



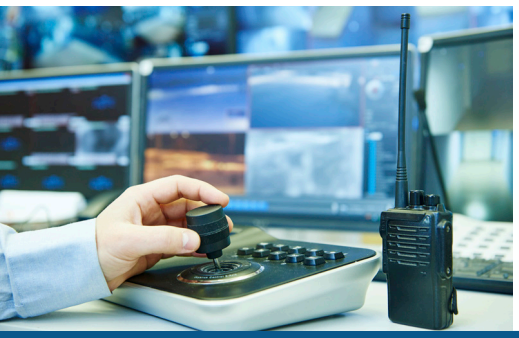

The International Forum to Advance First Responder Innovation

Capability Gap 8 “Deep Dive” Analysis

September 2019

International Forum to Advance
FIRST RESPONDER INNOVATION

Homeland Security

Science and Technology

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International Forum to Advance
FIRST RESPONDER INNOVATION

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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 8: *The ability to monitor the physiological signs of emergency responders.* 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 eighth of ten Common Global Capability Gaps identified by IFAFRI. 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
Capability Gap 5	The ability to maintain interoperable communications with responders in any environmental conditions
Capability Gap 6	The ability to obtain critical information remotely about the extent, perimeter, or interior of the incident
Capability Gap 7	The ability to conduct on-scene operations remotely without endangering responders
Capability Gap 8	The ability to monitor the physiological signs of emergency responders
Capability Gap 9	The ability to create actionable intelligence based on data and information from multiple sources
Capability Gap 10	The ability to provide appropriate and advanced personal protective equipment

The first four capability gaps on this list were adopted by IFAFRI in 2016. 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 the first four *Common Global Capability Gaps* in 2016.

Between 2016 and 2018, IFAFRI's Capability Gaps Committee further refined and formalized its process for adding capability gaps to the list. In 2018, individual countries solicited national capability gaps from first responders in their countries and submitted these to the Capability Gaps

Committee. In total, 78 national capability gaps were received from IFAFRI countries. These gaps were then synthesized to eliminate redundancy and provide overarching gaps that aggregate multiple similar gaps when needed, which resulted in a set of 45 gaps. Three of the gaps corresponded to the initial four *Common Global Capability Gaps*, leaving 42 gaps for prioritization. The prioritization process resulted in the addition of the Capability Gaps 5-10 to the *Common Global Capability Gaps* list.

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 to 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.

Capability Gap 8

The ability to monitor physiological signs of emergency responders

Monitoring physiological (and cognitive) indicators may allow responders, medical personnel, and command to identify changes in health and performance. The demands of emergency response can lead to physical and mental performance degradation, endangering individuals or teams of responders.

Responders cannot operate at peak levels if physiological factors are outside of normal parameters. Responders want to be able to monitor physiological signs to identify when personnel are experiencing or are developing symptoms related to a medical issue or emergency. The ability to monitor responders' vital signs would enable commanders to direct personnel to rehabilitation or medical stations before measurements reach critical levels.

Cognitive performance is affected by factors such as cardiovascular strain, psychological stress, thermal stress, and dehydration.[2] This is important because effective mental processing through attention, perception, memory, etc., is critical for assessing and responding to unfolding emergency events.[3] The ability to monitor cognitive performance can help to identify when responders are no longer able to complete their task or mission safely or effectively.

While there are a number of solutions in use by responders, these solutions still have shortcomings when considering the state of technology today for physiological monitoring. However, this capability exists in fields outside of public safety. From remote monitoring of astronauts in space to measurement of an athlete's vital signs, many of the requirements listed in the sections below are technologically feasible today. Despite expanding use of physiological sensors in other industries, responders do not currently monitor physiological signs in the field. This is primarily because commercial systems are not built to withstand the demands of the response environment. Yet, according to the National Fire Protection Association (NFPA), "overexertion/stress/medical" causes are the leading source of firefighter fatalities (53 percent).[4] While the percentage of law enforcement and emergency medical technician and paramedic deaths tied to medical causes is lower, responders in both disciplines regularly experience high levels of physical, physiological, and cognitive stress.[5]

While there is a high level of public and private funding for advancing technology for physiological monitoring, emergency responders in IFAFRI nations continue to face challenges. Many factors contribute to this lack of progress, such as country size and degree of centralized response functions, but the main obstacle is a lack of a comprehensive, affordable solution.

Responders and their respective agencies would like a solution that monitors, analyzes, and alerts based on physiological, cognitive, and behavioral signs and indicators. Components may be attached to the body, personal protective equipment (PPE), or embedded in responder garments. The system should be able to compare measurements against the normal parameters for each responder (as appropriate). Some responders, for example, have a lower normal range for blood pressure or pulse. Data, analysis, and corresponding guidance should be transmitted in real time, as appropriate, to responders, on-scene supervisors, command staff, safety officers, and/or medical personnel. An alert should be generated when measurements are outside of the responder- or indicator-specific ranges or levels. Different alerts should be generated for the responder, medical staff, and command to avoid alarm overload. Physiological sensors should be integrated with other

threat and hazard sensors to provide a comprehensive picture of responder health and safety. In addition, false negatives and positives can have a significant impact; these should be minimized to the lowest possible levels.

This study uses the list of existing first responder gear in the SOO document for Gap 8. This list encompasses the current methods of physiological monitoring available for first responders. Each method was considered a "technology type" with a corresponding, relevant market. There are four technology types for this capability gap:

- Annual physicals;
- On-scene rehabilitation and wellness checks;
- Distress signal units (e.g., Personal Alert Safety System (PASS), Automatic Distress Signal Unit (ADSU)); and
- Body-worn physiological/sport monitors (personal use) (e.g., Garmin, Fitbit).

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 Quantification

All relevant markets are quantified utilizing overall global revenue figures, unless otherwise noted, for the forecast period 2019-2023. 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.

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.[6] 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. 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.

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 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 8. This synopsis highlights key data and analysis identified as part of this study.

Market Definitions and Segmentation

This study uses the list of existing first responder gear in the *Statement of Objectives 8* (SOO 8) document to further define and segment the relevant markets for Capability Gap 8. For the four types of gear given for this capability gap, it was determined that no one market best represents these technology types, and therefore only six markets were selected. These markets are used for market definition, segmentation, quantification and further assessment.

Market Quantification

These six markets are quantified utilizing overall revenue figures derived from global markets. Growth is measured using an estimated CAGR. The Vital Sign Monitoring Market is estimated to be worth more than $4.4 billion USD in 2018 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 6.3% through 2023. This equates to a market value of more than **$6 billion USD** in 2023. The Wearable Medical Devices Market is estimated to be worth **$5.5 billion USD** in 2016 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 28.8% through 2023. This equates to a market value of more than $32 billion USD in 2023. The Wearable Technology Market is estimated to be worth **$21.7 billion USD** in 2016 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 15.5% through 2023. This equates to a market value of more than $59 billion USD in 2023. The Patient Monitoring Devices Market is estimated to be worth more than **$22.6 billion USD** in 2017 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 6.4% through 2023. This equates to a market value of more than $32 billion USD in 2023. The Brain Monitoring Devices Market is estimated to be worth more than **$3.8 billion USD** in 2017 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 7.2% through 2023. This equates to a market value of more than $5.7 billion USD in 2023. Finally, the Heat Stress Monitor Market is estimated to be worth **$39.8 billion USD** in 2017 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 7.3% through 2023. This equates to a market value of $60.9 billion USD in 2023.

Competitive Landscape

Based upon third-party market research reports, there are 113 key players and innovators identified within the global, primary markets for Capability Gap 8. These key global players and innovators appear to offer solutions that address, in part, the ability to monitor the physiological signs of emergency responders. However, none of the solutions identified within this assessment appear to meet all of first responders' target objectives for this gap.

Summary

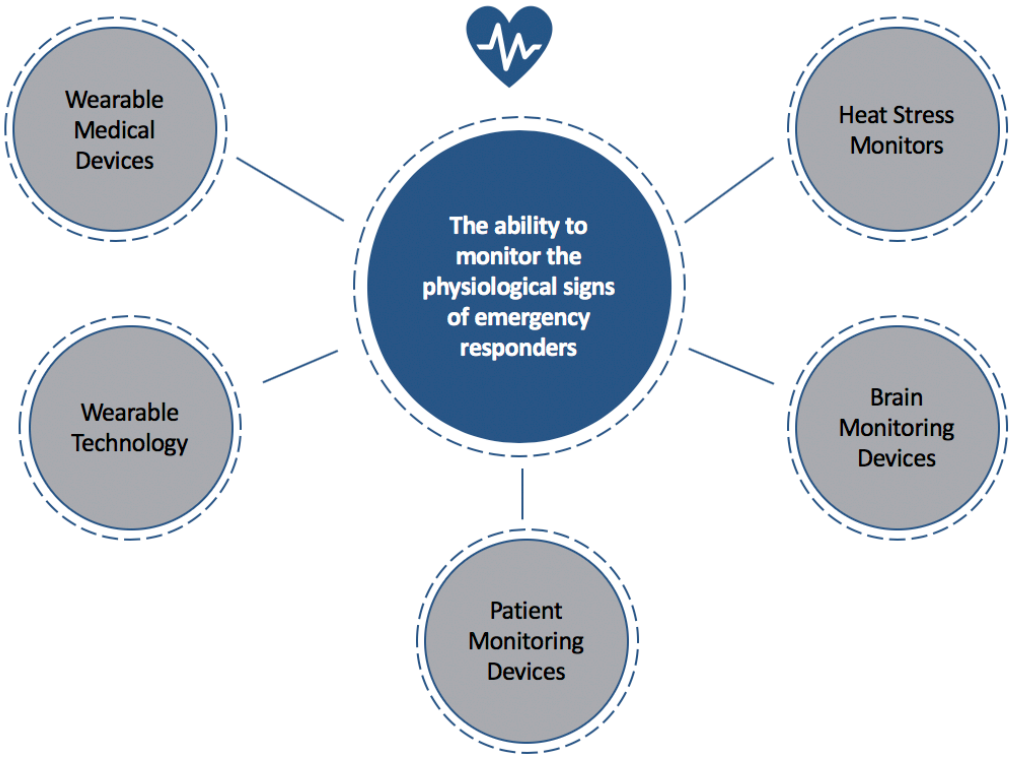
In summary, the primary markets identified to represent this capability gap are relatively large and growing. This growth in and of itself presents a great opportunity for new solutions to enter the market. When examining 74 existing solutions in this assessment, none fulfilled all of the

objectives for this gap. Therefore, any solutions that address these target objectives and allow continuous, remote physiological monitoring will likely have the greatest commercial potential.

Market Overview

Capability Gap 8 is **the ability to monitor the physiological signs of emergency responders**. This gap is largely focused on tracking responder physiological indicators during field operations.

Market Segmentation



Due to the broadness of this gap, one overarching market was not able to be identified.

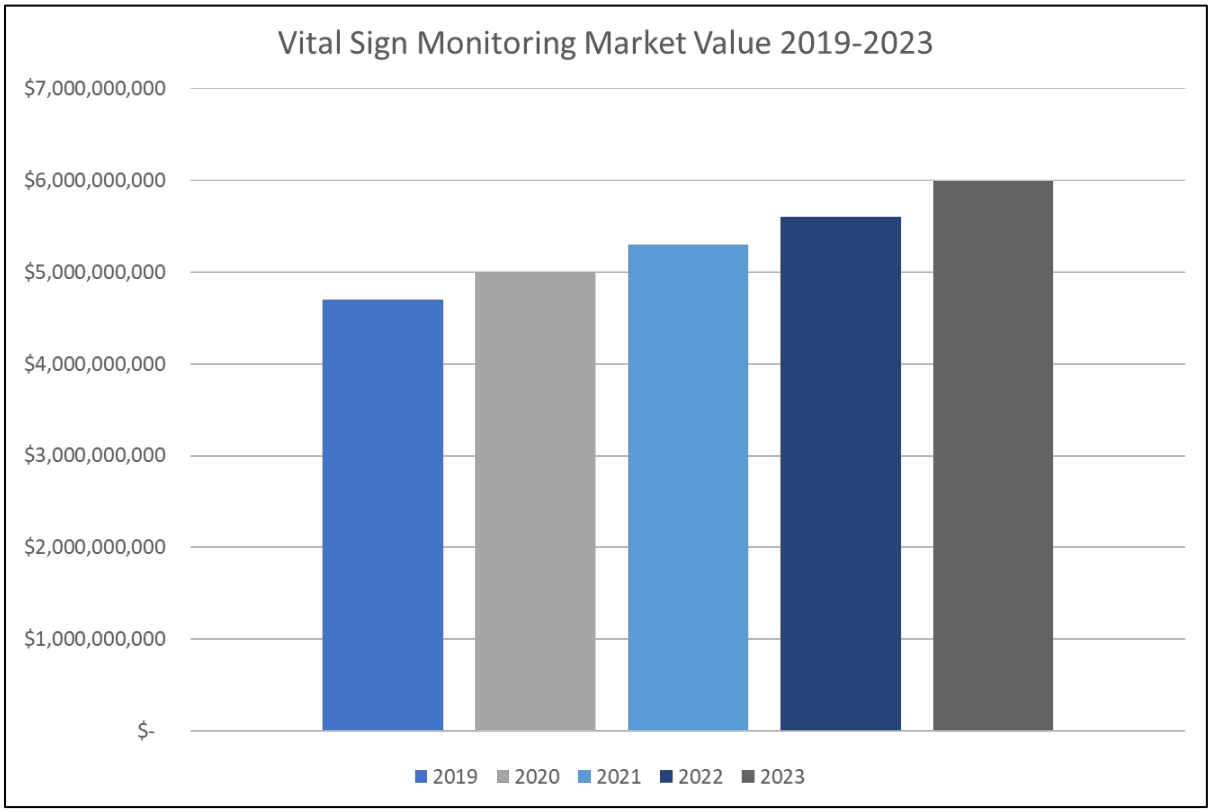
Capability Gap 8 – The ability to monitor the physiological signs of emergency responders

First responders need solutions that allow for continuous physiological monitoring of personnel in the field as well as the ability to assess that data in both real time and for comparison against historical data for each responder. When responders become overly physically fatigued, they face significant challenges to performing their jobs more safely and effectively. Having this capability will likely improve responders' abilities to help during incident response.

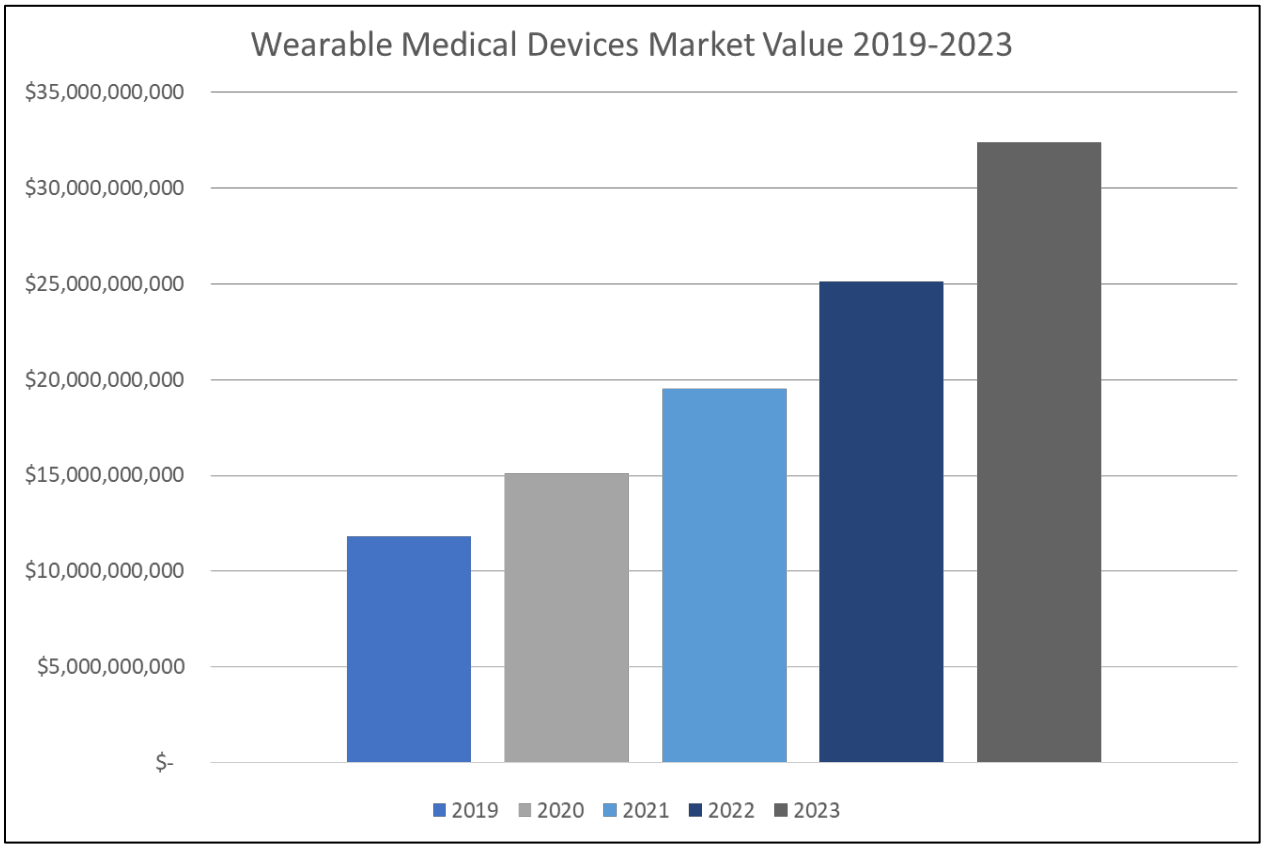
A myriad of physiological monitoring solutions currently exist within the market. However, not one of these solutions appears to meet all of responders' target objectives, which include persistent measurement of responder physiological data; assessment of data against responder-specific parameters; and integration of components into personal protective equipment (PPE) or garments.

Due to the disparity of the market segments contained with this capability gap, one, all-encompassing primary market was not able to be identified. Therefore, multiple markets are used for market quantification.

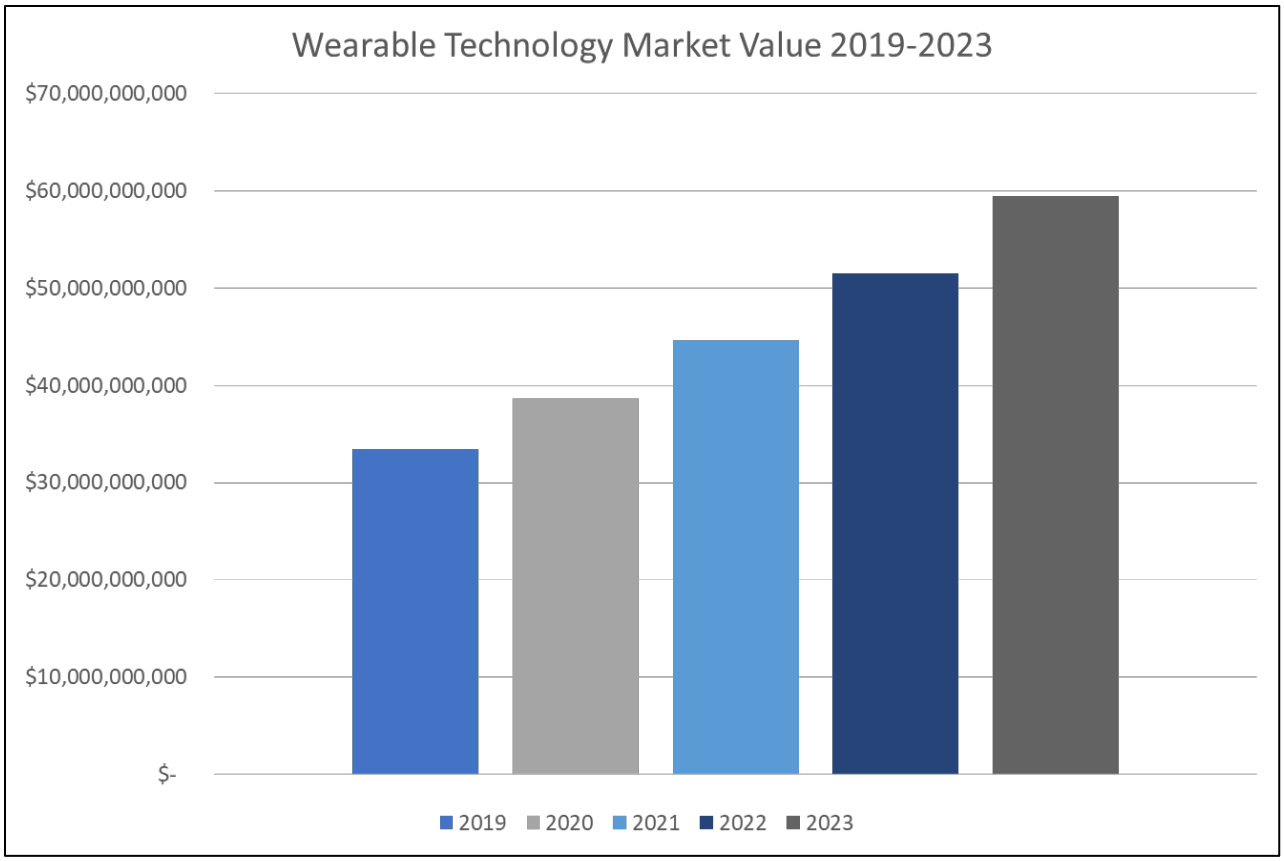
The Vital Sign Monitoring Market is used to define, quantify and assess the various types of solutions available. This market was worth more than $4.4 billion USD in 2018 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 6.3% through 2023. This equates to a market value of more than $6 billion USD in 2023.



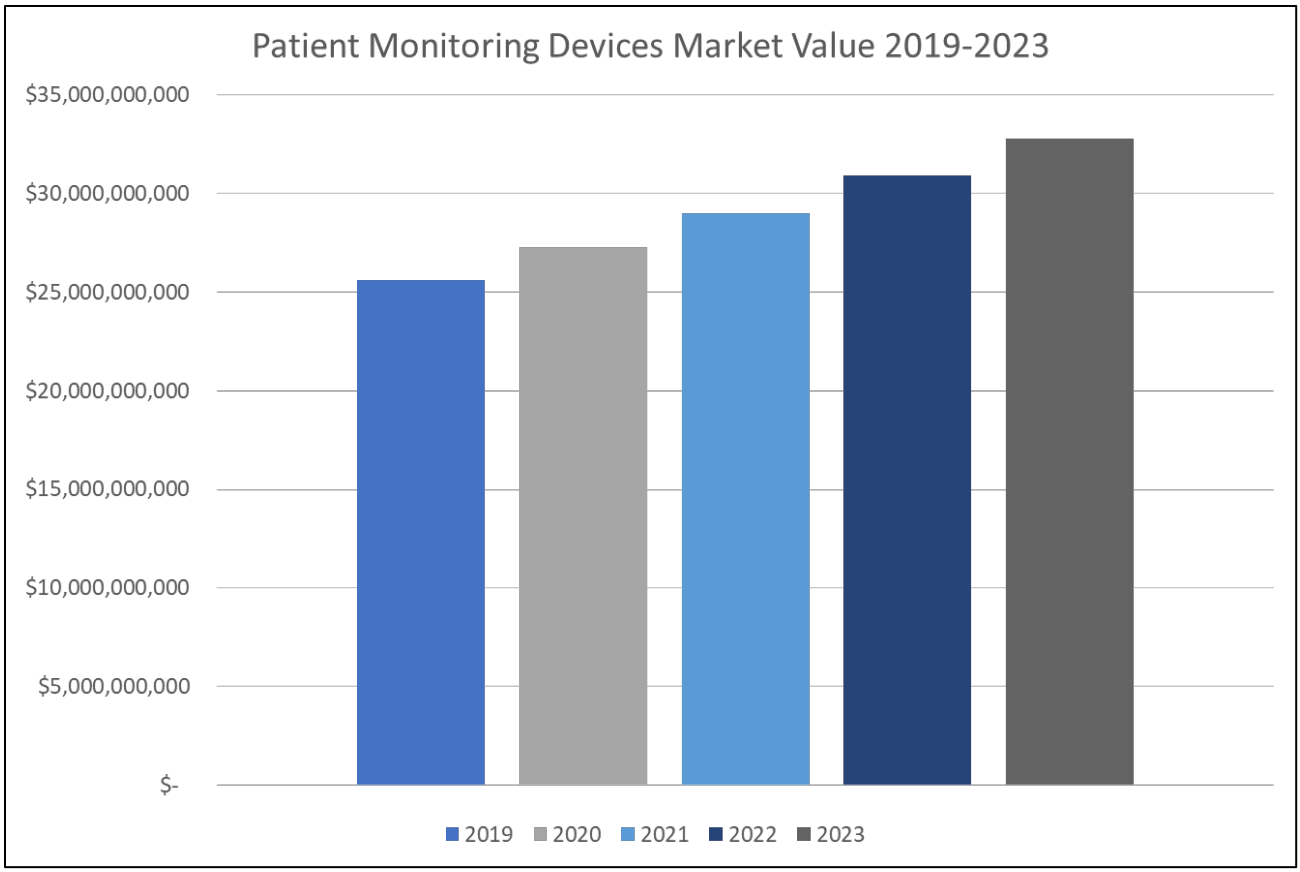
The Wearable Medical Devices Market is used to define, quantify and assess the various types of solutions available. This market was worth $5.5 billion USD in 2016 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 28.8% through 2023. This equates to a market value of more than $32 billion USD in 2023.



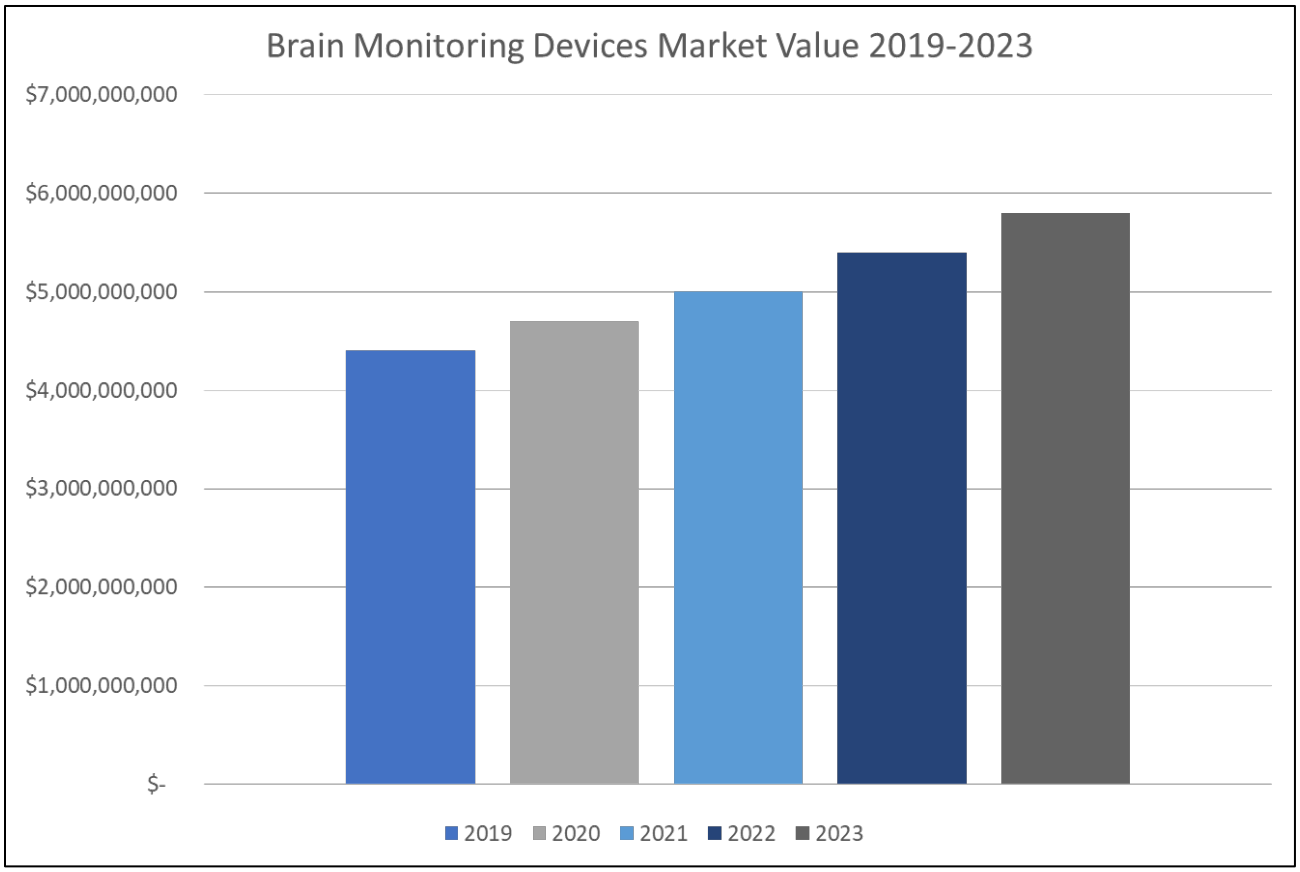
The Wearable Technology Market is used to define, quantify and assess the various types of solutions available. This market was worth $21.7 billion USD in 2016 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 15.5% through 2023. This equates to a market value of more than $59 billion USD in 2023.



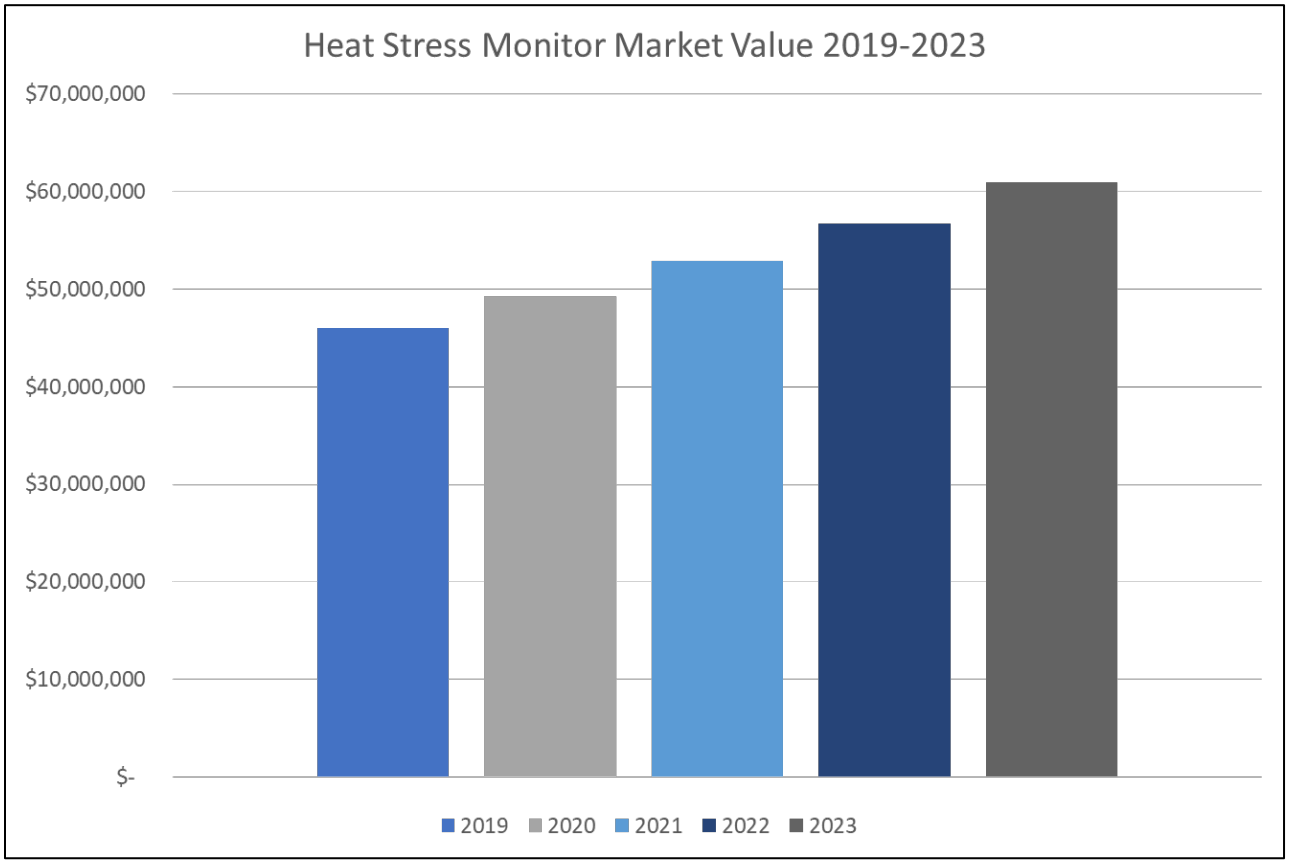
The Patient Monitoring Devices Market is used to define, quantify and assess the various types of solutions available. This market was worth more than $22.6 billion USD in 2017 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 6.4% through 2023. This equates to a market value of more than $32 billion USD in 2023.



The Brain Monitoring Devices Market is used to define, quantify and assess the various types of solutions available. This market was worth more than $3.8 billion USD in 2017 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 7.2% through 2023. This equates to a market value of more than $5.7 billion USD in 2023.



The Heat Stress Monitor Market is used to define, quantify and assess the various types of solutions available. This market was worth $39.8 billion USD in 2017 and is projected to grow at a Compound Annual Growth Rate (CAGR) of 7.3% through 2023. This equates to a market value of $60.9 billion USD in 2023.



Market Figures

The following table presents the estimated revenue figures for the various sub-markets identified for the Capability Gap 8 market. The colored row represents the primary market used to quantify this gap in this study.

Disclaimer

Note, all figures have been rounded to the nearest hundred thousand. The market forecast period examined is 2019 to 2023. 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.

Physiological Monitoring

	Revenue by Year (in $1,000,000 USD)					CAGR
	2019	2020	2021	2022	2023	
Global Vital Sign Monitoring Market[7]	$4,693.8	$4,991.8	$5,308.8	$5,645.9	$6,004.4	6.3%
Global Wearable Medical Device Market[8]	$11,753.5	$15,139.1	$19,500.0	$25,117.1*	$32,352.2*	28.8%
Global Wearable Technology Market[9]	$33,444.3	$38,628.2	$44,615.5	$51,530.0	$59,518.2*	15.5%
Global Patient Monitoring Devices Market[10]	$25,631.2*	$27,271.3*	$29,016.4*	$30,873.1*	$32,848.6*	6.4%
Global Brain Monitoring Devices Market[11]	$4,404.5*	$4,711.1*	$5,038.9*	$5,389.6*	$5,764.7*	7.2%
Global Heat Stress Monitor Market[12]	$45,862.8*	$49,232.3*	$52,849.3*	$56,732.0*	$60,900.0	7.3%

Market Highlights

The ability to monitor the physiological signs of emergency responders describes the need to allow responders, medical personnel, and command to identify changes in heath and performance.

Physiological Monitoring

Current Capability: Current solutions related to monitoring of physiological signs are focused on solutions that are designed for standalone use rather than incorporation into existing equipment. A growing number of solutions are able to be incorporated into apps or dashboards for easy collection of data. There is limited ability to incorporate these solutions into personal protective equipment (PPE).

Market Quantification

Market Size (2019):	No primary market identified	**Compound Annual Growth Rate (2016-2023):**	No primary market identified

Competitive Landscape

Number of Firms:	113	**Number of Responder-Specific Solutions:**	13

Market Phase

No primary market identified

Market Factors

The figure below summarizes the market factors associated with physiological monitoring.

Opportunities

- ✓ Increasing demand for advanced algorithm-based and home care monitoring equipment
- ✓ Increasing demand for vital sign monitoring devices
- ✓ Increase in awareness of fitness and healthcare as well as increase in consumer expectations
- ✓ Increasing prevalence of chronic diseases and lifestyle diseases such as diabetes, and ease of use
- ✓ Rise in cardiovascular diseases due to sedentary lifestyle and growth in geriatric population
- ✓ Rise in adoption of remote patient monitoring devices at home care setting and increase in awareness regarding availability of monitoring devices that could be used in patient's home
- ✓ High purchasing power among the populations and rise in adoption rate of portable monitors
- ✓ Increase in the demand for electroencephalography devices among healthcare providers
- ✓ Technological advancements are expected to boost the market growth
- ✓ Growing adoption of heat stress monitoring in athletics and military applications
- ✓ Growing concerns of environmental and safety regulations for heat stress management
- ✓ AI integrated heat stress monitor system is expected to emerge as game changers as such system will reduce human intervention and boost the overall efficiency of the production

Barriers

- x High costs of devices
- x Unfavorable reimbursement policies
- x Lack of awareness in the developing countries, such as India, Brazil, and Mexico
- x Stringent government regulations are expected to hamper the market growth
- x Lack of strict enforcement across industries in emerging economies
- x Lack of awareness and necessary training to deal with heat stress conditions are creating challenges for this market

Competitive Landscape

A total of 113 firms were identified as operating in the markets listed above, 10 of which are considered key global market players, including:

- Medtronic (United States)
- Fitbit (United States)
- Garmen (United States)
- Dragerwerk (Germany)
- Samsung (South Korea)
- Apple (United States)
- LifeWatch AG (Switzerland)
- Koninklijke Philips NV (The Netherlands)
- Xiaomi Technology (China)
- GE Healthcare (United States)

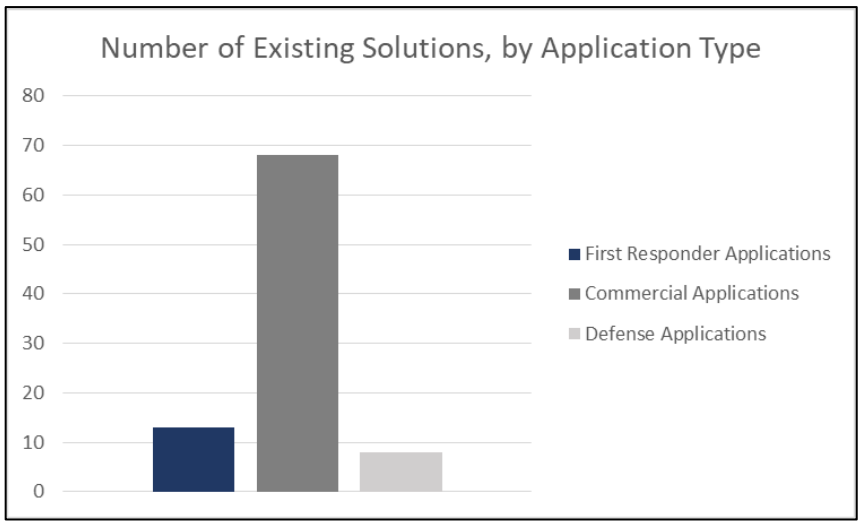
Within this study there are a total of 74 existing solutions and 13 research and development (R&D) initiatives with relevance to Capability Gap 8 identified. This landscape is non-exhaustive, as the number of solutions is vast and ever-changing at a rapid pace.

Among the existing and developing solutions identified, 13 solutions (18 percent) appear to have first responder applications and one solution (7 percent) appears to be in development for first responder use. These numbers may indicate that industry is not as aware as it could be 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:

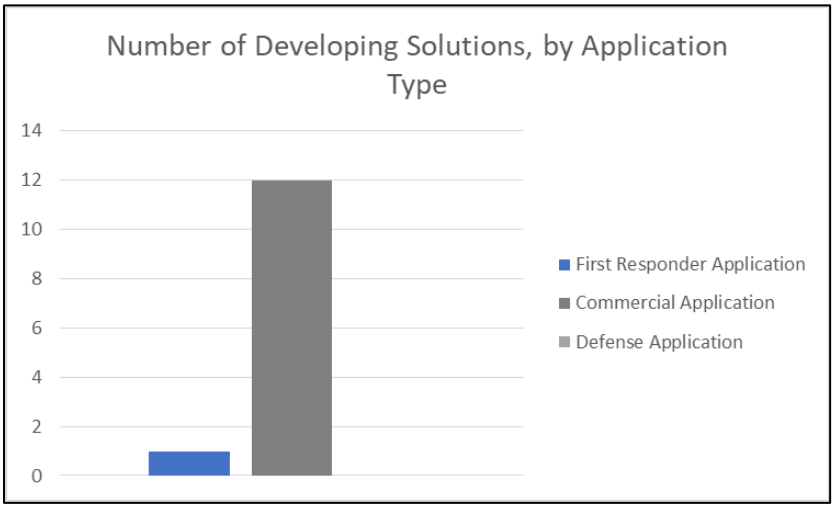
1. Persistent measurement of responder physiological data;
2. Assessment of data against responder-specific parameters; and
3. Integration of components into personal protective equipment (PPE) or garments.

It appears that the greatest gap exists for systems capable of integration into PPE. Most of the existing solutions are designed for standalone use rather than incorporation into existing equipment.

While the greatest number of existing solutions (68) identified in this assessment appear to have commercial applications, 13 solutions have first responder applications and eight have defense applications.



There are also a total of 13 R&D initiatives related to Capability Gap 8 identified in this assessment. Among the developing solutions identified, industry is involved in the development of nine solutions, academia is involved in four solutions, and government is not involved in the development of any solutions. One developing solution is focused on first responder application, 12 are focused on commercial applications, and none are focused on defense applications.



Based upon the data presented, less than ten percent of all existing and developing solutions appear to be targeting first responder applications. Therefore, industry is likely not aware that a first responder need exists within this technology space.

Looking more closely at these solutions, the ability of any identified existing or in development solutions would not meet all the needs of responders' target objectives cited previously. More specifically, the ability for responders to incorporate monitoring technology into PPE and garments is particularly underserved. This presents any opportunity for industry to develop solutions that can fit all of the target objectives, with a special focus on object two.

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 Gap 8 Statement of Objectives (SOO) document. None of the solutions identified during this study meet all of the requirements detailed in the SOO document. However, those presented below offer increased levels of integration or newer features than what is generally used by response agencies currently. There are a large number of potential solutions that exist or are in-development and therefore this section should not be considered exhaustive. Further, additional concepts exist in academic literature 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.

Training

Meditronic

Meditronic acquired Zephyr in 2015. Zephyr produced one of the first wearable, wireless and field-deployable physiological status monitoring systems for use in high stress operational environments. The company manufactures a range of heart rate and fitness monitoring devices capable of measuring heart rate, respiration, and activity level, among other biometrics.[13]

Medtronic (United States) offers **Zephyr**, a performance system that measures six key inputs that report on more than 20 biometrics. This system is composed of a sensor which is worn on a Zephyr shirt, a communication forum such as Bluetooth that connects the sensor to the display screen, and a software platform called OmniSense that analyzes and displays the data. Further, Zephyr tracks data such as heart rate, breathing rate, heart rate variability, posture, activity, peak acceleration, impact, and body temperature to accurately analyze how a person's body reacts during periods of performance. With this information, performers are able to analyze their fatigue and recovery time, readiness levels, safety, undertraining and or overtraining and much more. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.[14]

Figure 1: Zephyr shirt

Catapult

Catapult (Australia) was founded in 2006 to build and improve the performance of athletes at all levels. The wearable technologies developed by Catapult are designed to address central questions related to performance. Catapult is a global leader in sports technology offering

solutions for every element of the performance gamut from wearable tracking to athlete management and video analysis.[15]

Catapult offers the **Vector** tracker which is a small wearable device that is worn on a catapult vest. This device is often used by athletes to track different movements. Vector monitors a person's performance by detecting heart rate, location, direction, intensity of movement, and more. Through Bluetooth, many different devices can be tracked at once. The software can alert when a user needs to push harder or slow down. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.[16]

Figure 2: Catapult Vector

Physiological

Hexoskin Inc.

Hexoskin Inc. (Canada) is an industry leader offering a line of smart clothing. This clothing has body sensors incorporated into comfortable garments for precise health monitoring. These sensors are a component of the Hexoskin Connected Health Platform. The Hexoskin Smart Garments offer activity and sleep trackers to monitor the evolution of the wearer's physical condition over time. Hexoskin products are clinically validated and capable of continuously tracking cardiac, respiratory, sleep, and activity data.[17]

Hexoskin Inc. offers the **Hexoskin Smart Shirt**, a validated shirt and system that allows precise electrocardiogram (ECG) monitoring with lung function as well as activity monitoring over the long-term. This shirt provides tools to help doctors, nurses and caregivers improve the standards of care for outpatients. The Smart Shirt monitors heart rate, breathing rate, movement, energy levels and other biometrics. The Hexoskin shirt is light-weight with built in sensors to monitor physiological signs. The shirt is washable, stretch resistant and quick drying. Hexoskin has an online dashboard that allows the user to connect the device to the computer through Bluetooth. With this information, users are able to monitor their body signs while in action. The cost of these shirts and the system is $499 USD for both women and men respectively. Information regarding specific deployment within the first responder community does not appear to be publicly available.[18]

Figure 3: Hexoskin Smart Shirt

RAE Systems, Inc.

RAE Systems, Inc. (United States) is a global provider of rapidly deployable gas and radiation detection systems that enable real-time safety and security threat detection. The solutions RAE Systems provides offer wirelessly enabled personal, hand-held, transportable, and fixed instruments designed to meet the needs of diverse operational scenarios.[19]

Rae Systems offers the **BioHarness**. This lightweight, wearable monitor measures personal vital statistics such as heart rate, body temperature, breathing rate, and posture. The BioHarness attaches around the chest, is easy to put on and set up, and doesn't hinder movement. This proactive measurement can help one manage worker safety, prevent heat stress injuries, and make decisions about overwork/stress levels, ambient temperature, and other factors. Combined with other detectors, it helps to provide a complete picture of the safety of the workforce. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.[20]

Figure 4: BioHarness

Equivital

Equivital (United Kingdom) develops wearable tech products which provide accurate and precise, real-time mobile human data to help users monitor health. Equivital offers 3 product lines: TnR for researchers, Orann for clinical trials and healthcare applications, and Black Ghost for professional safety and welfare in military and emergency response. These products combine physiological metrics with communications and software allowing users to collect and transmit data for observation and review.[21]

Equivital offers the **EQ02 LifeMonitor**, a body-worn sensor that provides real-time safety, welfare and location information on users. LifeMonitor measures ECG, heart rate, breathing rate, skin temperature, activity and body position, and connects with external sensors to store and transmit the data. This information is sent using Radio/Satcom/GSM/WiFi and can be viewed either locally or remotely. LifeMonitor collected environmental data, sensor data and subject data can be used to provide actionable intelligence. This device is used by a variety of different sectors, including first responders. Information regarding price a does not appear to be publicly available.[22]

VitalConnect

VitalConnect (United States) was founded in 2011. VitalConnect provides physicians, nurses and patients with advancements in continuous healthcare monitoring of vital signs in a single, small device. VitalConnect's mission is to provide the healthcare industry with predictive data analytics that can be used to reduce expenses, increase efficiency, provide better care, and save lives.[23]

VitalConnect offers the **VitalPatch**. This device is a small patch that provides a variety of valuable information to physicians and nurses. The biosensor continuously collects data on eight physiological signs, giving clinical-grade accuracy without the need for monitors. These physiological signs include heart rate, heart rate variability, respiratory rate, body temperature, body posture, fall detection, activity, blood pressure, weight, and oxygen saturation. VitalPatch is used in hospitals as well as home settings. The battery life is 120 hours, only weighs 11 grams, and can be placed in multiple areas to assist with patient comfort. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.[24]

Figure 5: VitalConnect VitalPatch

Komodo Technologies

Komodo Technologies (Canada) develops smart wearable solutions. The Komodo development team has a combined 40 years of experience in fitness and medical technology. Komodo has developed the first smart compression sleeve.[25]

Komodo Technologies offers the **All In One (AIO) Sleeve**. The AIO Smart Sleeve is the first smart compression sleeve with integrated sensors that gives the user a better look into his fitness, activity and overall health. This sleeve is used by athletes and active people. There are three different parts to this device: The sleeve which holds a small chip and an electrode which is placed directly on the skin. The electrode provides ECG monitoring and beats per minute (BPM). The final component is the app with collects the data via Bluetooth connection. The AIO Sleeve can also monitor physiological activity, stress levels and sleep quality. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.[26]

Figure 6: Komodo AIO Sleeve

Five Vital Signs (5VS)

5VS's (United States) mission is to identify and prioritize anyone in critical condition within seconds, while also providing incident command with a tactical medical picture in real time. 5VS provides solutions targeted to the military, first responders, and veterans.[27]

5VS provides the **Triage-On-Demand (TOD) Biosensor**. The device is the size of a Band-Aid, weighs 11 grams, and adheres to the chest. Vital signs are captured and relayed to the Incident Command dashboard. Any critical (red) or non-critical (yellow) change is flagged on the first responder's smartphone display and also flagged and prioritized on the Incident Command dashboard. Responders and Incident Commanders can tap on any first responder or patient listed on the display causing his real-time vital signs to appear complete with a precise location. TOD captures and relays a single lead ECG, heart rate, respiratory rate, and body temperature. The biosensor detects falls with a high degree of probability and may diagnose traumatic brain injuries. TOD can make responders safer through consistent monitoring, both during and after an incident response, when most firefighter heart attacks occur. TOD can be applied to patients at the incident scene and within 60 seconds help to identify and prioritize the care of critically injured individuals in a mass casualty incident. Information regarding price does not appear to be publicly available.[28]

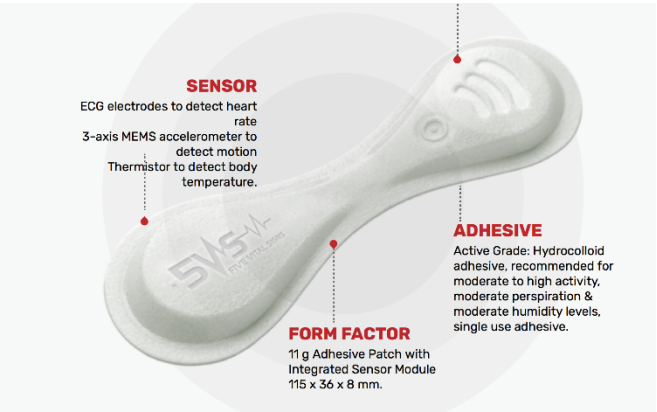


Figure 7: 5VS TOD Biosensor

FireHUD Inc.

FireHUD Inc. (United States) was founded with the focus of starting a technological revolution in responder safety and has a goal of "Protecting our Protectors." FireHUD is aware that the leading cause of injury and death in firefighting is due to overexertion and heat exhaustion. However, heat stress is not just limited to firefighting. Therefore, FireHUD has designed a product that functions on a standalone infrastructure thus allowing it to be easily integrated into use by any responder entity.[29]

FireHUD (United States) provides the **BioTrac Platform**. This platform provides passive biometric monitoring and accountability for firefighters via arm-worn wearable devices. The data can be viewed in real-time and post-incident by authorized officials to allow for more informed decisions and prevent injuries and deaths due to overexertion. FireHUD provides text alerts in order to prevent overexertion, which is the number one cause of injury in firefighting and responsible for nearly 60 percent of firefighter line of duty deaths. Further, this device states heart rate, core temperature, exertion, calories burned and distance traveled. Information regarding price does not appear to be publicly available.[30]

Figure 8: FireHUD BioTrac

Health

Intel

Intel Corporation (United States) is a technology company headquartered in Santa Clara, California. The corporation is world's largest manufacturer of PC microprocessors. Intel's innovation in cloud computing, data center, Internet of Things, and PC solutions helps customers stay connected to the digital world.[31]

Intel offers the **Recon Jet**, a pair of wirelessly connected sunglasses, equipped with a head-mounted display positioned over the right eye. It is always on and hands-free, allowing responders to focus on their tasks. Responders' locations are always tracked by global positioning system (GPS), as part of the safety requirements. Using the built-in camera, responders can record and stream videos to dispatch. On the display, responders can visualize spatial and graphical information, which is difficult to convey verbally over the radio. Maps and navigation guide responders to objectives or fellow responders, increasing situational awareness and efficiency. The Recon Jet is extendable with numerous sensors by connecting to ANT+ peripherals. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.[32]

Figure 9: Recon Jet

Samsung Group

Samsung (South Korea) is a conglomerate headquartered in Seoul and was founded in 1938 as a trading company. The company is one of the world's largest producers of electronic devices. Products include consumer and industry electronics such as appliances, digital media devices, semiconductors, memory chips, and integrated systems.[33]

Samsung offers the **Galaxy** watch, which supports secure and standalone deployment for enterprise-level management capabilities while providing employees with a choice in size. With custom app and device configuration support, one can personalize it to meet the specific needs of their business and employees. This watch monitors heart rate, perception of fatigue and mood or energy levels. It is equipped with a GPS monitoring system to track location. This watch costs $349.99 USD. Information regarding specific deployment within the first responder community does not appear to be publicly available.[34]

Figure 10: Galaxy Watch

Intelesens Ltd.

Intelesens (United Kingdom) is a leading innovator in targeted vital signs monitoring. The company focuses on developing medical technology with a portfolio of intelligent, wearable, non-invasive, wireless vital signs monitoring devices for various settings. Intelesens has created a robust technology platform that is increasingly being used to improve patient care, reduce diagnosis times, and help deliver healthcare savings.[35]

Intelesens (United Kingdom) offers the **Bespoke ECG Electrodes**. The defibrillator electrodes use high quality components combined with smart handling design to ensure the highest operator confidence and performance. These electrodes are suitable for all ages, are time and cost efficient, and are designed for easy use. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.[36]

Figure 11: Intelesens Bespoke Electrodes

CJPS Medical Systems

CJPS Medical Systems (United States) was founded in 2007. CJPS Medical develops technology, products, and services in key medical device areas, including dialysis, mobility, respiratory care, monitoring, and infusion systems.[37]

CJPS Medical Systems offers the **Vital Point Patient Monitor**. This remote patient monitoring system connects patients, in the comfort of their own homes, to their health care provider's office. The small, single-unit device measures blood pressure, blood oxygen saturation, pulse rate, weight, glucose level, prothrombin time, temperature, fluid status, and collects electrocardiogram data. This device costs $2,400.00 USD. Information regarding specific deployment within the first responder community does not appear to be publicly available.[38]

Figure 12: CJPS Medical Vital Point Monitor

Bodytrak

Bodytrak (United Kingdom) is a small technology company focused on delivering solutions for health, wellness, and fitness. The company has targeted its technology toward several sectors including sport, defense, first response and healthcare. Bodytrak is a trademark of Inova Design Solutions Ltd.[39] Inova is a technology company specializing in wireless body sensing devices. Inova specializes in the research, design, development and commercialization of body sensing solutions for health and performance.[40]

Bodytrak offers a **Bodytrak** in-ear device that exploits the only body site from which all vital signs can be measured. From one small non-invasive, in-ear device, key vital sign parameters including core body temperature, heart rate, VO2 and motion (including fall detection) are measured continuously and sent in real-time to their powerful cloud-based analytics platform. From there, people can monitor how bodies react to the conditions they are in. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.[41]

Figure 13: Bodytrack

Dräger

Dräger (Germany) is an international leader in medical and safety technology and has been operating since 1889. The company's products are used in clinical, industrial and mining applications, as well as in firefighting or rescue services.[42]

Dräger offers the **Dräger Pac 6000**, a disposable personal gas detector that measures CO, H2S, SO2 or O2 reliably and precisely, even in the toughest conditions. The robust design, quick sensor response times, and a powerful battery ensure maximum safety for up to two years with virtually no maintenance required. This device can help first responders monitor the conditions they are entering to ensu*re safety. Information regarding price and specific deployment within the* first responder community does not appear to be publicly available.[43]

Figure 14: Dräger Pac 6000

Dräger offers the **Dräger Pac 6500** which is considered a reliable companion under tough conditions. The personal single-gas detection device measures CO, H2S, SO2 or O2 quickly and precisely. Quick sensor response times and a replaceable battery also ensure safety. This device can help first responders monitor the conditions they are entering to ensure safety. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.[44]

Figure 15: Dräger Pac 6500

Sper Scientific Direct

Sper Scientific (United States) was established in 1984. The company focuses on providing reliable environmental measurement instruments that assist with maintaining regulatory compliance and providing safer work environments.[45]

Sper Scientific (United States) offers the **Mini Environmental Quality Meter**. This meter is light weight, tiny in size with simple, one-hand, operation. They are perfect for workers whom need accurate information to properly access environmental conditions and make crucial decisions. This device reads air speed, senses airflow, etc. This device can be bought for $202.00 USD. Information regarding specific deployment within the first responder community does not appear to be publicly available.[46]

Figure 16: Sper Scientific Mini Environmental Quality Monitor

Nielsen-Kellerman Company

The Nielsen-Kellerman Company (NK) (United States) designs, manufactures and distributes a variety of products. These products focus on environmental and sports performance and include instruments such as Kestrel Weather & Environmental Meters, Kestrel Ballistics Meters, NK Electronics for Rowing and Paddling, and Blue Ocean Rugged Megaphones PA Systems.[47]

NK offers the **Kestrel 3000HS Heat Stress Meter** that monitors environmental conditions. This device will make sure that unsafe working conditions are avoided. This device measures relative humidity, dewpoint, wind chill and the heat stress index. The device is put to use by firefighters considering their lives depend on accurate weather data. This device is sold from the company for $149.00 USD.[48]

Figure 17: NK Kestral Heat Stress Meter

Envirolive

EnviroLive (Canada) provides turnkey solutions for monitoring. EnviroLive products work with existing wireless or wired communications systems to retrieve data. For applications used in areas with limited communications, Cloud-Connect and Cloud-Ready packages are available. EnviroLive provides monitoring solutions for areas including: air quality, water levels, weather, hazardous gas, air pollution, sound level, and heat stress.[49]

EnvrioLive (Canada) offers the **Heat Stress Monitoring System**. This sensor measures WGBT, humidity, humidex, and temperature. Further, this device has an alarm callout that sends notifications via SMS, Text, and/or voice. Data is accessible online via desktops, tablets, and mobile devices. A hosted-monitoring option and a data-push-to-SCADA option allows clients the flexibility of choosing the capability that suits their industrial operation. Information regarding price and specific deployment within the first responder community does not appear to be publicly available.[50]

Figure 18: Envirolive Heat Stress Monitoring System

Exercise/Fitness

Scosche, Industries

Scosche (United States) was founded in 1980 in California. It provides cutting edge, innovative accessories for a variety of needs including automotive, audio, switches, cables and transmitters. However, Scosche also offers a line of health and fitness, and portable electronics products.[51]

Scosche offers the **Rhythm24**. This device is a small waterproof armband worn near the elbow. The Rhythm24 has memory for up to 13 hours of training time, connects with nearly any other fitness device on the market through Bluetooth connection, has five heart rate zone indicators and provides real time feedback during activity. Further, the device has a long life battery allowing up to 24 hours of continuous use. This device accurately monitors, measures, records and transmits heart rate data over an extended period of time to maximize the user's workout. This device can be bought for $99.99 USD. Information regarding specific deployment within the first responder community does not appear to be publicly available.[52]

Figure 19: Scosche Rhythm24

Appendix A

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

All-Source Collection, Integration and Validation of Data		
Existing Solutions		
Solution	**Solution Provider(s)**	**Country**
Zephyr	Medtronic	United States
Hexoskin Smart Shirt	Hexoskin Inc	Canada
Recon Jet	Intel	United States
Galaxy Watch	Samsung	South Korea
Bodytrak	Inova Design Solutions Ltd	United Kingdom
Kestrel 3000HS Heat Stress Monitor	Nielsen-Kellerman Company	United States
BioHarness	RAE Systems	United States
Drager Pac 6000	Drager	Germany
Drager Pac 6500	Drager	Germany
Bespoke ECG Electrodes	Intelesens	United Kingdom
Mini Environmental Quality Meter	Sper Scientific	United States
Triage On Demand (TOD) Biosensor	5VS	United States
BioTrac Platform	FireHUD	United States

In-Development Solutions		
Solution	**Solution Developer(s)**	**Country**
Wearable System for Heat Stress Monitoring in Firefighting Applications	Polytehnica University	Romania

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.

- Wearable Medical Devices Market
  Market figures and a CAGR were available for the time period 2016 through 2021. A CAGR of 28.8 percent was used to estimate the revenue values for 2022 and 2023.
- Wearable Technology Market
  Market figures and a CAGR were available for the time period 2016 through 2022. A CAGR of 15.5 percent was used to estimate the revenue values for 2023.

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.
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.

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