allows for easier interoperability	– Proprietary nature of trunking technology can make interoperability difficult – Creation of new talk groups organizational lines can be done in real time
Policy Impact	– FCC is beginning to move away from conventional systems by requiring small entities with minimal requirements to join together in using a single system	– The FCC is encouraging the use of trunking as a spectrum-efficient technology – Trunking now permitted in lower LMR bands
Required User Discipline	– Significant amount of user discipline required to ensure that all the users on the system can share the channel	– Channel assignments are computer controlled, so users on trunked systems do not have to monitor the system for an available channel to make a call
System Management	– Manual management required	– Many system management features are automated. Systems provide extensive management reporting capabilities
System Operator Training	– Generally, less training required, but some large systems require a more detailed knowledge of system configuration from an operator or dispatcher	– More training required for technicians and managers
System Cost Effectiveness	– Less expensive than trunked	– More expensive than conventional
Subscriber Unit Cost	– Less expensive – Equipment available from various vendors – Non-proprietary technology allows for competitive procurements	– More expensive due to additional features and functions – Radios are highly computerized – Proprietary technologies limit competitive marketplace for equipment

Figure 7
Key Characteristics of Conventional and Trunked Radio Systems

As Figure 7 displays, the decision regarding which architecture to choose relies upon the specific needs and operational requirements of an agency. Generally, trunked systems come out ahead when the following features are weighed:

- Spectrum Efficiency
- Grade of Service
- System Capacity
- System Scalability
- System Security
- System Redundancy/Reliability
- Policy Impact
- Required User Discipline
- System Management

However, conventional systems tend to fare better when the following features are considered:

- Call Setup Time
- System Architecture
- Multi-organizational Interoperability
- System Operator Training
- System Cost Effectiveness
- Subscriber Unit Cost

For many public safety agencies, the cost of the system can be the key factor in determining which architecture to pursue. Costs are highly influenced by the system options selected, technology used (i.e., digital, analog), and coverage area. The following should be considered when building and determining the costs of a system:[20]

- Mission
- Number of users
- Number of user groups
- User group sizes
- Available spectrum
- Coverage requirements
- Type of terrain
- Acceptable call setup delay
- Data transmission requirements
- Security and encryption requirements
- Interoperability requirements
- Available interconnect options.

Summary

Although conventional radio systems have historically been the industry standard for public safety agencies, trunked systems are becoming much more prevalent. Presently, existing trunked systems are able to serve more users with the same amount of spectrum. The emerging digital trunking technologies are promising even greater spectral efficiency and enhanced interoperability opportunities. As public safety personnel are increasingly required to compete with commercial entities and other public safety agencies for available spectrum, trunked systems will continue to be the preferred choice of the industry. The biggest obstacle facing many public safety agencies interested in trunked radio systems is the increased cost. For many

[20] Public Safety Wireless Network Program. *Comparisons of Conventional and Trunked Systems*. May 1999.

agencies, the increase in cost can be easily justified based on coverage area, number of users, technology features desired, and spectrum availability. Additionally, these increased costs can be offset through shared systems solutions that incorporate local, state, federal, and tribal agencies participating in wide area, regional systems or state systems. In this type of deployment, public safety agencies realize the highest degree of interoperability because they are all members of the same system. As with any decision in procuring a new radio system, each public safety agency should carefully weigh all the advantages and disadvantages of each system to determine which architecture meets its priorities.

APPENDIX C.   ANALOG AND DIGITAL TECHNOLOGY

Historically, public safety agencies have used analog radio systems to support their communications requirements. While these systems continue to serve many of the Nation's public safety agencies, digital systems are beginning to noticeably impact the public safety marketplace. Features such as improved voice quality within designated coverage areas and encrypted voice and data communications, as well as other advantages like spectral efficiency, have made digital signal modulation the preferred technology for future LMR system deployments. As a result, much of the literature and discussion regarding public safety communications today has focused on the transition from analog to digital systems. The development of the Telecommunications Industry Association /Electronics Industries Association (TIA/EIA) 102 suite of standards,[21] for instance, is grounded in the anticipated migration of public safety agencies to digital trunked LMR systems.

To understand the key differences between analog and digital technology, it is important to consider how each technology transmits information. In this report, the focus remains on voice communications.

Analog Signal Modulation

All voice sounds exist as distinct analog signals.[22] For a two-way analog radio user, communication transmission begins with the modulation of the analog radio frequency (RF) carrier signal to match that of the user's voice signal. The RF carrier signal is modulated either by FM or AM methods. FM alters the analog signal's number of cycles per second, measured in hertz (Hz) while AM modifies the carrier signal's amplitude for each cycle. Next, the modulated RF carrier signal is electronically transmitted through the network on a channel occupying a certain amount of frequency—typically 4 kHz for a single analog voice channel.[23] Upon "hearing" the RF analog signal, the corresponding subscriber unit's receiver demodulates the RF signal into audio signals matching the original voice signals and amplifies the sound through the radio's speaker.

An analog signal's shape varies consistently between a specified range of values. Figure 8 illustrates 2 Hz of an unmodulated and modulated RF carrier signal. The values along the vertical axis are voltages indicating the electrical force supplied by the radio to the RF signal for transmission. Also demonstrated are the amplitude and frequency of the signal to show the portions of the signal that can be modulated.

Analog systems devote one channel per voice transmission. The RF carrier signal occupies the full frequency of the channel while it travels through it. Because the carrier signal hosts a single voice transmission, the channel's allotted spectrum supports one voice transmission (one user speaking) at a time.

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[21] See Appendix D for further discussion of TIA/EIA 102.
[22] The term "analog" implies a signal composed of a continuous waveform.
[23] Singer, Edward. *Land Mobile Radio Technologies*, 2nd edition. Prentice Hall, April 1994.

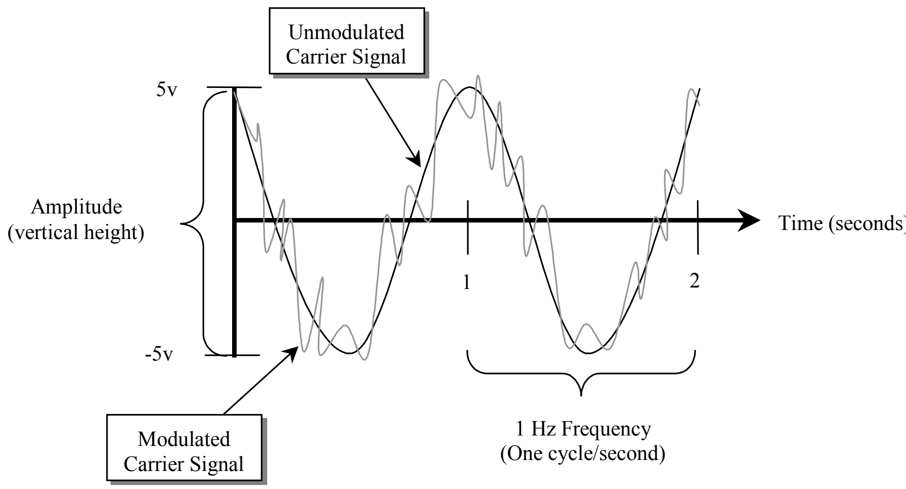

Figure 8
Analog RF Carrier Signal

Digital Signal Modulation

Digital signals represent distinct values at distinct points in time. Unlike the continuous flow of an analog signal, a digital signal transmits information in discrete bits. The voice coder, or vocoder, featured on digital radios first samples the user's analog voice signals and converts the voice signals into binary code "bits," each representing a 1 or a 0. Digital LMR circuits process the sequence of 1s and 0s to reform original voice signals or data. Figure 9 demonstrates the pattern of a digital signal format representing binary code.

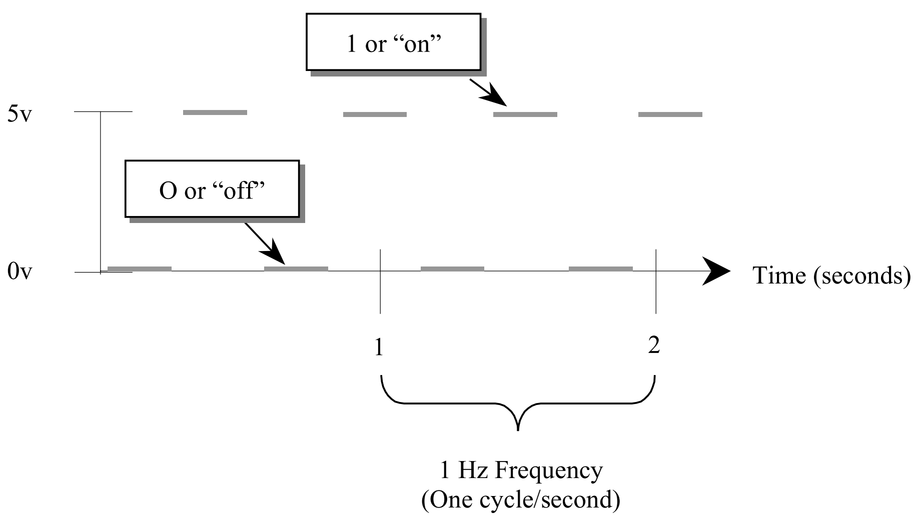

Figure 9
Digital Signal Representing Binary Code

For digital voice communications, each digital bit represents segments of a converted analog voice signal. After the vocoder converts the user's voice into binary code, the analog RF carrier signal is digitally modulated and then transmitted over the wireless network. Numerous types of digital modulation methods exist. For digital LMR systems, the most common form of digital modulation alternates the carrier signal for each binary bit. In this case, each digital mobile and portable radio features a frequency shift key (FSK) modulator and demodulator. All digital radios contain some type of modulator and demodulator technology.

When the digitally formatted RF carrier wave reaches the corresponding digital radio, the carrier wave is demodulated, all the digital bits received are extracted, and the digital signal is transferred to the vocoder in the appropriate sequence. The vocoder reconverts the digital signal into analog voice sounds, which are amplified by the radio's speaker. Figure 10 is a simple diagram showing this process for a digital radio equipped with FSK.

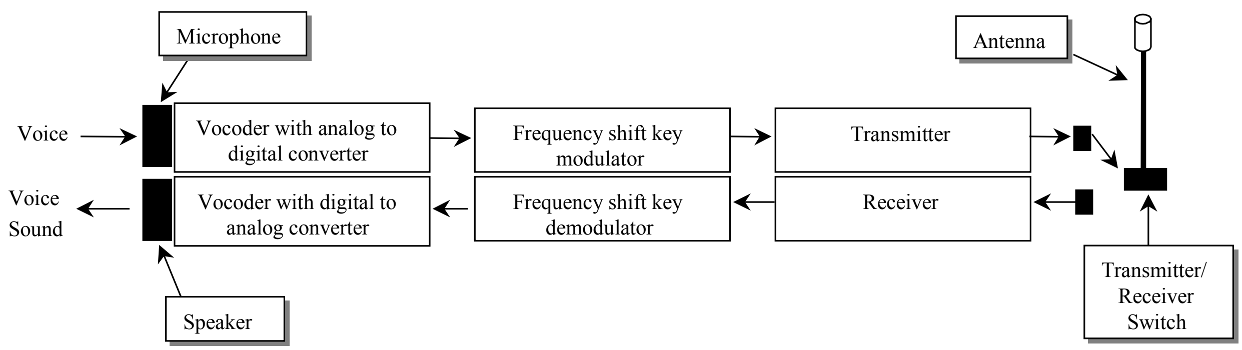

Figure 10
Block Diagram of Digital Radio Voice Transmission

Key Analog and Digital Features for Public Safety

The wireless community at large is now experiencing a broad migration to digital technology, encompassing LMR systems and wireless telephones alike, which is expected to continue for the foreseeable future. Vendors are driving this transition in the LMR market. New product lines feature digital equipment and systems while most analog products are being phased out of production. Legacy LMR analog systems and equipment are beginning to be replaced with the digital equivalents—a growing trend impacting the LMR public safety user community today.

Coupled with trunking technology, digital LMR systems offer the most spectrally efficient LMR technology on the market today. Spectral efficiency has become more important in light of the decreasing availability of spectrum in some areas, particularly urban, and has noticeably affected the technological development of LMR, beginning with conventional analog through today's digital trunked systems. Conventional analog systems devote one channel to each voice transmission, limiting the channel's occupancy to one user at a time. Trunked LMR systems feature channel access technologies, such as frequency division multiple access (FDMA), that retain and use all available channels as options for each voice transmission. Controlled by computers, FDMA is used for both analog and digital trunked systems, providing a more efficient use of a system's available channels (i.e., frequency) than conventional systems. The discrete nature of a digital signal, however, allows for channel accessing methods that are more spectrally efficient than FDMA but whose use is limited to digital trunked LMR systems. Time division multiple access (TDMA) technology, in particular, divides each channel into multiple time "slots" that host individual voice transmissions. TDMA simultaneously modulates several—depending on the number of slots—packets of binary bits from different voice transmissions onto a single carrier signal. When added the system's trunking capabilities, this access technique allows for multiple conversations at a time transmitted over one channel, expanding the system's capacity to host many simultaneous users.

Digital trunked channel capacity can significantly benefit public safety agencies in certain instances. A system's concurrent communications capacity seriously affects an agency's ability to successfully handle major incidents, e.g., a bombing, multivehicle collision, or shooting, that involve several isolated respondents. With conventional analog limitations, dialogue pertaining to the incident is limited to one user (including the dispatcher) at a time, blocking other respondents from simultaneously sharing important information related to the incident. The resulting loss of time and information can debilitate an agency's coordinated response.

Digital technology also supports more services than analog. Most of these services are a result of the discrete sequence of digital signals and the technology's ability to transmit information from multiple points simultaneously. Several public safety agencies today use digital wireless systems to transmit data. Similar to the vocoder conversion of a voice signal to binary bits, data can be digitally formatted to binary code and transmitted on a RF carrier signal by digital modulation. For example, today's law enforcement, fire services, and EMS agencies, have installed mobile data devices in their vehicles. Without having to contact a central dispatcher, personnel can use the mobile data devices to send and receive information wirelessly from the agency's information technology systems.

Digital LMR systems also better support encryption capabilities. As previously noted, the digital signal exists as binary code, i.e.,1s and 0s, which is converted into either voice or data for the user. Similarly, encryption algorithms encrypt (for transmission) or decrypt (for reception) the digital signal by adding binary bits of information indicating how to properly reassemble the original binary signal. This reconfiguration allows the transmitted signal to be virtually unintelligible without the use of the specific encryption technology. Encryption can serve as a valuable tool for public safety agencies by protecting the private and confidential information often transmitted over a public safety LMR system.

In areas of weak system coverage, digital LMR technology has one shortfall. The speech quality of digital radios has a distinct operating distance threshold at a certain distance from the system's transmitters. At this point, the mobile or portable digital radio's speech quality degrades suddenly. This is a function of the vocoder's voice signal sampling scheme. Beyond a certain distance from the transmitter, several factors, such as path loss, conflicting signals, or noise, obstruct the number of binary bits received by the corresponding radio to the point that the sampling scheme no longer functions properly. The result is a total loss in the intelligibility of transmitted speech. Compared with analog radios operating in similar areas of weak coverage, the digital threshold in speech quality limits the practical use of digital radios for some public safety agencies. At the same distance, an analog signal remains audible, albeit at a lesser quality. Figure 11 graphically displays this comparison.

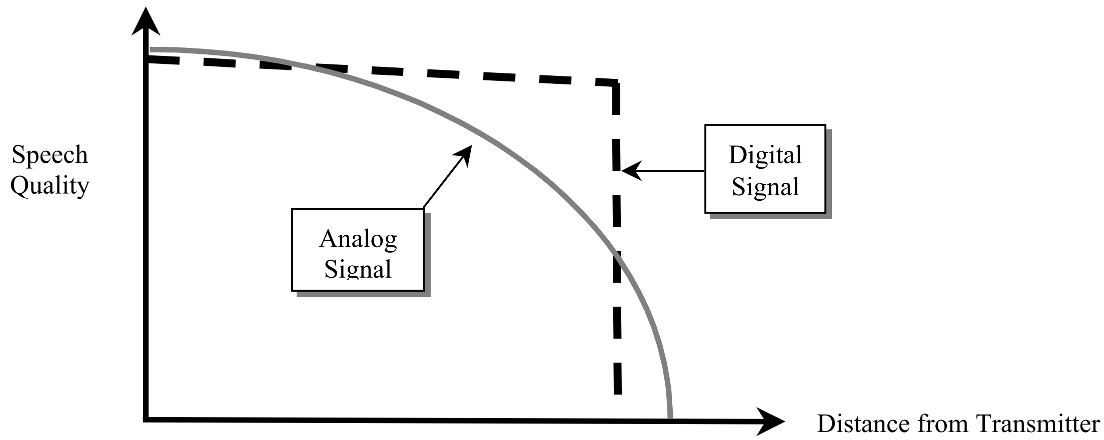

Figure 11
Voice Quality Comparison in Areas of Weak System Coverage

Digital Costs

Cost remains the determining factor for many public safety agencies considering digital equipment and systems. In the LMR market, the technology is relatively new, although it appears at the top of most vendors' product offerings and price lists. Auxiliary digital equipment is also higher priced. Correcting the speech quality threshold in areas of weak system coverage may be achieved by deploying a digital mobile transmitter or remote receiver. The acquisition of such equipment, however, will incur comparatively higher costs to previously offered analog equivalents. Consequently, the decision to procure digital systems often weighs against a public safety agency's available budget.

Digital subscriber units involve pricing schedules that also affect the decision for public safety agencies. Again, vendors tend to consider digital mobile and portable radios their top of the line equipment and, therefore, they tend to be higher priced. The overall price also increases when digital services and features are taken into account. Encryption capability adds costs to the base price of a mobile or portable digital radio and the infrastructure components. The inclusion of standards specifications, such as CAI,[24] related to digital trunked LMR systems, mean added costs as well. These supplementary costs are major considerations for public safety agencies because their acquisition often includes large quantities of subscriber units. For an additional cost, agencies can also opt for dual mode radios, programmed to function in either an analog or digital mode. This feature allows for public safety agencies operating analog systems to phase-in digital technology, beginning with subscriber units, without squandering available funds. Like other digital features, dual mode capability adds extra cost.

[24] CAI is part of the TIA/EIA 102 suite of standards.

Summary

The public safety LMR community is experiencing a wide-ranging transition to digital technology. Driven by LMR vendors, this transition introduces new services and greater user capacity than legacy analog systems while conserving spectrum. The cost of the digital transition, however, remains high. For public safety agencies, which commonly face budgeting constraints, the digital features and advantages must often be weighed against the technology's cost. However, when considering costs incurred over the system's life cycle, public safety agencies must also consider that vendors will likely phase-out analog equipment and system support.

APPENDIX D. PUBLIC SAFETY STANDARDS

Although multiple manufacturers produce hundreds of mobile and portable radio types, only a select set is appropriate for public safety use. Unlike the communications requirements of other two-way radio users, those of public safety personnel are specific and greatly influenced by variations in conditions and operational environments. Standards help codify public safety-grade radio equipment. The standards considered in this section define technical and test specifications for mobile and portable radios that help determine the radio's suitability for public safety use.

Standards development organizations (SDO) in the telecommunications industry serve as the formal organizational bodies responsible for the development of radio equipment standards. TIA, in particular, is an SDO noticeably impacting the public safety community today. TIA has thus far managed Phase I of the TIA/EIA 102 standard development process, which focuses on enhancing unit-to-unit and unit-to-infrastructure compatibility and performance, and will continue to do so through Phases II and III. Phase I of the TIA/EIA 102 standard identifies equipment features, such as vocoder interface and encryption that are critical to the mission of public safety agencies.

The U.S. Department of Defense (DoD) also initiates standards development processes relevant to public safety agencies. Military Standard (MIL-STD) 810, in particular, establishes testing procedures that can be used to assess the climatic and physical durability of mobile and portable radios intended for use by various armed services. Because the nature of the operating environment of public safety agencies often parallels that of some military agencies, MIL-STD 810 serves as a useful benchmark for assessing the suitability of mobile and portable radios for public safety agencies as well.

To help the reader better understand the impetus behind the development of these standards and their relevance to public safety users, the following subsections describe the background, features, and progress of TIA/EIA 102 and MIL-STD 810.

TIA/EIA 102—Development, Key Features, and Progress

Rapid development of wireless communications technologies, the current and foreseeable problems caused by incompatible neighboring radio systems, and a lack of vendor competition alerted local, state, federal, and tribal public safety radio users in 1989 to the need of an "open" standards development process. Dubbed Project 25 (P25) and spearheaded by APCO and the National Association of State Telecommunications Directors (NASTD), the initiative originally concentrated on two goals: improving interoperability among public safety radio systems and introducing market competition to the life cycle of radio equipment. APCO and NASTD representatives, as well as Federal Government officials from the NTIA, the National Communications System (NCS), and DoD sit on the P25 Steering Committee. Overall, P25 participants represent local, state, federal, and tribal public safety agencies and private sector communications system manufacturers.

P25 drove the development of the TIA/EIA 102 standard series. TIA/EIA 102 designates specifications for trunked digital LMR systems and equipment. It is important to note that P25 is not an SDO. The P25 standard suite is formally accredited by TIA and the American National Standards Institute (ANSI)—two prominent SDOs. The Mobile and Personal Private Standards Committee, recognized as TIA Technical Research Group 8 (TR.8), administers the ongoing development of TIA/EIA 102, as specified by the formal standards process defined in TIA's engineering manual. ANSI monitors TR.8's review and assessment process. The functional relationship among the P25 Steering Committee, TR.8, and ANSI with regard to the standards development and approval process is outlined in Figure 12.

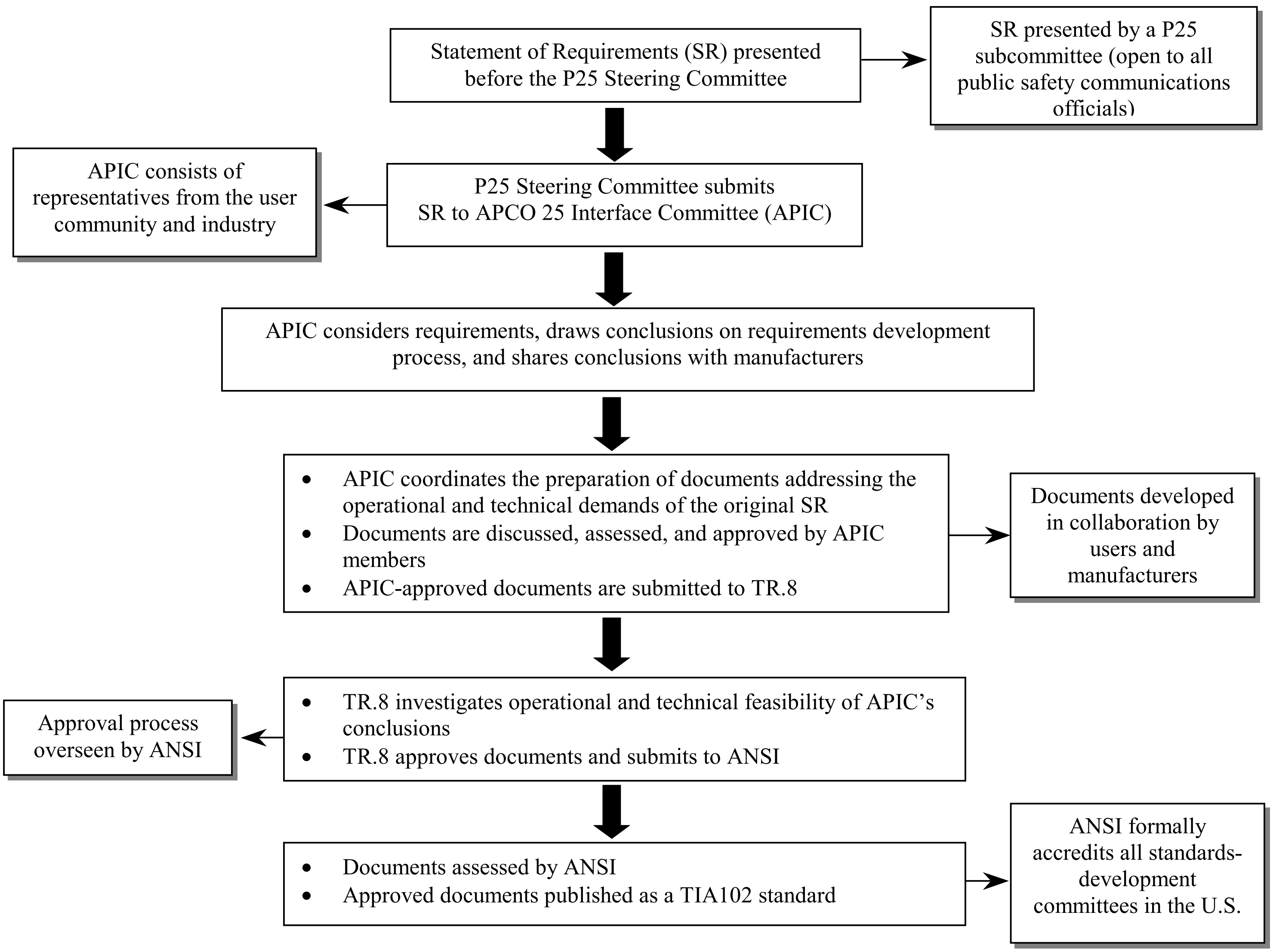

Figure 12
Development and Approval Process of TIA/EIA 102 Standards

The TIA/EIA 102 standards development process is carried out in each of the standard's three developmental phases. Each phase, identified as TIA/EIA 102 Phase I, II, and III, focuses on unique software applications for digital trunked radio systems. At the time of this report, TIA/EIA 102 Phase I was nearing completion, Phase II remained in progress, and Phase III was in its developmental stages.

The initial P25 objectives of improving public safety interoperability and instilling market competition in the LMR equipment marketplace underlie the development of each TIA/EIA 102 phase. At the most basic level, TIA/EIA 102-compliant radios are "backward compatible," this is, they are functional on digital and conventional analog systems. TIA/EIA 102 also includes only "open"—or non-proprietary—technical standards defining the unit-to-infrastructure and unit-to-unit interface. The need for open standards is clear in the case of public safety agencies operating systems with proprietary digital or trunking protocols. LMR mobile and portable equipment may be replaced multiple times throughout the life of a system. With proprietary digital or trunked protocols, the public safety agency is limited in its choice of equipment. This fact limits vendor choice, forcing users to procure new equipment only offered by the system vendor and also suppresses the potential of price competition or competitive procurements. The institution of open standards allows standards-compliant digital LMR equipment from multiple manufacturers to function on any vendor's system. Increasing the number of manufacturers offering comparable equipment, in turn, offers public safety agencies more choices and increases competition in the digital LMR equipment market.

TIA/EIA 102 Phase I

The Phase I suite of standards encompasses both system standards and service standards. System standards form the basis of Phase I and are required for all Phase I-compliant systems and equipment. Service standards apply to the services, e.g., encryption, trunking, or over-the-air rekeying (OTAR), that a P25 Phase I system can feature. Judging from the system users' needs, system operators decide which services to employ. For purposes of interoperability, the most relevant TIA/EIA 102 system standards for mobile and portable radio users in the public safety community include CAI and the IMBE vocoder. In the same regard, the key Phase I service standard is DES.

It is important to note that manufacturers commonly use the terms "APCO 25" or "Project 25" to describe TIA/EIA Phase I specifications. Vendors may identify a radio's encryption standard, for instance, as "APCO 25 DES" or its channel bandwidth as "Project 25 IMBE." In this report, the name "Project 25" (P25) will be used to describe radio equipment and systems meeting the TIA/EIA Phase I suite of standards.

CAI and IMBE serve as the key operational and technical standards for achieving interoperability. These standards define a uniform interface for digital LMR equipment and systems and help form the foundation of the open system architecture of P25. As open standards, CAI and IMBE help remove the obstacle of proprietary wireless communications protocols.

CAI standardizes the digital communications medium used for P25 digital trunked radio systems and equipment. P25 subscriber units and systems extract digital signals using FDMA technology. Digital technology appeals to two-way radio users as a more spectrally efficient means of wireless communications that is capable of using narrow bandwidth channels. In accordance with the stipulations of TIA/EIA Phase I, FDMA digital signals are capable of using

25 kHz and 12.5 kHz channel bandwidths. The ability to use less frequency bandwidth, or narrow bandwidth, is often highlighted as part of the desired transition to narrow bandwidths. This feature does not affect the backward capability of P25 mobile and portable radios. All P25 subscriber units are functionally capable of operating on 25 kHz analog channels—the typical bandwidth of analog channels—ensuring interoperability with legacy conventional analog systems.

IMBE standardizes the transmission and reception of P25 FDMA signals via a mobile or portable radio's vocoder. The vocoder can serve as the technical gateway to interoperable communications for public safety personnel in the field. Featured on all mobile and portable radios, a vocoder converts a user's voice sounds to the appropriate digital or analog signal format for the purposes of transmitting and receiving voice communications. For P25 mobiles and portable radios, the IMBE vocoder converts the user's voice to FDMA digital format for transmission. The IMBE vocoder is also capable of converting the user's voice sounds to conventional analog signals for transmission and reception. This feature ensures the backward capability requirement of P25 equipment.

Often, public safety personnel communicate confidential and tactical information using a mobile or portable radio. Interception of such information can seriously endanger the public safety mission, the public at large, or a citizen's privacy. Consequently many public safety agencies employ wireless encryption capabilities. P25 standardizes DES encryption and decryption modes for voice and data that comply with CAI. The strategic Phase I service standard applicable to public safety is DES. Encrypted voice communication remains a critical requirement for many local, state, federal, and tribal public safety agencies. As an optional service standard, however, the DES standard is incorporated only in the event that a system operator chooses DES as the optimal encryption standard for a P25 system. TIA/EIA 102 service standards documents identify other encryption services suitable for P25 systems but do not define operational specifications for those encryption services.

TIA/EIA 102 Phase II

Phase II of TIA/EIA 102 has primarily focused on providing a smooth transition to narrow bandwidth channels. Although P25 FDMA can operate in 25 kHz and 12.5 kHz channel bandwidths, the P25 Steering Committee has prioritized the transition to 6.25 kHz channel bandwidth to attain maximum spectral efficiency for digital trunked systems. The fundamental consideration at this stage of TIA/EIA 102 is the digital signal modulation method employed for the 6.25 kHz channel.

FDMA has yet to be proven as a reliable digital technology on 6.25 kHz channel bandwidths. Consequently, much of Phase II has involved consideration of digital technologies regularly used in the 6.25 kHz channel. In 1999, the P25 Steering Committee approved two-slot and four-slot TDMA technology for consideration. TDMA technology divides the frequency channel into multiple time slots. The division permits multiple conversations—equivalent to the number of time slot divisions—to simultaneously occur while using one 6.25 kHz channel bandwidth. TDMA has been proven to host several users while maximizing the use of a more narrow frequency bandwidth. Two-slot TDMA is a proprietary digital technology designed by Com-Net Ericsson.

TETRA four-slot TDMA technology remains the interoperable standard most frequently employed by public safety agencies, commercial businesses, and other two-radio users in Europe. Numerous European vendors offer TETRA. In the U.S. marketplace, only Motorola, as the sole bearers of TETRA's intellectual property rights (IPR), has the legal right to sell TETRA. Similar to the P25 standard development process, the European Telecommunications Standards Institute (ETSI), the primary telecommunications SDO in Europe, developed TETRA for public safety and commercial digital trunked radio systems.

Most important to interoperability, the modulation method will impact the backward compatibility of Phase II equipment and systems with Phase I equipment and systems. TDMA, both two-slot and TETRA, has not been verified as a technology compatible with FDMA. Despite this, TIA/EIA 102 Phase II specifications require technology that is interoperable with Phase I FDMA at a non-trunked minimum and compatible with the IMBE vocoder. In accordance with these requirements, much of TR.8 discussion today centers on assessment of the technological and operational feasibility of Phase I FDMA and Phase II TDMA interoperability.

TIA/EIA 102 Phase III

Phase III entails high-speed data transmission made possible with the incorporation of digital technology. The P25 Steering Committee originally tasked a Project 25/Project 34 user group to draft the Statement of Requirements for a high-speed data transmission standard for public safety radio systems. Concurrently however, ETSI had established a committee comparable in focus, entitled Digital Advanced Wireless System (DAWS). Senior officials at TIA and ETSI have since formed the cooperative initiative Project MESA, which will work on the development of a wideband public safety radio standard for the high-speed transmission and reception of voice, high-speed data, and streaming video. Such a standard would massively increase the amount of information transmitted to and from mobile and portable radios. Project MESA's recommendations will be subjected to the TIA/EIA 102 standards development process, beginning with TR.8.

Figure 13 summarizes the progress and key radio features of the TIA/EIA 102 standards relative to the transition from analog to digital radio equipment.

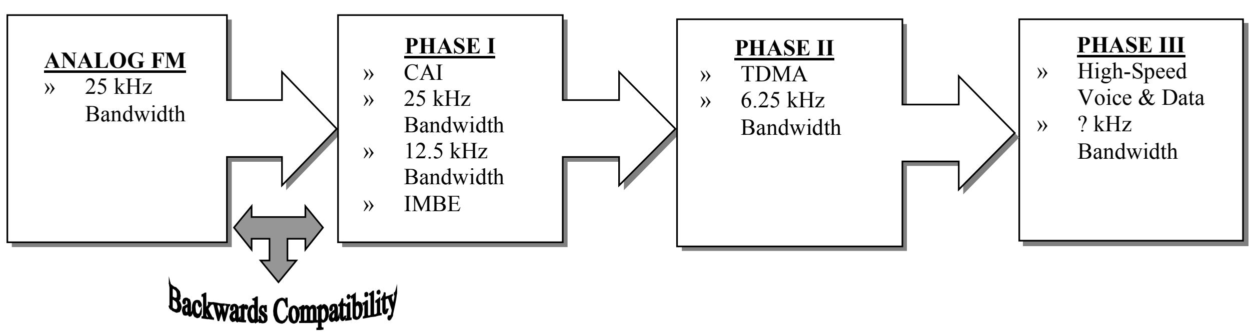

Figure 13
TIA/EIA 102 Equipment: Analog to Digital Transition

TIA/EIA 102—Key Considerations for Public Safety Agencies

The original objectives of P25 are beginning to be achieved in the public safety LMR market. Several vendors now offer P25-compliant, interoperable radios featuring CAI operation in 25 kHz and 12.5 kHz channel bandwidths, IMBE, DES, and 25 kHz analog channel compatibility. The continuing progress of TIA/EIA 102 should foster this trend. There are, however, some key issues regarding TIA/EIA 102 standards that public safety agencies must consider.

TIA/EIA 102 standards help set the stage for future interoperable public safety wireless communications systems. For the most part, public safety agencies today maintain a variety of wireless communications systems distinguished by proprietary protocols, operating frequencies, and age, among other aspects. Many agencies have deployed digital trunked radio systems operating on proprietary digital technology incompatible with P25 CAI or conventional analog systems. System replacement, in addition, usually involves high costs and can take several years to fully implement. Consequently, the near-term widespread incorporation of TIA/EIA 102 standards for most of the country is not possible.

The needs of public safety two-way radio users vary around the Nation, and in some cases do not parallel those underlying P25. Population density and topography are two characteristics that commonly determine these needs. An agency with a sparsely populated jurisdiction covering a significant geographic area may not consider interoperability important for its radio equipment. However, an agency with an urban, densely populated jurisdiction sharing borders with numerous other jurisdictions clearly has frequent need to communicate with neighboring public safety agencies—a need clearly addressed by P25. Transitioning from analog to digital systems may also not suit some agencies' practical needs. Although digital technology can host more users with less frequency, certain agencies may not need to accommodate several users simultaneously. Coupled with the fact that digital technology usually operates at UHF or higher frequencies less suitable for large coverage areas, a rural agency with a fairly small user base may not need to procure P25 digital equipment. Digital technology often carries a high price tag, discouraging purchase by public safety agencies with limited budgets. P25 equipment sold today is usually considered to be the vendor's finest, and most expensive, products.

Some elements of TIA/EIA 102 can also hinder interoperability. As a service standard, the incorporation of DES remains the choice of the system operator. Again, the user needs must be considered because certain agencies may or may not transmit confidential or tactical information over wireless communications systems. If the system operator implements DES, the system's subscriber units are programmed to one of 16 DES "keys" pursuant to TIA/EIA 102 specifications. The DES key for each mobile and portable radio encrypts and decrypts digitized signals uniformly, sustaining reliable unit-to-unit and unit-to-infrastructure voice communications within the system. As a unique element incorporated into the individual system, however, the DES key can obstruct interoperability with other P25 systems and equipment. In the event of an incident requiring multiple agency responses, the DES key of any involved P25 system must be known by all relevant system operators in order to achieve reliable interagency communications. P25 mobile and portable radios not programmed with the system's specific DES key will simply not be able to communicate encrypted information.

Military Standard 810—Background and Features

MIL-STD 810 is an environmental testing standard. U.S. military agencies created it to certify a basic level of performance for equipment deployed in the field. The U.S. Air Force drafted the original version of MIL-STD 810 in 1962—then a 66-page document that broadly outlined environmental testing methods. The standard has since undergone six developmental stages, each designated by a literal suffix, and its most recent version, MIL-STD 810 F, a document exceeding 500 pages in length, details the management, engineering, and technical tasks for the environmental design and test tailoring process. MIL-STD 810 F was released in January 2000.

Materials submitted for MIL-STD testing are used for manufacturing equipment military agencies plan to deploy in the field. Throughout its life span, this type of equipment may endure environmental conditions such as extreme temperature ranges, extended storage periods, desert-like conditions, or humidity, among others. The testing methods consequently attempt to replicate the harshest effects that the materials may endure in such environmental conditions. For the most part, each revision of MIL-STD 810 has modified the testing conditions and procedures to more accurately represent the environmental or physical effects common to the equipment's life span. These revisions are cooperatively developed by environmental engineering specialists, material acquisition program managers from DoD, and equipment manufacturers. MIL-STD 810 is a standard approved for use by all departments and agencies of the U.S. Department of Defense.

MIL-STD 810 can also be used for commercial applications. Most LMR equipment manufacturers use MIL-STD 810 specifications to verify the equipment's ability to withstand extreme environmental conditions—a key feature considered by public safety two-way radio users. Common MIL-STD 810 environmental and physical testing criteria listed by LMR equipment manufacturers for mobile and portable radio product specifications include—

Environmental Criteria

- Low pressure
- High temperature—storage
- High temperature—operational
- Low temperature
- Temperature shock
- Rain and blowing rain
- Humidity
- Salt fog
- Blowing sand and dust
- Solar radiation

Physical Criteria

- Vibration
- Shock

Each criterion involves tests replicating extreme conditions. For example, testing specifications for a "high temperature—storage" entails, at a minimum, seven consecutive 24-hour tests that put the product through a cycle of temperature changes ranging from 86 to 145 degrees Fahrenheit or 91 to 160 degrees Fahrenheit depending on the geographical regions simulated by the test. MIL-STD "blowing dust" specifications detail, among other conditions, the composition of various substances generally recognized as "dust," settlement and acceleration rates for dust relevant to the geographic region simulated, and the concentration of dust blown during the test.[25]

MIL-STD 810—Key Considerations for Public Safety

MIL-STD 810 specifications are widely used in the LMR community to distinguish the durability of certain radios. Public safety agencies and radio vendors alike have embraced the use of and compliance with MIL-STD 810 when selecting and manufacturing radio equipment. In light of the large DoD and public safety LMR markets, many vendors have built the proper facilities to apply MIL-STD 810 testing procedures to their products. Unlike the current P25 specifications, MIL-STD 810 applies to virtually all public safety radios currently in use and will continue to do so in the near term. The majority of vendors today apply MIL-STD 810 C, D, and E specifications to their mobile and portable radio products.

Each MIL-STD 810 criterion includes a series of tests identified as "procedures." For each criterion, LMR vendors usually employ one or several test procedures. Common "shock" test procedures, for example, include "functional shock" or "crash hazard." The "functional shock" procedure is designed to assess the equipment's ability to perform reliably during and after a physical shock. The "crash hazard" procedure applies to equipment mounted in vehicles and simulates crash conditions to examine the reliability of the equipment's mounting or containment features.[26] Vendors identify which tests were employed for each MIL-STD by listing the procedure's number following the testing criterion's listing (as designated by each version of MIL-STD 810), e.g., 501 1, 3. The actual procedure titles are usually not included in radio specification listings.

Public safety agencies benefit from LMR vendors' MIL-STD 810 testing. The standard provides a baseline environmental and physical durability for radios that is practical for public safety two-way radio use. It is critical, for instance, that a fireman's portable radio has been proven to endure extreme temperatures or physical impact and maintain reliable communications. A key factor distinguishing public safety-grade equipment, MIL-STD 810 must be factored by public safety agencies procuring new or replacement equipment.

[25] According to MIL-STD 810 F specifications.
[26] Ibid.

APPENDIX E. REFERENCE LIST

[1] *APCO Project 25 System and Standards Definition*. TSB102-A (revision of TSB102). *TIA/EIA Telecommunications Systems Bulletin*, Telecommunication Industry Association, November 1995.

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[3] Mary J. Taylor, Robert C. Epper, Thomas K. Tolman. *State and Local Law Enforcement Wireless Communications and Interoperability: A Quantitative Analysis*. National Institute of Justice Research Report. National Law Enforcement & Corrections Technology Center, Rocky Mountain Region, January 1998.

[4] Public Safety Wireless Network Program. *800 MHz Study: A Study to Assess the Relative Merits of Spectrum Around 800 MHz as an Operating Frequency Band for Public Safety Communications.* March 1998.

[5] Public Safety Wireless Network Program. *Comparisons of Conventional and Trunked Systems.* May 1999.

[6] Public Safety Wireless Network Program. *Maritime Public Safety Case Study: Results and Recommendations Report.* January 2001.

[7] Public Safety Wireless Network Program. *PSWN Program Analysis of Fire and EMS Communications Interoperability.* April 1999.

[8] Singer, Edward. *Land Mobile Radio Systems, 2nd Edition.* Prentice Hall, April 1994

APPENDIX F. LIST OF ACRONYMS

AM	Amplitude Modulation
ANSI	American National Standards Institute
APCO	Association of Public-Safety Communications Officials International
APIC	APCO Interface Committee
CAI	Common Air Interface (APCO 25)
DAWS	Digital Advanced Wireless System
DES	Data Encryption Standard
DoD	Department of Defense
DTMF	Dual Tone Multi Frequency
EDACS	Enhanced Digital Access Communications System
EIA	Electronics Industry Association
EMS	Emergency Medical Services
ESMR	Enhanced Specialized Mobile Radio
ETSI	European Telecommunications Standards Institute
FBI	Federal Bureau of Investigation
FCC	Federal Communications Commission
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
FSK	Frequency Shift Key
GHz	Gigahertz
GOS	Grade of Service
Hz	Hertz
KBps	Kilo Bytes Per Second
KHz	Kilohertz
iDEN	Integrated Dispatch Enhanced Network
IMBE	Improved Multi-Band Excitation
IPR	Intellectual Property Rights
LCD	Liquid Crystal Display
LEAA	Law Enforcement Assistance Administration
LED	Light Emitting Diode
LM	Linear Modulation
LMR	Land Mobile Radio
LTR	Logic Trunked Radio
MHz	Megahertz
MIL-STD	Military Standard
MPSCS	Michigan Public Safety Communications System
MS	Millisecond
NASTD	National Association of State Telecommunications Directors
NIST	National Institute of Standards and Technology
NLECTC	National Law Enforcement and Corrections Technology Center
NCS	National Communications System
NPSPAC	National Public Safety Planning Advisory Committee
NTIA	National Telecommunications and Information Administration
NRTC	National Rurual Telecommunications Cooperative

OARPS	Open Architecture Radios for Public Safety
OTAR	Over-the-Air Rekeying
P25	Project 25
PSTN	Public Switched Telephone Network
PSWN	Public Safety Wireless Network
RF	Radio Frequency
RNT	Radio Network Terminal
SCBA	Self-Contained Breathing Apparatus
SDO	Standards Development Organization
SMR	Specialized Mobile Radio
SWT	Securicor Wireless Technology
TDM	Time Division Multiplex
TDMA	Time Division Multiple Access
TETRA	Terrestrial Trunked Radio
TIA	Telecommunications Industry Association
TR.8	TIA Technical Research Group 8
TSB	Telecommunications System Bulletin
UHF	Ultra High Frequency
VHF	Very High Frequency
VSLI	Very Large Scale Integrated
VoIP	Voice-over-Internet Protocol

APPENDIX G. GLOSSARY

A	
access method	The ability and means necessary to store data, retrieve data, or communicate with a system. FDMA, TDMA, and CDMA are examples. [1]
analog modulation technique	Process whereby message signal, which is the analog of some physical quantity, is impressed on a carrier signal for transmission through a channel (e.g., FM). [3]
analog signal	**1**. A signal that has a continuous nature rather than a pulsed or discrete nature. *Note:* Electrical or physical analogies, such as continuously varying voltages, frequencies, or phases, may be used as analog signals. **2**. A nominally continuous electrical signal that varies in some direct correlation with another signal impressed on a transducer. *Note:* For example, an analog signal may vary in frequency, phase, or amplitude in response to changes in physical phenomena, such as sound, light, heat, position, or pressure. [2]
antenna	Any structure or device used to collect or radiate electromagnetic waves. [2]

B	
backward compatibility	Ability of new radio equipment to operate within an "old" system infrastructure or directly intercommunicate with an "old" radio unit. The term usually applies to digital radios that are also capable of analog signal transmission. [1]
bandwidth	The difference between the limiting frequencies of a continuous frequency band. Typically measured in kilohertz. May be considered the amount in kilohertz required for a single communications channel. [1] (e.g., 30, 25, 12.5, 6.25, 5)
base station	**1**. A land station in the land mobile service. **2**. In personal communication service, the common name for all the radio equipment located at one fixed location, and that is used for serving one or several calls. [2]

C	
call delay	The delay experienced when a call arriving at an automatic switching device finds no idle channel or facility available to process the call immediately. [1]
call setup time	The overall length of time required to establish a circuit-switched call between users or terminals. [1]
carrier	**1**. A wave suitable for modulation by an information-bearing signal. **2**. An unmodulated emission. *Note:* The carrier is usually a sinusoidal wave or a uniform or predictable series of pulses. *Synonym:* **carrier wave**.
channel	A single unidirectional or bidirectional path for transmitting or receiving, or both, of electrical or electromagnetic signals. [1]
channel capacity	The maximum possible information transfer rate through a channel, subject to specified constraints. [2]
channel spacing	Typically measured in kilohertz from the center of one channel to the center of the next-adjacent-channel. May, or may not, be identical to bandwidth. [1]
collision	In a transmission system, the situation that occurs when two or more demands are made simultaneously on equipment that can handle only one at any given instant. [2]
common air interface (CAI)	Standard for digital wireless communications medium employed for P25-compliant radio systems and equipment. The standard for P25 Phase I incorporates Frequency Division Multiple Access (FDMA) technology.
communications system	A collection of individual communications networks, transmission systems, relay stations, tributary stations, and data terminal equipment usually capable of interconnection and interoperation to form an integrated whole. Note: The components of a communications system serve a common purpose, are technically compatible, use common procedures, respond to controls, and operate in unison. [2]

conventional radio system	Non-trunked, similar to telephone party-line in that the user determines availability by listening for an open channel. [3]
coverage	**1**. In radio communications, the geographical area within which service from a radio communications facility can be received. [2] **2**. The geographic area included within the range of, or covered by, a wireless radio system. Two systems cannot be made compatible through patching unless the coverage areas overlap. [3]

D

data	Representation of facts, concepts, or instructions in a formalized manner suitable for communication, interpretation, or processing by humans or by automatic means. Any representations such as characters or analog quantities to which meaning is or might be assigned. [2]
delay time	The sum of waiting time and service time in a queue. [1]
demodulation	The recovery, from a modulated carrier, of a signal having substantially the same characteristics as the original modulating signal. [2]
digital	Characterized by discrete states. [2]
digital modulation technique	Technique for placing a digital data sequence on a carrier signal for subsequent transmission through a channel. [3]
digital signal	A signal in which discrete steps are used to represent information. *Note 1:* In a digital signal, the discrete steps may be further characterized by signal elements, such as significant conditions, significant instants, and transitions. *Note 2:* Digital signals contain many significant conditions. [2]
dynamic regrouping	A trunking system feature that allows multiple radios to be placed upon a specific talk group without manual manipulation of the radio's programming. Dynamic regrouping is initiated through a system control console and transmitted to the radio via the trunking systems control channel.

E

encipher	[To] Convert plain text into an unintelligible form by means of a cipher. [2]
encode	**1.** To convert data by the use of a code, frequently one consisting of binary numbers, in such a manner that reconversion to the original form is possible. 2. [To] convert plain text to equivalent cipher text by means of a code. 3. To append redundant check symbols to a message for the purpose of generating an error detection and correction code. [2]
encrypt	**1**. [A] generic term encompassing encipher and encode. **2**. To convert plain text into unintelligible forms by means of a cryptosystem. Note: The term *"encrypt"* covers the meanings of *"encipher"* and *"encode."* [2]
enhanced specialized mobile radio (ESMR)	Provides land mobile communications on a commercial (i.e., for profit) basis, and provides new features and services, such as two-way acknowledgment paging and inventory tracking, credit card authorization, automatic vehicle location, fleet management, inventory tracking, remote database access, and voicemail.

F

Federal Communications Commission	An independent regulatory commission which includes a board of Commissioners, nominated by the President and confirmed by the Senate, having the power to regulate non-Federal wire and radio telecommunications in the United States. [3]
frequency	For a periodic function, the number of cycles or events per unit time. [2]
frequency assignment	**1**. Authorization, given by an Administration, for a radio station to use a radio frequency or radio frequency channel to use a radio frequency or radio frequency channel under specified conditions. **2**. The process of authorizing a specific frequency, group of frequencies, or frequency band to be used at a certain location under specified conditions, such as bandwidth, power, azimuth, duty cycle, or modulation. *Synonym* **radio frequency channel assignment**. [2]

frequency hopping [The] repeated switching of frequencies during radio transmission according to a specified algorithm, to minimize unauthorized interception or jamming of telecommunications. Note: The overall bandwidth required for frequency hopping is much wider than that required to transmit the same information using only one carrier frequency. [2]

frequency modulation Modulation in which the instantaneous frequency of a sine wave carrier is caused to depart from the center frequency by an amount proportional to the instantaneous value of the modulating signal. *Note 1:* In FM, the carrier frequency is called the center frequency. *Note 2:* FM is a form of angle modulation. [2]

frequency sharing The assignment to or use of the same radio frequency by two or more stations that are separated geographically or that use the frequency at different times. *Note 1:* Frequency sharing reduces the potential for mutual interference where the assignment of different frequencies to each user is not practical or possible. *Note 2:* In a communications net, frequency sharing does not pertain to stations that use the same frequency. [2]

frequency-division multiple access (FDMA) **1**. The use of frequency division to provide multiple and simultaneous transmissions to a single transponder. [2] **2**. A channel access method in which different conversations are separated onto different frequencies. FDMA is employed in narrowest bandwidth, multiple-licensed channel operation. [3]

G

grade of service (GOS) **1**. The probability of a call's being blocked or delayed more than a specified interval, expressed as a decimal fraction. *Note:* Grade of service may be applied to the busy hour or to some other specified period or set of traffic conditions. Grade of service may be viewed independently from the perspective of incoming versus outgoing calls, and is not necessarily equal in each direction. **2**. In telephony, the quality of service for which a circuit is designed or conditioned to provide, e.g., voice grade or program grade. *Note:* Criteria for different grades of service may include equalization for amplitude over a specified band of frequencies, or in the case of digital data transported via analog circuits, equalization for phase also. [2]

H

high-band frequency Refers to the higher frequency levels in the VHF band, typically 138-222 MHz.

hybrid A functional unit in which two or more different technologies are combined to satisfy a given requirement. *Note:* Examples of hybrids include *(a)* an electric circuit having both vacuum tubes and transistors, *(b)* a mixture of thin-film and discrete integrated circuits, and *(c)* a computer that has both analog and digital capability.

I

interference The effect of unwanted energy due to one or a combination of emissions, radiation, or inductions upon reception in a radio communication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy. [2]

interoperability **1**. The ability of systems, units, or forces to provide services to and accept services from other systems, units, or forces and to use the services so exchanged to enable them to operate effectively together. **2**. The condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users. The degree of interoperability should be defined when referring to specific cases. [2]

interoperability standard	**1**. A document that establishes engineering and technical requirements that are necessary to be employed in the design of systems, units, or forces and to use the services so exchanged to enable them to operate effectively together. [2] **2**. Established protocol that provide common interface. [3]

K

key	The parameter defining an encryption code or method. [1]
kilohertz (kHz)	A unit of frequency denoting one thousand (10^3) Hz. [2]

L

linear modulation	A radio frequency transmission technique that is used to provide the physical transport layer of a radio system. This technology is compatible in digital and analog system environment and supports channel bandwidths of five kHz to 50 kHz.
lost call	A call that has not been completed for any reason other than cases where the call receiver (termination) is busy. [2]
low-band frequency	Refers to the lower frequency levels in the VHF band, typically 25-50 MHz.

M

megahertz (MHz)	A unit of frequency denoting one million (10^6) Hz. [2]
modulation	The process, or result of the process, of varying a characteristic of a carrier, in accordance with an information-bearing signal. [2]
multicast	To transmit identical data simultaneously to a selected set of destinations in a network.
multiplexing	The combining of two or more information channels onto a common transmission medium. *Note:* In electrical communications, the two basic forms of multiplexing are time-division multiplexing (TDM) and frequency-division multiplexing (FDM). [2]
mutual aid channel	A national or regional channel that has been set aside for use only in mutual aid interoperability situations, usually with restrictions and guidelines governing usage. [3]

N

narrowband channels	Refers to channels occupying less than 20 kHz.
narrowbanding	The migration to systems operating using narrower bandwidths.
National Public Safety Planning Advisory Committee	Committee established to conduct nationwide planning and allocation for the 821-824 MHz and 866-869 MHz bands.
National Telecommunications and Information Administration	The Executive Branch agency that serves as the President's principal advisor on telecommunications and information policies and is responsible for managing the Federal Government's use of the radio spectrum.
Network	An interconnection of three of more communicating entities. [2]

O

operation	The method, act, process, or effect of using a device or system. [2]
over-the-air re-keying (OTAR)	The ability to update or modify encryption keys programmed in a mobile or portable radio over radio frequency.

P

packet	A sequence of binary digits, including data and control signals, that is transmitted and switched as a composite whole. The data, control signals and possibly error control information, are arranged in a specific format. [1]

packet switching The process of routing and transferring data by means of addressed packets so that a channel is occupied during the transmission of the packet only, and upon completion of the transmission the channel is made available for the transfer of other traffic. [1]

priority **1**. Priority, unless specifically qualified, is the right to occupy a specific frequency for authorized uses, free of harmful interference from stations or other agencies. [2] **2**. In voice communications systems, one of the levels of precedence assigned to a user unit for the purpose of preemption of communication services.

Project 25 An open standards development initiative started in 1989 by APCO that focuses on digital, trunked LMR systems employed by the public safety community. P25 remains the foundation of the developing TIA/EIA 102 suite of standards.

propagation The motion of waves through or along a medium. *Note:* For electromagnetic waves, propagation may occur in a vacuum as well as in material media. [2]

protocol A set of unique rules specifying a sequence of actions necessary to perform a communications function. [1]

Q

queue A set of items, such as telephone calls or packets, arranged in sequence. *Note:* Queues are used to store events occurring at random times and to service them according to a prescribed discipline that may be fixed or adaptive. [2]

queuing delay In a radio communication system, the time between the completion of signaling by the call originator and the arrival of a permission to transmit to the call originator.

R

radio channel An assigned band of frequencies sufficient for radio communication. *Note 1:* The bandwidth of a radio channel depends upon the type of transmission and the frequency tolerance. *Note 2:* A channel is usually assigned for a specified radio service to be provided by a specified transmitter. [2]

radio equipment As defined in *Federal Information Management Regulations,* any equipment or interconnected system or subsystem of equipment (both transmission and reception) that is used to communicate over a distance by modulating and radiating electromagnetic waves in space without artificial guide. This does not include such items as microwave, satellite, or cellular telephone equipment. [2]

radio frequency (RF) Any frequency within the electromagnetic spectrum normally associated with radio wave propagation. [2]

RF repeater **1**. An analog device that amplifies an input signal regardless of its nature, *i.e.,* analog or digital. **2**. A digital device that amplifies, reshapes, retimes, or performs a combination of any of these functions on a digital input signal for retransmission. *Note:* The term *"repeater"* originated with telegraphy and referred to an electromechanical device used to regenerate telegraph signals. Use of the term has continued in telephony and data communications. [2]

S

scanning A subscriber unit feature that automatically allows the radio to change channels or talk groups to enable a user to listen to conversations occurring on different channels or groups. In some equipment, users may define the channels or talk groups to be scanned.

service delivery area See **coverage**

signal The detectable transmitted energy that carries information from a transmitter to a receiver. [1]

specialized mobile radio (SMR) A radio system in which licensees provide land mobile communications services in the 800 MHz and 900 MHz bands on a commercial basis (i.e., for profit) basis.

spectrum The usable radio frequencies in the electromagnetic distribution. Specific frequencies have been allocated to the public safety community. They include:

High HF	25-29.99 MHz
Low VHF	30-50 MHz
High VHF	150-174 MHz
Low UHF	406.1-420/450-470 MHz
UHF TV Sharing	470-512 MHz
700 MHz	764-776/794-806 MHz
800 MHz	806-824/851-869 MHz.

squelch A radio circuit that eliminates noise from the speaker when no transmitted signal is present. [1]

subscriber unit A mobile or portable radio unit used in a radio system. [1] *Synonym* **user unit, user radio**.

system Any organized assembly of resources and procedures united and regulated by interaction of interdependence to accomplish a set of specific functions. [1]

System architecture The design principles, physical structure, and functional organization of a land mobile radio system. Architectures may include single site, multi-site, simulcast, multicast, or voting receiver systems.

System redundancy The measure or extent of the ability of a system, such as a computer, communications, data processing, or weapons system, to continue to function despite the existence of faults in its component subsystems or parts. *Note:* System performance may be diminished or otherwise altered until the faults are corrected.

T

talk group A subgroup of radio users who share a common functional responsibility and, under normal circumstances, only coordinate actions among themselves and do not require radio interface with other subgroups. [3]

terminal A device capable of sending, receiving, or sending and receiving information over a communications channel. [2]

throughput The number of bits, characters, or blocks passing through a data communication system, or portion of that system. *Note 1:* Throughput may vary greatly from its theoretical maximum. *Note 2:* Throughput is expressed in data units per period of time. [2]

TIA/EIA-102 Standards A joint government/industry standards-setting effort to develop technical standards for the next generation of public safety radios, both voice and data. [3]

time division multiple access (TDMA) **1**. A digital communications technique that uses a common channel (multipoint or broadcast) for communications among multiple users by allocating unique time slots to different users. *Note:* TDMA is used extensively in satellite systems, local area networks, physical security systems, and combat-net radio systems. [2] **2**. A channel access method in which different conversations are separated into different time slots. [3]

trunk A single transmission channel between two points that are switching centers or nodes, or both. [1]

trunked (system) Systems with full feature sets in which all aspects of radio operation, including RF channel selection and access, are centrally managed. [1]

Trunked radio system A system that integrates multiple channel pairs into a single system. When a user wants to transmit a message, the trunked system automatically selects a currently unused channel pair and assigns it to the user, decreasing the probability of having to wait for a free channel for a given channel loading. [3]

U

user A person, organization, or other entity (including a computer of computer system), that employs the services provided by a telecommunication system, or by an information processing system, for transfer of information. *Note:* A user functions as a source of final destination of user information, or both. *Synonym* **subscriber**. [2]

V

vocoder *Abbreviation for* **voice-coder**. A device that usually consists of a speech analyzer, which converts analog speech waveforms into narrowband digital signals, and a speech synthesizer, which converts the digital signals into artificial speech sounds. *Note 1:* For communications security purposes, a vocoder may be used in conjunction with a key generator and a modulator-demodulator to transmit digitally encrypted speech signals over narrowband voice communications channels. These devices are used to reduce the bandwidth requirements for transmitting digitized speech signals. *Note 2:* Some analog vocoders move incoming signals from one portion of the spectrum to another portion. [2]

voice-over-Internet protocol (VoIP) The technology used to transmit voice conversations over a data network, such as a local or wide area network or the Internet, using the Internet Protocol.

W

wavelength The representation of a signal as a plot of amplitude versus time. [2]

wideband channel Refers to channels occupying more than 20 kHz.

APPENDIX H. LIST OF PARTICIPATING MANUFACTURERS

The PSWN Program would like to thank the following manufacturers and vendor representatives for their participation in the *Land Mobile Equipment Market Analysis Report*.

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APPENDIX I. VENDOR SPECIFICATION SHEETS