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NEXT GENERATION FIRST RESPONDER CASE STUDY



Physiological Monitoring

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EXECUTIVE SUMMARY

The Department of Homeland Security (DHS) Science and Technology Directorate (S&T) launched the [Next Generation First Responder \(NGFR\) Apex program](#) in January 2015 as a strategic initiative to develop and integrate next-generation technologies with the goal of expanding first responder mission effectiveness and safety. The NGFR Apex program seeks to help tomorrow's first responders be better protected, connected and fully aware.

NGFR has conducted three integration demonstrations to assess how prototype technologies integrate to support the NGFR Apex program. The first demonstration in January 2016 was primarily a tabletop demonstration, and the second in May 2016 was a combined tabletop and field demonstration in a large urban area. For the third NGFR integration demonstration, the NGFR Apex program wanted to collaborate with a more rural community where cutting-edge technologies face a unique set of deployment challenges.

NGFR partnered with first responders in Grant County, Washington, to assess the capabilities of numerous NGFR technologies to support their public safety operations. This effort, known as the *Grant County – DHS Science and Technology Directorate Next Generation First Responder Apex Program Technology Experiment (TechEx)*, involved deploying a suite of technologies. This case study identifies and explains the technologies that were used in the TechEx, and public safety agencies can use this case study as an example of how agencies can monitor the physical exertion of their first responders by capturing and transmitting their physiological parameters.

Initial discussions with Grant County identified five areas as priority needs for the Grant County first responders:

- Geo-location of first responder vehicles and personnel on map displays at the Grant County Multi-Agency Communications Center (MACC), command posts and on smartphones.
- Wireless data service at the Gorge Amphitheatre concert venue, campgrounds and along the Columbia River valley using various broadband technologies, including cellular broadband [Long Term Evolution (LTE)], Wi-Fi and digital television [datacasting](#).
- Ability to view real-time video at the MACC, command posts, emergency management centers and other destinations when captured and streamed from small Unmanned Aircraft Systems (sUAS) or first responder smartphones.
- Capability to monitor first responders' physiological conditions and send the data wirelessly to the MACC and command post(s) for viewing using a visual "dashboard" on a monitor.
- Support for communications and information dissemination using a combination of county-owned land mobile radios (800 MHz P25), commercial mobile networks and a deployable government-band public safety broadband network (Band 14 LTE) for data communications.



After further discussions, extensive planning, site visits, an integration and testing event, and a dry run of the experiment, NGFR and Grant County conducted the TechEx on June 6 and 7, 2017. The TechEx involved the deployment of more than 50 first responders from multiple Grant County first responder agencies, as well as 15 S&T NGFR staff and support contractors.

The scenario-based event was executed using three operational scenario vignettes, illustrated in Figure 1:

- **Vignette A** functioned as a systems check of the new technologies. Each technology was tested for the corresponding responders and vehicles (as applicable).
- **Vignette B** involved tracking down two notional lost hikers who wandered down into the Columbia River gorge. One hiker fell off a cliff and broke a leg. Sheriff's deputies were sent down into the gorge to find the victims with a sUAS used to assist in finding the hikers. Once the hikers were located, the fire district responders were dispatched to perform a ropes rescue to transport the victim up the cliff to be treated by responders.
- **Vignette C** involved the report of a notional brush fire, which was located by the sUAS. Fire Districts 3 and 5 personnel were dispatched to fight the fire. Soon after, a notional altercation occurred at the nearby campground and deputies pursued the perpetrator.

Figure 1: Grant County First Responders During the NGFR TechEx



The TechEx scenario provided sufficient realistic opportunities to assess the various technologies' utility and integration with existing systems (technical and human). The scenario also provided opportunities for participating first responders to identify gaps and required enhancements for future NGFR events. The evaluation team was able to verify the NGFR system architecture implemented and configured in Grant County was easy to install, easy to use and provided capabilities that were valued by the first responders.

The NGFR Apex program and their partners provided physiological monitoring solutions to support the TechEx by incorporating two different systems for capturing the physiological data. These systems provided physiological data from the first responders and, in one case, sent the data to a dashboard for viewing by the incident commander, enabling better-informed operational decisions.



INTRODUCTION

Next Generation First Responder Apex Program

The Department of Homeland Security (DHS) [Science and Technology Directorate](#) (S&T) launched the [Next Generation First Responder \(NGFR\) Apex program](#) in January 2015 as a strategic initiative to develop and integrate next-generation technologies with the goal of expanding first responder mission effectiveness and safety. The NGFR Apex program seeks to help tomorrow's first responders be better protected, connected and fully aware. When firefighters, law enforcement officers and emergency medical services have enhanced protection, resilient communications and advanced situational awareness, they are better able to protect communities and make it home safely. The NGFR Apex program develops, adapts and integrates cutting-edge technologies using open standards, increasing competition in the first responder technology marketplace and giving responders more options to build the systems they need for their mission and budget.



NGFR Integration Demonstrations

NGFR has conducted three integration demonstrations to assess how prototype technologies integrate to support the NGFR Apex program. The [first demonstration](#) in January 2016 was primarily a tabletop demonstration, and the [second](#) in May 2016 was a combined tabletop and field demonstration in a large urban area. For the third NGFR integration demonstration, the NGFR Apex program reached out to a more rural community where cutting-edge technologies face a unique set of deployment challenges.

The NGFR Apex program is both modular—meaning responders can select different components that will easily integrate via open standards and interfaces—and scalable—meaning responders can build a large and complex system or a small and streamlined system, depending on their mission needs and budget. Throughout the course of the NGFR Apex program, it is essential to test both the modularity and scalability of the system with first responders, so that by the end of the program, responders will be able to build their own NGFR system from tested, integrated and demonstrated components that have already been proven in real-world environments.

NGFR Technology Experiment in Grant County

The DHS S&T NGFR Apex program partnered with the Grant County, Washington, Sheriff's Office to assess how NGFR technologies could improve the mission capabilities of Grant County public safety. The county, comprised of more than 2,700 square miles of river valleys, rolling hills and agricultural farmland, is decidedly rural, and Grant County responders have frequently struggled with poor communications coverage when supporting major events, managing wildland fires and coordinating multi-agency responses to large incidents.

The overarching objective for the event was to conduct a Technology Experiment (TechEx) in Grant County, Washington, in collaboration with Grant County public safety officials and first responders. The TechEx integrated several NGFR technologies to support an operationally-relevant, mission-based scenario centered on law enforcement and emergency response operations. The TechEx goals were to demonstrate the various technologies, assist Grant County in incorporating them into their daily operations and to gather responder feedback to help improve both individual NGFR technologies and the program as a whole.

Purpose of This Case Study

This case study describes NGFR's recent efforts to provide a method of capturing physiological data from first responders and displaying that data to first responders and incident commanders. This study identifies and explains the technologies used in the TechEx and presents a case study for public safety agencies as an example of how to implement physiological monitoring to improve first responder monitoring and resource management.



TechEx OVERVIEW

Background

The NGFR Apex program and Grant County partnership resulted in the *Grant County – DHS S&T NGFR Technology Experiment*. The two-day experiment was held in and around Grant County's Gorge Amphitheatre, a popular music venue and campsite surrounded by open farmland and canyons. The venue draws crowds that increase the county's population by 30,000—a 30 percent increase from Grant County's regular 93,000 residents—on weekends during summer events, and poses a strain on existing responder communications capabilities. This particular venue provided the optimal environment to test various NGFR technologies during the TechEx.

Objectives

The overarching objective for the event was to conduct a TechEx in Grant County, Washington, in collaboration with Grant County public safety officials and first responders. The TechEx was based upon the integration of NGFR technologies to support an operationally-relevant mission-based scenario centered on law enforcement and emergency response operations. The goal of this TechEx was to demonstrate the various technologies and assist Grant County in integrating them into their daily operations and existing systems. By gathering feedback from first responders on the technologies and how they did or did not augment Grant County emergency response capabilities, the NGFR Apex program sought to improve the program's alignment with rural and urban responder needs.

Figure 2: Grant County Command Center Monitors TechEx Activities



Requirements

Initial discussions with Grant County in December 2016 resulted in the identification of the following technology requirements for the TechEx:

- **Extended and Increased Communications:** Provide a broadband ([Long Term Evolution (LTE)]) communications infrastructure that works with both existing commercial LTE providers and with a temporary public safety Band 14 LTE system to provide connectivity for the various technologies being demonstrated.
- **Video Capture, Storage and Distribution:** Capture video from responders' smartphones, small unmanned aerial systems (sUAS) also known as drones and other devices to forward to a centralized video storage service; and distribute captured video from the centralized service to responders, incident commanders (IC) and the Grant County Multi-Agency Communications Center (MACC).
- **Location Tracking:** Track the locations of first responder vehicles and smartphone-equipped first responders on map displays at the MACC, command posts and on smartphones.
- **Responder Physiological Monitoring:** Monitor first responders' heart rate and respiration rate data to send to the MACC and/or command post.
- **Situational Awareness:** Share first responder location, physiological data and captured video to the MACC, command posts, emergency management and other destinations for display on dashboards and maps.



TechEx Activities

Site Survey

NGFR and their primary support partners, Johns Hopkins University Applied Physics Lab (JHU APL) and the U.S. Department of Commerce National Institute of Standards and Technology's (NIST) Public Safety Communications Research (PSCR) division, performed a site survey of Grant County in February 2017, which specifically focused on the technology currently in use by the Sheriff's Office, the fire districts and at the Gorge concert venue. This survey enabled the NGFR TechEx team to identify the types of technologies that would fulfill the requirements and objectives of the TechEx. As part of the survey, the NGFR TechEx team developed an "as-is" configuration of Grant County's communications infrastructure and capabilities for use as a baseline.

Integration Testing

Once the technologies were identified and preliminary development and integration was complete, NGFR and their partners met at PSCR in Boulder, Colorado, in April 2017 to perform further integration testing. This three-day session enabled technical participants to connect all technologies in both laboratory and radio transmitter test-range field locations to test the integration of the components as a system of systems.

Dry Run

Soon after the Boulder integration testing, the team reassembled at the Gorge concert venue in Grant County to install antennas, test coverage and perform a dry run of the scenario vignettes. This testing assisted the participants in finalizing the systems, testing the new capabilities in the actual event setting and preparing for the actual TechEx.

Technical Experiment

The TechEx was conducted June 6-7, 2017. It was conducted using an operational scenario with three vignettes:

- **Vignette A** functioned as a systems check of the new technologies. Each technology was tested for each of the corresponding responders and vehicles (as applicable).
- **Vignette B** involved tracking down two notional lost hikers who wandered down into the Columbia River gorge. One hiker fell off a cliff and broke a leg. Sheriff's deputies were sent down into the gorge to find the victims with an sUAS used to assist in finding the hikers. Once the hikers were located, the Fire District responders were dispatched to perform a ropes rescue to transport the victim up the cliff to be treated by responders.
- **Vignette C** involved the report of a notional brush fire, which was located by the sUAS. Fire Districts 3 and 5 personnel were dispatched to fight the fire. Soon after, a notional altercation occurred at the nearby campground, and deputies pursued the perpetrator.

The TechEx scenario provided sufficient realistic opportunities to assess the various technologies' utility and integration with existing systems (technical and human). The scenario also provided opportunities for the first responder to identify gaps and required enhancements to be addressed in future NGFR events and technical development. The evaluation team was able to verify the architecture implemented and configured in Grant County was easy to install, easy to use and provided capabilities that were valued by the first responders.

Physiological Monitoring Architecture

Based upon the site visits, the baseline assessment and ongoing collaboration with Grant County, NGFR and their partners developed two versions of a physiological monitoring architecture that aligned with Grant County first responders' expectations and needs. Figure 3 shows the architecture provided by IS4S and Figure 4 shows the architecture used by ArdentMC for their physiological monitoring solutions.

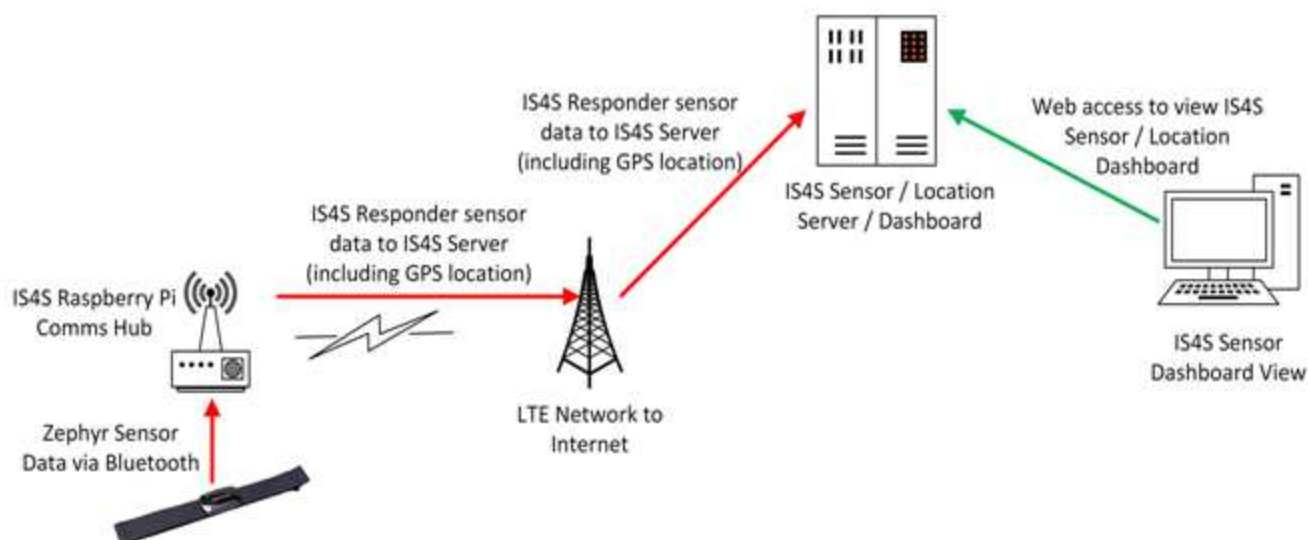


Figure 3: IS4S Physiological System Architecture

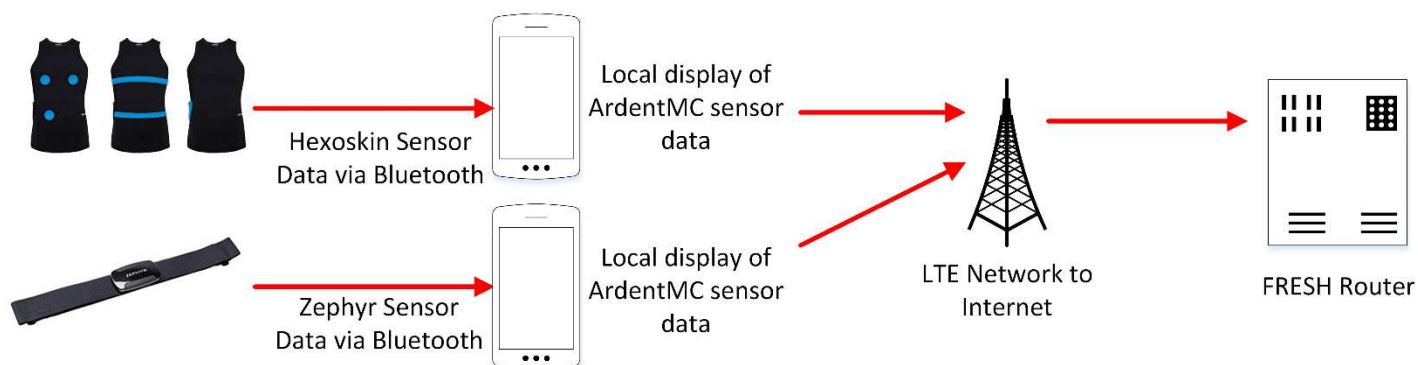


Figure 4: ArdentMC Physiological Monitoring Architecture

Grant County Constraints and Issues

There were several constraints/issues influencing the configuration and use of the physiological monitors:

1. Due to budgetary limitations, the sensors used were commercially available consumer-grade devices that captured heart and respiration rate and had Bluetooth connectivity. This limited the type and quality of the physiological readings that were sensed and transmitted.
2. Due to potential issues with health information privacy and associated Health Insurance Portability and Accountability Act (HIPAA) regulations, neither solution logged or stored the physiological data; it was displayed and then discarded.
3. Only one of the system integrators, IS4S, was able to transmit the physiological readings to a centralized dashboard for viewing by other first responders, incident commanders, etc. The other integrator, ArdentMC, only provided physiological data to each corresponding first responder's smartphone for viewing.



Physiological Monitoring Solutions Implemented

It is crucial for public safety agencies to maintain effective real-time situational awareness in the execution of their various law enforcement, emergency care and fire safety missions. Part of situational awareness is knowing when first responders are experiencing excessive physical stress indicated by increased heart or respiration rate. First responders have indicated (in Project Responder 4) that physiological monitoring is a key unfulfilled capability.

The DHS S&T NGFR Apex Project presents the following information regarding physiological monitoring of first responders as implemented for the Grant County Technical Experiment.

Physiological Monitoring Requirements

In order to develop and implement an effective first responder physiological monitoring system, NGFR and Grant County assessed their requirements for monitoring first responders' physiological data, and determined the existing capabilities of Grant County's internal and commercial infrastructure to support the collection, transmission and display of the physiological information.



Which first responders to monitor – Grant County determined they wanted to monitor both firefighters and Sheriff's Deputies as the scenario vignettes were executed.

What parameters to monitor – Grant County and NGFR decided heart rate and respiration rate were the two most

important first responder physiological parameters to monitor.



Who should monitor the parameters – Grant County identified first responders, incident commanders and the Multi-Agency Communications Center (MACC) as the entities that should monitor first responder physiological parameters.

Baseline Grant County Physiological Monitoring Environment

Once Grant County determined their physiological monitoring requirements, NGFR and Grant County evaluated the existing environment, including the communications infrastructure, available monitoring equipment and existing physiological monitoring devices used by Grant County first responders.

Existing Communications Infrastructure – The commercial LTE coverage in Grant County was determined to be adequate for use in transferring physiological data from first responders to incident commanders and the MACC. Grant County determined they would not use Land Mobile Radio (LMR) as the transfer medium for physiological data, even though they have an 800 MHz P25 LMR system.

Existing First Responder Technology – Some deputies and firefighters had personal fitness monitors (e.g., Fitbits, Apple Watches, Samsung Fit2, Garmin Forerunner, etc.); however, no standardization of devices, data sets or interfaces could be leveraged for use.

Candidate Monitor Devices – NGFR identified two possible devices for use as physiological monitors. Both devices used Bluetooth for connectivity to a smartphone or Raspberry Pi, and both measured heart rate, respiration rate and wearer activity. The two devices chosen were:

1. Hexoskin – a data transmission device tucked into a pocket of a specialized sensor-containing t-shirt – <https://www.hexoskin.com/>.
2. Zephyr – a sensor attached to a chest band – <https://www.zephyranywhere.com/>.



Physiological Monitoring Solution Tested During the TechEx

IS4S Comms Hub and Dashboard

The IS4S Comms Hub system used a Raspberry Pi computer with Bluetooth connectivity as the interface to the Zephyr sensors. The Raspberry Pi on each of four first responders then transmitted the physiological data (and GPS location) via Wi-Fi to a smartphone, which passed the data via LTE and the Internet to the central IS4S dashboard (separate from the ESRI Ops Dashboard) to display each first responder's location and physiological data on a map of the area. The information on the IS4S dashboard was viewable through a Web browser and available to any device with access to the Internet.

ArdentMC Sensor Interface and Watchtower Display

The ArdentMC sensor interface connected the Hexoskin and Zephyr devices to smartphones via Bluetooth and displayed the physiological data on an ArdentMC smartphone app. While the data was forwarded to the FRESH Message Router, there was insufficient time to incorporate this data into the ESRI Ops Dashboard.

RESULTS

The TechEx proved to be successful in demonstrating both the advantages of the systems and their shortfalls as currently implemented. All of the requirements were fulfilled with the delivered capabilities, but with varying degrees of success. The input from Grant County first responders was overwhelmingly favorable. The first responders were very pleased to be able to view video from the drone and other first responders on their smartphones. The incident commander and MACC staff greatly appreciated the capability to monitor first responder heart and respiration rates, but they were also concerned about the inaccuracy of the readings. A complete [TechEx After Action Report](#) is available online.

Additional sources are provided in the References and Recommended Reading section.



IMPLEMENTATION FOR YOUR AGENCY

The NGFR TechEx demonstrated physiological monitoring of first responders to improve first responder safety. How can your agency apply this case study and best practices to improve your capabilities? The NGFR Apex program has developed the following checklist to assist your agency with planning how to implement physiological monitoring.

Physiological Monitoring Checklist

Identify Physiological Monitoring Requirements and Needs

- ☐ Physiological Data Sources – From what first responders does the agency want to capture data:
 - ☐ Law enforcement?
 - ☐ Firefighters?
 - ☐ EMTs?
 - ☐ Other?
- ☐ Physiological Data Destinations – To whom does the agency want to send the data:
 - ☐ First responders?
 - ☐ Incident commanders?
 - ☐ Command centers?
 - ☐ Medical facility staff?
 - ☐ Other?
- ☐ Physical Data Types – What physiological data does the agency want to monitor:
 - ☐ Heart rate?
 - ☐ Respiration rate?
 - ☐ Blood pressure?
 - ☐ Hydration?
 - ☐ Blood sugar?
 - ☐ Oxygenation?
 - ☐ Skin temperature?
 - ☐ Core temperature?
 - ☐ Other?
- ☐ Physiological Data Purposes:
 - ☐ Continuous monitoring?
 - ☐ Out-of-range alerting?
 - ☐ Distress alerting?
 - ☐ Other?

Identify Current Agency Physiological Monitoring Capabilities

- ☐ Existing Physiological Monitoring Devices – What existing physiological monitoring devices do the first responders or the agency have:
 - ☐ Fitbit?
 - ☐ Hexoskin?
 - ☐ Zephyr?
 - ☐ Apple Watch?
 - ☐ Samsung Fit2?
 - ☐ Garmin Forerunner?
 - ☐ Other?



- ☐ Existing Physiological Monitoring Data Standards – What are the data standards currently in use or available for use for the agency’s physiological monitoring devices:
 - ☐ Open Geospatial Consortium (OGC) Sensor Markup Language (ML) (OGC 12-000)?
 - ☐ National Information Exchange Model (NIEM) Emergency Management Loose Coupler (EMLC) Information Exchange Package (IEP)?
 - ☐ Observation and Measurement (O&M) Extensible Markup Language (XML) (OGC 10-025r1)?
 - ☐ Sensor Web Enablement (SWE) Common Data?
 - ☐ Health Level Seven (HL7) Version 2 (V2)?
 - ☐ Other?
- ☐ Existing Physiological Monitoring Applications – What existing physiological monitoring applications (for smartphones) do the first responders or the agency have:
 - ☐ Fitbit?
 - ☐ Hexoskin?
 - ☐ Zephyr?
 - ☐ Apple Watch?
 - ☐ Samsung Fit2?
 - ☐ Garmin Forerunner?
 - ☐ Other?
- ☐ Existing Physiological Monitoring Dashboards – What existing physiological monitoring dashboards does the agency have:
 - ☐ Smartphone app only?
 - ☐ Centralized multi-sensor app?
 - ☐ Other?

Identify Current Agency Infrastructure Capabilities

- ☐ LTE Coverage – Does the agency have adequate LTE coverage:
 - ☐ Over the entire jurisdiction?
 - ☐ Only over parts of the jurisdiction?
- ☐ Wi-Fi Coverage – Does the agency have adequate Wi-Fi coverage:
 - ☐ Over the entire jurisdiction?
 - ☐ Only over parts of the jurisdiction?
 - ☐ Only at limited hot-spots?
- ☐ LMR Coverage / Capability – Does the agency have LTE capability:
 - ☐ Adequate coverage?
 - ☐ Digital capability?
 - ☐ Adequate capacity?
 - ☐ Other?
- ☐ Smartphones – Do the first responders have smartphones:
 - ☐ Smartphones issued by the agency?
 - ☐ Personal smartphones only?
 - ☐ No smartphones?

Identify Solutions

- ☐ Physiological sensor – What sensor to use:
 - ☐ Fitness tracker?
 - ☐ Physiological sensor?
 - ☐ Other?



- ☐ Sensor data:
 - ☐ Heart rate?
 - ☐ Respiration rate?
 - ☐ Blood pressure?
 - ☐ Hydration?
 - ☐ Blood sugar?
 - ☐ Oxygenation?
 - ☐ Skin temperature?
 - ☐ Core temperature?
 - ☐ Other?
- ☐ Sensor controller – To what device will the sensor connect:
 - ☐ Smartphone?
 - ☐ Single board computer (e.g., Raspberry Pi)?
 - ☐ Other?
- ☐ Communications Link:
 - ☐ LTE?
 - ☐ Wi-Fi?
 - ☐ Combined Wi-Fi / LTE?
 - ☐ LMR data?
 - ☐ Other?
- ☐ Physiological Dashboard:
 - ☐ Smartphone application?
 - ☐ Centralized multi-user application?
 - ☐ Other?

Determine Necessary Changes and Execute

- ☐ Procurement of software and hardware.
- ☐ Installation of components.
- ☐ Configuration of devices and associated applications.
- ☐ Training support personnel on maintenance of the devices and applications.
- ☐ Training the first responders in use of the systems.

Technical Implementation Issues to Consider

Physiological Sensor Accuracy

The sensors used in the TechEx lacked the type of accuracy first responders need. Anecdotal data indicates the sensor readings sometimes did not reflect the actual physiological conditions of the first responder. Table 1 shows the detected heart rate versus the actual heart rate for four first responders observed during the TechEx.

User	Hexoskin/Zeyphr Heart Rate	Actual Heart Rate
1	162	110
2	170	120
3	94	94
4	129	100

Table 1: Physiological Sensor Heart Rate Readings versus Actual Heart Rate



More accurate sensors are available, but at considerably higher cost. If sensors were to be used for clinical assessment of first responders' physiological data, they would require approval as medical devices by the Food and Drug Administration – a lengthy and expensive process. Until low-cost, accurate FDA-approved physiological sensors are available, monitoring first responder physiological data will have limited effectiveness.

Physical Sensor Ergonomics

The ergonomics of the two sensors employed was not optimal. According to the first responders, the Hexoskin fabric did not “breathe” well and was therefore uncomfortable to wear. The Zephyr chest band did not exhibit the same problem, but did restrict normal first responder physical movements and did not report physiological data unless the chest strap was very tight.

Physiological Data Monitoring

Providing continuous physiological readings to first responders, an incident commander or a dispatcher could easily overwhelm or impede the recipient due to information overload. Consideration should be given to reducing the data flow to an “exception handling” solution, where upper and lower limits for the data are set and the recipient is alerted if the physiological readings are outside those limits – in an “out of tolerance” condition.

Bluetooth Pairing

One issue noted with the Bluetooth connectivity of the sensor devices was that smartphones tried to connect with all Bluetooth-equipped sensors within range, instead of the appropriate first responder's sensor. First responders had to move away from each other in order to pair their sensors correctly to their smartphones via Bluetooth the first time.

SUMMARY

There are multiple ways for an agency to implement first responder physiological monitoring depending upon requirements and current capabilities. Physiological monitoring can provide valuable health and exertion data to incident commanders and public safety leadership, increasing their situational awareness and contributing to first responder health and safety.

If your agency finds this S&T NGFR case study useful for improving your physiological monitoring capabilities, the S&T NGFR Apex program would greatly appreciate your feedback. Please contact the S&T NGFR team with stories from the field, questions or comments by emailing NGFR@hq.dhs.gov.





REFERENCES & RECOMMENDED READING

DHS Science and Technology Directorate

Next Generation First Responder Apex Program (<https://dhs.gov/ngfr>)

This website provides NGFR Apex program descriptions, updates and knowledge products.

NGFR TechEx After Action Report, October 2017 (<https://www.dhs.gov/publication/st-frg-grant-county-dhs-st-ngfr-apex-program-techex-after-action-report>)

This document thoroughly describes the planning, execution and results of the NGFR TechEx.

NGFR TechEx Playbook, June 2017 (available upon request from NGFR@hq.dhs.gov)

This document is the guide used to execute the NGFR TechEx in Grant County.

Personal Physiological Monitoring Systems, January 2017 (https://www.dhs.gov/sites/default/files/publications/PSM-TN_0117-508.pdf)

Wireless Physiological and Environmental Monitoring (WiPEM) Fact Sheet, December 2015
(<https://www.dhs.gov/sites/default/files/publications/R-Tech%20WiPEM%20One%20Pager.pdf>)

First Responder Physiological Monitoring Fact Sheet, August 2016
(https://www.dhs.gov/sites/default/files/publications/Physiological-Monitoring_v2-508.pdf)

Pacific Northwest National Laboratory

Remote Physiological Health and Status Monitoring of First Responders: Promises, Practicalities, and Prospects, February 2015, PNNL-24112
(<http://nwrtpc.pnnl.gov/PDFs/RemotePhysiologicalHealthandStatusMonitoringofFirstRespondersR13.pdf>)

PubMed

Physiological monitoring in firefighter ensembles: wearable plethysmographic sensor vest versus standard equipment. February 2010. Coca AI, Roberge RJ, Williams WJ, Landsittel DP, Powell JB, Palmiero A.
(<https://www.ncbi.nlm.nih.gov/pubmed/20017053>)

This article is a study of data transfer and the accuracy of wearable sensor vests for monitoring firefighters.

Integrating the Healthcare Enterprise, International

Integrating the Healthcare Enterprise (IHE) is a standards body for healthcare interoperability. IHE Profiles provide a common language for purchasers and vendors to discuss the integration needs of healthcare sites and the integration capabilities of healthcare IT products. They offer developers an implementation path for communication standards supported by industry partners and documented, reviewed and tested. (<http://www.ihe.net/Profiles/>)

Health Level Seven, International

Medical Data Transfer Standard “HL7 V2” is a standard for data exchange of clinical data between systems.
(http://www.hl7.org/implement/standards/product_brief.cfm?product_id=185)