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Project 25: The Quest for Interoperable Radios

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Project 25. Few terms have been more closely associated with the quest for communications interoperability among public safety agencies. But what exactly is Project 25? Where did it come from and where is it headed? What is its value to public safety agencies and technology managers?

This *Issue Brief* attempts to answer those questions, providing background and current information for decision-makers who may be considering use of radios and radio systems built around standards that have arisen from the project.

A Short History of Project 25

The late 1980s were the beginning of significant technological change in the realm of police, fire, and other public safety radio systems. After many years of analog (FM or frequency modulated) radio technologies predominating, and after several years of early trunked radio systems evolution, leaders in the public safety communications community saw digital technologies emerging. They identified a need—and an opportunity—to escape proprietary systems by setting future standards.

The Origin

Project 25 began in 1989 as a joint effort of the Association of Public-Safety Communications Officials–International, Inc. (APCO) and the National Association of State Telecommunications Directors (NASTD) to ensure a future with an open, standards-based alternative for digital radio systems. With support of other public safety organizations, federal agency radio users, and industry, the effort has progressed for many years.

Today, Project 25 provides those standards and is being extended to eliminate the vendor lock-in that adopters of proprietary trunked systems have faced.

The Name

Project 25 received its name following APCO's tradition of numbering its broad initiatives that affect the public safety communications world. Project 25 or P25, as it is also commonly known, is the association's best-known project. Today, "P25" has come to be synonymous with "public safety digital radio standards."

The Work

Three key aspects of Project 25 make it particularly important for improved communications interoperability.

1. The standards initiative was begun and driven by public safety agencies and organizations.
2. It proceeded with both a vision of forthcoming technological change and the need for graceful migration between technologies used by public safety agencies.
3. Competition founded on open standards would produce the best technology, at the best prices for public safety agencies.

Many individuals representing agencies at all levels of government and throughout the land mobile radio industry have contributed to P25 over the years. Many continue to contribute to this day. Some of the biggest contributors were public safety agencies that adopted the technology early, in effect serving as testers while standards and their implementations were honed.

Early on, public safety participants provided specifications in the form the P25 Statement of Requirements (SOR) document. This became the base document for future standards. Today, portions of

Trunking 101: How Trunked and Conventional Radio Systems Differ

Trunked radio systems dynamically assign radio frequencies and physical channels to users. From the perspective of users, talkgroups are selected on their radio to steer transmissions to the intended audience. The user does not know which frequency or physical radio channel that a given transmission will be made upon. By contrast, users of conventional radio systems select fixed frequencies or physical channels when they transmit, anticipating that a predetermined set of users will be on that channel.

The primary value of trunked radio is channel efficiency: More users can share a fixed number of channels without regularly interfering with one another. The number of simultaneous transmissions that can occur is essentially the same between conventional and trunked systems.

these specifications have been codified by the American National Standards Institute (ANSI) through efforts of the Telecommunications Industry Association (TIA) and the Electronic Industries Alliance (EIA). Formally, P25 specifications are defined in the ANSI/TIA/EIA 102 suite of standards.

Interface Standards

Project 25 defined a general system model for public safety radio communications with eight open interfaces. These interfaces connected components, or subsystems, of radio systems that were becoming increasingly complex year after year. Beyond just transmitters, receivers, and dispatch consoles, today's advanced radio systems may have data, telephone, and network management subsystems, as well as connections with other radio systems. Between each subsystem is some type of interface.

> The **Common Air Interface** (CAI) is the heart of the technological interoperability between P25 radios.

The Common Air Interface

The first set of standards developed through Project 25 dealt with the **Common Air Interface** or CAI—the point of connection between radio transmitters and receivers. Simply put, the CAI defines the technical form and function of the digital signal that goes over the airwaves. It specifies how audio is digitized and encoded on inherently analog radio waves. The CAI specifies the data rate of the digital signal stream and how that stream is split into frames variously controlling communications, carrying the audio payload, and passing forward error correction information to help receivers recover missing bits and pieces.

The CAI was a major step because it defined how P25 radios would communicate with one another at the most basic level. Where the analog world of conventional FM radio is both well standardized and devoid of proprietary techniques that hinder compatibility between manufacturers, digital radio technology is not. Project 25 undertook a major effort to assure that intellectual property rights of inventors and manufacturers did not impede development of and competition in providing public safety digital radio. The CAI, therefore, is key for technological interoperability between P25 systems.

Other Interfaces

But P25 is much more than just the CAI. It goes well beyond to define more than 30 services provided across its CAI and seven other interfaces. A full explanation of the P25 system model is beyond the scope of this article, but recent work on three key interfaces offers promise for future interoperability of digital radio systems.

- **Inter-RF Subsystem Interface (ISSI)**: Defines how different P25 radio networks can connect with one another—a key issue of communications interoperability.
- **Console Subsystem Interface (CSSI):** Defines how the radio frequency (RF) components of a P25 system and consoles, as are commonly used by public safety dispatchers, connect with one another.
- **Fixed Station Interface (FSI):** Defines how components of a P25 radio system that are fixed in place—as contrasted to those that are mobile or portable in operation—connect with other components of the system. Dispatcher consoles are typically used to access fixed RF stations, so the CSSI and FSI are interdependent in most applications.

These three interfaces are crucial to interoperability between digital radio systems using P25 standards. As of early 2007 they are still under development and the timeframe for availability of equipment meeting a full complement of standards is unknown. Each interface provides multiple services, eventually involving baseline and increasingly complex standards. By comparison, the CAI is incorporated in equipment widely available today.

How Does P25 Improve Interoperability?

P25 has matured during a period of great need and demand for communication interoperability among first responders. Its value for interoperability is twofold: First, harnessing the naturally disruptive trend of technological change and, second, requiring backward compatibility. Let's look at these two effects on interoperability individually.

A Digital Standard

As mentioned, P25 was born from the widespread trend toward digital radio technologies across most communications markets. Analog transmission technologies have been replaced with digital in many commercial and common carrier systems, such as cellular telephone. Demand for greater capacity and features, combined with limited radio frequency spectrum, has driven a transition to digital technologies in the public safety world as it has elsewhere.

Digital radios of any form—the first responder's portable radio, a cellular telephone, or otherwise—are not inherently more or less interoperable than analog radios. Both use technologies that convert the human voice and other consumable forms of information into forms unintelligible to humans, then move it invisibly over the airwaves to other radios where the process is reversed. The difference is that digital techniques require more complex electronics and often involve proprietary standards. Singularly, Project 25 provides the means to standardize digital voice radio systems for public safety. Early on, it provided a common system model to guide the development of standards, assurances for inventors and manufacturers that intellectual property rights would be protected, and the guarantee that fair licensing of component technologies would provide competition. These steps, alone, provided a nucleus around which standards for emerging technology arose, promoting interoperability.

Backward Compatibility

If standards for future systems were all that P25 meant to interoperability, that alone would be significant. But technological change doesn't occur in a vacuum. Analog radio uses will continue in public safety applications for the foreseeable future. P25 established early on that the first and subsequent phases of technology under its banner would be backwardly compatible. That is, radios built to P25 standards would be technically capable of communicating with earlier analog radios, including within trunked systems. The standard specifies that each vendor's P25 equipment must be backwardly compatible with its own analog trunked technology.

This principle of backward compatibility will ensure that as P25 evolves, emerging P25-compatible radios likewise will be capable of communicating with earlier P25 generations.

When Is P25 Required?

The factors influencing interoperability have led to much discussion and some promotion of Project 25-compliant radios to solve the nation's interoperability woes. Early enthusiasm for requiring it as a condition of all federal funding for public safety radios has waned as it became apparent that, nationwide, some analog systems will continue to be used well into the future. Funding was far from sufficient to replace all existing systems, meaning that requirements to use digital technology could actually *reduce* interoperability.

On the other hand, since P25-compliant radios are backwardly compatible, newly purchased radios can be used on legacy systems. There is a cost premium today for P25-capable radios, but many consider this the cost of cross-systems compatibility and expect it to disappear over time. Some agencies have purchased P25-capable radios to operate solely on analog systems, expecting their neighbors to transition to digital or even to make the transition themselves at some point.

Federal funding requirements for the use of P25 are simply advisory today. For example, consider the following Department of Homeland Security grant program statement:

> "When procuring equipment for communication system development and expansion, a standards based approach should be used to begin migration to multi-jurisdictional and multi-disciplinary interoperability. Specifically, all new voice systems *should* be compatible with the ANSI/TIA/EIAA-102 Phase 1 (Project 25 or P25) suite of standards. This recommendation is intended for government owned or leased land mobile public safety radio equipment and its purpose is to make sure that such equipment or systems are capable of interoperating with other public safety land mobile equipment or systems. It is not intended to apply to commercial services that offer other types of interoperability solutions and does not exclude any application if it demonstrates that the system or equipment being proposed will lead to enhanced interoperability."[1]

1 *FY 2006 Homeland Security Grant Program: Program Guidance and Application Kit*, (Washington, D.C.: U.S. Department of Homeland Security, December 2005) at p. K-1. Emphasis in original.

One realm where P25 is required by federal regulation is in the use of interoperability frequencies specifically designated by the Federal Communications Commission (FCC) in public safety segments of the 700 MHz band. Anticipating broad use of digital technologies in this band and to standardize use, the FCC designated P25 as the only authorized mode of transmission on the interagency frequencies.

Does P25 Guarantee Interoperability?

No technology can guarantee that public safety agencies have communications interoperability with their cooperators in emergency response. Other factors, such as how the technology is used, whether common or compatible procedures are in use, and whether they are incorporated into a single incident management system, greatly affect how well agencies communicate with one another.

Even in the realm of technology, P25 is not a guarantor of technological interoperability. Radios in different frequency bands using P25 digital standards are today no more able to communicate directly with one another than if they were using FM analog transmissions. The CAI provides a standard of technological interoperability between radios operating across a common network, or in a common band on separate systems by direct unit-to-unit transmissions. However, P25 user radios in different bands still must be interconnected through a gateway of some form to communicate, just as they would be if using traditional FM analog or even proprietary systems.

For example, responders from an agency using a P25 system with conventional repeaters in VHF-high band and those from another agency using a P25 800 MHz trunked system will have to rely on their systems being connected together through gateways just as they would if no P25 standards were in use.

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This is not a P25 flaw, but rather an unfortunate reality. Different frequency bands offer differing advantages. The advantages of VHF for state highway patrol officers spread widely across a rural state are different from those of 800 MHz for police officers in the concrete and steel canyons of our major cities. As long as different radio types are needed for such widely separated frequency bands, interoperability issues remain—regardless of P25 standardization.

What Value Is P25 to My Agency?

The increased availability of funding for public safety radio systems has led to many new systems in recent years. Agencies looking to take advantage of the efficiencies and capabilities of digital technologies have turned to P25 as the public safety standard for voice radio systems. Federal funding has promoted this for interoperability purposes, but P25 offers much in addition to technological compatibility.

Most commonly used in trunked radio systems, P25 brings the natural spectrum efficiency of both digital and narrowband radio techniques. P25 trunked systems are largely still proprietary today, but portable and mobile radios operating on them are technologically capable of communicating with conventional (non-trunked) digital and analog users of the same frequency band, offering additional interoperability options.

Narrowband Channels

Most public safety radio users in the United States are facing an FCC requirement to cut the width of their channels in half over the next few years. P25 users have already met this "narrowbanding" mandate because their digital technology already operates within the narrower channel widths. It was designed that way. The FCC requirement can also be met with most existing, FM analog radios without migrating to digital technologies simply by reprogramming channels. Analog users, however, face likely reductions in transmission range with channels half as wide, while evidence suggests that P25 signals, using no more bandwidth, have a range comparable to that of traditional, wider FM transmissions.

Shared Systems

P25 has found favor in systems shared among multiple agencies, primarily in trunked systems where each can have virtually private channels for intra-agency communications. Use of shared systems of any form provides the technological compatibility between agencies needed for interagency communications as well.

Whether trunked or conventional, shared systems generally improve both intra- and interagency communications.

Embedded Data Capabilities

Digital radio techniques are a natural and efficient tool for data transmission. In effect, they turn analog audio and signaling information into data anyway, so status codes, text, and other forms of data can be transmitted as easily as voice. In addition, data can be embedded in the digital stream independent of the encoded voice signal. Useful information, such as the transmitting unit's identification number, location, and other information useful for tracking the status of the radio user, can be carried along with the voice signal payload.

Project 25 foresaw the value in this for public safety, squeezing every bit out of the digital data stream to help make the transmission more resilient to fading and interference, as well as making it suitable for carrying embedded data. Many of the proprietary signaling techniques used with analog radios can be implemented as standard features in P25 systems.

Encryption

Encryption has long been difficult to implement well in analog systems. Being naturally encoded, the P25 digital signal is at once less susceptible to interception than an FM signal, but more important, the digital payload can be truly encrypted with no additional overhead on the ever-limited communications channel.

Traditional encryption techniques on analog channels have invariably brought reduced range and management challenges. Not only is an encrypted P25 signal indistinguishable in terms of range from its unencrypted counterpart, but the standards effort sought strongly to make encryption a more practical tool for public safety agencies. It brought the term "over the air re-keying" (OTAR) into the mainstream to greatly reduce the need for technicians to physically touch each and every user radio when a new encryption key is established to maintain security—ideally fairly often.

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Are There Disadvantages?

Despite these advantages, there are disadvantages of P25 radios and systems. The two most oft-cited disadvantages—cost and conventional use interference—have more to do with the newness of the technology and effects of digital radio rather than with the standard suite itself. The third disadvantage, complexity, is unfortunately inherent in the use of more and more advanced technologies to support public safety response.

Disadvantage #1: Cost

As with any technology, early adopters have paid a premium for P25 radios compared to more "mature" technologies. Use of P25 is limited largely to government agencies in the United States, leading to higher costs compared to less specialized technology. While P25 equipment will drop in price as use spreads, it likely will always sell at something of a premium over radio technologies in broader, more general use.

Disadvantage #2: Conventional Use and Interference

P25 has found limited adoption in conventional systems. This may be due to difficulty in justifying the added cost without the need for and benefits of trunked systems. It may also be because without the inherent channel access controls that trunked systems impose, transmission collisions between conventional system users are more significant when using digital channels than when using analog channels.

To explain this latter point, consider that it is not uncommon for two field users of a conventional repeater to transmit simultaneously, leading to a noticeable distortion of the input signals retransmitted by the repeater. It is equally common in direct, nonrepeated use of a channel for users to "walk on" one another unintentionally through simultaneous attempts to talk.

Trunked systems prevent this through an automatic request-to-send/clear-to-send handshake between user radios and a central controller connected to fixed sites. Since trunked user radios talk to and through these fixed sites to communicate with one another, the system regulates who talks when. Trunked radio users are trained to press the push-to-talk (PTT) button on their radios and wait for a particular tone signaling that they are clear to talk. If no channel is available, they hear a different tone.

As illustrated in Figure 1 on page 6, conventional (nontrunked) system users can easily interfere with one another. In this example, User 1 transmits while User 2 is listening to User 3. User 1 can't hear User 3, so is unaware that the transmission will interfere with another one in progress.

Whether digital or analog, conventional radio use suffers this sort of interference problem. Analog radio users quickly come to recognize the sound of colliding transmissions and typically announce that someone "walked on" another radio user.

In the digital world, however, this sort of interference results in the receiver losing the signal altogether. That is, the stream of digital bits flowing to the receiver suddenly has another stream interspersed. The result is that the receiver goes silent, unable to extract an intelligent signal from the airwaves. Interference isn't heard; both signals are considered noise and discarded.

This effect is not unique to Project 25 digital radios. Most users of digital cellular telephones recognize the audible effect when a signal starts to go bad, for example. By definition, there is no central controller or control channel in a conventional radio system regulating which radio gets to transmit at a given time. Direct digital transmissions between P25 radios are susceptible to this particularly

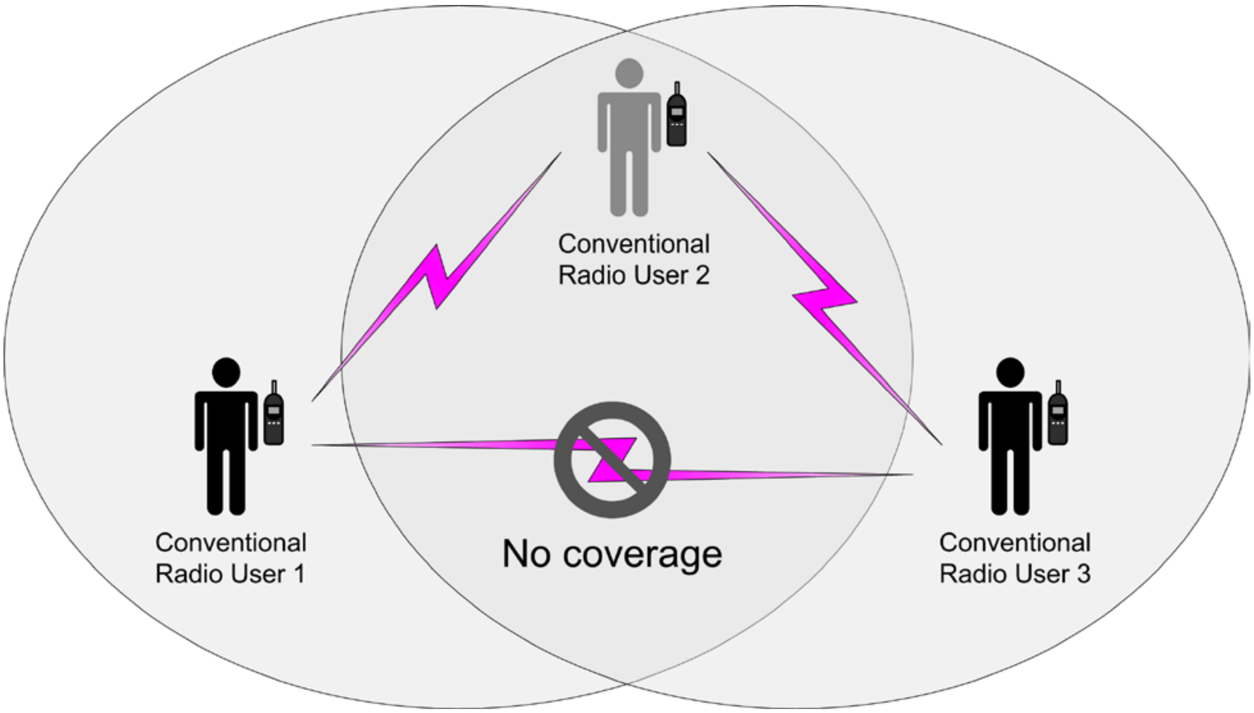

Figure 1: Interfering Users

destructive form of radio interference, reducing the value of digital techniques in conventional radio use.

Disadvantage #3: Complexity Breeds Incompatibilities

P25 (ANSI/TIA/EIA-102) is a rich set of standards that can be interpreted and implemented in different ways. This isn't to say that it is vague, but rather that it has many features and configuration options.

Encryption is a seemingly simple, but often important, feature with many configuration options that can lead to interoperability challenges. Under normal operations, two agencies using otherwise compatible systems may need to secure their communications from all others; yet in an emergency requiring joint operations, they need to share their secured channels. This requires a good deal of shared infrastructure, not to mention careful preplanning. It doesn't happen simply by virtue of having adopted P25.

The complexity and richness of technology made possible by P25 brings opportunities for various implementations that don't necessarily or automatically allow interoperability. Incompatibilities have arisen between equipment and systems nominally built to the first phase of P25 standards.

Today, there is no general conformance testing program to guarantee that a particular system, in all of its options and complexity, meets a composite standard of compatibility.

What Is the Current Status of P25?

The status of P25 standards is constantly changing as more and more of the complex suite is fleshed out. Of the 90 or so standards eventually anticipated as part of the suite, 34 have been established. These are the central, most fundamental standards defining public safety digital radio. Standards to follow will build upon the broad base they have established, incrementally defining finer and finer points necessary to meet P25 goals.

P25 Phase 1

Efforts to establish a system model, define core and interface standards, and provide the first technological specifications for digital radios are referred to as Project 25 Phase 1. During this period, specifications necessary for digital radios transmitting within the FCC's currently defined "narrowband" channel widths (12.5 kHz) have been established. Much of the effort necessary to complete such a far-reaching standards suite has been completed. Subsequent standards build upon the central ones.

Today, mobile and portable radios that can communicate with one another are available from multiple manufacturers. Though the feature sets of modern trunked radio systems are rich and complex, there have been successful demonstrations of field radios from different manufacturers being used on systems made by others.

Beyond the CAI, other key baseline standards for interfaces have been approved in the past year, including for the key ISSI and FSI interfaces. These standards are pending publication by TIA, after which compliant equipment will begin to be available. The Project 25 Steering Committee established and met its goals for completion of further aspects of these interface standards, as well as preliminary CSSI specifications by the end of 2006.

Though standards exist, there is no guarantee that manufacturers will build equipment that complies with the standards. The market will determine when equipment meeting some or all of the P25 standards is available. For example, as more and more agencies specified P25-compliant radios in procurements involving federal grant funds, the availability and compatibility of equipment from multiple manufacturers increased. Also, prices declined due to demand and competition. Likewise, radio system infrastructure built upon the ISSI, FSI, and CSSI will become available and competitively priced as the market demands.

Conformity Assessment Program

Vendors have used self-certification to this point to identify equipment as compliant with P25 standards. A product is considered "P25 compliant" today if it uses the CAI and P25 voice encoder/decoder (vocoder) that converts sound into a digital bit stream.

Over the past few years, multivendor implementations have identified some issues of technical incompatibility. This has led the Project 25 Steering Committee, in concert with TIA and the National Institute of Justice, to establish a process to identify and address these issues. Concurrently, Congress directed the Department of Homeland Security's Office of Interoperability and Compatibility to work with the National Institute of Standards and Technology (NIST), a division of the U.S. Department of Commerce, to create a conformity assessment program. This program is intended to assure that P25 equipment purchased with federal grant funds conforms to the standards suite.

As of the publication of this *Issue Brief*, several changes to existing P25 standards are being considered to resolve identified issues. Since much of the capability of digital radios is contained in software, it is hoped that most changes to the standards can be implemented in equipment through routine upgrades or all together without changing end-user equipment.

In the future, "P25 compliance" will be a more formal, tested measure of conformance with the standards suite. The NIST Office of Law Enforcement Standards has called for increased practitioner and industry participation.

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What Will the Future Bring?

Technology standards are never easy to develop. Efforts to do so generally bring compromises and the persistent reminder that technological progress marches on while the standards are being set. Even while P25 Phase 1 standards are still in development, Phase 2 efforts are underway.

Project 25 Phase 2

Radio spectrum managers and technologists expect that some day in the future, demands for more public safety channels will require further reduction of the channel widths, allowing more radio communications into a limited amount of spectrum.

Project 25 Phase 2 standards setting has proceeded quietly as Phase 1 standards are solidified. Participants anticipate that federal spectrum regulators will again require channel widths to be halved—or their effective use doubled. P25 Phase 2 has proceeded down a technological path that would interleave two voice transmissions within the space of a single, current channel. This time division multiple access (TDMA) technique effectively doubles the capacity of a channel, gaining capacity in exchange for greater complexity and dependence on system infrastructure to synchronize channel sharing. Further technical details are beyond the scope of this article, but it should be noted that TDMA is already widely used in telecommunications systems, including in the most widespread cellular telephone technology worldwide.

Once again backward compatibility will be required, particularly compatibility with Phase 1 technology. Most observers expect P25 Phase 1 technology to serve many users indefinitely into the future. Urban areas with high demand for radio spectrum will push the development of P25 Phase 2 standards and equipment manufacture. At this point, it is impossible to predict when P25 Phase 2 equipment will become available or even when the standards will be settled. However, TDMA is already used in some public

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safety radio systems with user radios also capable of using P25 Phase 1.

A Lasting Legacy

The most lasting legacy of Project 25 will not be the digital radio technology that bears its stamp of compatibility, but rather the model of standards development that it built, led by public agencies that created an SOR for industry to address. The P25 SOR broke new ground by establishing architectural and functional needs for advanced two-way radio capabilities and standard interfaces between public safety subsystem components. This document alone set a benchmark for other public safety communications standardization efforts that followed in the intervening years.

Through Project 25, the public safety community has matured in conceiving technology to serve its ever-growing demands for communications, just as the hue and cry for greater interoperability has risen to new heights. The effort to create technology standards, in and of itself, has served to raise the level of discourse about just what communications interoperability entails. Toward that end and even more practically, Project 25 has served well in the quest for interoperability. ■

Further Information

For further information on Project 25, see the following web sites:

APCO – The Association of Public-Safety Communications Officials, International, Inc.: **http://www.apcointl.org/frequency/project25/**.

PTIG – The Project 25 Technology Interest Group: **http://www.project25.org**.

OLES – The Office of Law Enforcement Standards at NIST: **http://www.eeel.nist.gov/oles/public_safety.html**.

CommTech – The Communications Technology Program at the National Institute of Justice: **http://www.ojp.usdoj.gov/nij/topics/commtech/welcome.html**.

Technical Assistance Available

SEARCH is the technical assistance (TA) provider to the U.S. Department of Justice Office of Community Oriented Policing Services (COPS) Interoperable Communications Technology Program (ICTP). SEARCH is a national nonprofit organization that has provided more than 37 years of expert assistance to state and local criminal justice agencies on the use of information and identification technology. SEARCH has a long-standing program of providing direct, no-cost, tailored TA to law enforcement and public safety agencies in planning for, procuring, implementing, and managing information technology.

Areas of Assistance:

- Effective governance structures development
- Strategic planning
- Infrastructure assessment and development
- Needs analysis and assessment
- Operational requirements development
- Policy and procedure development
- Risk management

To apply for TA in these areas or review additional SEARCH TA focus areas, see **http://www.search.org/services/ta/**.

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