

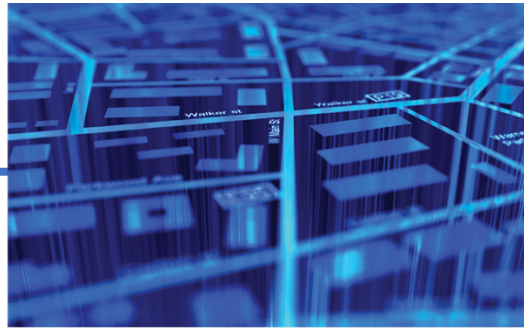





The International Forum to Advance First Responder Innovation

Capability Gap 1 “Deep Dive” Analysis Synopsis

August 2018

International Forum to Advance
FIRST RESPONDER INNOVATION

Homeland Security
Science and Technology

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International Forum to Advance
FIRST RESPONDER INNOVATION

Endorsed By:

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Introduction

Background

The International Forum to Advance First Responder Innovation (IFAFRI) is an organization of government leaders from across the globe, focused on enhancing and expanding the development of affordable and innovative technology for first responders worldwide.

IFAFRI does this by:

1. Working with the global first responder community to define a list of common, high priority capability gaps;
2. Providing a platform for international collaboration on innovative research and development (R&D) initiatives and solutions;
3. Characterizing the global first responder markets, to inform and guide industry and academia about market opportunities and to incentivize these actors to develop and produce innovative technology solutions to first responder capability gaps; and
4. Providing information about relevant and available first responder technologies to the first responder community, while not endorsing any specific technology, product, or manufacturer.

In order to respond more safely, efficiently, and effectively to everyday and catastrophic incidents, first responders around the world need technologically advanced tools and equipment that are affordable and innovative. However, there is no centralized mechanism for first responders to identify and discuss shared needs and requirements. In addition, overall purchasing of tools and equipment is fragmented into smaller quantities, which provides little incentive for industry to commercialize innovative technologies. Therefore, the lack of consolidated requirements for first responders, along with fragmented purchasing, results in an inadequate amount of affordable, new technology being available for first responder use.

The purpose of this document is to characterize the markets and identify technology solutions relevant to IFAFRI's Capability Gap 1: *The ability to know the location of responders and their proximity to risks and hazards in real time*. IFAFRI is publishing this information to identify potential areas of R&D where there may be opportunity for industry and academia to develop innovative solutions. Further, it is intended to provide industry and academia with key data points and analysis that will inform their decision on entering or expanding into related markets.

IFAFRI Membership

IFAFRI is currently composed of members from 13 different countries and the European Commission, including Australia, Canada, Finland, Germany, Israel, Japan, the Netherlands, New Zealand, Singapore, Spain, Sweden, the United Kingdom, and the United States. The figure below illustrates the global composition of IFAFRI.[1]

[1] Note, IFAFRI membership for France and Mexico is pending.

IFAFRI *Common Global Capability Gaps*

This document is focused on the first of four Common Global Capability Gaps that were identified by IFAFRI in 2016. The list of current gaps includes:

Capability Gap 1	The ability to know the location of responders and their proximity to risks and hazards in real time
Capability Gap 2	The ability to detect, monitor, and analyze passive and active threats and hazards at incident scenes in real time
Capability Gap 3	The ability to rapidly identify hazardous agents and contaminants
Capability Gap 4	The ability to incorporate information from multiple and nontraditional sources into incident command operations

To arrive at this initial set of capability gaps, the IFAFRI membership conducted analyses of first responder capability gaps in their countries. Some of the IFAFRI participants used the methodology presented in the U.S. Department of Homeland Security (DHS) Science and Technology Directorate's (S&T) Project Responder 4 (PR4) report, as a guide in their analyses. Project Responder 4 is the fourth in a series of studies that focuses on identifying capability needs, shortfalls, and priorities for catastrophic incident response. The methodology is based upon discussions with federal, state, and local first responders, as well as technical subject matter experts.

After submission of first responder capability gaps from IFAFRI participants, a comparative analysis of all submitted gaps was conducted. The analysis found a significant level of overlap among the various countries' gaps, which resulted in the proposal and adoption of an initial set of *Common Global Capability Gaps*.

To date, similar "deep dive" analyses have been conducted for each of IFAFRI's *Common Global Capability Gaps*. Each of these documents has been published on the IFAFRI Web site, and is available for download. It is important to note that continued market research will be required to ensure awareness of current efforts and account for new actors in these capability gap areas. Furthermore, the IFAFRI membership is currently in the process of identifying additional common global capability gaps, and it is anticipated similar analysis efforts will be conducted for each of these gaps.

This is the second version of this document. It was updated because there have been advances in technology over the past two years that have an impact on the market analysis. This version contains updated market figures and additional technology solutions.

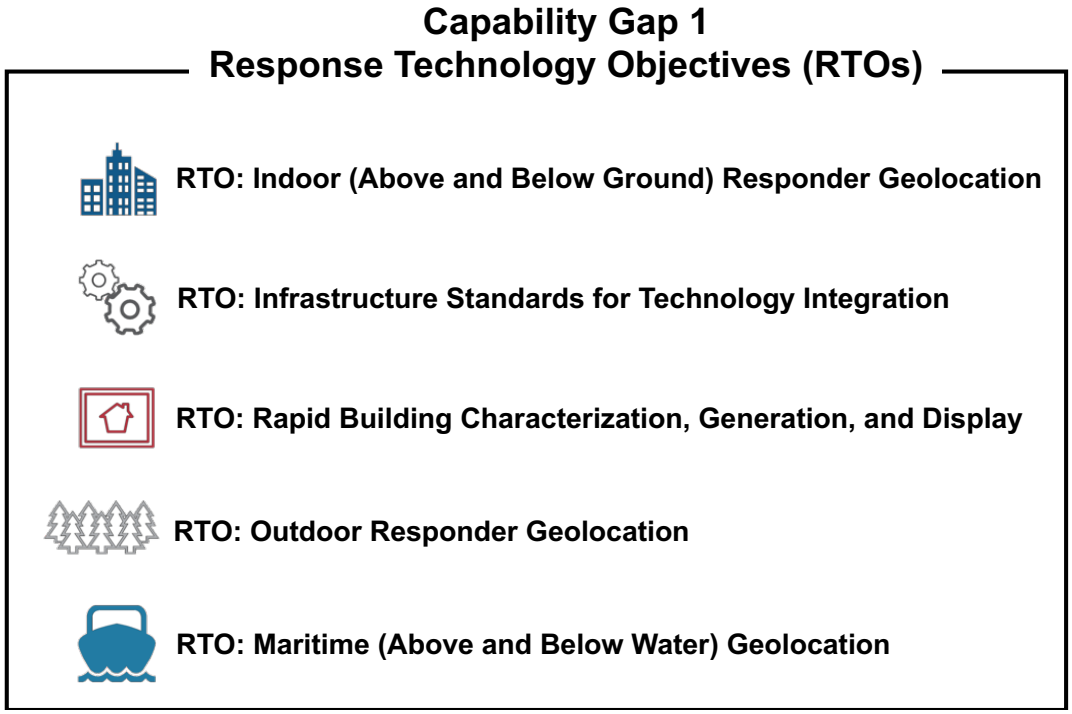
Capability Gap 1

The ability to know the location of responders and their proximity to risks and hazards in real time.

This capability gap involves the development of responder geolocation in all environments and subsequent software or devices enabled to display the precise location of responders (i.e. x, y, and z coordinates) on an intuitive user interface.

As IFAFRI participants examined gaps within their countries, first responders consistently stated there is a need to precisely identify the location of responders in real time. Incident commanders and team leaders expressed a need for a tool that displays the location of responders and their proximity to potential threats. The ability to geolocate responders in all environments, coupled with simultaneous awareness of incident risks and hazards, could potentially improve safety, efficiency and effectiveness.

This analysis uses the Response Technology Objectives (RTOs) identified in PR4 as a starting point for further defining and segmenting Capability Gap 1.[2] RTOs identify broad technology solutions designed to improve the capabilities of the first responder community. There are five corresponding RTOs for this capability gap:



Indoor (above and below ground) responder geolocation refers to the need to locate responders in three dimensions when they are operating inside of a building, underground, and below debris and rubble. Responders need the ability to locate, evacuate or rescue at-risk or trapped

[2] "*Project Responder 4: 2014 National Technology Plan for Emergency Response to Catastrophic Incidents,*" (Washington: Department of Homeland Security, Science and Technology Directorate,) July 2014, 24. https://www.dhs.gov/sites/default/files/publications/Project%20Responder%204_1.pdf

responders, identify personnel at key locations and notify responders if they are in proximity to threats and hazards.[3]

Infrastructure standards for technology integration refers to the need for standards related to mapping of new or existing buildings. Specifically, there is not a standard requiring building construction to include technology that would facilitate the use of responder locating devices inside structures.[4]

Rapid building characterization, generation, and display refers to the need for responders to have better understanding of building layouts, including the location of doors, exits, stairwells, power and technology infrastructure, and known hazards in the building. Responder positioning could be notably enhanced if combined with a three-dimensional rendering of buildings on the incident scene.[5]

Outdoor responder geolocation refers to the need to know the location of responders that operate outside of buildings on the incident scene. These operations often include extensive geographic areas and austere conditions. Knowing the location of these responders and their proximity to threats is extremely important for outdoor incidents that span long distances, such as wildland firefighting.[6]

Maritime (above and below water) geolocation refers to the need to locate responders, including divers below the surface in fresh and salt water. The capability to monitor the location will improve safety and responder tactics during swift-water rescues or incidents involving boats and other water-borne vehicles. [7]

[3] Ibid, p. 25
[4] Ibid, p. 34
[5] Ibid, p. 36
[6] Ibid, p. 30
[7] Ibid, p. 32

Methodology

This section provides a brief overview of the processes used to obtain and assess the findings presented in this report.

Research Methods

The data presented in this report was gathered from publicly-available information sources, including market reports and company web sites. The study team conducted a global scan of existing and in-development technology solutions with the aim of identifying and assessing the primary market for technologies related to this gap. However, the data presented in this report should not be considered exhaustive. This document does not contain any proprietary data, nor does it endorse or advocate for any of the technology solutions described herein. Further, the study team did not validate any of the manufacturers' claims found in their product descriptions.

Market Definition and Segmentation

As described above, the RTOs developed as part of the Project Responder 4 study, were used as a starting point for further defining and segmenting technologies associated with Gap 1. More specifically, each RTO was considered to represent one segment of the market for the overall capability gap. Then, each RTO description was mapped to a corresponding primary market within open-source market research reports with a market definition similar to the RTO description.

Market Quantification

All relevant markets are quantified utilizing overall global revenue figures, unless otherwise noted, for the forecast period 2018 to 2022. The Compound Annual Growth Rate (CAGR) within each segment is used to measure growth within the forecast period and to extrapolate data when figures were not publicly available. As the first responder segments of the relevant markets appear to be underdeveloped, overarching market figures are presented. Data for the primary markets is used in the aggregated findings presented in the body of this report.

Market Phase and Factors

Market phase is determined using factors in the Industry Life Cycle Model. The adapted market phase definitions are presented in the following table.[i] Market factors are assessed by examining barriers to entry and market opportunities, as determined through secondary research.

Nascent	New market need with dominant solutions not yet determined; growth begins increasing toward end of cycle
Growth	Dominant solutions begin to emerge; high growth rates
Mature	Often fewer firms than growth phase, as dominant solutions continue to capture the majority of market share and market consolidation occurs; lower growth rates that are typically on par with the general economy
Decline	Further market consolidation; rapidly declining growth rates

Competitive Landscape

This study also examines the competitive landscape within each market, accounting for the total number of firms, along with the number of responder-specific solutions. Total number of firms was estimated using the number of key players given within publicly available market reports for each segment. Although there may be additional firms operating in the market, this figure captures just the market leaders. Responder-specific solutions were identified using a more tailored search. This search included examining the product offerings of key players listed in publicly available market reports to determine their relevance to the capability gap and conducting targeted keyword searches in order to identify solutions from additional companies.

Dominant Solutions

Dominant solutions are determined by examining market share breakdown, as available in publicly available market reports. These market reports provide data regarding which solutions are capturing the majority of market share. Solutions capturing the majority of the market share are considered to be dominant.

Presentation

This report includes a “Market Overview” that summarizes the overall market and provides the market quantification data for each segment. The report also presents the key findings for each market segment in the “Market Highlights” section, with a one-page summary for each segment. In addition, the “Competitive Landscape” section further categorizes the total number of firms participating in the market by segment and highlights responder-specific solutions currently available or in-development.

Synopsis Overview

IFAFRI has been conducting an ongoing global capability gaps market analysis in order to meet its objectives of characterizing global first responder markets to inform and guide industry and academia. The key objective of this study is to characterize the markets relevant to Capability Gap 1. This synopsis highlights key findings identified as part of this study.

The ability to know the location of responders and their proximity to risks and hazards in real time.

Market Definitions and Segmentation

This study uses the response technology objectives (RTOs) identified in *Project Responder 4* to further define and segment the relevant markets for Capability Gap 1. A primary market is identified for each RTO and is used for market quantification. The RTOs and their corresponding primary markets are presented below:

Capability Gap 1: Primary Markets

RTO: Indoor (Above and Below Ground) Responder Geolocation	Global Indoor Positioning and Navigation System Market
RTO: Infrastructure Standards for Technology Integration	Global Smart Building Market
RTO: Rapid Building Characterization, Generation, and Display	Global Building Information Modeling (BIM) Market
RTO: Outdoor Responder Geolocation	Global Navigation Satellite System (GNSS) Market
RTO: Maritime (Above and Below Water) Geolocation	GNSS Market [Maritime]

In addition to the RTOs listed above, the study team identified an additional technology objective for Capability Gap 1, which is *Hybrid (Indoor and Outdoor) Responder Geolocation*. The primary market for this objective is the Global Location-Based Services (LBS) and Real-Time Location Systems (RTLS) market.

RTO: Hybrid (Indoor and Outdoor) Geolocation	Global Location-Based Services (LBS) and Real-Time Location Systems (RTLS) Market

Market Quantification

Each primary market is quantified utilizing overall revenue figures derived from global markets. Growth is measured using an estimated CAGR. In this study, it was found that the identified

primary markets for this capability gap **accounted for approximately $208.9 billion in revenue in 2018.** This figure could reach approximately $410.2 billion by 2022.

Competitive Landscape

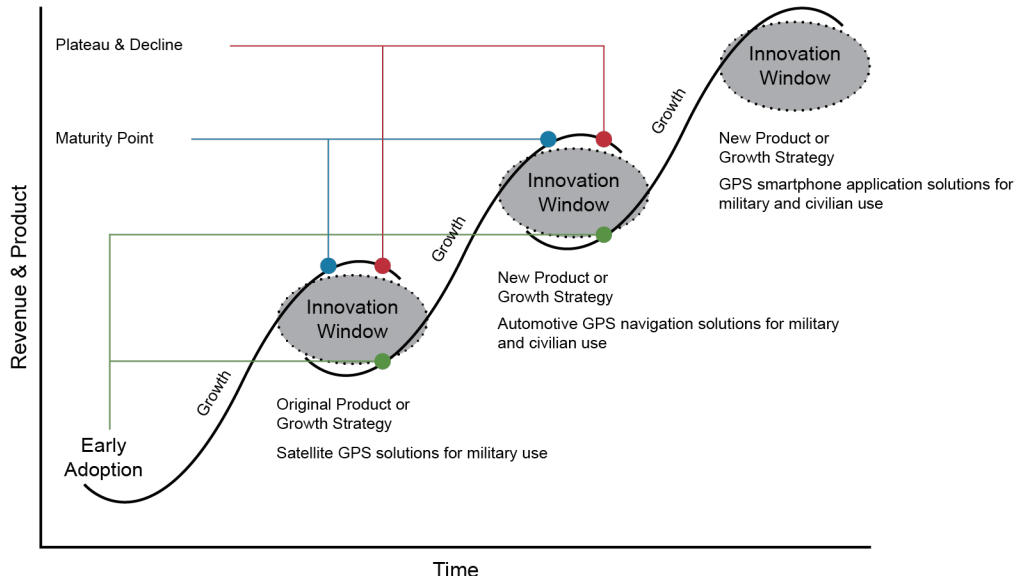
In this study, 140 key players and innovators were identified within the global, primary markets associated with this capability gap. These key global players and innovators appear to offer solutions that address, in part, the ability to identify and track the location of responders and their proximity to risks and hazards in real-time. However, there are no solutions identified within this assessment that fully address responders' needs.

Dominant Solutions, Market Factors, and Market Phase

The aspects of each market, which include dominant solutions, market factors, and market phase are summarized within the "Market Highlights" section of this report. Notably, it appears that half of the primary markets associated with this gap are in a similar nascent market phase prior to early adoption on the S-Curve Life Cycle model, while two others have reached maturity and one enters the growth phase. During an S-Curve life cycle, the performance of a new technology starts out poor and improves slowly to early adoption. Then, as the technology becomes more familiar, its performance improves rapidly during its growth phase. Eventually, the technology reaches a ceiling or maturity point and plateaus to a decline.

The figure below illustrates the S-Curve Life Cycle model using the Global Positioning System (GPS) Market as an example. Originally, satellite GPS was for military use only. It then expanded into automotive use for civilians and today is used in smartphone application solutions for broad applications.

Innovation S-Curve: Global Positioning System (GPS) Market, Example



Summary

In summary, there appears to be market opportunity within each of the primary markets associated with Capability Gap 1. However, the Hybrid (Indoor and Outdoor) Responder Geolocation market is expected to experience the highest growth during the 2018 to 2022

forecast period, and by definition, may offer the most efficient and effective solutions for first responders that work in various types of environments or areas during emergency response. Notably, a relatively low number of first responder-specific solutions (both existing and in-development) were identified in the market, when compared with the total number of key players operating in the broader market. In general, it is likely that there is a potentially large opportunity for firms to adapt their existing solutions to meet the needs of first responders, particularly firms that are operating in the hybrid (indoor and outdoor) geolocation market segment.

Market Overview

Capability Gap 1 is largely focused on *geolocation*, which is described as the geographical position of an object, usually defined by latitude, longitude, and altitude coordinates or area-specific designations (such as a street address) in all environments (i.e., indoors, outdoors, and maritime).

Market Segmentation

Indoor Geolocation

The **Global Indoor Positioning and Navigation System Market** was used to quantify this RTO.

Hybrid Geolocation

The **Global Location-Based Services (LBS) and Real-Time Location Systems (RTLS) Market** was used to quantify this RTO.

Infrastructure Standards for Technology Integration

The **Global Smart Building Market** was used to quantify this RTO.

Outdoor Geolocation

The **Global Navigation Satellite System (GNSS) Market** was used to quantify this RTO.

Rapid Building Characterization, Generation, and Display

The **Global Building Information Modeling (BIM) Market** was used to quantify this RTO.

Maritime Geolocation

The **GNSS Market [Maritime]** was used to quantify this RTO.

The table below provides descriptions for each of the primary markets identified during this study.

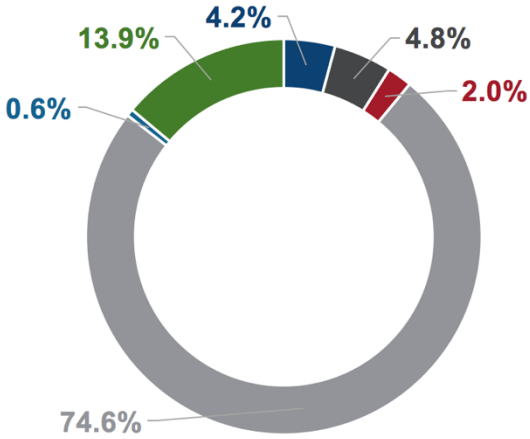
Capability Gap 1: Market Definitions

 Global Indoor Positioning and Navigation System Market	This market includes indoor location-based analytics and indoor navigation & maps enabled by RFID, cellular, WLAN and Bluetooth technologies.
 Global Smart Building Market	This market includes building automation software and services.
 Global Building Information Modeling (BIM) Market	This market includes software for architectural design; construction; sustainability; structures; mechanical, electrical, and plumbing (MEP); and facility management; and project management support services; and software support and maintenance services.
 Global Navigation Satellite System (GNSS) Market	This market includes the infrastructure that allows users with a compatible device to determine their position, velocity and time by processing signals from satellites.
 GNSS Market [Maritime]	This market includes the infrastructure that allows users with a compatible device to determine their position, velocity and time by processing signals from satellites in maritime applications.
 Global Location-Based Services (LBS) and Real-Time Location Systems (RTLS) Market	This market includes software for geocoding and reverse geocoding; location and predictive analytics; reporting and visualization; database management and spatial Extract, Transform and Load (ETL); and risk analytics and threat prevention; and services related to deployment and integration; application support and maintenance; and consulting and advisory.

Capability Gap 1 - The Ability to Know the Location of Responders and Their Proximity to Risks and Hazards in Real Time

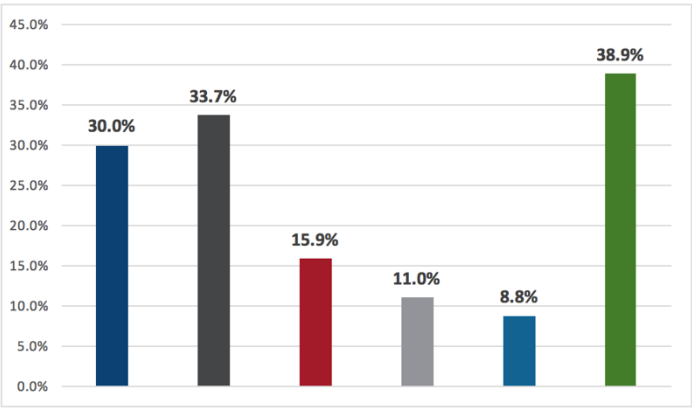
The ability to know the location of responders and their proximity to risks and hazards in real time involves the development of responder geolocation in all environments and subsequent software or devices enabled to display the precise location of responders (i.e., x, y, and z coordinates) on an intuitive user interface. Further, the establishment of operational standards or requirements is likely to aid the development of responder safety, efficiency and effectiveness.

A myriad of geolocation solutions currently exist within the market, many of which have first responder applications. Outdoor responder geolocation appears to be the most mature market. However, the emergence of hybrid (indoor and outdoor) responder geolocation solutions, such as Location-Based Services, may provide the best means of capturing geolocation needs within a single, seamless solution for the first responder community.



Geolocation Market, 2018

- Indoor (Above and Below Ground) Responder Geolocation
- Infrastructure Standards for Technology Integration
- Rapid Building Characterization, Generation and Display
- Outdoor Responder Geolocation
- Maritime (Above and Below Water) Geolocation
- Hybrid (Indoor and Outdoor) Responder Geolocation



Geolocation Market (CAGR), 2018 to 2022

- Indoor (Above and Below Ground) Responder Geolocation
- Infrastructure Standards for Technology Integration
- Rapid Building Characterization, Generation and Display
- Outdoor Responder Geolocation
- Maritime (Above and Below Water) Geolocation
- Hybrid (Indoor and Outdoor) Responder Geolocation

As of 2018, the Outdoor Responder Geolocation Market captures the greatest market share at 74.6 percent, followed by Hybrid (Indoor and Outdoor) Responder Geolocation at 13.9 percent. Infrastructure Standards for Technology Integration, which will support the development of indoor responder geolocation solutions is expected to grow at the second highest CAGR of 33.7 percent during the forecast period of 2018 to 2022. Hybrid (Indoor and Outdoor) Responder Geolocation is growing at the highest CAGR of 38.9 percent during the forecast period, which may be attributed to the increasing use of mobile smartphones and other connected devices.

Market Figures

The following tables present the estimated revenue figures for the various global markets identified for each segment within the Capability Gap 1 market. The figures in the first row of each table represent the primary markets used to quantify each segment in this analysis activity.

Disclaimer

Note, all figures have been rounded to the nearest hundred million. The market forecast period examined is 2018 to 2022. When a market value was not available, it was estimated using the corresponding CAGR given over the forecast period to represent growth or decline. For consistency, data that fell outside of the forecast period has been extrapolated, as denoted by an asterisk (*). A more detailed explanation of how the extrapolated figures were estimated can be found in Appendix B of this report.

Indoor (Above and Below Ground) Responder Geolocation

	Revenue by Year (in $1,000,000 USD)					CAGR
	2018	2019	2020	2021	2022	
Indoor Positioning and Navigation System[2]	$8,753.2	$11,379.2	$14,792.9	$19,230.8	$25,000.0	30.0%
Acoustic Wave Sensor[3]	$519.3	$575.5	$637.9	$706.9	$783.5	10.8%
Indoor Location[4]	$10,375.4	$14,627.6	$20,622.5	$29,074.4	$40,990.0	41.0%
Inertial Navigation System (INS)[5]	$10,065.3	$10,574.1	$11,108.6	$11,670.1	$12,260.0	5.1%
Infrared Light Emitting Diode (LED)[6]	$402.3	$459.8	$525.6	$600.7	$686.6	14.3%
Light Detection and Ranging (LiDAR)[7]	$798.0	$940.0	$1,107.2	$1,304.2	$1,536.2	17.8%
Magnetic Field Sensor[8]	$3,492.2	$3,806.0	$4,148.1	$4,520.9	$4,927.2	9.0%
Radio Frequency Identification (RFID)[9]	$20,218.6	$22,082.2	$24,117.6	$26,340.5	$28,768.4	9.2%
Vision Positioning System[10]	$6,173.6	$6,830.3	$7,556.8	$8,360.7	$9,250.0	10.6%

Infrastructure Standards for Technology Integration

	Revenue by Year (in $1,000,000 USD)					CAGR
	2018	2019	2020	2021	2022	
Smart Building[11]	$9,923.0	$13,270.4	$17,747.0	$23,733.7	$31,740.0	33.7%
Free Space Optics (FSO)[12]	$300.2	$424.4	$600.0	$848.1	$1,198.9	41.4%
In-Building Wireless[13]	$10,171.0	$13,036.8	$16,710.0	$21,418.2*	$27,452.9*	28.2%
Public Safety In-Building Wireless Distributed Antenna System (DAS)[14]	$724.7	$970.5	$1,299.5	$1,740.1	$2,330.1*	33.9%
Visible Light Communication (VLC)[15]	$2,117.6	$3,449.5	$5,619.1	$9,153.2	$14,910.0	62.9%
Wi-Fi[16]	$7,422.6	$8,937.1	$10,760.7	$12,956.3	$15,600.0	20.4%

Rapid Building Characterization, Generation, and Display

	Revenue by Year (in $1,000,000 USD)					CAGR
	2018	2019	2020	2021	2022	
Building Information Modeling (BIM)[17]	$4,241.2	$4,913.5	$5,692.3	$6,594.7	$7,640.0	15.9%
3D Mapping and 3D Modeling[18]	$4,858.6	$6,644.1	$9,085.6	$12,424.3	$16,990.0	36.7%
Digital Map[19]	$9,260.0	$10,840.4	$12,690.5	$14,856.3	$17,391.8	17.1%
Mobile Mapping[20]	$15,450.6	$17,698.2	$20,272.8	$23,221.9	$26,600.0	14.5%
Geolocation Information System (GIS)[21]	$6,401.6	$7,015.6	$7,688.5	$8,426.0	$9,234.2	9.6%

Outdoor Responder Geolocation

	Revenue by Year (in $1,000,000 USD)					CAGR
	2018	2019	2020	2021	2022	
Global Navigation Satellite System (GNSS)[22]	$155,716.2	$172,718.6	$191,615.1	$212,622.4	$235,982.4	11.0%
Anti-Jamming Market for Global Positioning System (GPS)[23]	$3,661.9	$3,918.2	$4,192.5	$4,486.0	$4,800.0	7.0%
GPS Receiver Market for Mid/High Level Real-Time Kinematics (RTK) Precision[24]	$1,685.6	$1,961.3	$2,282.2	$2,655.6	$3,090.0	16.4%

Maritime (Above and Below Water) Geolocation

	Revenue by Year (in $1,000,000 USD)					CAGR
	2018	2019	2020	2021	2022	
GNSS [Maritime][25]	$1,205.0	$1,310.7	$1,425.8	$1,550.9	$1,687.0	8.8%
Sound Navigation and Ranging (SONAR) System[26]	$3,565.0	$3,603.2	$3,641.7	$3,680.6	$3,720.0	1.1%
Automatic Identification System (AIS)[27]	$206.8	$215.7	$225.1	$234.8*	$245.0*	4.3%
Sonobuoy[28]	$276.7	$296.0	$316.6	$338.6*	$362.2*	7.0%

Hybrid (Indoor and Outdoor) Responder Geolocation

	Revenue by Year (in $1,000,000 USD)					CAGR
	2018	2019	2020	2021	2022	
Location-Based Services (LBS) and Real Time Location Systems (RTLS)[29]	$29,028.9	$40,329.3	$56,028.9	$77,840.0	$108,141.9*	38.9%
Emergency Beacon Transmitter[30]	$157.2	$166.0	$175.4	$185.3*	$195.8*	5.6%

Market Highlights

Indoor (Above and Below Ground) Responder Geolocation describes the need of first responders to identify and track the precise location (i.e., x, y, and z coordinates) of responders operating in indoor environments or where there is "no line of sight" to the sky. For example, multi-story residential and commercial buildings, subway systems, caves, and under rubble piles.

Indoor Responder Geolocation

Current Capability:

This capability is largely unavailable to most first responder agencies. First responders more commonly use paper tag and tally systems or verbally communicate their location via radio during indoor response activities. Advancements in commercially-deployed indoor positioning and indoor navigation (IPIN) systems, largely facilitated through smartphone devices, may provide a means to adopt similar systems for use in the first responder community.

Primary Market Quantification

Market Size (2018): $8,753M

Compound Annual Growth Rate (2018-2022): 30.0%

Competitive Landscape

Number of Key Market Players: 32

Number of Responder-Specific Existing Solutions: 6

Number of Responder-Specific R&D Solutions: 2

Dominant Solution

None, to date

Multiple technologies such as Wi-Fi, Radio Frequency Identification (RFID), Ultra-Wideband (UWB), and Bluetooth can provide IPIN capabilities. Additional R&D is warranted to determine the most efficient and effective solution.

Market Factors

Opportunities

- Increased adoption of connected devices
- Cost-effective solutions deployable at the responder level
- Solutions that plot x, y, *and* z coordinates
- Integration of GIS or other map overlays

Market Phase

NASCENT

Barriers

- Privacy concerns and lack of standards
- Deployment and maintenance
- Complex infrastructure layouts

Market Highlights

Infrastructure Standards for Technology Integration describes the need of first responders to leverage the information, technology, surveillance, and power infrastructure in buildings on an incident scene to enhance indoor responder geolocation. This market segment does not necessarily implicate specific technological solutions, rather it is largely focused on government legislation and construction standards that may help to address this need.

Current Capability:
There do not appear to be any standards for infrastructure mapping of new or existing buildings. In addition, there does not appear to be a standard requiring building construction to include technology (such as Bluetooth Low Energy [BLE] beacons) that would facilitate the use of responder locating devices inside structures.

Primary Market Quantification

Market Size (2018): $9,923M

Compound Annual Growth Rate (2018-2022): 33.7%

Competitive Landscape

Number of Key Market Players: 23

Number of Responder-Specific Existing Solutions: 2

Number of Responder-Specific R&D Solutions: 0

Dominant Solution

None, to date

Market Factors

Infrastructure standards and guidelines for smart cities and subsequently, smart buildings with integrated systems, are currently in development. The transition to smart buildings equipped with IoT devices and other enhancements may help to improve first responder interoperability with building systems.

Opportunities

- Increase of government initiatives to transition to “smart cities” and adopt next-generation technologies
- Implementation of IoT platforms within building automation technologies

Market Phase

NASCENT

Barriers

- High upfront costs
- Privacy and security concerns (e.g., cyber threats)
- Limited open standards

Market Highlights

Rapid Building Characterization, Generation, and Display describes the need of first responders to obtain knowledge of building layouts and information to improve situational awareness. Responders would benefit from knowing the location of doors, exits, stairwells, power and technology infrastructure, and known hazards in buildings (e.g. gas lines). Further, responder geolocation would be enhanced if combined with a three-dimensional (3D) rendering of buildings on the incident scene.

Building Characterization

Current Capability:

This capability is largely unavailable to most first responder agencies. Open-source imagery can be used to gain insight about target buildings. However, these images are typically limited to external visualizations of a building and do not provide indoor mapping capability. In addition, digitized building blueprints are not readily available or accessible to responders.

Primary Market Quantification

Market Size (2018): $4,241M

Compound Annual Growth Rate (2018-2022): 15.9%

Competitive Landscape

Number of Key Market Players: 19

Number of Responder-Specific Existing Solutions: 1

Number of Responder-Specific R&D Solutions: 4

Dominant Solution

None, to date

Building Information Modeling (BIM) is an intelligent 3D model-based system that provides architecture, engineering, and construction professionals with insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure. This system could be adapted for use in emergency response operations. However, additional R&D is warranted to determine the most efficient and effective solution.

Market Factors

Opportunities

- Advancements in 3D scanners and 3D sensors
- Increase of devices with 3D display
- Increased availability of open source imagery
- Integration with unmanned aerial systems

Market Phase

NASCENT

Barriers

- High cost of software and extra subscription fees
- Training and technical expertise (often) required

Market Highlights

Outdoor Responder Geolocation describes the need of first responders to identify and track the precise location (i.e., x, y, and z coordinates) of responders operating in outdoor environments in both urban and rural areas.

Outdoor Responder Geolocation

Current Capability:

This capability is largely unavailable to most first responder agencies. First responders more commonly use paper tag and tally systems or verbally communicate their location via radio during outdoor response activities. Some first responder agencies may have access to Global Navigation Satellite System (GNSS)-enabled devices. However, these devices are often fixed to a vehicle rather than the individual responder.

Primary Market Quantification

Market Size (2018): $155,716M

Compound Annual Growth Rate (2018-2022): 11.0%

Competitive Landscape

Number of Key Market Players: 15

Number of Responder-Specific Existing Solutions: 20

Number of Responder-Specific R&D Solutions: 1

Dominant Solution

Global Positioning System (GPS)

GPS is a satellite-based navigation system that is owned and maintained by the U.S. Department of Defense. This system provides users with positioning, navigation, and timing (PNT) services via a GPS-enabled device in various outdoor environments.

Market Factors

Opportunities

- Cost-effective solutions deployable at the responder level
- Integration of multiple constellations (e.g., GPS, GLONASS, Galileo) to improve signal strength and coverage
- Integration of GIS or other map overlays

Market Phase

MATURE

Barriers

- Cost of development and implementation to the individual responder level
- Signal interference and GNSS-denied environments
- Energy consumption and durability

Market Highlights

Maritime (Above and Below Water) Responder Geolocation describes the need of first responders to identify and track the precise location (i.e., x, y, and z coordinates) of responders operating in maritime environments, both above and below the surface of a body of water.

Maritime Geolocation

Current Capability:

This capability is largely unavailable to most first responder agencies. Real-time geolocation can be achieved using Global Navigation Satellite System (GNSS)-enabled devices. However, these units are costly and often fixed to an apparatus, such as rescue vessel, rather than an individual responder. In addition, these devices are limited to operating above or near the surface of a body of water.

Primary Market Quantification

Market Size (2018): $1,205M

Compound Annual Growth Rate (2018-2022): 8.8%

Competitive Landscape

Number of Key Market Players: 9

Number of Responder-Specific Existing Solutions: 3

Number of Responder-Specific R&D Solutions: 2

Dominant Solution

EPIRBs and PLBs

Emergency Position Indicating Radio Beacons (EPIRBs) and Personal Locator Beacons (PLBs) are compact radio transmitters that connect to the Cospas-Sarsat satellite system, which feeds positioning information to search and rescue agencies when distress signals are detected.

Market Factors

Opportunities

- Cost-effective solutions deployable at the responder level
- Geolocation underwater
- Integration of GIS or other map overlays

Market Phase

MATURE

Barriers

- Strict standards, operational requirements, and regulations
- Cost of development and implementation to the individual responder level

Market Highlights

Hybrid (Indoor and Outdoor) Responder Geolocation describes the need of first responders to seamlessly identify and track the precise location (i.e., x, y, and z coordinates) of responders operating in all environments. Continuous responder geolocation will enable enhanced safety, efficiency, and effectiveness of first responders on the incident scene.

Hybrid Responder Geolocation

Current Capability:

This capability is largely unavailable to most first responder agencies. In outdoor environments, responders may rely on Global Navigation Satellite System (GNSS)-enabled devices. However, these devices do not operate indoors. Further, within indoor environments, there does not appear to be a dominant solution that meets the needs of responders. A combination of GNSS and indoor solutions may provide the best means to address this need. However, additional R&D is warranted to determine the most efficient and effective solution.

Primary Market Quantification

Market Size (2018): $29,029M

Compound Annual Growth Rate (2018-2022): 38.9%

Competitive Landscape

Number of Key Market Players: 42

Number of Responder-Specific Existing Solutions: 13

Number of Responder-Specific R&D Solutions: 7

Dominant Solution

None, to date

Since hybrid responder geolocation allows for tracking responders in all operating environments, it inherently requires both outdoor and indoor location capabilities. A dominant solution does not currently exist in the indoor geolocation technology landscape, thus meaning that there is also not a dominant solution for hybrid geolocation either.

Market Factors

Opportunities

- Increased adoption of connected devices and wearable devices
- Cost-effective solutions deployable at the responder level
- Solutions that plot x, y, *and* z coordinates
- Integration of GIS or other map overlays

Market Phase

GROWTH

Barriers

- Privacy and security concerns
- Lack of governing standards
- Energy consumption and durability
- Connectivity and data integration issues

Opportunities

- ✓ Increased adoption of connected devices
- ✓ Cost-effective solutions deployable at the responder level
- ✓ Solutions that plot x, y, and z coordinates
- ✓ Integration of GIS or other map overlays

Barriers

- X Privacy concerns and lack of standards
- X Deployment and maintenance
- X Complex infrastructure layouts

Opportunities

- ✓ Increase of government initiatives to transition to "smart cities" and adopt next-generation technologies
- ✓ Implementation of IoT platforms within building automation technologies

Barriers

- X High upfront costs
- X Privacy and security concerns (e.g., cyber threats)
- X Limited open standards

Opportunities

- ✓ Advancements in 3D scanners and 3D sensors
- ✓ Increase of devices with 3D display
- ✓ Increased availability of open source imagery
- ✓ Integration with unmanned aerial systems

Barriers

- X High cost of software and extra subscription fees
- X Training and technical expertise (often) required

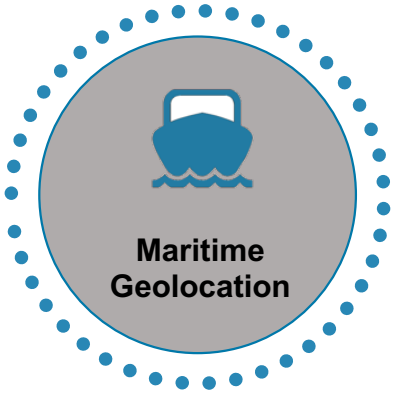
Outdoor Responder Geolocation

Opportunities

- ✓ Advancements in 3D scanners and 3D sensors
- ✓ Increase of devices with 3D display
- ✓ Increased availability of open source imagery
- ✓ Integration with unmanned aerial systems

Barriers

- X High cost of software and extra subscription fees
- X Training and technical expertise (often) required



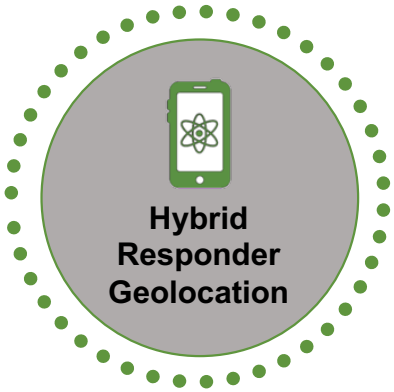
Maritime Geolocation

Opportunities

- ✓ Cost-effective solutions deployable at the responder level
- ✓ Geolocation underwater
- ✓ Integration of GIS or other map overlays

Barriers

- X Strict standards, operational requirements, and regulations
- X Cost of development and implementation to the individual responder level



Hybrid Responder Geolocation

Opportunities

- ✓ Increased adoption of connected devices and wearable devices
- ✓ Cost-effective solutions deployable at the responder level
- ✓ Solutions that plot x, y, and z coordinates
- ✓ Integration of GIS or other map overlays

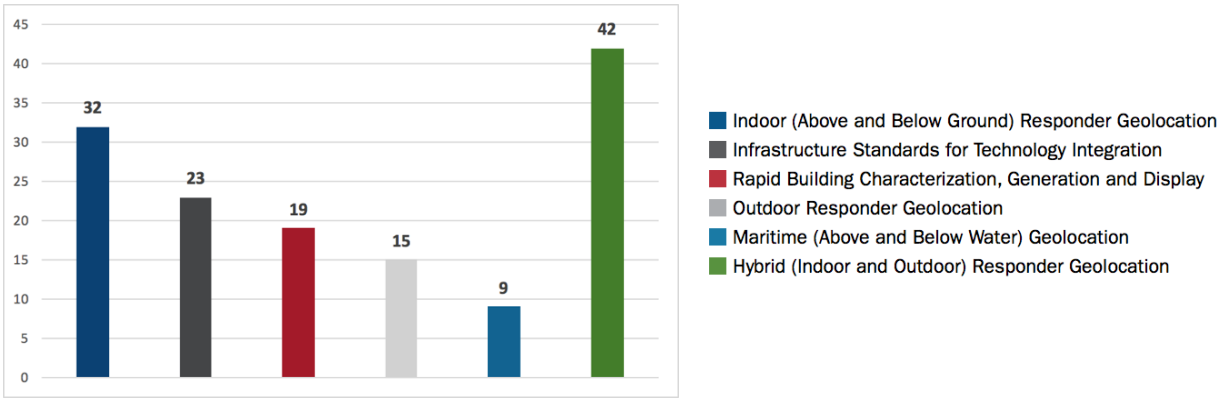
Barriers

- X Privacy and security concerns
- X Lack of governing standards
- X Energy consumption and durability
- X Connectivity and data integration issues

Competitive Landscape

A total of 140 global firms were recognized as key players and innovators within the primary markets of Capability Gap 1, which, for the purpose of this study, represent the global geolocation market. The specific breakdown of each primary market is presented below:

Geolocation Market:
Number of Key Players and Innovators, 2018



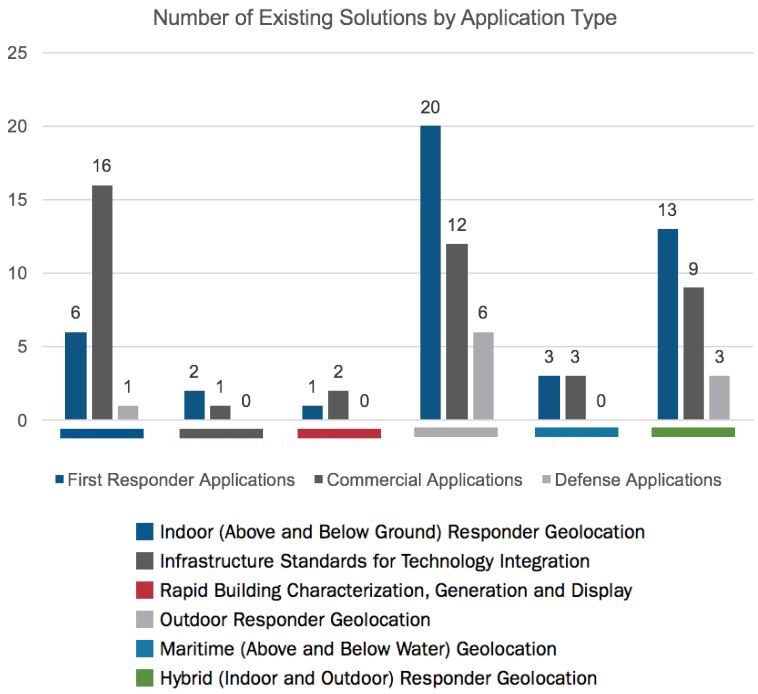
These figures are not all encompassing; it is likely that additional firms exist within each market.

As of 2018, Hybrid (Indoor and Outdoor) Responder Geolocation appears to have the most key players and innovators competing within the market space, followed by Indoor (Above and Below Ground) Responder Geolocation. This competition will help drive innovative research and development, which may ultimately benefit first responders. The Hybrid Responder Geolocation market is also favorable for first responders, since the providers in this market space aim to develop inclusive geolocation solutions. First responders would likely benefit the most from (and therefore may be more inclined to purchase) a device or system that can seamlessly operate and provide location tracking information in all environments.

The following firms were identified as key players and innovators in at least three of the six primary market segments regarding geolocation solutions: Ericsson (Sweden), Qualcomm (United States), and Trimble Inc. (United States).

The study team identified a total of 70 existing solutions and 20 research and development (R&D) initiatives with relevance to Capability Gap 1. This landscape is non-exhaustive, as the number of solutions, particularly related to hybrid forms of geolocation, is vast and ever-changing at a rapid pace.

Among the existing and developing solutions identified, 45 solutions (64 percent) appear to have first responder applications and 16 solutions (80 percent) appear to be in development for first responder use. These numbers may indicate that industry is aware that a first responder need exists within this technology space. However, when examining how existing solutions meet responders' needs related to this capability gap, it does not appear that any existing solution meets all of responders' target objectives. These objectives include a graphic display of real-

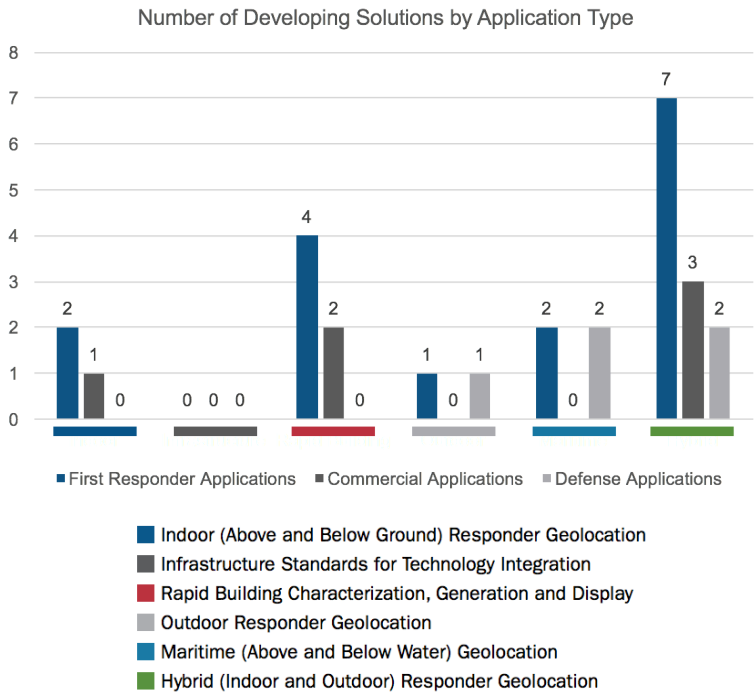


time, three-dimensional (i.e., x, y, and z coordinates) responder geolocation and integration with situational awareness systems and data sources.

It appears a significant gap exists in indoor responder geolocation, which also involves rapid building characterization, generation, and display, and infrastructure standards for technology integration. Firms with existing indoor location solutions may find opportunity in adapting their offerings to meet the needs of first responders, while incorporating data from building infrastructure to provide an enhanced display of the environment.

Among the existing solutions identified, it appears 45 solutions have first responder applications, 43 solutions have commercial applications, and 10 have defense applications. Note that these numbers add to more than the total number of solutions because some solutions have more than one intended application (e.g.: one solution may have both first responder and commercial applications).

There is also a total of 20 R&D initiatives related to Capability Gap 1 identified in this assessment. Among the developing solutions identified, industry is involved in the development of 14 solutions, academia is involved in the development of 7 solutions, and government is involved in the development of 5 solutions. 16 developing solutions are focused on first responder applications, 6 are focused on commercial applications, and 5 are focused on defense applications.



Based upon the data presented, there appears to be a number of geolocation solutions that currently exist or, more significantly, are in-development for first responder use. This finding may indicate that industry is aware that a first responder need exists within this technology space. With closer examination of these solutions though, the reason why this gap still exists is apparent. A limited number of the existing or developing solutions identified meets all of responders' target objectives cited previously. In particular, the identification of altitude or the "z" coordinate for three-dimensional responder geolocation requires additional development. This objective refers to, in part, the ability to identify which floor of a building a first responder is operating in.

However, there appears to be a general opportunity for firms already developing solutions for commercial applications to make slight adaptations to their offerings to meet the needs of first responders. By engaging with responders, particularly on a global level through IFAFRI, firms can begin to further assess how close they are to providing meaningful solutions for responders. Furthermore, they can engage responders throughout their development process to ensure that their efforts will meet responders' needs.

For questions or comments about the information presented in this assessment, please contact IFAFRI at info@internationalresponderforum.org.

First Responder-Specific Technology Solutions

The following section presents a selection of the first responder-specific technology solutions that align with responder requirements for this gap. The responder requirements are identified in the IFAFRI-developed Capability 1 Statement of Objectives (SOO) document. None of the solutions identified during this study meet all of the requirements detailed in the SOO document. It is likely that there are additional potential solutions that exist or are in-development and therefore, this section should not be considered exhaustive. Further, additional concepts exist in academic literature, particularly related to indoor geolocation, but these are not included in this study. A complete list of responder-specific technology solutions identified during this study can be found in Appendix A of this report.

The data and information provided in this section is publicly available from manufacturers' web sites. The study team did not validate product claims made by the manufacturers.

Indoor (Above and Below Ground) Responder Geolocation

ARIANNA[8]

DUNE Srl (Italy) offers ARIANNA, a pedestrian localization and tracking system that is operable in environments where GPS signals are unreliable or absent (e.g., buildings, underground areas, GPS-denied environments). The system is composed of an inertial sensing unit attached inside or outside a shoe heel, a computing unit processing raw data and a man-machine interface (MMI) shifting window (SW) used to acquire, integrate and display the path walked by the operators wearing the system. Further, ARIANNA integrates additional information including GPS (when available) and compass to overlap inertial position data with existing maps and magnetic charting sensing unit. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

First Responder Tracking System[9]

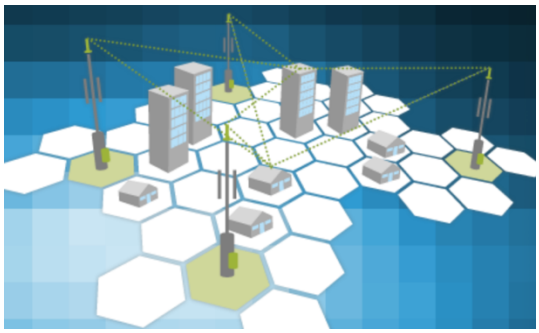
iTrack LLC (United States) offers the First Responder Tracking System, a customized version of its Local Position Tracking System for locating firefighters in unknown indoor environments. The system consists of a small strap-down, foot-mounted module and a vest-worn network radio module. The system is portable and can provide tracking and accountability of a team of firefighters in a building. The system provides operational command and control with a visual overview of the responders' location and stores a trace of the responders' movement. Fire trucks and other response vehicles are deployed with reference beacons and additional beacons can be placed at the incident scene for improved coverage.

Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

[8] "ARIANNA," *Dune Srl*, n.d., http://www.dune-sistemi.it/inertial-localization/
[9] "First Responder Tracking System," *iTrack LLC*, n.d., http://www.itrack-llc.com/download/pts.pdf

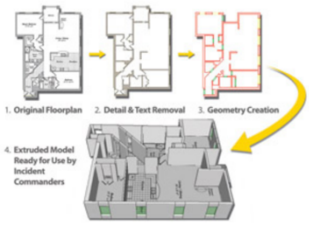
Metropolitan Beacon System (MBS)[10]

NextNav, LLC (United States) deploys urban and indoor positioning services across the United States. Specifically, NextNav seeks to enhance urban and indoor positioning for public safety and commercial applications. NextNav integrates terrestrial-based transmitters into buildings and urban areas where satellite-based GPS signals are denied. The NextNav network transmits timed signals and information regarding the placement of the transmitters over a secured channel. In addition, the solution computes height information using differential barometric pressure measurements, similar to an aircraft altimeter. NextNav is available on any mobile device with GPS capabilities. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.



Personnel Navigation, Locating, and Tracking[11]

ENSCO, Inc. (United States) offers custom pedestrian navigation solutions that feature real-time positioning, tracking and locating where GPS service is degraded or unavailable. ENSCO claims its solutions can be integrated with other navigation or positioning systems, vision-based sensors, foot-to-foot radio frequency ranging and other orthogonal technologies designed to increase positional accuracy over longer periods without GPS. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.



Situational Awareness - Visual Environment (SAVE)[12]

Kutta Technologies Inc. (United States), in conjunction with researchers at the Arizona State University (ASU) Polytechnic Institute, was awarded a Phase I and Phase II Small Business Technology Transfer (STTR) contract to develop a two-dimensional (2D) and three-dimensional (3D) visualization tool for incident commanders. This tool provides incident commanders from multiple disciplines (e.g., fire service, law enforcement, Federal Emergency Management Agency [FEMA]) with the ability to visualize responders in multi-storied structures.

The SAVE tool also provides personnel with the ability to annotate the incident scene by dragging and dropping standard Department of Homeland Security (DHS) symbology on a comprehensive display in a geo-referenced 2D and 3D environment. The tool also comes with a sketching option that allows an incident commander to edit the 3D structure by adding or deleting walls in real-time.

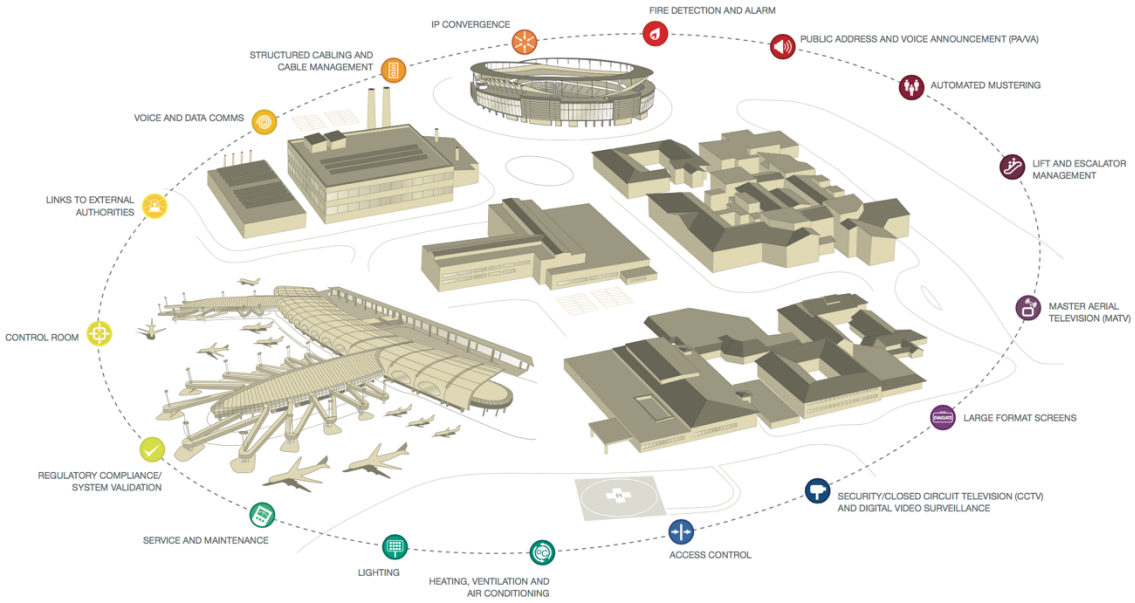
[10] "Home Page," *NextNav*, n.d., http://www.nextnav.com/
[11] "Home Page," *ENSCO Inc.*, n.d. http://ensco.com/
[12] "Situational Awareness - Virtual Environment (SAVE)," *Kutta Technologies Inc.*, n.d., https://www.kuttatech.com/3D-BVT.html

Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

Infrastructure Standards for Technology Integration

Enterprise Buildings Integrator (EBI)[13]

Honeywell International Inc. (United States) offers a "total" system solution for building automation and enterprise-wide management through its Enterprise Buildings Integrator (EBI).



This system includes a "smart" integrated fire detection and life safety management component, as well as direct links to external authorities (e.g., fire service, law enforcement, other emergency authorities). In addition, a control room provides a central point of emergency and disaster management and enables interoperability with other systems.

Information regarding price and specific deployment of the solution within the responder community does not appear to be publicly available.

MeshTrack[14]

Motorola Solutions Inc. (United States) offers MeshTrack, a location system that enables users to leverage broadband data to locate personnel and resources, as well as stream live video, audio, and telemetry data to incident command. Components of MeshTrack include the following:

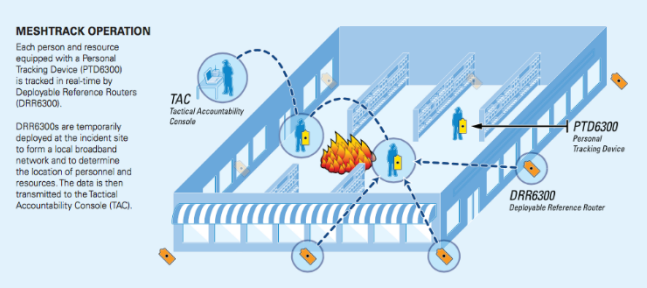
- *PTD6300/Personal Tracking Device* – The Personal Tracking Device is a small, ruggedized transmitter worn by emergency responders, public safety personnel, and

[13] "Fire & Life Safety," *Honeywell International Inc.*, n.d., https://buildingsolutions.honeywell.com/en-US/solutions/firelifesaftey/Pages/default.aspx

[14] *MeshTrack,* Motorola Solutions Inc., n.d., http://motorolaproducts.net/MotoMesh/Product%20Data%20Sheets/MeshTrack_System_Brochure.pdf

anyone else that needs to be accounted for. This device contains a remotely monitored battery indicator, and features an "alert button" for notifying incident command.

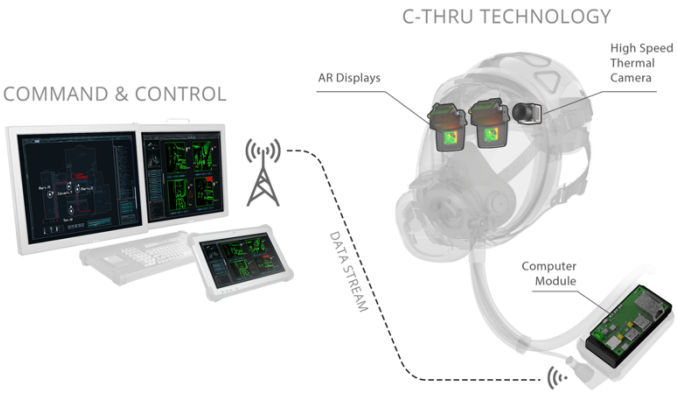
- *DRR6300/Deployable Reference Router* – Deployable Reference Routers are placed around an incident to form an instant, ad hoc mesh network for integrated position location and data networking. These devices determine and relay location data, and provide a path for broadband radio signals to enter and exit structures.
- *IAP6300/Intelligent Access Point* – The Intelligent Access Point provides the wireless gateway between a MeshTrack deployment and the Tactical Accountability Console.
- *TAC/Tactical Accountability Console* – the Tactical Accountability Console consists of MeshTrack location software operating on off-the-shelf computers, laptops, or tablet PCs. Primarily intended for personnel and resource management functions, the Tactical Accountability Console provides a central point where all tracking data and telemetry can be quickly communicated to incident command for immediate decisions.



Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

Rapid Building Characterization, Generation, and Display

C-Thru[15]



Quake Technologies (United States) is developing C-Thru, which creates an augmented reality solution for firefighters in real-time to aid with navigation through smoke-filled zero-visibility environments. Simultaneously, C-Thru connects those on the front line with incident command wirelessly, transmitting a firefighter's visual point-of-view and location to command and control. C-Thru features include edge detection, hot spot identification, fire event recording, and live streaming. Future features will include object recognition and flow path tracking. C-Thru is a software-as-a-service (SaaS), from which any original equipment manufacturer (OEM) can make a self-contained breathing apparatus (SCBA) C-Thru compatible, by integrating C-Thru certified hardware into the SCBA.

Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

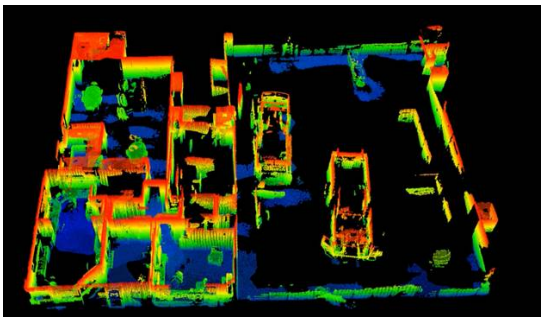
[15] "Home Page," *Quake Technologies*, n.d., https://www.qwake.tech

ORBI® 3D City Operating System[16]

The Digit Group Inc. (United States) offers smart city services and solutions, including the ORBI® 3D City Operating System. In a previous edition of this report, this operating system appeared to include OrbiFire™, which offered the ability to compile various sources of data to develop an on-demand, real-time 3D environment display of an incident scene, including building interiors. The solution also included a "check-in/check-out" geofencing feature to inform incident commanders of the location of responders.

It is uncertain if this solution is still available. However, a demonstration video of OrbiFire™ is available online.

Point Cloud Library (PCL)[17]



Open Perception Inc. (United States) is a nonprofit organization that supports the Point Cloud Library (PCL). PCL is a large scale, open project for two-dimensional (2D) and 3D image and point cloud processing. A point cloud is a data structure used to represent a collection of multi-dimensional points and is commonly used to represent 3D data. In a 3D point cloud, the points usually represent the x, y, and z geometric coordinates of an underlying sampled surface. When color information is present, the point cloud becomes 4D. The PCL framework is free for commercial and research use and contains numerous algorithms including filtering, feature estimation, surface reconstruction, registration, model fitting, and segmentation. These algorithms can be used, for example, to filter outliers from data, stitch 3D point clouds together, segment relevant parts of a scene, extract key points, and compute descriptors to recognize objects based on their geometric appearance, and create surfaces from point clouds and visualize them.

Data sets like Point Cloud, may provide situational awareness for first responders during emergencies.[18]

Outdoor Responder Geolocation

CommandWear[19]

CommandWear Systems Inc. (Canada) develops real-time situational awareness tools for public safety and security professionals. The company's solution, CommandWear, is a cloud or enterprise-based system that works with users' existing equipment and networks. Features of CommandWear include the following:

- The HUB securely stores all messages and location information for review and analysis.
- The Commander HTML5 web app provides a map-based view of all personnel, a messaging interface, and access to administrative tools.

[16] "Home Page," *The Digit Group*, n.d., https://www.thedigitgroupinc.com/
[17] "What is PCL?," *Creative Commons*, n.d., http://pointclouds.org/about/
[18] "Next Generation SMART Concept - 911 Go,"*Cosumnes Fire Department*, n.d., https://www.yourcsd.com/805/Next-Generation-SMART-Concept---911-Go
[19] "Features," *CommandWear Systems Inc.*, n.d., https://commandwear.com/features/

- The Communicator app runs on a smartphone (Android and iOS) and uses the phone's GPS for tracking, camera for photo/video sharing, and provides a secure two-way text messaging interface.
- The Smartwatch App integrates through Bluetooth on the smartphone and provides messaging, heart rate monitoring, and alerting functions.
- An Application Programming Interface (API) allows data to be fused from external devices/sensors and shared with fleet management, dispatch, operations center software, or other systems.
- The situation map is updated in real-time with controls to adjust the update frequency and turn on/off tracking of devices, heart rate monitoring, and video/audio feeds from each tracked resource. Pictures and video can be shared and streamed among responders and command, with notes, timestamped, and geo-tag, while groups can be set up to manage monitoring of different teams. Map overlays, such as routes or floor plans, can be added to the map and toggled on/off, and drawing tools allow annotations and plans to be shared instantly.

Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

Echo Responder™[20]

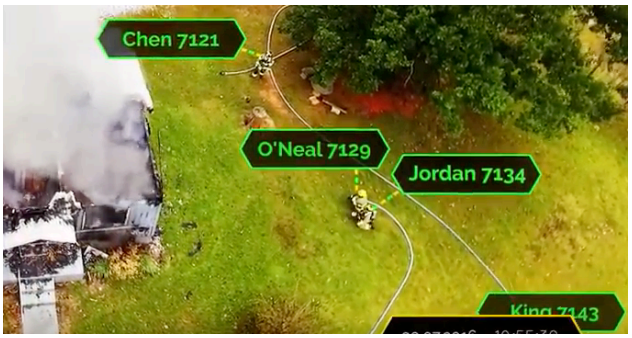
Echo Response Technologies, LLC (United States) develops mobile applications and tactical tools for emergency first responders. The mobile application provides tactical intelligence such as dispatch instructions, location of responders and apparatuses, incident scene footage and responder-to-responder messaging. Echo Responder™ is available for purchase at the user ($2.00 per month), department ($75.00 per month) and country level. Information regarding specific deployment within the first responder community does not appear to be publicly available.

First Response[21]

Edgybees Ltd. (Israel) offers First Response, a drone applications suite for emergency services. The suite contains three software tools that enhance the situational awareness of pilots and commanders:

[20] "Home Page," *EchoResponder*, n.d., https://echoresponder.com
[21] "Augmented Reality for First Responders," *Edgybees Ltd.*, n.d., https://edgybees.com/first-response/

- First Response Air Pilot app augments live drone video feeds with geo-information layers. Overlays including maps, building layouts, points of interest, user-generated markers, and other data layers are available.
- Command and Control provides aerial situational awareness to a user's computer, mobile device, and control room. Commanders can see all video feeds, maps, assets locations, and additional information layers on a unified display.
- Tracker app allows pilots and commanders to track personnel and assets in real-time by integrating them into video streams and maps on iOS and Android devices.



Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

PremierOne™ Smart Public Safety Solution[22]

Motorola Solutions Inc. (United States) provides first responder location tracking through a combination of its PremierOne™ Smart Public Safety Solutions, ASTRO® 25 Voice and Integrated Data systems, and GPS-equipped radios. PremierOne™ mapping creates a real-time view of resources and active incidents for a complete picture of organizational deployment. Configurable map icons provide visual indicators to confirm if a resource is in or out of their vehicle, as well as their location and agency type. These icons also display additional details such as first name, last name, unit ID, and incident type for immediate confirmation of responder information.

Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

STING™ Mobile Application[23]

Incident Response Technologies Inc. (United States) developed the STING™ mobile application, which is a native iOS and Android application that allows incident command staff to track responder locations in the field. With STING™, the location of responders assigned to an incident is readily accessible. The location of responders not yet assigned to the incident can also be made available, allowing commanders to quickly identify the closest available resources. In addition to location information, responders can share notes and images directly from their mobile phones. Incident Response Technologies Inc. also offers the Rhodium™ Incident Management Suite, which provides additional GPS tracking and location display solutions for compatible land mobile radios and automated vehicle location (AVL) systems.

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[22] *PremierOne Responder Location Data Sheet*, Motorola Solutions Inc., n.d., https://www.motorolasolutions.com/content/dam/msi/docs/products/smart-public-safety-solutions/integrated-command-control/premierone/mot_premierone_data_sheet_location.pdf

[23] "STING™ Mobile Application," *Incident Response Technologies Inc.*, n.d., https://irtsoftware.com/GPS-Tracking/

Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

Maritime (Above and Below Water) Geolocation

Micro-Ranger 2[24]

Sonardyne International Ltd. (United Kingdom) offers its Micro-Ranger 2, which uses a positioning technique known as Ultra-Short Baseline (USBL) to calculate the position of underwater targets including divers and small remotely operated and autonomous underwater vehicles. A transceiver at the surface transmits an acoustic signal to transponders attached to each target. Using the return signal from each transponder, Micro-Ranger 2 determines the target's range (distance), bearing (heading), and depth, displaying the results on a radar-style software display.

Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

Navimate™[25]

Shb Instruments Inc. (United States) developed Navimate™ to provide GPS capabilities to divers. Navimate™ functions through use of a small unit that is most commonly hung from a diver boat or buoy, referred to as the GPS gateway. The GPS gateway has a floating radio antenna in order to determine its exact location, and communicates with the wrist units (attached to divers) through its underwater transducer portion, using acoustic signals. As a result of this communication, the wrist units know their range and bearing from the GPS gateway, as well as the exact position of the gateway. This allows the wrist units to calculate their own absolute position, independent of the position or motion of the GPS gateway. The position is displayed on the Navimate™ screen both as latitude and longitude values as well as a "dot". Additional Navimate™ features include display of detailed maps of underwater terrain (as available), a computer interface that allows users to save marked points of interest, and the ability to communicate with other Navimate™ users (e.g., air pressure information, SOS call).

Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

[24] "Micro-Ranger 2 Shallow Water USBL System," *Sonardyne*, n.d., https://www.sonardyne.com/product/micro-ranger-2-shallow-water-usbl-system/

[25] "Home Page," *Shb Instruments Inc.*, n.d., https://www.navimate.com

Hybrid (Indoor and Outdoor) Responder Geolocation

All Hazard Response Network (AHRN)[26]

Radiant RFID, LLC (United States) develops radio frequency identification (RFID) and Internet of Things (IoT) solutions that assist private and public organizations. The company's All Hazard Response Network (AHRN) is an RFID system that aids emergency managers with large-scale disaster management and evacuations. Incident commanders can receive real-time and historical location data for evacuees and responders to determine equipment and asset needs. In addition, incident commanders can access data from the solution's user-configurable dashboard. AHRN combines RFID at an individual level with GPS tracking on response vehicles to monitor transportation and integrates with patient management systems such as EM Track™. Radiant RFID's *Responder Application*, is an extension of AHRN that delivers critical all-hazard operational data to emergency managers.

Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

Intelligent Accountability™[27]

Salamander Technologies LLC (United States) offers its SalamanderLive Intelligent Accountability™ suite, which combines three functions—TAG, TRACK, & REPORT—to provide businesses, organizations, and emergency management with situational awareness in a common operational picture. Some of the features of the Intelligent Accountability™ suite include the following:

- Creation of interoperable identifications to track all responders, volunteers, patients, evacuees, civilians, and equipment;
- Management of personnel qualifications, rostering, and medical data;
- Remote check-in via a geographic information system (GIS)-enabled map to view resources; and
- Perimeter security.

It appears the SalamanderLive Dashboard is available to purchase for $500.00 USD. Individual tags (with quick response [QR] code information) are sold separately and training is available from $450.00 to $750.00 USD, depending on the length of training. The Intelligent Accountability™ suite is currently deployed in more than 19,000 federal, emergency service, and health agencies in the United States. However, information regarding specific deployment within the first responder community does not appear to be publicly available.

[26] "Emergency, Evacuation, & Shelter Management," *Radiant RFID LLC*, n.d., https://radiantrfid.com/emergency-management/

[27] "Home Page," *SalamanderLive.com*, n.d., https://www.salamanderlive.com

NEON® Personnel Tracker

TRX Systems Inc. (United States) offers its NEON® Personnel Tracker as a 3D mapping and tracking solution for industrial, security, public safety, and defense applications. Personnel Tracker provides 3D location, tracking, and mapping for personnel operating indoors and in any GPS-denied location. Personnel Tracker is an Android application integrated with the NEON® Location Service where a suite of patented algorithms combine inertial sensor data, Bluetooth, and Wi-Fi readings and inferred map and building data to deliver 3D location. Specifically, NEON® Personnel Tracker features include:

- Cloud-based, scalable solution;
- Flexible pre-planning and deployment options;
- Centralized 3D mapping and visualization;
- Quick 3D building map creation;
- Indoor and outdoor location support; and
- API for third party application integration.

Available pricing information is provided below:

BASIC	STANDARD	PRO
NEON® Location Service	NEON® + Cloud Mapping	Real Time 3D Tracking
$14 USD/Per User Per Month	$20 USD/Per User Per Month	$29 USD/Per User Per Month

NEON® Personnel Tracker development kits are also available to purchase, which range from $1,499.00 USD to $5,499.00 USD.

Information regarding specific deployment within the first responder community does not appear to be publicly available.

Omnisense S500[28]

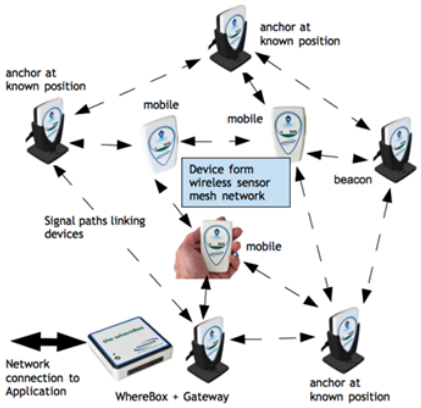
Omnisense Ltd. (United Kingdom) provides advanced real-time locating systems (RTLS) with 20 cm accuracy. The company's patented 'Cluster' technology uses relative positioning to allow multiple nodes in a wireless sensor network to communicate with any neighbors in radio range Each device in the network periodically broadcasts a positioning message to all neighbors within range, and also receives and measures messages transmitted by neighbors. Omnisense solutions can be utilized in various market sectors including emergency services. For emergency services, the Omnisense S500 solution claims to provide the following benefits:

- Continual awareness of location where GPS cannot be relied upon
- Enhanced command, control and safety
- Support for rapid deployment of personnel in hazardous environments attending incidents, safe recovery of personnel and objects
- Situational Awareness – accurately identifying and locating assets and individuals
- Improved monitoring, analysis and debriefing of training events
- Detection and monitoring of activity intensity and behavioral patterns

[28] "Home Page," *Omnisense Ltd.*, n.d., http://www.omnisense.co.uk/

- An auditable record of the history of behavioral and positioning information
- A tool for improved post-incident analysis and debriefing

The S500 solution claims to be optimized for position, motion and behavior tracking in local areas, indoors and outdoors for groups or teams of objects. The solution is a full 3D system and the Nodes include motion sensors that allow it to deliver information about the attitude (heading, pitch and roll) of the sensor. It also includes smart algorithms to interpret the position and behavior in a contextual way (e.g. zone occupancy, neighbor associations, fall alert). Information regarding price and specific deployment within the first responder community does not appear to be publicly available.



PENS – Personal Navigation System[29]

Israel Aerospace Industries Ltd. (IAI) offers the Personal Navigation System (PENS), a mobile multi-sensor inertial navigation system, composed of two units: (1) Navigation and Computation Unit and (2) Sensors Unit. PENS provides each user with personal navigation, positioning, pointing and orientation data in various terrain, including urban and indoor areas. PENS is designed for infantry soldiers, special forces, rescue forces and fire brigades. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

Precision Outdoor and Indoor Navigation and Tracking for Emergency Responders (POINTER)[30]

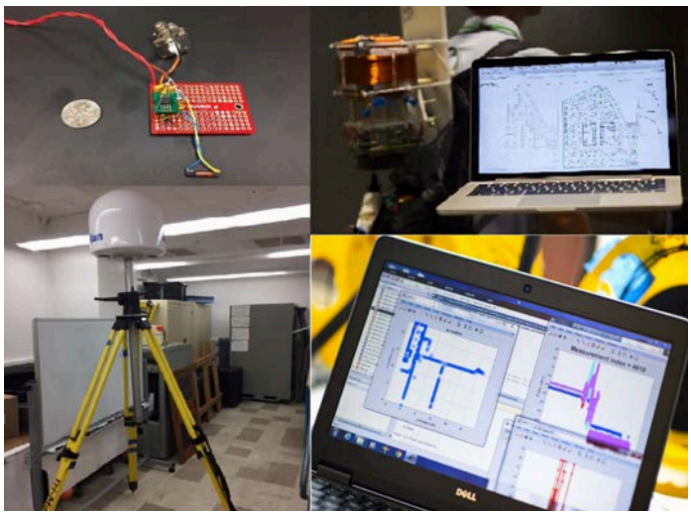
The U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) and the National Aeronautics and Space Administration Jet Propulsion Laboratory (NASA JPL) are currently developing the Precision Outdoor and Indoor Navigation and Tracking for Emergency Responders (POINTER) solution. POINTER is a precision positioning sensor system that can locate first responders via low-frequency magnetic fields that can transmit signals through materials such as wood, concrete, brick, and rebar. Specifically, POINTER:

- Monitors 3-D location and motion tracking;
- Works in- and out-doors, above- and below- ground, and underwater; and
- Enables precise positioning for several response applications.

[29] "PENS Personal Navigation System," *Israel Aerospace Industries Ltd.*, n.d., http://www.iai.co.il/2013/37289-42785-en/Business_Areas_Land.aspx

[30] *Precision Outdoor and Indoor Navigation and Tracking for Emergency Responders (POINTER) Fact Sheet*, Department of Homeland Security Science and Technology Directorate, 29 March 2018, https://www.dhs.gov/sites/default/files/publications/873_R-Tech_POINTER-FactSheet_180329-508.pdf

The first version of POINTER includes long-range in-building positioning and use in heavily-cluttered electromagnetic environments where line-of-sight to the device may be blocked. Future versions will include ground-to-underground positioning for individuals inside tunnels, mines, or bunkers.



Prototype components of the POINTER system are tested. The receiver worn by first responders will be approximately the size of a cell phone.

POINTER is currently able to track first responders at a distance of 70 meters (m) with an error rate of less than 2 m. The project team is working on increasing this distance while maintaining or improving the error rate and miniaturizing the device. POINTER should be available to first responders in 2019. This version will be designed for use in single family homes, warehouses, and buildings that are 12 stories or less. Future versions of POINTER will accurately track first responders in high-rise buildings, outdoors, and underground.

SolePower Ensoles[31]

SolePower (United States) is exploring the use of its patented SolePower Ensoles in industrial, first responder, and defense applications. The "smart boot" integrates Global Positioning System (GPS), radio frequency (RF), inertial measurement unit (IMU), and Wi-Fi sensors, powered by kinetic energy, to gather data and provide real-time monitoring and reporting. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.

[31] "Home Page," *SolePower*, n.d., http://www.solepowertech.com/#solepower

Appendix A

The following section includes tables that list the potential first responder-specific solutions, both existing and in-development, as identified in this study. It is likely that there are additional potential solutions in the market and therefore this section should not be considered exhaustive.

Indoor (Above and Below Ground) Responder Geolocation		
Existing Solutions		
Solution	**Solution Provider(s)**	**Country**
ARIANNA	DUNE Srl	Israel
First Responder Tracking System	iTrack LLC	United States
Indoor Navigation Solution	Accuware	United States
IndoorSpirit	SPIRIT DSP	Russia
Metropolitan Beacon System (MBS)	NextNav LLC	United States
Personnel Navigation, Locating & Tracking Solution	ENSCO Inc.	United States

In-Development Solutions		
Solution	**Solution Provider(s)**	**Country**
Situational Awareness – Visual Environment (SAVE)	Kutta Technologies Inc.	United States
FireBee Project	Saxion University of Applied Sciences	Netherlands

Infrastructure Standards for Technology Integration		
Existing Solutions		
Solution	**Solution Provider(s)**	**Country**
Enterprise Buildings Integrator (EBI)	Honeywell International Inc.	United States
MeshTrack	Motorola Solutions Inc.	United States

In-Development Solutions
None identified.

Rapid Building Characterization, Generation, and Display		
Existing Solutions		
Solution	**Solution Provider(s)**	**Country**
OrbiFire™	Digit Group Inc.	United States

In-Development Solutions		
Solution	**Solution Provider(s)**	**Country**
C-Thru	Quake Technologies	United States
FireTracks	York Technical LLC	United States
Hyper-Reality Helmet for Mapping and Visualizing Public Safety Data	Carnegie Mellon University	United States
Point Cloud Library (PCL)	Open Perception Inc.	United States

Outdoor Responder Geolocation		
Existing Solutions		
Solution	**Solution Provider(s)**	**Country**
ASTRO 25 Outdoor Location Solution	Motorola Inc.	United States
Blackbird Asset Tracker™ (BAT™) Personnel Tracking Device	Raytheon Company	United States
BlueForce Tactical (BTAC)	Blueforce Development	United States
CommandWear	CommandWear Systems Inc.	Canada
Echo Responder	Echo Response Technologies LLc	United States
First Response	Edgybees Ltd.	Israel
IamResponding (IaR) Application	Emergency Services Marketing Corporation Inc.	United States
MOSAIC	Airbox Systems Limited	United Kingdom
PremierOne™ Smart Public Safety Solution	Motorola Solutions Inc.	United States
SARLink™	ACR Electronics Inc.	United States
SayVu	SayVu Technologies	Israel
Siren Tactical	SirenGPS	United States
Situational Awareness Command & Control (SCC) Titan Platform	EPE	Australia
Spark Nano 6.0 GPS Tracker	BrickHouse Secrity	United States
SPOT Gen3	SPOT LLC	United States
SPOT Trace®	SPOT LLC	United States
STING™ Mobile Application	Incident Response Technologies Inc.	United States
Tactical Collaboration Node (TCN)	Mutualink	United States
WatchTower Application	Department of Homeland Security (DHS) Science and Technology Directorate (S&T)	United States

In-Development Solutions		
Solution	**Solution Provider(s)**	**Country**
Pedestrian Detection from Moving Unmanned Ground Vehicles	SRI International	United States

Maritime (Above and Below Water) Geolocation		
Existing Solutions		
Solution	**Solution Provider(s)**	**Country**
Micro-Ranger 2	Sonardyne International Ltd	United Kingdom
Navimate™	Shb Instruments Inc.	United States
USBL Diver Tracking	Tritech International Ltd.	United Kingdom

In-Development Solutions		
Solution	**Solution Provider(s)**	**Country**
POSYDON	BAE Systems Ins.	United States
spyGlass	Aster S.p.A.	Italy

Hybrid (Indoor and Outdoor) Responder Geolocation		
Existing Solutions		
Solution	**Solution Provider(s)**	**Country**
All Hazards Response Network	Radiant RFID LLC	United States
First Responders Assets and Personnel Tracking System	Cloud Collected	United States
Indoor/Outdoor Positioning and Tracking Solution	JVCKENWOOD Corporation	United States
Intelligent Accountability™ Suite	Salamander Technologies LLC	Salamander Technologies Inc.
MOLE Dismount Localization	Robotic Research LLC	United States
NAViSEER® Personnel Tracking	SEER Technology Inc.	United States
NEON® Personnel Tracker	TRX Systems Inc.	United States
OmniLocate	PolarisWireless	United States
Omnisense S500	Omnisense Ltd.	United Kingdom
Personal Navigation System (PENS)	Israel Aerospace Industries Ltd.	Israel
Positioning over LTD (PoLTE)™	PoLTE	United States
SmarTrack	Elbit Systems Ltd.	Israel
vTrack™	Remote Tracking Systems Inc.	United States

In-Development Solutions		
Solution	**Solution Provider(s)**	**Country**
An Infrastructure-Free Localization System for Firefighters	Carnegie Mellon University	United States
Autonomous Indoor Outdoor SafetyTracking System (AIOSAT)	CEIT-IK4 Technology Center	Spain
Pervasive, Accurate, and Reliable LBS for Emergency Responders	University of Oxford	United Kingdom
Precision Outdoor and Indoor Navigation and Tracking for Emergency Responders (POINTER)	Department of Homeland Security (DHS) Science and Technology Directorate (S&T)	United States
SolePower Ensoles	SolePower	United States
TaskForce Tracker	ResponderX Inc.	United States
Tracking Humans in Crowds	SRI International	United States

Appendix B

The following section includes notes (where applicable) regarding extrapolation methods for some of the revenue figures presented in the "Market Figures" section of this report. In addition, there are instances when the CAGR cited by a third-party data source does not equate to the market figures presented. In these cases, the CAGR as calculated based upon the market figures presented is utilized.

Indoor (Above and Below Ground) Responder Geolocation

- N/A

Infrastructure Standards for Technology Integration

- Global In-Building Wireless Market
  Market figures were available for 2015 and 2020. A CAGR of 28.2% was used to estimate the revenue values for 2021 to 2022. Market figures were rounded to the nearest hundred million.
- Global Public Safety In-Building Wireless Distributed Antenna System (DAS) Market
  Market figures were available for 2016 and 2021. A CAGR of 33.9% was used to estimate the revenue value for 2022. Market figures were rounded to the nearest hundred million.

Rapid Building Characterization, Generation, and Display

- *N/A*

Outdoor Responder Geolocation

- GNSS Market
  Currency conversion rates were obtained from the U.S. Federal Reserve and were conducted using the rate $1.2050 USD per EUR. Market figures were rounded to the nearest hundred million.

Maritime (Above and Below Water) Geolocation

- GNSS Market [Maritime]
  Currency conversion rates were obtained from the U.S. Federal Reserve and were conducted using the rate $1.2050 USD per EUR. Market figures were rounded to the nearest hundred million.
- Global Automatic Identification System (AIS) Market
  Market figures were available for 2014 and 2020. A CAGR of 4.3% was used to estimate the revenue values for 2021 to 2022. Market figures were rounded to the nearest hundred million.
- Global Sonobuoy Market
  Market figures were available for 2015 and 2020. A CAGR of 7.0% was used to estimate the revenue values for 2021 to 2022. Market figures were rounded to the nearest hundred million.

Hybrid (Indoor and Outdoor) Responder Geolocation

- Global Location-Based Services (LBS) and Real Time Location Systems (RTLS) Market
  Market figures were available for 2016 and 2021. A CAGR of 38.9% was used to estimate the revenue value for 2022. Market figures were rounded to the nearest hundred million.
- Global Emergency Beacon Transmitter Market
  Market figures were available for 2015 and 2020. A CAGR of 5.6% was used to estimate the revenue values for 2021 to 2022. Market figures were rounded to the nearest hundred million.

Glossary

Compound Annual Growth Rate (CAGR)	The average annual growth rate when compounding is taken into account; its formula is as follows: CAGR = (FV/PV)^(1/n)-1, where FV is the future or ending value, PV is the present or starting value, and n is the number of years between PV and FV.
First Responder	Those individuals who, in the early stages of an incident, are responsible for the protection and preservation of life, property, evidence, and the environment, including fire service, law enforcement, and emergency medical services.
Geolocation	The geographical position of an object, usually defined by latitude, longitude, and altitude coordinates or area-specific designations (such as a street address) in all environment (i.e., indoors, outdoors, and maritime).
Hybrid (Indoor and Outdoor) Responder Geolocation	A component of Capability Gap 1 that describes the need to identify the precise location of first responders within or outside any type of commercial or residential building, structure, or enclosed setting underground (e.g., basements, caves, subway systems, tunnels). Solutions for this need must be operable in all environments, which may require the use of a combination of different devices and systems.
Indoor (Above and Below Ground) Responder Geolocation	A component of Capability Gap 1 that describes the need to identify the precise location of first responders within any type of commercial or residential building, structure, or enclosed setting underground (e.g., basement, cave, subway system, tunnel, etc.). In addition, according to ISO/IEC 18305:2016, indoor responder geolocation may be defined as any environment where there is no *line of sight in the sky*.[31] This proposed standard would

	therefore include responders working within or under rubble piles.
Infrastructure Standards for Technology Integration	A component of Capability Gap 1 that describes the need of requirement standards for technology integration in infrastructure, especially in regards to indoor environments that would enable first responder location identification and tracking capabilities (e.g., Bluetooth beacons in commercial buildings).
Maritime (Above and Below Water) Geolocation	A component of Capability Gap 1 that describes the need of first responders to identify the precise location of one or more other responders above or below the surface of a body of water.
Outdoor Responder Geolocation	A component of Capability Gap 1 that describes the need to identify the precise location of first responders outside any type of commercial or residential building, structure, or enclosed setting underground (e.g., basement, cave, subway system, tunnel, etc.).
Project Responder 4	The fourth in a series of studies that focuses on identifying capability needs, shortfalls, and priorities for catastrophic incident response. The methodology is based upon discussions with federal, state, and local first responders, as well as technical subject matter experts.
Rapid Building Characterization, Generation, and Display	A component of Capability Gap 1 that describes the need of first responders to rapidly characterize, generate, and display 3D visualizations of buildings to provide enhanced situational awareness to responders at incident scenes and support indoor (above and below ground) responder geolocation.
Response Technology Objective (RTO)	A term used within Project Responder 4 to translate a capability statement or need into an actionable, technology-centric objective.

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