Global Positioning System (GPS) for Public Safety Location Services: Use Cases and Best Practices

Introduction: GPS for Public Safety Land Mobile Radio (LMR)

GPS (global positioning system) is a near-ubiquitous technology commonly embedded in cellular phones, laptops, vehicles, and other consumer devices to support location tracking and navigation capabilities used by many applications and software programs. In public safety communications, Project 25 (P25) land mobile radio (LMR) systems use these same capabilities to maintain situational awareness and to protect the safety and well-being of first responders as they fight fires, respond to emergencies, and perform their day-to-day duties.

This document examines P25 GPS through the lens of public safety practitioners tasked with providing real-time location capabilities to their agencies. It explores real-world applications of P25 GPS, its limitations, and implementation considerations as learned through a series of interviews, a review of the P25 technical standards, and research into current application of GPS technology for public safety.

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- Department of Interior (DOI), Office of the Chief Information Officer (OCIO)
- Iowa Department of Public Safety
- Los Angeles County, California, Fire Department
- Montgomery County, Texas, Hospital District
- National Park Service

GPS and LMR Defined

GPS uses a constellation of earth-orbiting satellites maintained by the United States Department of Defense (DoD) for the purpose of providing geographic positions on and above the surface of the earth (see **Figure 1: Earth Orbiting Satellites**). These satellites transmit position, navigation, and timing (PNT) information to GPS receivers when adequate line-of-sight (LOS) is achieved.

LMR systems (see **Figure 2: LMR System**) are terrestrially based, wireless, two-way communications systems commonly used by federal, state, local, tribal, and territorial emergency public safety responders; public works; commercial companies; and the military in

Figure 1: Earth Orbiting Satellites

tactical and non-tactical environments al and non-tactical environments. Supporting voice and low-speed data communications, LMR systems typically consist of handheld portable radios, mobile radios, base stations, repeaters, and a network[1] to bring these components together. The LMR radios are often referred to as subscriber units (SUs).
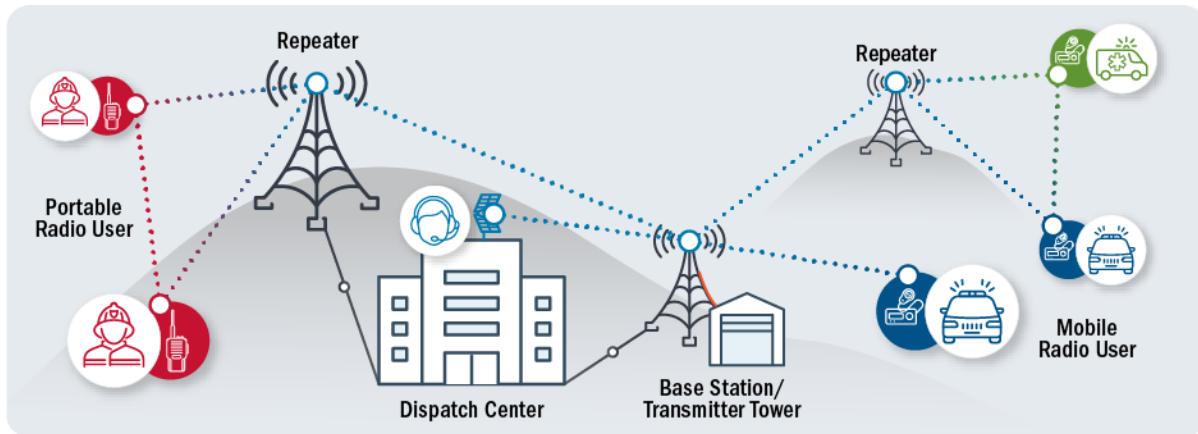

Figure 2: LMR System

The ability to monitor the SU's location, either internal or external to the SU, is an important feature because it allows for active real-time tracking of personnel during emergency incidents, situational awareness of personnel during missions, and waypoint mapping for areas of interest. Ultimately, the GPS feature increases the personnel safety, transparency, and accountability of a workforce and fleet of vehicles.

Public Safety GPS Marketplace

Since the development of the P25 Location Services technical standards in 2009, manufacturers have introduced both "Tier 1" and "Tier 2" GPS capabilities into their LMR systems to share the location of public safety personnel and vehicles. (see **Figure 3: Tier 1 and Tier 2 Location Services**) These terms, as defined by the P25 Standards, define two different levels of complexity for how GPS data is shared with and supported by P25 infrastructure.

Tier 1 location services support direct mode sharing of GPS information between SUs and LMR fixed station repeaters and applies to conventional equipment. This basic mode of providing GPS information does not provide Internet Protocol (IP) addressing or fixed host routing information. In this type of configuration, the location service host system (LSHS)[2] may reside in the SU or outside of the LMR system.

Tier 2 location services support more complex implementations involving network routing and transport of location data across the P25 infrastructure and to other IP-connected networks. Tier 2

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[1] Cybersecurity and Infrastructure Security Agency, "Land Mobile Radio 101" February 2016
[2] Location Service Host System (LSHS) is a system, outside of the LMR system, that operates on the SU location information, issues commands to the SU to obtain location information, or instructs the SU when to provide location information.

can be used in direct data, repeated data, conventional Fixed Network Equipment (FNE) data, or trunked FNE data configurations.

Location Services Summary

Tier 1
- Simple SU to SU interface for Direct or Repeated Data
- Does not provide IP Addressing, fixed host routing, or advanced triggering/reporting
- Does not provide location to host device on fixed network

Tier 2
- Used for Direct and Repeated Data, Conventional or Trunked FNE Data
- Complex protocol for triggering and reporting location to fixed host
- Uses User Datagram Protocol(UDP)/IP for routing and transport in a fixed network between fixed host and SU

Figure 3: Tier 1 and Tier 2 Location Services

Appendix A: Tier 1 and Tier 2 Location Services; How GPS Works with LMR Systems provides a more detailed explanation of Tier 1 and Tier 2 location services for P25.

Today, Tier 1 and Tier 2 location services are available on select P25 radios and supported by some systems. In situations where they are unavailable or cost prohibitive, auxiliary devices (e.g., SU lapel microphones) that incorporate P25 GPS capabilities are available to provide desired GPS functionality without the need to purchase a new radio (SU).

The location data from P25 devices can be viewed through standalone mapping/monitoring systems displaying the GPS data, or via interfaces to computer-aided dispatch (CAD) systems. Completely integrated offerings display the SU location on commercially available mapping software platforms within the LMR systems or via web-based applications, eliminating the need for additional stand-alone client devices. Several LMR system manufacturers have successfully implemented the use of embedded GPS capabilities throughout their conventional and trunked systems. Voice/data logging[3] recorders and CAD systems capture the user's location information when the GPS enabled device transmits voice traffic. The P25 location services technical standard is meant to improve GPS interoperable functionality. However, there have been cases where the GPS feature may not work properly across disparate vendor systems via the P25 Inter-RF Subsystem Interface (ISSI) and/or Console Subsystem Interface (CSSI). Manufacturers' implementation of proprietary features using the GPS standard may prohibit interoperability where multiple vendor LMR SUs are operating on a different vendor's LMR network, even when voice traffic protocol over the common air interface is compatible.

For organizations that may not have funding for a complete system overhaul to include GPS, non-integrated solutions exist. These systems employ standalone computer systems and devices to send GPS data to a device, such as a gateway, to integrate with the LMR system. There are also traditional GPS handheld devices available that are often pocket-sized with the sole purpose to provide location information such as coordinates, directions, and waypoints at a much cheaper cost point than GPS capable LMR SUs. As stand-alone GPS devices do not interface with the LMR network without the use of an integration platform, the user is required to verbally relay the GPS information to the

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[3] Voice logging recorders enable accurate call recording solutions to conduct thorough post-incident reviews and analysis. They enable retrieval of audio and data from radio and telephony calls to recreate the communications around an incident.

dispatcher or another SU user. Some LMR SUs that were purchased without GPS capability can be retrofitted via firmware upgrades to avoid a complete fleet purchase of GPS capable units. SUs without GPS capability that are not upgradable cannot be retrofitted, therefore, non-integrated GPS devices may have to be used.

With the recent integration between LMR and Long-Term Evolution (LTE) broadband cellular devices, GPS data can be shared across broadband cellular networks in addition to the LMR networks. LMR-LTE devices take advantage of the GPS and mapping features in the cellular devices to transmit Tier 2 GPS data to other SUs or to dispatchers. Third-party situational awareness software may be integrated into the LMR systems to deliver location tracking over LTE networks where GPS is not initially integrated into the LMR-LTE system.

Benefits and Limitations of GPS Within Public Safety

P25 location services (GPS) are used to provide real-time positional information for first responders and public safety personnel within an LMR system's areas of responsibility through the P25 LMR. The radio's location is represented on a map via specific mapping software on dispatch monitors or LMR devices. Not all LMR devices can transmit GPS information; however, the P25 location services standards provide the means for manufacturers to integrate the location services capability into their devices. The use of GPS as part of the P25 radio or peripheral devices, such as a lapel microphone, can increase employee safety and situational awareness by accurately tracking personnel locations. It has been argued that GPS tracking is an invasion of privacy; however, organizations believe it increases personnel safety and provides more transparency and accountability to employers. The accuracy of GPS data could allow disaster relief to arrive at a precise location in a timelier manner than when GPS is not used. Some agencies use LMR GPS location services to assist with mapping wildfires via geofencing[4] applications that allow accurate virtual boundaries to be created around the fires. Personnel who may be within the boundary's danger zone are tracked by their GPS-capable LMR SUs. LMR GPS is also used to map the location of vehicles with mobile LMR devices to improve safety conditions, such as driving on snow-covered roads along mountainous areas. LMR GPS is often used to dispatch specific first responders based on their proximity to an incident to decrease response times for disaster relief, medical emergencies, and tactical missions.

Traditionally, GPS devices provide locations using latitudinal and longitudinal coordinates that translate to a location on the earth's surface. In a multilevel building, the inability to determine which floor the emergency alert is coming from only delays the first responders in administering aid. However, GPS technology is improving to include the ability to map vertical coordinates (also known as Z axis) in reference to locations above ground level to refine the location services within multilevel buildings, as shown below in **Figure 4: Example of Z-Axis Coordinate Providing Vertical Location of Subscriber Unit**. Z-axis mapping capabilities are a generational leap in location and position technology that is incorporated in Next Generation 911 (NG911) systems. As public safety access points (PSAPs)/emergency communications centers (ECCs) move to NG911, the Z-axis information will provide vertical locations of 911 callers who may be in tall buildings many stories away from the

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[4] Geofencing is a boundary established around a geographical area in an information system, so that a particular action is triggered when an electronic device enters the designated area. (https://www.collinsdictionary.com/us/dictionary/english/geofence)

actual XY coordinates of the street address. Z-axis information should expedite critical public safety responses in large multi-story above ground structures.

Beyond its vital role in providing location services, GPS also enables precision timing and time interval (PTTI) capabilities, which enable key functions across many critical infrastructure sectors.[5] LMR is no exception, as many P25 systems rely on GPS reference timing to support network synchronization.

Figure 4: Example of Z-Axis Coordinate Providing Vertical Location of Subscriber Unit

There are, however, limitations to GPS technology that must be considered. The GPS capability within the LMR system may be impacted by the inability of the GPS-enabled device to get sufficient receive signal because it lacks a clear LOS to the GPS satellites. This may occur when the radio frequency (RF) signal of GPS satellites orbiting the earth becomes obstructed by natural and man-made structures, degrading the SU's receive signal strength. The LOS between LMR devices and GPS satellites are further degraded within buildings, tunnels, underground, or underwater, making GPS functionality inoperable.

GPS may also be negatively affected when electromagnetic interference is introduced by other electrical devices near the GPS device. Any disruptions to GPS signals may also impact the accuracy of GPS Location-Based Services and cause synchronization timing deviation issues when transmitting RF signals in simulcast radio systems.[6] The use of GPS functionality within the P25 LMR

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[5] For more information on the full scope of GPS capabilities, including its critical importance to navigation and timing, please visit: https://www.cisa.gov/topics/risk-management/positioning-navigation-and-timing

[6] The SAFECOM/NCSWIC white paper titled *Public Safety Communications Dependencies on Non-Agency Infrastructure and Services* provides additional information and best practices for managing risks associated with non-agency infrastructure and services, such as GPS.

radios comes at a cost of reduced portable radio battery life and may require the user to charge or exchange the portable radios batteries more frequently. Mapping software is used in conjunction with LMR devices to provide a visual representation of the user's location depicted by the latitude (X-axis), longitude (Y-axis), and potentially elevation (Z-axis) coordinates. Interoperability of the mapping software between various agencies and organizations may become an issue when incompatible mapping programs using dissimilar coordinate systems are used, or LMR devices are used during joint exercises or when a user roams into another jurisdiction.

Examples of GPS Implementation in Public Safety

Currently, GPS is not widely implemented across the public safety community; however, there are multiple ways to implement this technology. The following section provides a snapshot of the different technologies as well as implementation strategies.

United States Department of Interior

The United States Department of Interior (DOI) is responsible for managing over 800 independent LMR communications systems throughout the United States with more than 45,000 LMR users primarily using GPS for situational awareness and tracking of personnel during emergency incidents. Tier 1 P25 GPS use is relatively limited on DOI's LMR systems and is predominantly used by law enforcement agencies. The majority of its LMR systems are conventional systems with less than one percent trunked systems across the organization. DOI operates multiple networks and systems across multiple manufacturers; however, they do not currently connect the systems via ISSI or CSSI.

Commercial handheld GPS devices are being used to augment LMR SUs that do not have built-in GPS capability. The use of an enterprise-wide service contract allows a private vendor to provide dispatchers that monitor the DOI emergency calls and track personnel locations via GPS devices with an integrated solution comprised of handheld GPS devices and Bluetooth phone-to-satellite devices, which are monitored on a web portal. This Iridium-based satellite service can be expensive, and its satellite links can be impacted by obstructions (e.g., trees, mountains, smoke) and the movement of the orbiting satellite. Other agencies within DOI are using subscription-based handheld satellite communicators with two-way text messaging and emergency alert capabilities. These devices are also distributed ad hoc during events and incidents for situational awareness. This solution typically operates flawlessly in emergency situations with 10-meter (32.81 ft) accuracy from the last known location. These devices are equipped with an emergency button but do not offer a means of verbally communicating with dispatchers or other personnel. The worst is assumed when the emergency button is activated without a follow up text or communications through the LMR device. In this situation, responding personnel are sent to the last known GPS location to begin searching for the user who activated the emergency call. DOI intends to keep this system operating for redundancy even if LMR SUs with GPS capability are procured because of its ability to work at sea and in areas with limited or no LMR coverage.

Integrated GPS Alternatives

A universal integrated LMR GPS platform is currently not in DOI's budget. The following alternatives are used:

o   Commercial handheld GPS devices with basic location services
o   Subscription-based GPS with two-way texting and emergency alerting
o   Lightweight compact satellite communicators

Finding a common P25 GPS solution with the existing funding limitations is difficult due to the high cost to upgrade disparate LMR systems and large quantity of SUs being used by DOI. An upgrade to a common GPS solution would require purchasing over 7,000 GPS capable LMR SUs for the entire organization. DOI has requested funding for a country-wide overhaul of its LMR systems, which would include ISSI interfacing to public safety broadband networks, mission critical push to talk, federal and commercial first responder networks, and other features. In the meantime, experiments with applications that send GPS situational awareness information on P25 LMR and cellular devices are underway; however, this solution will unfortunately require a full communication channel for data transmissions.

DOI reports that there is at least one personnel or civilian rescue a week that requires the use of GPS, which emphasizes the importance of GPS technology to support its mission. Civilian GPS information is not transmitted on the government's LMR network. Therefore, if a civilian needing assistance is a customer of the same cellular network as the cellular carrier in a particular area, that cellular carrier routes the call to the appropriate PSAP within DOI for assistance. If a different carrier is providing service in that area, it will be a best effort attempt to contact the proper 911 PSAP/ECC relative to the location that the call is coming from.

Montgomery County, Texas – Hospital District

The Montgomery County, Texas Hospital District (MCHD) operates on a single vendor infrastructure for its county-wide P25 trunked LMR system. They use a location on PTT (LOP) application (currently vendor proprietary) using GPS embedded in the voice packet when the SUs PTT button is pressed. Most of the organization's approximately 500 mobile and portable radios are deployed with GPS capability. The remaining radios will be upgraded to allow the use of GPS at a later date. Eventually, MCHD will deploy up to 5,000 radios with GPS capability for situational awareness, accountability,

Montgomery County Hospital District GPS Implementation

o   Mutual aid automatic GPS location reporting on scenario-specified intervals
o   GPS tracking of a variety of vehicles to include aircraft and boats
o   GPS used to geofence users during operations

and personnel tracking once they exit their vehicles in wooded or remote areas. The system is transitioning to a Tier 2 GPS platform to allow any mutual aid subscriber unit's location to be tracked. This capability allows the GPS location information to be automatically delivered when the PTT button is activated, on system-defined time intervals, and for other predetermined specific scenarios. For example, under normal conditions, GPS information is reported every 30 minutes. However, GPS information can be reported every two minutes during emergency conditions.

The benefits of these P25 GPS capabilities were demonstrated during Hurricane Harvey response and recovery operations when MCHD found it easy to track the GPS location of SUs in police cars and fire public safety vehicles. However, MCHD experienced issues tracking some of the boats,
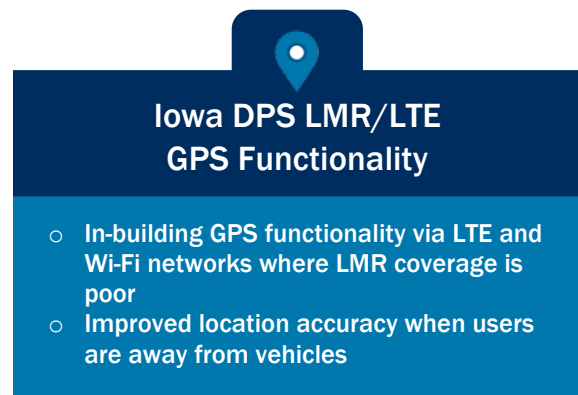
dump trucks, and aircraft without GPS-capable SUs, validating the need to upgrade their remaining equipment to support GPS.

To archive GPS data, a logging recorder keeps a log of the latitude and longitude information, caller information, and geofence information as the GPS data is transmitted. GPS is not fully integrated into the CAD system; plans are to do so in the future. GPS information is not transmitted across ISSI/CSSI; however, plans are underway to begin testing Tier 2 products once it is better understood how the manufacturer implements this capability. When testing GPS across ISSI/CSSI, MCHD discovered that the P25 technical standards do not include some requirements to address passing GPS coordinate data across ISSI/CSSI.

MCHD is deploying integrated LMR-LTE SUs with GPS capability on LMR and broadband cellular networks. It also uses applications with GPS capability integrated into a single database to track the devices. Collaboration with the LMR vendor continues as they customize what GPS data and information can be shared with other LMR-LTE SUs on the system. The goal is to allow the LMR-LTE SU to select the group to be tracked on a map and provide better team situational awareness during incidents and special events. MCHD is also working to integrate the separate maps used by 911, CAD, and LMR systems into a single map to streamline information. The collaboration effort with the manufacturer has strengthened their relationship, and MCHD continues to share its issues and resolutions with the vendor to help refine GPS offerings for future users. As a testament to the success of this collaboration, the vendor is working with the P25 standards body to standardize the LOP application using the voice packet embedded GPS solution that MCHD uses. By including this functionality in the P25 Suite of Standards, other vendors will be able to develop similar GPS solutions by following the standard, which will allow for better operability and interoperability across systems with these GPS features.

Iowa Department of Public Safety

The Iowa Department of Public Safety (DPS) statewide P25 trunked LMR system provides communication services to public safety and first responder agencies via a single manufacturer system. The LMR system is integrated with an LTE broadband cellular network and uses SUs with LMR-LTE capability. These SUs have built-in GPS functionality, are typically used in LTE-dense areas, and are programmed to have access to in-building Wi-Fi networks in state operated buildings. This allows continued communications even when in-building LMR coverage is poor or when the LOS to the GPS satellites is typically obstructed by a building. The GPS feature proved beneficial when an officer involved in a foot pursuit became incapacitated approximately 200 yards from his vehicle and assistance was quickly provided based on his SU's location rather than his vehicle's location.

Iowa DPS LMR/LTE GPS Functionality

- In-building GPS functionality via LTE and Wi-Fi networks where LMR coverage is poor
- Improved location accuracy when users are away from vehicles

Historically, GPS has been used throughout the state to track vehicles with an independent (i.e., not integrated into the LMR system) automatic vehicle location (AVL) Tier 2 product managed by the Iowa Department of Transportation (DOT). Iowa DOT manages statewide access to the AVL system. Each county within the state pays for a license to access the system and has a geofence specific to the county and state-level assets. All vehicles in the system are equipped with GPS units and a

wireless data card to relay their location to a central server managed by the Iowa DOT. To improve on the original AVL system, including better GPS accuracy, status of the vehicle, etc., the system was upgraded to allow law enforcement users to change their status during various scenarios like traffic stops, out of the vehicle, or foot pursuit. The AVL system allows dispatchers to have approximate vehicle location to help improve location awareness when assistance is needed.

Tier 2 GPS functionality was integrated into the design of the statewide trunked LMR system. The statewide system utilizes six voice paths to the state-built LMR sites with data taking up a full channel while providing enough voice capacity for voice communications. Location data is transmitted across the system's single data channel and at least one agency within the state is updating the SUs' location on a set cadence or on the push of the PTT button. This type of location reporting consumes a lot of data, and if many users simultaneously report locations while the system is sending encryption keys via over the air rekeying (OTAR), the data channel could become overwhelmed. When more voice communication capacity is needed, the system employs ruthless preemption over data communications. However, this could delay the transmission of the GPS and OTAR data transactions.

When integrating the AVL and LMR systems, the state has experienced issues where local- or state-level terminals are unable to process the amount of vehicle GPS locations at one time or receive the information in an efficient manner. For example, Iowa State Patrol will either see state-level assets and possibly some local assets but not all of them. County police may see some state patrol assets and possibly one other county's assets but not all assets. It appears that these issues are based on data capacity limitations within the AVL and LMR systems. Some other issues experienced are SU naming conventions, LMR-LTE device aliases, and the AVL component nomenclatures not being recognized across the state by different agencies.

In the future, the AVL and LMR GPS capabilities will need to be further integrated to improve the reporting of personnel and vehicle locations. This includes overlaying the data sets from each application to provide a blended display for the metro area dispatchers. Having the ability for agnostic GPS data to be transmitted into multiple, sometimes neighboring, CAD systems would improve the response to incidents along the neighboring jurisdictional borders.

LACoFD's Benefits of LMR Integrated GPS

- Improved situational awareness
- GPS transmitted through LMR, LTE, and/or Wi-Fi network
- Automatic GPS data transmitted with PTT messages
- Geofencing and dead reckoning capabilities

Los Angeles County, CA – Fire Department

The Los Angeles County Fire Department (LACoFD) employs a new single-vendor digital P25 Phase 1 and Phase 2 LMR system, covering more than 5,000 square miles (about the area of Connecticut). The department also uses an analog very high frequency LMR infrastructure for mutual aid operations. Any in-building and wildland fire fighting communications are performed over the analog system. The county's P25 LMR system consists of 22 communications sites augmented by LTE broadband cellular service. The LMR system provides coverage in the valleys and all wildland areas and utilizes LTE services as a backup if fires incapacitate the LMR system.

LACoFD's LMR system interoperates with neighboring agencies with systems from the same manufacturer via ISSI; however, GPS data is not transmitted over the ISSI. The P25 LMR system uses

geo-gating that allows the radio users to specify which channels are scanned based on the current location or area. The geo-gating feature is specific to a single SU channel and allows the user's radio to automatically switch to available radio channels in whatever zone they may be driving though based on the GPS location.

GPS is primarily used for situational awareness and personnel tracking within the county. The primary day to day fire operations and dispatching are performed on the P25 LMR system. The county is in the process of interfacing AVL and handheld GPS devices with its P25 system to utilize the GPS capabilities in the SUs. The county teamed with the manufacturer to design a method to use GPS to control scanning within the LMR infrastructure. They have implemented an algorithm through a commercial application that connects LMR-LTE devices to Wi-Fi networks at the fire stations, which automatically switches an SU to the cellular network once it leaves the fire station. This feature may be offered by the manufacturer in the future to other customers. The commercial application sends all GPS information to the LMR network and uses dead reckoning[7] as a redundant measure for GPS data if the radio loses its ability to communicate to the GPS satellites. GPS data is also transmitted through PTT transmissions. The system's GPS is used for geofencing, AVL, channel scanning, dispatching, and as a timing source. A GPS gateway was built into the LMR system to allow ad hoc users from local agencies to receive GPS information, which can be tailored by the system administrator.

Considerations for Implementing GPS for Public Safety Organizations

As demonstrated by the case studies above, the proper integration of GPS with P25 LMR systems by public safety organizations requires thoughtful planning to ensure the users can fully take advantage of GPS benefits and services. The following are some considerations that should be addressed before purchasing GPS capabilities to integrate in LMR systems.

- Determine the type of GPS service your system can support. Some systems will only be able to support Tier 1 GPS protocols and will not accept the complex protocols that are included with Tier 2 GPS.

- Determine if the existing SUs can support GPS functionality. Not all SUs can provide GPS functionality, and in some cases new SUs will need to be purchased to support GPS. Some SUs may only require a firmware update if the functionality was built into the device, while others may have to be sent to an authorized dealer to install a specific module in the SU.

- For SUs that do not have GPS functionality built in, peripheral devices such as lapel microphones with GPS capabilities can be attached to the SU to provide location services. However, not all radio manufacturers have peripheral devices that can support this functionality. And those that do may not be interoperable with other manufacturer radios. Before making any purchase decisions, confirm that peripheral devices will support GPS capabilities and work with your existing SUs, network configuration, and will satisfy identified interoperability needs.

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[7] Dead reckoning is the calculation of one's position on the basis of distance run on various headings since the last precisely observed position, with as accurate allowance as possible being made for wind, currents, compass errors, etc. (https://www.dictionary.com/browse/dead-reckoning)

- GPS functionality is only as good as the SU's LOS to the GPS satellite constellation. The GPS receive signal and LOS is reduced inside structures or in tunnels. Expectations of GPS service in these situations must be managed accordingly.

- The use of GPS functionality comes at a cost of reduced battery life and may require SUs to be recharged or swapped for fresh batteries more often.

- Agencies may use different mapping software to display GPS data. Ensure the mapping software is interoperable with those already being used by partnering agencies and jurisdictions.

- Protecting the GPS data is essential to the safety of personnel and operations. Implementing secure/encrypted GPS data is not specifically addressed in the P25 standards and differs from manufacturer to manufacturer. It is often left up to the system implementers to configure. Verify with implementers that the GPS data can support advanced encryption standard (AES) 256-bit encryption along with the voice/data packet, or if other forms of security mechanisms are required for your system.

- Consider the need and availability of Z-axis GPS coordinates for areas with multilevel buildings.

- Include specific GPS needs and requirements in requests for proposals to ensure vendors deliver interoperable and fully functioning GPS capabilities.

- Ensure a comprehensive integration and acceptance test plan is conducted to ensure that all required features, functionality, and interoperability perform as expected and as required by procurement documentation, proposals and responses, and contractual terms.

Summary

GPS capabilities for public safety have evolved well beyond providing directions and navigation. P25 GPS technical standards now allow the public safety community to monitor personnel, vehicles, and provide robust situational awareness during planned activities and unplanned incidents. While once viewed as an invasion of privacy, the benefits of P25 GPS capability have been realized in life saving situations, firefighting missions, and tactical scenarios. By understanding the agency's needs, current communications system and SU capabilities, mutual aid partner requirements, along with proper coordination and planning, public safety organizations can now manage personnel and assets more efficiently with the best GPS solution for the organization. For more information on Project 25 services and capabilities, visit [Project 25 (P25) | CISA](#)

Appendix A: Tier 1 and Tier 2 Location Services; How GPS Works with LMR Systems

Within public safety land mobile radio (LMR) systems, the global positioning system (GPS) feature is used to monitor accurate real-time locations of a subscriber unit (SU) that is carried by public safety personnel, thus providing the location of the SU's user as shown in **Figure 5: Global Navigation Satellite System** (GNSS). The location information is provided by a location information system (LIS) to the LMR system and SUs when a clear LOS is achieved between the satellites and the LMR system/SU. The LIS can be in the form of various GNSSs, most notable is the U.S. Global Positioning System (GPS) that is operated by United States Department of Defense (DoD). DoD's GPS system consist of 31 satellites, each precisely orbiting the earth once every 12 hours at approximately 12,000 miles above the earth. These satellites transmit unique signals containing the satellite's exact location, which is used by GPS receivers to calculate the SU's location through trilateration. Trilateration[8] is a process of determining a position by knowing the distance from a point to at least three known points (i.e., the SU location to three GPS satellite locations.)

Figure 5: Global Navigation Satellite System

The Telecommunications Industry Association (TIA)-TR8.5 Subcommittee has developed the Project 25 (P25) standards for Tier 1 and Tier 2 location services, which are described in Tier 1 Location Services Specification (TIA-102.BAJB-A) and Tier 2 Location Services Specification (TIA-102.BAJC-B),[9] respectively. These technical standards describe how the automatic reporting of SU location via the LMR voice channel[10] occurs during emergencies with activation of the emergency button on the SU, when the push to talk function is used on the SU, and on a programmable time interval.

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[8] How GPS Receivers Work – Trilateration vs Triangulation https://gisgeography.com/trilateration-triangulation-gps/

[9] Public safety agencies may request free access to the P25 Standards through the TIA website.

[10] Location information is transmitted utilizing the P25 Common Air Interface (CAI) Data Bearer Service protocol, which can be found in TIA-102.BAEA-C, Project 25 Data Overview, published December 9, 2015.
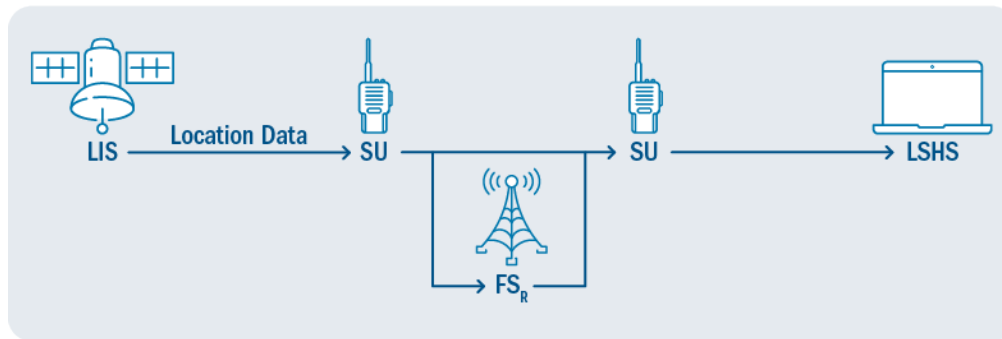
Figure 6: Tier 1: GPS Communication Streams[11]

The P25 Tier 1 location services standard describes how GPS data is communicated through a basic SU to SU interface within direct mode and LMR fixed station repeater configurations. This basic mode of providing GPS information does not provide Internet Protocol (IP) addressing or fixed host routing information. In this type of configuration, the location service host system[12] may reside in the SU or outside of the LMR system. Tier 1 GPS information communication streams are shown in **Figure 6: Tier 1: GPS Communication Streams**.

The P25 Tier 2 location services standard is used with direct data, repeated data, conventional Fixed Network Equipment (FNE) data, or trunked FNE data configurations. The protocol used with Tier 2 location services is more complex due to the triggering[13] and reporting (request/response) capability within the SU from a fixed data host (FDH)[14] or mobile data peripheral (MDP)[15] that allows protocols for network routing and transport between fixed host and SU. The various GPS information communication streams for Tier 2 location services are shown in **Figure 7: Tier 2: GPS Location Streams** on the following page.

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[11] TIA-102.BAJB-B, Project 25 Tier 1 Location Services Specification, December 2019
[12] Location Service Host System (LSHS) is a system, outside of the LMR system, that operates on the SU location information, issues commands to the SU to obtain location information, or instructs the SU when to provide location information.
[13] Triggering is a condition that might cause the SU to send location information it receives to a LSHS.
[14] Fixed Data Host (FDH) role with respect to location services is to provide uncompressed location information to the LSHS and provide compressed commands from the LSHS to the SU. FDH resides within the Fixed Data Network (FDN).
[15] Mobile Data Peripheral (MDP) responsibility is to receive location information from the LIS and forward it to the SU, encapsulated in UDP/IP over an interface, or to send location information from the SU to LSHS, and provide commands from the LSHS to the SU.
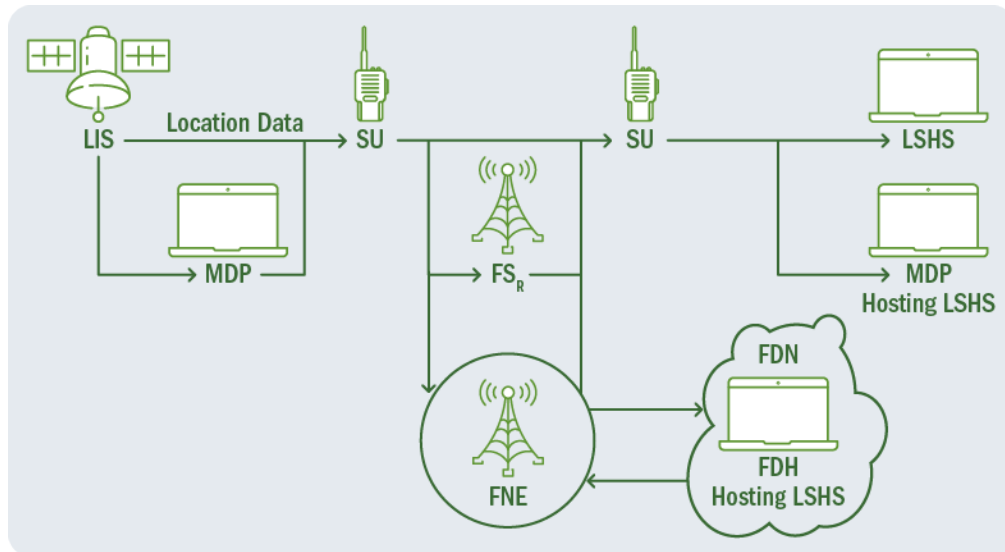
Figure 7: Tier 2: GPS Location Streams[16]

Location Services System Architecture identifies the paths that GPS data can be transmitted across an LMR network. GPS data is transmitted across Trunked and Conventional LMR networks in the following ways:

- Conventional: SU direct to SU, SU to FSR to SU, SU to FDH

- Trunked: SU to FDH, SU to SU, MDP to SU

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[16] Tier 2 Location Services Specification, March 2019