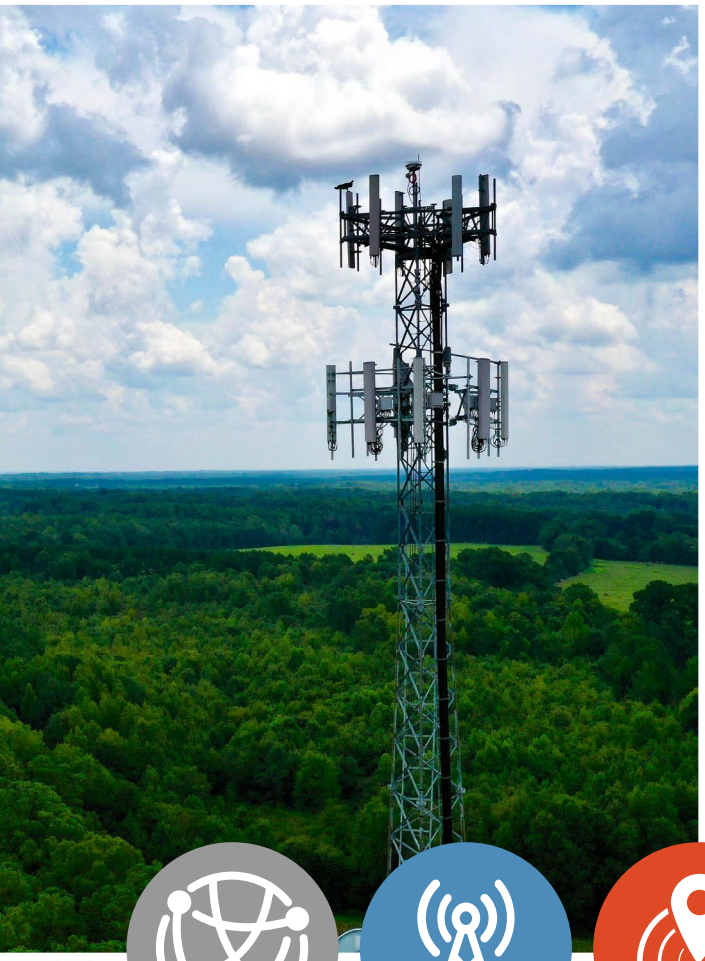


First Responder Network Authority

ROADMAP

FirstNet® Authority

FirstNet® Authority

The FirstNet Authority was established in light of 9/11 to lead the creation of a dedicated nationwide broadband network using spectrum set aside for the public safety community (Band 14). Through a combination of government, commercial, and public safety partnerships, we are committed to delivering a network and supporting ecosystem of apps, devices, and capabilities that are innovative, reliable, accessible and secure. By modernizing public safety communications with our partners, we can help responders keep America safe – every day and in every emergency.

To learn more, visit **FirstNet.gov**.

CONTENTS


MDFR
MIAMI-DADE COUNTY
FIRE RESCUE
Paramedic

LETTER *FROM THE* **FIRSTNET AUTHORITY BOARD CHAIR**

On behalf of the First Responder Network Authority (FirstNet Authority), I am pleased to issue this updated FirstNet Authority Roadmap—our strategic plan for the continuous development and improvement of FirstNet, the nationwide public safety broadband network. The Roadmap was initially developed in 2019 through intense consultation with the public safety community, and this update reflects the evolving interests and priorities of present and prospective users of the network.

Our challenge remains to build a network that performs by traditional metrics, as well as with the best commercial networks, but then add additional capabilities not available elsewhere, keeping in mind that users do not want to think about the network; they care only about whether or not they can do with it what they need to do. This Roadmap sets the strategic direction for how the FirstNet Authority and stakeholders will meet that challenge and evolve the network to satisfy first responders' communications needs today and tomorrow. It provides a vision for the future, but it goes beyond that by also including concrete priorities that we will execute along the way. Most importantly, the Roadmap is tied directly to the FirstNet Authority's resource allocation process, ensuring that investments in the network are fully aligned with the specific needs of the public safety community as expressed in the Roadmap.

In closing, the public safety community has always thoughtfully engaged the FirstNet Authority and will always drive the development of FirstNet. We are thankful for the efforts of the first responders who shaped this update to the Roadmap, and we pledge to continue our dialogue with you as we transform the future of public safety communications.

Robert "Tip" Osterthaler
FirstNet Authority Board Chair

INTRODUCTION

Committed to a Differentiated Public Safety Network Experience

The U.S. Congress charged the First Responder Network Authority (FirstNet Authority) with ensuring the development, build-out, and maintenance of FirstNet, the nationwide public safety broadband network. The FirstNet Authority's programs, activities, and investments support the creation of a dedicated and differentiated broadband communications experience that transforms public safety operations to save lives. The FirstNet Authority Roadmap (Roadmap) is essential to this mission. Since its original publication in August 2019, the Roadmap continues to reflect stakeholder input and expresses areas of focus for the FirstNet Authority in evolving and advancing the FirstNet Experience – from the FirstNet Solution being delivered by network contractor AT&T to the FirstNet Authority's value-adding activities and network investments that make FirstNet different from any other network.

FirstNet Authority Roadmap Framework

The Roadmap is organized into a framework of six domains representing groupings of related technologies and capabilities that are essential to the public safety community's mobile broadband communications experience. The two principal domains are the **Core**, which provides the essential intelligence for the functioning of the network, and **Coverage**, which enables robust and ubiquitous access to that network. Two domains relate to specific public safety features: **Situational Awareness**, which envisions real-time access, collection, and distribution of critical information, and **Voice Communications**, which envisions high-quality, reliable voice communications nationwide working seamlessly across analog and digital platforms. The final two domains concern tailoring public safety users' experience: **Secure Information Exchange** relates to the assurance that all access is secure, reliable, and easy-to-use, and **User Experience** concerns ensuring interfaces are designed for specific public safety users' operational challenges.

Roadmap Evolves with Public Safety's Needs

This edition of the Roadmap reflects new research and current stakeholder input and remains the basis for continued collaboration with the public safety community, industry, government, and AT&T. The six domains remain unchanged; however, revisions to the primary underlying relevant technologies and the domain priorities reflect the ongoing evolution of public safety needs and trends in mobile broadband technology. Figure 1 identifies the priorities within each Roadmap domain.

Roadmap Leads to Investments

In June 2020, the FirstNet Authority Board approved the first set of investments to upgrade the FirstNet Core to be 5G ready and further expand the dedicated fleet of deployable assets. These investments are a direct result of Roadmap priorities in the Core and Coverage domains and represent the first strategic investments toward advancing the network beyond its contractual baseline and responding to first responders' evolving operational needs. The Roadmap will continue to be a critical strategic planning document to guide the FirstNet Authority on future investments, programs, and activities.

Updating the Roadmap

As before, the FirstNet Authority based updates to the Roadmap deliberately on stakeholder input and recent research. Since the August 2019 release of the Roadmap, the FirstNet Authority has participated in nearly 1,300 engagements with first responders and hundreds of discussions with industry, as well as executed substantive engagement-driven polling and data collection.

While the pandemic impacted in-person discussions, the FirstNet Authority was able to quickly implement a virtual engagement program with public safety across the country. In addition to typical public safety engagements, the FirstNet Authority conducted a series of more in-depth and targeted research efforts to further hone the Roadmap focus areas. These efforts included:

- A series of interviews with academic and industry-leading technologists focused on long-term technology trends
- An analysis of applicable research publications and trade press spanning law enforcement, fire service, emergency medical services, emergency communications, and emergency management
- A rigorous technology prioritization survey of first responders

These efforts focused on the current and future impact of communications technology on the effectiveness of public safety operations, as well as emerging technology trends. In the near term, first responder priorities include coverage improvement, mission critical services, and land mobile

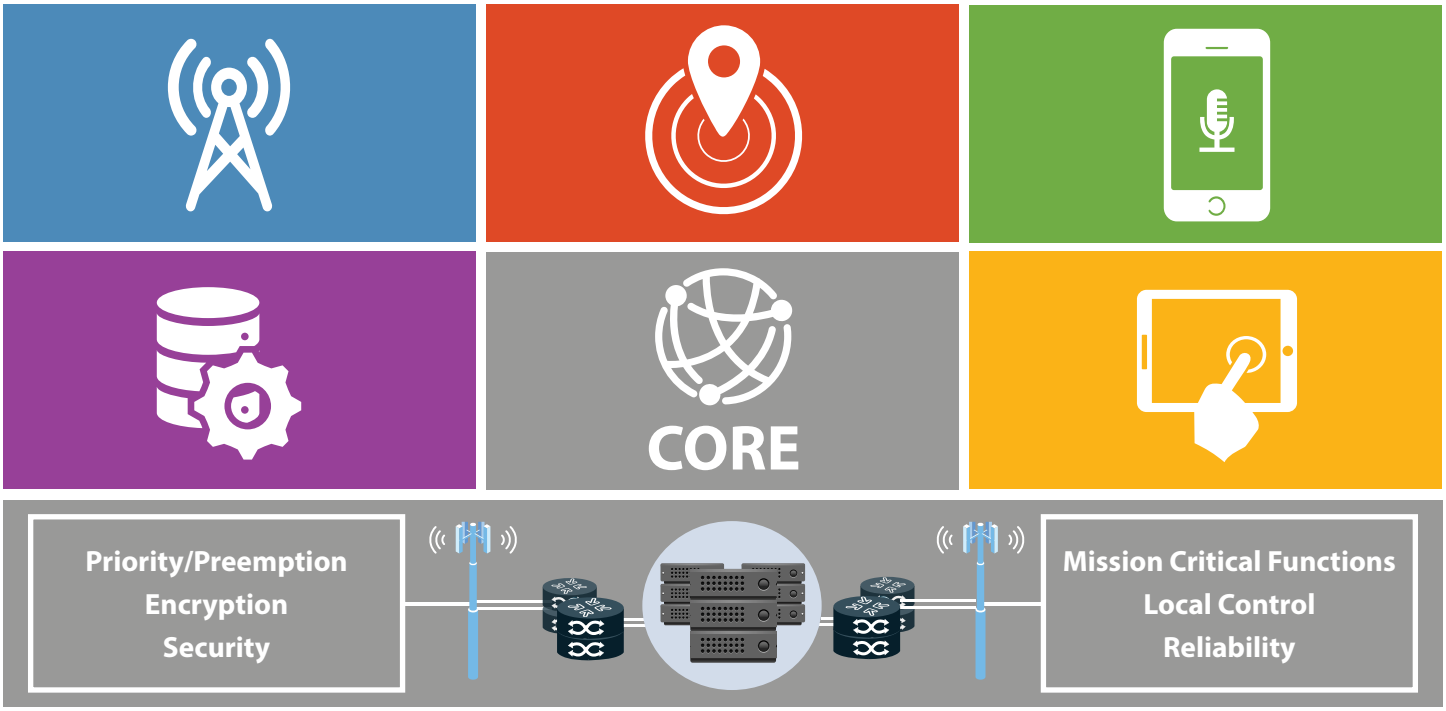
Figure 1: Roadmap Domains and Updated Priorities

radio (LMR)-to-long term evolution (LTE) interconnectivity. First responders prioritized the concrete items they see and use on a daily basis that impact today's operations. Technologists, who naturally have a different focus and were specifically asked about future trends, suggested real-time data analytics and non-intrusive user communications, among others, as the most promising technologies in the long term. More details about the research are included in the Roadmap Addendum.

As a result of substantive stakeholder input and the noted research, the FirstNet Authority updated the Roadmap to continue its focus on items that may advance the FirstNet Experience. The 2020 Roadmap includes updates to priorities and focused technology areas, refinement of "public safety's take" on each domain, and updates to the FirstNet Authority's "key takeaways." All updates are centered on those items with the most potential to improve first responder effectiveness.

The Roadmap will continue to be the FirstNet Authority's guide for applying resources to the most promising and impactful priorities, both short- and long-term.

CORE



The Vision

The FirstNet Authority envisions the FirstNet Core will be technologically current and possess the necessary features and enablers to support mission critical services and applications at appropriate levels of availability, performance, and security to meet the public safety community's expectations.

Domain Overview

FirstNet is the only nationwide cellular network built specifically for the nation's first responder community. A part of FirstNet, the Core serves as the brain and nervous system of the network, separates public safety traffic from commercial traffic, and supports FirstNet functions, including quality of service, priority, and preemption (QPP). The FirstNet Core is the foundation for the delivery of advanced public safety features that are unique to the FirstNet service offering, including end-to-end encryption, continuous security monitoring, superior reliability and availability, local control, and mission critical services.

Roadmap Priorities for the FirstNet Core

The FirstNet Authority will prioritize the following areas in alignment with stakeholder contributions, evolving 3rd Generation Partnership Project (3GPP) standards, and the prioritized needs of other Roadmap domains.

- **Generational Updates (e.g., 4G/5G):** Evolve the core and radio access network consistent with 3GPP generational upgrades.
- **Priority and Preemption, including Uplift on 5G:** Advance QPP implementation in the network with new standards-based systems and features available in 5G.
- **Mission Critical Services Platforms and Enablers on 5G:** Implement standards-based systems and features providing mission critical services, such as mission critical push-to-talk (MCPTT), mission critical video (MCVideo), and mission critical data (MCData) on 5G.
- **Network Security on 5G:** Implement standards-based systems and features providing cybersecurity to public safety users on 5G in support of the network security requirements.

Key Technologies and Solutions that Impact the FirstNet Core

The FirstNet Core acts as the network's central controller and orchestrates the following technologies:

- **Evolved Packet Core (EPC):** The standard 3GPP core architecture for 4G networks, which provides control and switching of data for the FirstNet LTE network, including user authentication, session and mobility management, network security, and QPP. On 5G, the EPC evolves to the 5G next-generation core, the standard 3GPP core network architecture in 5G networks.
- **Internet Protocol (IP) Multimedia Subsystem:** The standard 3GPP architecture for session initiation protocol-based services, including voice over LTE, rich communication services, and IP-based messaging.
- **Services Platforms and Enablers:** Standards-based servers supporting basic network services (e.g., telephony, messaging, location, presence), mission critical services (i.e., MCPTT, MCVideo, and MCData), proximity services, and evolved multimedia broadcast multicast services.
- **Application Servers:** Computing solutions providing network-integrated public safety applications, such as Identity, Credential, and Access Management and local control.
- **Operating and Business Support Systems:** Key functions in the core, providing administration of the end-to-end network, including but not limited to alarm monitoring, traffic measuring, billing, and subscriptions.
- **Radio Access Network:** Foundational network elements that interwork with the user equipment and the EPC, ensuring an end-to-end, all-IP evolved packet system (EPS). The core uses the EPS to implement access control, user authentication, security, session management, mobility management, and QPP.

Public Safety's Take on the FirstNet Core

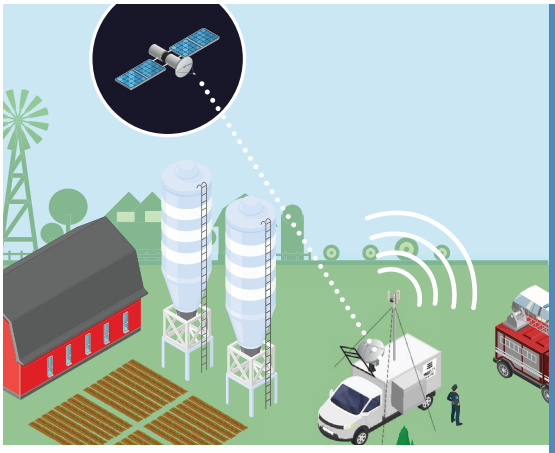
- Availability, reliability, resiliency, and hardening are foundational elements to meeting public safety's operational requirements. Each of these items are, to one degree or another, enabled by FirstNet's distributed core architecture.
- Providing mission critical services (i.e., MCPTT, MCData, and MCVideo), strong cybersecurity, and priority services enhances public safety broadband communications.
- Maintaining competitive parity (e.g., network functionality, throughput, latency, wearables, phone number synchronization, international roaming) and staying current with the continued evolution of features, functions, and capabilities as specified in standards and as made available by technology providers ensures that FirstNet never lags behind offerings from commercial providers.

Public safety engagements that addressed Core (October 1, 2019 – September 30, 2020)

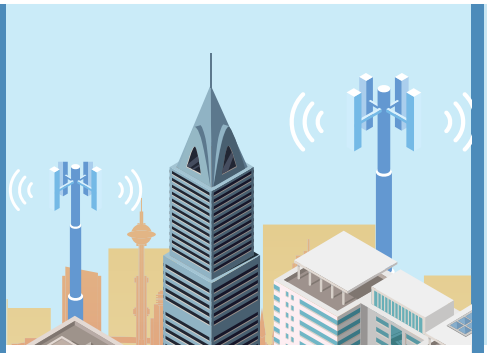
Key Takeaways from the FirstNet Authority's Analysis of Learnings from Stakeholders

- The FirstNet Core is an enabler to each of the Roadmap domains, and a continually evolving core will provide the means necessary to fulfill public safety's operational requirements both today and in the future.
- The FirstNet Authority needs to ensure that the FirstNet Core is equipped to enable advanced technological capabilities that support ongoing network operation and longevity.
- The FirstNet Authority is uniquely positioned to continue advocating for relevant standards that emphasize public safety's evolving operational and technical needs.

COVERAGE

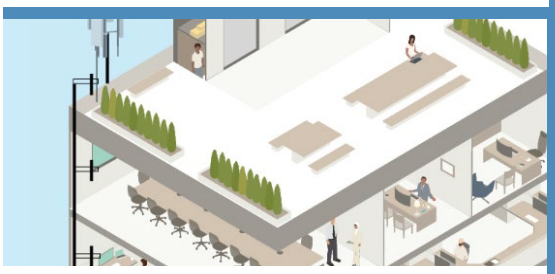


Deployables



Outdoor Coverage

Drone/Airborne Coverage



In-building Coverage

Maritime Coverage

COVERAGE

The Vision

The FirstNet Authority envisions the FirstNet network will be available to public safety personnel when and where they need it most.

Domain Overview

Access to mobile broadband with reliable, dependable, and consistent coverage with sufficient capacity fundamentally enables first responder operations. A principal focus of the FirstNet Authority's contract with AT&T is to build a robust nationwide broadband network for public safety's use on Band 14 spectrum. Coupled with public safety's access to all of AT&T's commercial spectrum on its permanent terrestrial network with the same features, public safety agencies have access to the differentiated FirstNet network, enhancing their ability to access network services that can transform operations.

Roadmap Priorities for Coverage

The FirstNet Authority will prioritize the following areas in alignment with stakeholder contributions and the prioritized needs of other Roadmap domains.

- **Outdoor Coverage Expansion:** Increase outdoor coverage, particularly Band 14, at locations deemed to be strategic public safety priorities.
- **Indoor Coverage Expansion:** Increase indoor coverage and advocate for changes in policies, codes, and standards to facilitate in-building coverage enhancements.
- **Unique Coverage Solutions Advancement:** Address and support unique coverage solutions that enable public safety to rapidly provide coverage in specialized circumstances and various outage scenarios.

Key Technologies and Solutions that Impact Coverage

- **Outdoor Coverage:** A broad coverage footprint typically enabled by fixed cell sites and commonly referred to as the macro network.
- **In-Building Coverage:** Persistent coverage in areas that may be hard to reach by the macro network (e.g., inside commercial buildings, underground public transit stations, crowded sports arenas) typically enabled by various technology solutions.
- **Deployables:** Solutions that deliver or help restore coverage on an on-demand basis (e.g., AT&T FirstNet deployable solutions, customer-owned and maintained deployable solutions, satellite).
- **Drone and Airborne Coverage:** Solutions that enable operations and the use of broadband applications while in the air (e.g., unmanned aerial systems, aircraft).
- **Maritime Coverage:** Solutions that enable operations and use of voice and broadband applications while operating in coastal and inland waterways.

Public Safety's Take on Coverage

- First responders need transparency on where coverage exists today and want the ability to guide where coverage will expand in the future across all operational areas, including outdoors, indoors, and for airborne and maritime operations.
- Fixed, reliable wireless broadband coverage is preferred for public safety operations, especially as it becomes foundational to public safety communications.
- Temporary and public safety-unique coverage solutions must be readily available to an agency and their use must easily integrate into ongoing operations.
- Network availability, reliability, resiliency, and hardening are fundamental to meeting public safety's operational needs.

Public safety engagements that addressed Coverage (October 1, 2019 – September 30, 2020)

Key Takeaways from the FirstNet Authority's Analysis of Learnings from Stakeholders

- Coverage expansion investments that address critical operational areas will have a direct and meaningful impact on public safety operations and will improve confidence in the FirstNet network.
- Significant improvements to indoor coverage can be achieved by investing in existing and new technology solutions, as well as updating relevant policies to encourage cooperation from building developers and owners.
- Public safety operations occasionally require unique coverage solutions to address mission needs, including but not limited to rapid coverage restoration during emergencies and immediate accessibility to coverage solutions in remote locales or atypical operational areas (e.g., tunnels, parking garages), and off-network coverage at a level that public safety is accustomed to today.

SITUATIONAL AWARENESS

Location Services

Mapping/GIS

Camera and Video

Data Analytics and Artificial Intelligence

Sensors

SITUATIONAL AWARENESS

The Vision

The FirstNet Authority envisions real-time access, collection, and distribution of information concerning personnel, threats, hazards, and conditions in a manner tailored to public safety operations.

Domain Overview

Public safety agencies across the nation have access to an unprecedented amount of ever-increasing information as technologies evolve and sensors proliferate. Situational awareness refers to the ability to aggregate and synthesize that information in real time from multiple sources (e.g., humans, machines, sensors) and derive and present actionable insights to public safety professionals. The FirstNet network provides access to technology capabilities that can automatically collect and analyze data, provide operationally relevant insights, and enable quick decision-making under a variety of challenging or difficult circumstances.

The FirstNet Authority approaches situational awareness with both a near- and long-term technology evolution perspective. Various capabilities are expected to emerge in the coming years associated with situational awareness that may have a significant impact on the effectiveness, safety, and health of the first responder community. The Internet of Things, cameras, data from other applications and networks, and sensors continue to produce increasing amounts of data. Artificial intelligence and data analytics are envisioned to be increasingly important mechanisms to assist public safety in making timely and more informed decisions. The ability to distill useful information from massive amounts of data, prioritized and effectively presented to first responders, helps ensure the right people receive the correct information, when they need it.

Roadmap Priorities for Situational Awareness

The FirstNet Authority will prioritize the following areas in alignment with stakeholder contributions and the prioritized needs of other Roadmap domains.

- **Locate and Present Personnel Location:** Promote technology solutions that provide accurate locations of first responders and the ability to display that information through effective mapping and visualization.
- **Location Services Integration:** Promote the integration of x-, y-, and z-axis data with 3D mapping solutions and with public safety's existing technology platforms.

Key Technologies and Solutions that Impact Situational Awareness

- **Location Services:** Solutions using geographic and position data to provide information to users, such as the physical whereabouts and tracking of personnel, vehicles, and other assets.
- **Mapping/Geographic Information Systems (GIS):** Maps can be two-dimensional or three-dimensional and represent a particular physical area of outdoor or indoor topology. They provide context to the location of a specific object, person, or place for situational awareness and are often annotated with specific data, such as responder/asset location, potential hazards, and relational information between personnel or assets.
- **Cameras and Video:** Devices that capture still images and/or video (e.g., fixed, temporary, portable, vehicle-mounted, worn, airborne) and present that data in nearly real time or through access to archived/historical data.
- **Data Analytics and Artificial Intelligence:** Automated processes to inspect, cleanse, transform, and model data with the goal of discovering useful information and supporting public safety's decision-making, as well as perform or assist tasks that normally require human intelligence (e.g., object recognition, speech recognition).
- **Sensors:** Devices that collect, process, and transmit data from various sources (e.g., smart buildings, weather sensors, traffic sensors, environmental sensors, biometric sensors) to provide insight into existing conditions and monitor personnel health and safety.

Public Safety's Take on Situational Awareness

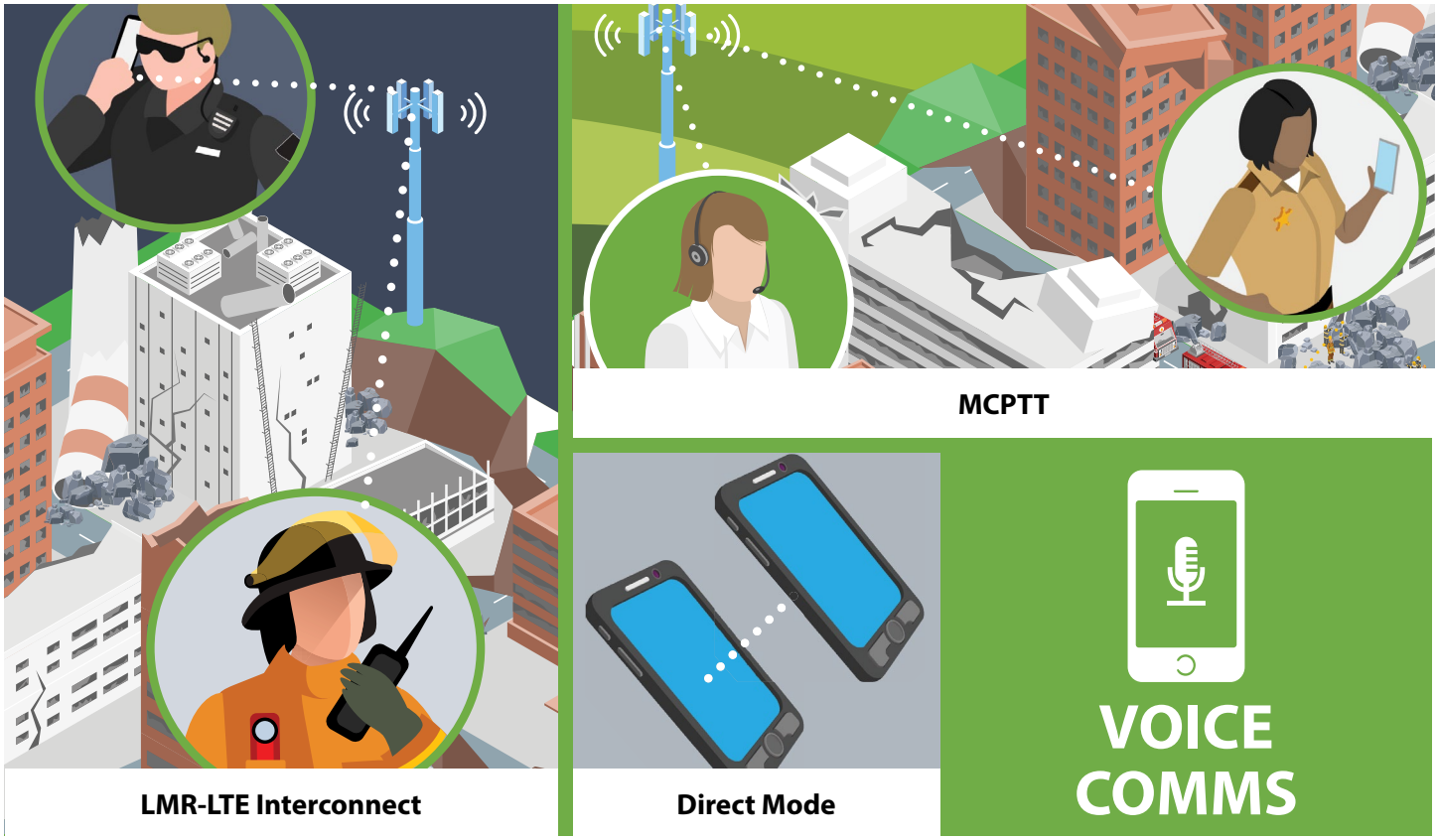
- Location services, including vertical location (z-axis), is a priority for public safety and must be presented in a way that is easily consumable.
- The public safety community needs tools to process large volumes of data and turn that data into useful, actionable information that can inform decision-making processes and combat information overload for first responders.

Key Takeaways from the FirstNet Authority's Analysis of Learnings from Stakeholders

- Today's market offers many solutions for tracking first responder vehicles but does not adequately address the public safety community's requirements for locating individual personnel in a three-dimensional environment.
- Indoor mapping technologies that include z-axis (vertical location) are not widely available to meet the community's needs. As indoor 3D location becomes available, situational awareness/mapping platforms must effectively integrate and present this information.
- Cameras and sensors are becoming increasingly ubiquitous; there is a need to focus on integrating the location data from these various sources into existing data visualization platforms that reduce information overload and facilitate effective decision-making.
- Actionable information will need to be presented to first responders or decision makers in easily digestible, non-intrusive formats that fit the given situation.

Public safety engagements that addressed Situational Awareness (October 1, 2019 – September 30, 2020)

VOICE COMMUNICATIONS



The Vision

The FirstNet Authority envisions a nationwide network that provides high-quality, reliable voice communications leveraging mission critical technologies to ensure the most advanced feature set is available for first responders.

Domain Overview

Voice communications continues to be the fundamental form of public safety communications. In the current market, public safety agencies continue to rely on LMR for critical communications while augmenting voice communications with LTE. A 3GPP-compliant MCPTT offering is a requirement of the FirstNet Authority's contract with AT&T, and AT&T launched the initial introduction of FirstNet Push-To-Talk (FirstNet PTT) in March 2020. The coexistence of FirstNet PTT and LMR will provide for integrated voice capabilities in the near term.

Public safety's use of data and video is becoming increasingly commonplace in daily operations and may soon be of equal importance to PTT voice and telephony. The FirstNet Authority and AT&T recognize this evolution, and AT&T will introduce MCData and MCVideo capabilities to complement the MCPTT voice offering as part of a suite of mission critical services (MCX) based on the 3GPP standards. The MCX suite is being designed to interoperate with legacy LMR networks for integrated voice, video, and data capabilities.

Roadmap Priorities for Voice Communications

The FirstNet Authority will prioritize the following areas in alignment with stakeholder contributions, evolving 3GPP standards, and the prioritized needs of other Roadmap domains.

- **Operationalize FirstNet PTT:** Work with public safety to assist in operationalizing the FirstNet PTT solution by educating on relevant use cases and supporting efforts to establish relevant nationwide governance and policies.
- **Active Role in Standards:** Continue to play an active role in emerging 3GPP and other relevant standards development focused on MCPTT, MCVideo, and MCData, as well as dispatch advancement.
- **Critical Features:** Advocate for continued implementation of critical MCX features such as device-to-device communications, LMR-LTE interconnection, and dispatch capabilities based on public safety operational needs.

Key Technologies and Solutions that Impact Voice Communications

- **LMR-LTE Interconnect:** Technology that enables interworking of LMR systems with FirstNet PTT.
- **Mission Critical Push-to-Talk (inclusive of voice, video, and data):** A standards-based, group-enabled PTT voice, data, and video ecosystem that is designed for the acute demands of public safety.
- **Direct Mode:** Capability for devices to communicate directly between or among other devices without relying on central network infrastructure.

Public Safety's Take on Voice Communications

- MCPTT solutions must be able to communicate with legacy systems (including dispatch consoles) and offer comparable features and performance.
- First responders will not consider FirstNet's PTT solution to be "mission critical capable" until it has been validated in real-world scenarios.
- The public safety community foresees various governance, standards, and policy challenges with multi-agency use of FirstNet PTT and expects the FirstNet Authority to assist in addressing those.

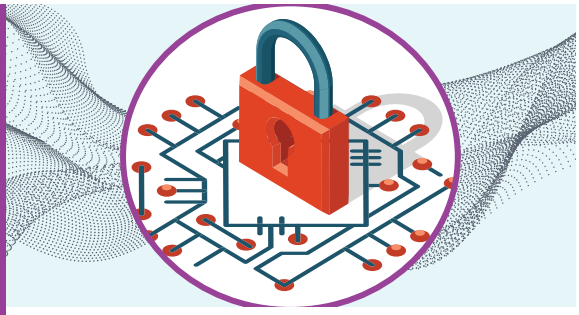
Key Takeaways from the FirstNet Authority's Analysis of Learnings from Stakeholders

- The FirstNet Authority has contributed significantly toward the initial introduction of FirstNet PTT, and the first responder community expects the FirstNet Authority's continued involvement as FirstNet PTT evolves.
- Crucial MCX features (e.g., direct mode; interconnection, including dispatch consoles) need the FirstNet Authority's continued engagement and active refinement to allow full adoption by public safety.
- Public safety envisions migration to LTE that is coexistent with LMR, requiring an economical, easy-to-implement interworking solution.

Public safety engagements that addressed Voice Communications (October 1, 2019 – September 30, 2020)

SECURE INFORMATION EXCHANGE

Secure Data Sharing, Data Access, and Identity Management



Cybersecurity

SECURE INFORMATION EXCHANGE

The Vision

The FirstNet Authority envisions secure, reliable, and easy-to-use access to and sharing of critical information across a variety of sources.

Domain Overview

Secure information exchange is essential to public safety's mission. First responders require access to many data sources, and the information gathered, accessed, compiled, and stored by first responders must be secure from unauthorized access, adhere to security best practices, and comply with all relevant laws and regulations. The Secure Information Exchange domain addresses end-user security by focusing on the management, access, and flow of data among end users and applications across public safety jurisdictions and agencies.

Roadmap Priorities for Secure Information Exchange

The FirstNet Authority will prioritize the following areas in alignment with stakeholder contributions and the prioritized needs of other Roadmap domains.

- **Database Integration:** Integrate FirstNet's secure access and information exchange solutions with select national-level datasets.
- **Application Integration:** Leverage standardized security controls and industry best practices for application-based access to critical data.

Key Technologies and Solutions that Impact Secure Information Exchange

- **Secure Data Sharing, Data Access, and Identity Management:** Seamless and secure public safety data access and information sharing among common technology platforms, agencies and jurisdictions, internal and external data sources, and with the appropriate level of access control enabled by a robust Identity, Credential, and Access Management solution.
- **Cybersecurity:** A comprehensive management of data access and security throughout the FirstNet network to ensure end-to-end protection of data at rest, in motion, and in use.

Public Safety's Take on Secure Information Exchange

- Data access, sharing, interoperability, and cybersecurity are near- and long-term priorities for public safety.
- The need to securely share data transcends disciplines, jurisdictions, and solutions.
- Standardized and consistent cybersecurity procedures ensure the safe exchange of critical, sensitive information and the overall protection of the network.
- Mobile security solutions are required to fully leverage data sharing capabilities on mobile devices and applications.

Key Takeaways from the FirstNet Authority's Analysis of Learnings from Stakeholders

- The FirstNet Authority is uniquely positioned to support public safety's access to national data sets through government coordination.
- Deployment of Identity, Credential, and Access Management on the FirstNet network is a valuable technical advancement, and support to public safety is needed to operationalize the capability.

Public safety engagements that addressed Secure Information Exchange (October 1, 2019 – September 30, 2020)

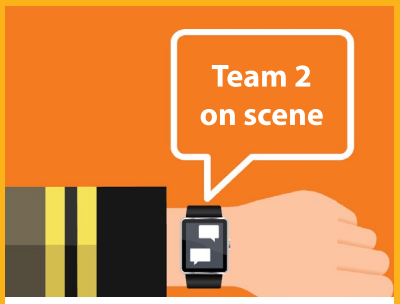
- Network data and cybersecurity are an essential shared responsibility of the public-private partnership and the public safety community.
- Many public safety agencies are unable to prioritize investments in technical expertise and resources to implement robust cybersecurity and Identity, Credential, and Access Management programs.

USER EXPERIENCE

Augmented/Virtual Reality

Devices

Applications



Hands-Free Interfaces

The Vision

The FirstNet Authority envisions a user experience driven by public safety operational needs that enables users to stay focused on their primary mission.

Domain Overview

The FirstNet network is specifically designed to meet the needs and requirements of public safety professionals. First responders need simple, easy-to-use devices and applications with the ability to communicate, collaborate, and access information during routine daily operations and emergency response incidents. Due to the critical nature of public safety communications, all the various ways that responders can and will interface with, or experience, the network must be considered. Device and application technologies utilized must be effective, reliable, and resilient, and they must enhance rather than hinder public safety operations.

The FirstNet Authority approaches the domain with both a near- and long-term technology evolution perspective. There are a variety of technology capabilities expected to emerge in the coming years to address operational gaps in new and unanticipated ways. Looking forward, first responders will experience the network and communicate via methods beyond today's traditional smart devices. Examples include hands-free interfaces, which will provide critical information and analysis to responders in a non-intrusive manner and mixed realities that will enhance responder effectiveness by creating more realistic training sessions and providing pivotal, real-time information in the field.

Roadmap Priorities for User Experience

The FirstNet Authority will prioritize the following areas in alignment with stakeholder contributions and the prioritized needs of other Roadmap domains.

- **Mission-Enabling Applications:** Promote the development and use of applications that are operationally sound, offer intuitive user interfaces, and support seamless collaboration for public safety.
- **Mission-Capable Devices:** Promote the development and use of devices that support the successful execution of public safety operations.

Key Technologies and Solutions that Impact User Experience

- **Devices:** User equipment relevant to public safety's use and mission, including commercial devices and those adapted to public safety operations and suitable for various environmental conditions.
- **Applications:** Software solutions and enabling technologies relevant to and designed for public safety use cases.
- **Augmented/Virtual Reality:** An enhanced version of reality created by the use of technology, which overlays digital information on an image of something being viewed through a device, such as a smartphone camera (augmented reality) or an entirely computer-generated simulation (virtual reality) that improves public safety training and operations.
- **Hands-Free Interfaces:** Non-intrusive delivery methods that enable users to interact with technology and consume information without the use of their hands (e.g., virtual assistant, heads up display, voice-to-text, haptics).

Public Safety's Take on User Experience

- Public safety agencies want a convenient avenue to learn about relevant applications that could provide valuable operational benefits and efficiencies.
- Users want the familiarity of commercially available devices as well as devices that are easy-to-use, ruggedized, and that enable the public safety mission.
- Device and application user interfaces must be tailored for, and evolve with, public safety's needs; they need to be intuitive, reliable, and non-intrusive as they communicate relevant information to all types of responders.

Key Takeaways from the FirstNet Authority's Analysis of Learnings from Stakeholders

- By demonstrating the viability of the public safety marketplace, the FirstNet Authority can prompt industry to provide the public safety community with affordable, reliable software solutions that support various capabilities, including seamless collaboration.
- First responder disciplines have different operational needs and perform under different environmental conditions, which should be taken into consideration for device design. The FirstNet Authority can present a strong centralized voice for these device requirements to device manufacturers.

Public safety engagements that addressed Situational Awareness (October 1, 2019 – September 30, 2020)

ADDENDUM: ROADMAP RESEARCH

Background

Since the First Responder Network Authority (FirstNet Authority) first released the FirstNet Authority Roadmap (Roadmap) in August 2019, the FirstNet Authority has continued to engage with public safety stakeholders directly in discussions regarding the Roadmap domains, technologies, and priorities. These discussions provided key operational needs and quantitative data to inform the 2020 Roadmap update. The FirstNet Authority additionally undertook a three-pronged effort to evaluate short-term first responder priorities and gain general industry perspective on the most promising emerging technologies relevant to public safety. These research efforts included:

- A series of interviews with academic and industry-leading technologists focused on long-term technology trends applicable to public safety communications
- An analysis of applicable research publications and trade press spanning law enforcement, fire service, emergency medical services, emergency communications, and emergency management
- A rigorous technology prioritization survey of first responders

This addendum summarizes these research efforts and the resulting conclusions that shaped updates to the FirstNet Authority Roadmap.

Executive Interviews with Technologists

FirstNet Authority staff conducted a series of 35 executive interviews with industry technologists (e.g., leaders from telecommunications companies, device and equipment manufacturers, application or software developers), as well as members of academia and government (i.e., state, local, federal, and tribal). Interviewers posed two overarching questions:

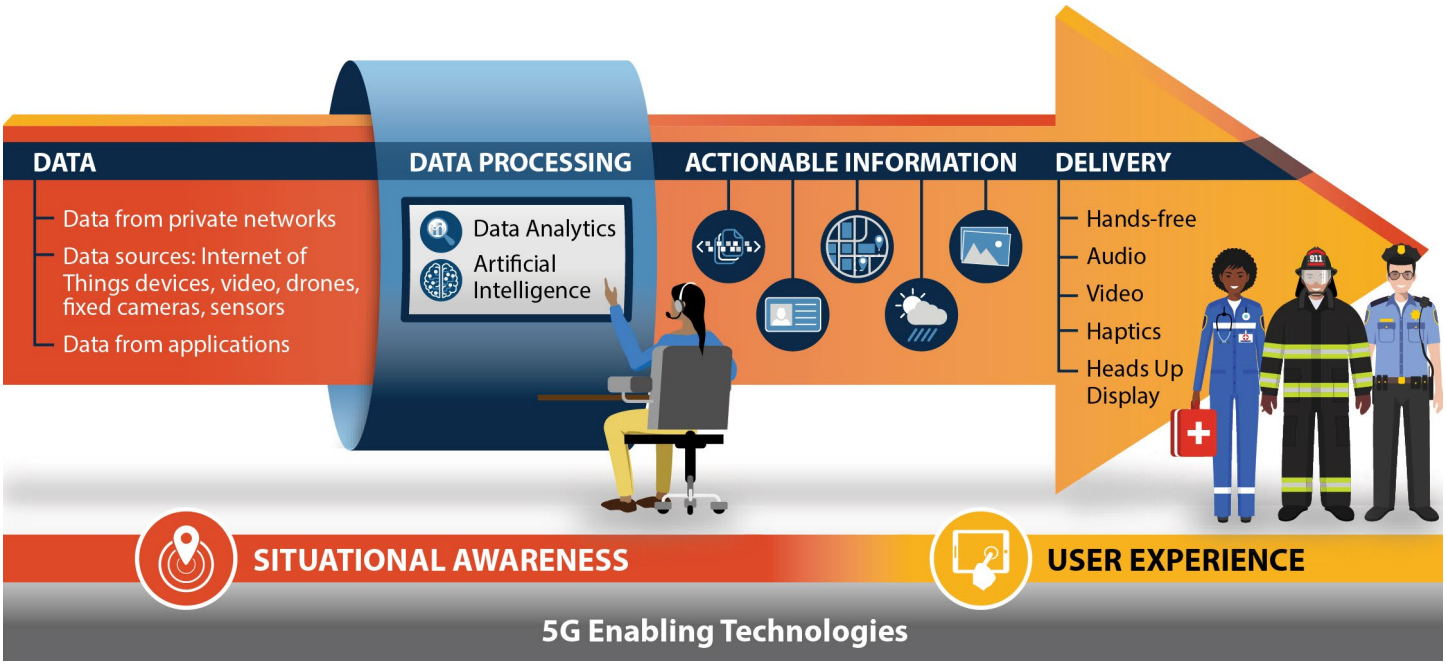
- What technologies, currently in infancy, do you see as most promising for public safety communications in the next five to seven years?
- What technologies are available today that have the potential to impact public safety communications in the next one to three years?

Interviewees were well-versed in applicable technologies and in the many ways that first responders might benefit from technology advancement. Some technologies or capabilities surfaced frequently across nearly all 35 interviews. As such, a common narrative emerged that is best described as "situational awareness" and transcends the Situational Awareness and User Experience domains defined in the Roadmap. The term situational awareness relates to the overarching collection of data from sensors to the use of artificial intelligence (AI) to analyze said data and ultimately provide actionable information to the first responder, incident command, telecommunicators, and the like. The actual methods for delivering information to various parties fall under the User Experience Roadmap domain but is nonetheless a key element of the overarching situational awareness theme. An interviewee shared an experience when she was observing first responder behavior and a responder asked her bluntly, "Can you just give us more information about what we are walking into?" This simple question succinctly demonstrates the importance and relevance of the identified situational awareness theme to the first responder community.

Interviewees identified various data sources for such awareness, including location-based services, wearable and fixed sensors (e.g., biometric data), unmanned aerial systems, autonomous platforms (e.g., robots, other airborne vehicles), video (e.g., fixed, mobile, aerial cameras), and devices that detect motion, proximity, speed, temperature, and hazardous materials. Simultaneously, interviewees noted first responders will be overwhelmed by the ever-increasing data sources. This observation is consistent with research regarding information processing, which states that "emergency services may extract actionable or situational information from eyewitness reports, photos or videos, yet due to limited personal or organizational resources the issue of information overload constitutes a severe problem."[1]

1 Kaufhold, Marc-André, Markus Bayer, and Christian Reuter. "Rapid relevance classification of social media posts in disasters and emergencies: A system and evaluation featuring active, incremental and online learning." *Information Processing & Management*. Vol. 57, Issue 1, January 2020. Available online: https://doi.org/10.1016/j.ipm.2019.102132.

Figure A: Situational awareness process grounded in the 5G enabling technologies delivering actionable information



"We have to figure out how we make information accessible, digestible, and useful in challenging tactical environments."

To process and make sense of such volumes of seemingly disparate data, interviewees repeatedly noted the need for robust data analytics and AI.[2] One interviewee noted the goal is to bring multimodal data streams together "meaningfully at the right point, with the right level of information, for the right person in a dynamic situation." The public safety community needs tools to process large volumes of data and turn it into useful, actionable information that can inform decision-making processes and combat information overload for first responders, as well as incident command, emergency operations centers, and dispatchers. Interviewees relayed examples such as searching for patterns in existing data sets, analyzing real-time video, contact tracing, guiding resource allocation, and deriving the probability of fires and other incidents. The actionable information will then need to be presented to the first responder, or supporting staff, in an easily digestible, non-intrusive manner appropriate for their operational situation. For example, first responders could receive information in any number of hands-free methods (e.g., visually, verbally, via haptics or heads-up displays) to best serve them and minimize interruption to ongoing operations while an incident commander could view multiple dashboards with detailed information, if desired. Figure A provides a simple representation of the situational awareness process, including data sources, data analytics and AI tools, and the presentation of actionable information to the first responder.

"We believe AI will play a bigger role just because of high bandwidth and low latency you can achieve with 5G."

Public safety agencies today leverage 4G to achieve variations of the process depicted in Figure A; however,

2 All interviewees used the terminology "artificial intelligence," which is defined as the theory and development of computer systems able to perform tasks that normally require human intelligence (e.g., visual perception, speech recognition, decision-making). However, interviewees offered different perspectives when it comes to discerning whether one is interacting with an AI system. Some stressed the importance of a seamless experience while others suggested a public safety professional must be able to not only understand that an AI system made a decision but also understand how that decision was made.

many interviewees identified the need for 5G capabilities to support the extensive nature of the desired situational awareness, especially the sheer number of anticipated Internet of Things (IoT) devices and other data sources. Interviewees addressed 5G elements or anticipated benefits, including low latency, improved throughput, and massive IoT capabilities. Several brought up the concepts of network slicing and edge computing technologies associated with 5G that will enable the collection and processing of massive amounts of data, as well as the distribution of information, instantaneously and without disruption, back to the "right" person in a given situation.

Interviewees mentioned many other technologies or capabilities consistent with their respective areas of interest or professional focus. These topics included location services, device consolidation, in-building coverage, application interoperability, autonomous platforms, and biometrics, among others. However, even with this variety, situational awareness and ever-increasing amounts of data that require distillation, analysis, and interpretation remain the overarching theme.

Other Considerations

Additionally, several interviewees noted the impact COVID-19 is having on the first responder workflow in the near term. One public safety practitioner even referred to the increased adoption of technologies to assist in the response to COVID-19 as the "industrial revolution" of this generation. As the operational environment changes, public safety agencies are accelerating technology roll-out and adoption and embracing previously unexplored approaches (e.g., cloud-based services, dispatch from home).

Lastly, many interviewees reflected on the challenges associated with interoperability in past and current land mobile radio (LMR) systems. While the FirstNet network enables public safety users to seamlessly interoperate across agencies, jurisdictions, or disciplines, public safety agencies continue to face application and/or data interoperability challenges. Interviewees suggested the FirstNet Authority should explore this broad interoperability topic to adequately respond to industry and the public safety community.

Publication Review and Analysis

In addition to the executive interviews, FirstNet Authority personnel conducted a review of public safety or technology-focused publications, trade press, and analyses. The review primarily focused on publications or studies published since 2019; however, the review also included some foundational, discipline-specific publications from the last five years. These publications are comprehensive and address public safety topics beyond technology use, including but not limited to responder safety, training and education, doctrine and tactics, and vehicle management. Collectively, the publications identify overarching objectives for the first responder disciplines (e.g., improve first responder safety), provide compilations of public safety operational needs, and examine the application of existing and emerging technologies to public safety operations.

> *"The greatest need for cutting-edge technology, across disciplines, is for devices that provide information to the first responders in real time. First responders want timely, accurate information during incident response."*[3]

The publications identify common challenges for first responders across disciplines such as increasing data volumes, the flood of information pushed to responders, distracting information delivery methods, as well as the lack of global positioning system (GPS)-enabled tracking capabilities, robust systems to ensure a common operating picture, and data interoperability. Similarly, the studies and trade press suggest various technologies that could prove beneficial to the first responder community in the near- and long-term, ranging from mobile communications technologies (e.g., mobile computers, telehealth systems) to IoT devices (e.g., drones, sensors, robots) to data analytics to cloud capabilities, edge computing, and 5G capabilities.

The following sections demonstrate some parallels between the executive interview findings and some of the items reported in the discipline-specific publications.

3 Dawkins, Shaneé, et al. "Voices of First Responders – Examining Public Safety Communication Problems and Requested Functionality Findings from User-Centered Interviews Phase 1, Volume 2.1." National Institute of Standards and Technology. May 2019. Available online: https://nvlpubs.nist.gov/nistpubs/ir/2019/NIST.IR.8245.pdf.

Table A: Table A: Example issues and needs from the 2017 RAND study *Fostering Innovation in U.S. Law Enforcement*

Issue	Need
Many information displays result in information overload for responding officers.	Assist software vendors with identifying the pieces of information that are relevant to officers at particular stages in a response or an investigation.[4]
Many officers are experiencing data overload and information overload.	Measures and methodologies for deciding whether new technologies are sufficiently mature and truly value added.[5]
Human factors design of reporting and displays need to be improved, especially on mobile devices. Autofill (but concerns about data accuracy), display/order of prompts, and eliminating retyping are common requests.	Research and development on reporting interfaces (broadly defined) that are easier to use—and can be readily and easily customized to how people actually work—while ensuring data accuracy.[6]
Existing Records Management Systems (RMS) and computer-aided dispatch (CAD) systems do a poor job of supporting analysis.	Identify standards for RMS/CAD systems to include analytic capabilities.[7]

Law Enforcement

The law enforcement-specific materials from the publication review focus on several key areas for future development, including information collection and delivery, data sources, analytics, and AI. In several instances, the technologies identified as potentially impactful align with key themes identified by executive interviewees. The 2017 RAND Corporation study titled *Fostering Innovation in U.S. Law Enforcement: Identifying High-Priority Technology and Other Needs for Improving Law Enforcement Operations and Outcomes*[8] identifies issues and corresponding needs to address them.

Additionally, the July 2020 issue of the International Association of Chiefs of Police's *Police Chief* magazine[9] examines ideas that have already shaped or could potentially transform modern policing. "Great Ideas 2020" presents 33 concepts from people across the industry and the world in six high-level categories: personnel, crime prevention and investigation, community-oriented policing, mental health response, training and education, and technology. Several of the presented ideas align with the executive interviews' primary theme of situational awareness and echo individual elements relayed by executive interviewees. For example, AI appears in several places, with one author explaining, "… as the Internet of Things continues to produce an increasing amount of data, the use of artificial intelligence and machine learning will allow police agencies to identify new associations, explore trends never identified before, and make smarter decisions faster."[10] Additionally, several ideas addressed various data sources, such as how "police efficiency and operations could be significantly enhanced if small drones were mounted on police vehicles … the drone can assist with situational awareness."[11]

4 Hollywood, John S., et al. "Fostering Innovation in U.S. Law Enforcement: Identifying High-Priority Technology and Other Needs for Improving Law Enforcement Operations and Outcomes." RAND Corporation, 2017. Page 112. Available online: https://www.rand.org/pubs/research_reports/RR1814.html.
5 Ibid. Page 113.
6 Ibid. Page 115.
7 Ibid. Page 118.
8 Hollywood, John S., et al. "Fostering Innovation in U.S. Law Enforcement: Identifying High-Priority Technology and Other Needs for Improving Law Enforcement Operations and Outcomes." RAND Corporation, 2017. Available online: https://www.rand.org/pubs/research_reports/RR1814.html.
9 "Great Ideas 2020: Shaping the Future of Policing." Police Chief 2020. July 2020. Available online: https://www.policechiefmagazine.org/magazine-issues/july-2020/.
10 Ibid. Page 66.
11 Ibid. Page 60.

Fire Service

For the fire service, the review included the May 2015 report, *National Institute of Standards and Technology (NIST) Special Publication 1191 Research Roadmap for Smart Fire Fighting.* The research roadmap identifies the following motivations "to improve fire protection and fire fighting:"

- Save lives and minimize injuries to building occupants and community members
- Improve firefighter occupational health and safety
- Enhance the overall operational efficiency of the fire service and the effectiveness of fire prevention and protection
- Minimize property loss from fire
- Minimize business interruption and loss of mission continuity due to fire[12]

> *"The Smart Fire Fighting vision includes the collection and integration of information from a wide range of databases and sensor networks. It also includes computational tools to analyze that information to make predictions of fire growth, building performance, occupant evacuation, and fire suppression … The vision … can be realized by harnessing the power of emerging information, communication, sensor, and simulation technologies to enable markedly better situational awareness, predictive models, and decision making."*[13]

This aforementioned vision for firefighting is also consistent with the executive interview theme of situational awareness. Additionally, the research roadmap details potential data sources (e.g., physiological monitoring, building information models, hospital status) and various communications technologies and user interface delivery methods (e.g., touch/haptics, heads-up displays, mobile devices), which are the book ends of Figure A.

12 Grant, Casey, et al. "NIST Special Publication 1191, Research Roadmap for Smart Fire Fighting Summary Report." The Fire Protection Research Foundation. Page 5. May 2015. Available online: https://www.nist.gov/publications/research-roadmap-smart-fire-fighting.

13 "EMS Agenda 2050: A People-Centered Vision for the Future of Emergency Medical Services." (Report No. DOT HS 812 664). National Highway Traffic Safety Administration. Page 21. January 2019. Available online: https://www.ems.gov/pdf/EMS-Agenda-2050.pdf.

Table B: Aligning executive interview themes and topics to the vision for the future outlined in "EMS Agenda 2050."

Interview Theme/Topic	EMS Agenda 2050
Actionable Information	"EMS data systems deliver real-time knowledge about patterns of disease, injury and access to care. Information collected and shared in these systems informs decisions made related to healthcare operations, public health and interventions related to social determinants of health and injury and illness prevention."[14]
General Situational Awareness	"Integrated technology provides real-time situational awareness and decision support to improve safety and reduce errors."[15]
General Situational Awareness	"Real-time and predictive information is delivered to emergency medical telecommunicators and first responders prior to their arrival on the scene, including video and sensor data provided by patients, bystanders or devices such as drones. With this information, responders are better able to assess the safety of a scene and determine what resources might be needed early in the response."[16]
Data Source: Wearables	"Wearable devices alert EMS professionals to any potential safety hazard, from threats including nuclear, chemical or biological contamination to personal health issues that might impede their performance, such as heat exhaustion or excessive fatigue."[17]
Artificial Intelligence	"Real-time, automated artificial intelligence supports clinician decision-making by analyzing information instantaneously, including data from patient records, diagnostic equipment and other inputs."[18]

Emergency Medical Services

The emergency medical services (EMS)-specific materials—in particular the U.S. Department of Transportation, National Highway Traffic Safety Administration's *EMS Agenda 2050: A People-Centered Vision for the Future of Emergency Medical Services*—focus on improving patient care and responder safety through seamless communication and coordination and innovation. In several instances, the technologies identified as potentially impactful align with the key themes identified by executive interviewees.

First Responder Technology Prioritization Survey

During July 2020, the FirstNet Authority conducted a prioritization survey of the 22 technologies identified in the updated Roadmap; these technologies are listed in each of the Roadmap domain sections, as well as collectively in Figure C below. The 244 survey respondents are from all first responder disciplines, all levels of management, rural and non-rural areas, and represent 46 states, two territories, and the District of Columbia. The overall sample size of 244 affords a margin-of-error of plus or minus six percent at the 95-percent confidence level for proportional results.

The survey methodology leveraged the MaxDiff (best-worst scaling) exercise that presents a respondent with

14 "EMS Agenda 2050: A People-Centered Vision for the Future of Emergency Medical Services." (Report No. DOT HS 812 664). National Highway Traffic Safety Administration. Page 21. January 2019. Available online: https://www.ems.gov/pdf/EMS-Agenda-2050.pdf.
15 Ibid. Page 16.
16 Ibid. Page 16.
17 Ibid. Page 16.
18 Ibid. Page 16.

Figure B: Example MaxDiff question from FirstNet Authority technology prioritization survey

(1/12) Consider the five items shown below. Please choose the items that have the greatest and least potential to improve first responder effectiveness.

Greatest Potential		Least Potential
◯	Generational Updates (e.g., 4G to 5G)	◯
◯	Cameras and Video (e.g., fixed, mobile)	◯
◯	Deployables	◯
◯	Location Services (for personnel and assets)	◯
◯	Secure Data Sharing, Data Access, and Identity Management (ICAM)	◯

Figure C. Survey results demonstrate highest preference share for mission critical services, outdoor coverage expansion, and in-building coverage expansion .

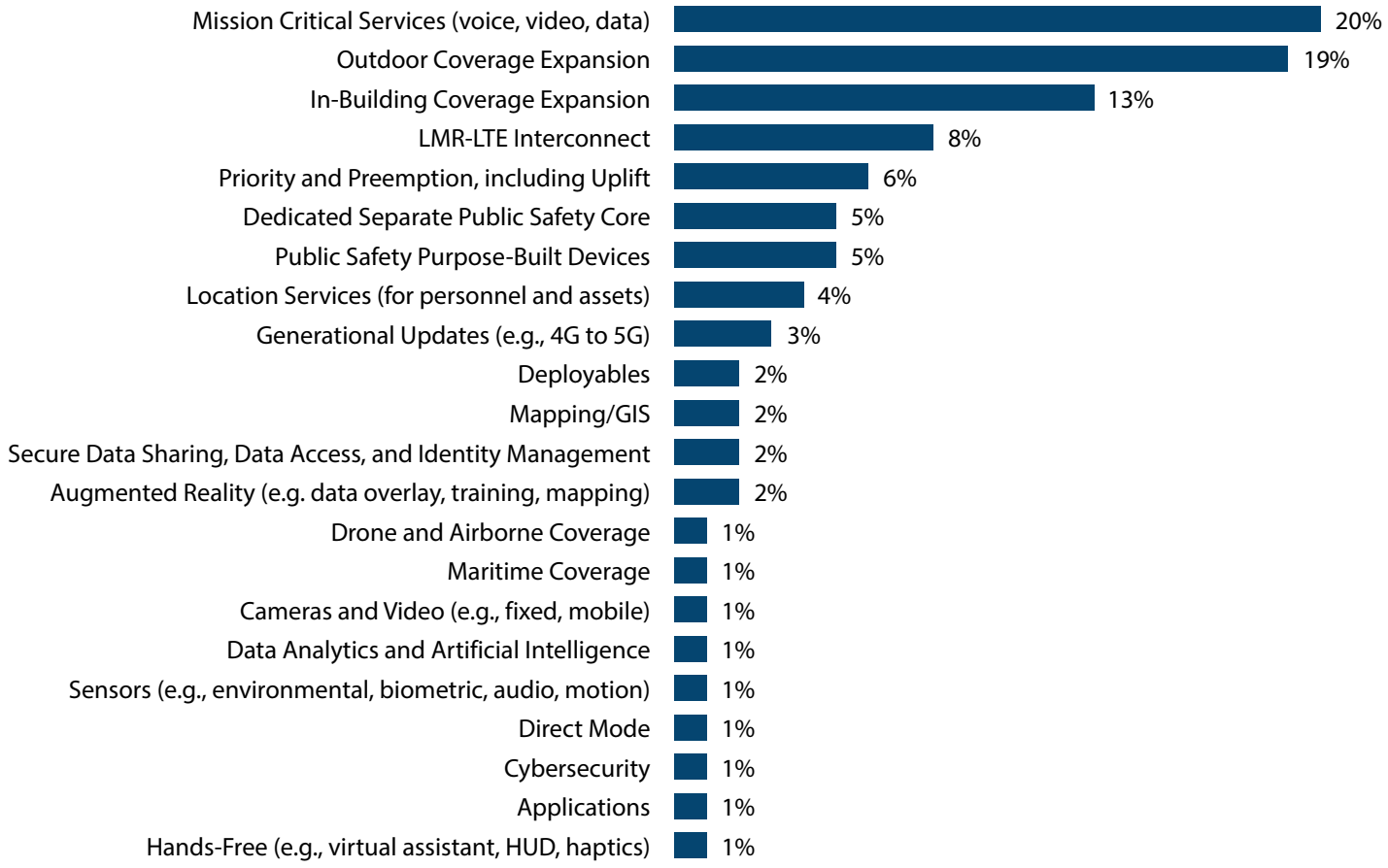
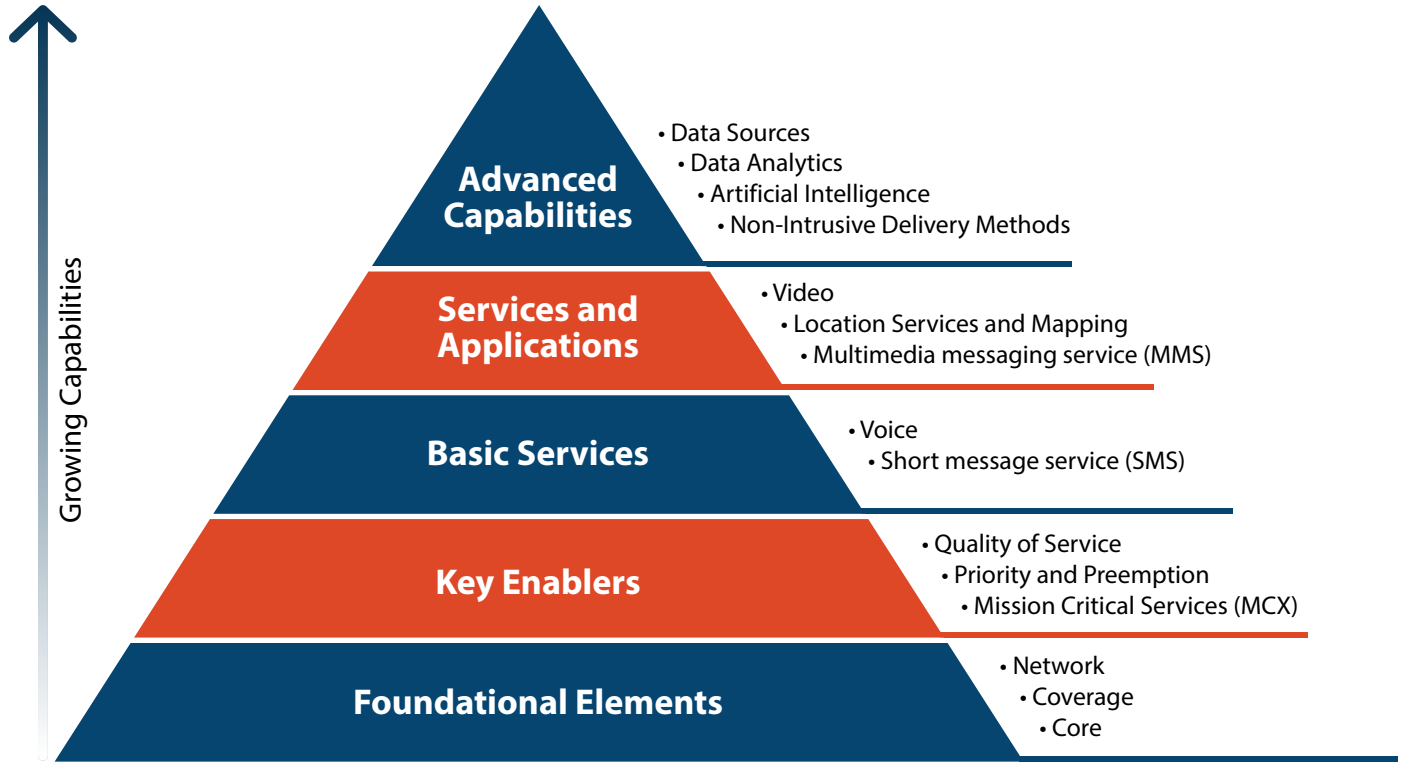


Figure D: First Responder Technology Hierarchy demonstrates growing capabilities to improve first responder effectiveness



five technologies at a time and asks the respondent to choose the single item with the most potential to improve first responder effectiveness and the single item with the least potential to improve first responder effectiveness. Respondents received 12 screens with five items at a time as demonstrated in Figure B.

Results are presented in Figure C noting "preference share" ranked from highest to lowest; values sum to 100 and can be understood as the likelihood that the attribute truly is the most preferred item.

Mission critical services and outdoor coverage expansion stand out with the highest rating at a nearly identical 20 percent preference share, closely followed by in-building coverage expansion, LMR-Long Term Evolution (LTE) interconnect, and priority and preemption. Figure C represents the results for all 244 respondents. There were no statistically significant clusters, suggesting that there is little variance in preference share based on the captured demographics.

Conclusion

The situational awareness theme and its many components emerged as the singular focus from the interviews with strong parallels across the publication review. The items identified through these two research efforts as most impactful over the long term have low preference share amongst first responders in the short term (as depicted in Figure C). These technologies include hands-free interfaces, sensors, data analytics, cameras and video, secure data sharing and data access, and location services. In contrast, the first responder technology prioritization survey results identified concrete priorities, including coverage, mission critical services, and LMR-LTE interconnect. First responders appear most interested in the foundational technologies that they experience now and that affect their daily operations. The interviewed technologists, who naturally have a different focus and were specifically asked about future trends, are more interested in potential capabilities rather than what is offered today. The FirstNet Authority expects that these promising technologies will increase in importance to first responders as they are realized and operationalized.

Figure D presents the findings within the framework of a First Responder Technology "Hierarchy of Needs." As noted, first responders prioritize foundational elements (i.e., network, core, coverage) that must operate with high reliability. Without coverage or the network, nothing else is operational. Key enablers support basic voice services, which continues to be the highest priority and most-used application. Location and mapping services are rated as important, and generally

available today, but need improvement. Finally, the most promising future technologies, dubbed in the hierarchy as "advanced capabilities," are built upon the underlying elements. These capabilities are currently a low priority for the public safety community but will provide great benefit in the future.

The FirstNet Authority Roadmap will continue to identify promising technologies, for both the short and long term, and apply appropriate resources to corresponding technology areas most likely to improve first responder effectiveness.

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