NEXT GENERATION FIRST RESPONDER
CASE STUDY
SENSORS

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Homeland Security
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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 to help tomorrow's first responder become better protected, connected and fully aware. DHS S&T has held a series of NGFR Integration Demonstrations to incrementally test and evaluate interoperable technologies currently in development. These demonstrations have evolved from tabletop integrations to field exercises with partner public safety agencies and have involved increasingly complex technology integration.

DHS S&T partnered with Harris County, Texas, and the City of Houston to host the first major urban NGFR Integration Demonstration in December 2018. The NGFR – Harris County Operational Experimentation (OpEx) involved testing a variety of integrated technologies in an operational environment with participating first responders from Harris County, City of Houston, U.S Coast Guard (USCG), SouthEast Texas Regional Advisory Council, Cy-Fair Volunteer Fire Department and the Atascocita Fire Department.

During the OpEx, Harris County, Houston-area responders and federal partners used integrated responder technologies to enhance their mission capabilities in a hazardous materials (HAZMAT) scenario that included a simulated gas leak from a USCG Cutter (USCGC) vessel in the Port of Houston. Together, responders and DHS S&T evaluated how DHS-funded and commercial technologies integrated with existing public safety systems using open standards and how those integrated capabilities enhanced emergency communications, increased operational coordination, improved responder safety and augmented situational awareness.

The NGFR – Harris County OpEx included 23 different DHS and industry-provided technologies, including six Internet of Things (IoT) sensors, five situational awareness applications and platforms, and live-stream video feeds. Additional OpEx technologies included body-worn cameras, deployable communications systems, and real-time data aggregation and access across multiple agencies.

This case study identifies and explains the IoT sensor technologies that were used in the OpEx and discusses how nationwide public safety agencies could implement sensors to improve responder safety and effectiveness.

DHS S&T's technical team, DHS-funded and industry partners provided the sensors and integration work to support the OpEx, incorporating the feeds from multiple sensors to multiple situational awareness applications. The OpEx scenario provided sufficient realistic opportunities to assess the technologies and allowed participating responders to identify gaps and required enhancements to improve the participating technologies.

Figure 1. Participants Conduct Simulated Emergency Response Activities During the NGFR - Harris County OpEx

DHS S&T and partners brought new sensor capabilities to Houston-area responders. By integrating data from multiple sensor types into unified situational awareness applications, the NGFR Apex program enhanced operational communications, increased operational coordination, improved responder safety, and augmented situational awareness. The OpEx demonstrated that the first responders, incident commanders and emergency managers were able to access real-time sensor information and alerts during the scenario by interacting with the various situational awareness platforms provided for the OpEx.

Administrative and Handling Instructions

The title of this document is the "Next Generation First Responder Case Study: Sensors." This document provides public safety agencies with an overview of how DHS S&T incorporated IoT sensors during the NGFR – Harris County OpEx and provides some areas that an agency may consider if they choose to implement the capability within their organization. All preparation and documentation for the NGFR – Harris County OpEx is unclassified.

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If you have any questions about this case study, or to request more information about the NGFR – Harris County OpEx, please contact NGFR@hq.dhs.gov. Public release of information is at the discretion of DHS S&T.

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INTRODUCTION

Next Generation First Responder Apex Program

The Department of Homeland Security (DHS) Science and Technology Directorate (S&T) works with America's first responders to ensure they are more effective and safer—regardless of the hazards they face. DHS S&T develops and adapts innovative technologies that help first responders make communities more secure and resilient, because homeland security truly starts with hometown security.

The Next Generation First Responder (NGFR) Apex program is a five-year program that began in January 2015 and is part of a longer-term DHS S&T commitment to envision and assist the responder of the future. The NGFR Apex program works to make responders better protected, connected and fully aware by developing, adopting and integrating cutting-edge first responder technologies using open standards. This complex, multi-disciplinary program consists of a diverse but related portfolio of projects that span from basic research to advanced technology development, and an initiative to define a common set of open standards for technology integration. These open standards enable industry partners to develop standards-based solutions that easily plug-and-play into an interoperable responder ecosystem, including legacy systems. This approach opens doors to industry while lowering costs and increasing choices for public safety organizations, helping them rapidly adapt to changing environments and evolving threats as they secure communities nationwide.

NGFR Integration Demonstrations

Since 2016, DHS S&T has held a series of NGFR Integration Demonstrations to incrementally test and evaluate interoperable technologies currently in development. These demonstrations have evolved from tabletop integrations to field exercises with partner public safety agencies, including the rural 2017 Grant County—DHS S&T NGFR Apex Program Technology Experiment. This case study highlights the efforts, lessons-learned and guidance from the NGFR – Harris County Operational Experimentation (OpEx) that was held in December 2018 in Houston, Texas, to demonstrate the interoperability of DHS S&T and industry-developed responder technology and increase community resilience.

DHS S&T has incorporated the results and responder feedback from the NGFR Integration Demonstrations into the NGFR Integration Handbook, which outlines a standards-based environment that enables commercially-developed technologies to integrate with existing first responder infrastructure. Using the lessons learned and responder feedback from these integration demonstrations, DHS S&T has also produced materials to help public safety agencies implement new technologies that address their operational priorities, such as the NGFR Case Study series, which this document is part of.

NGFR Operational Experimentation in Harris County, Texas

DHS S&T collaborated with public safety agencies from Harris County and the Houston area to host the NGFR – Harris County OpEx from December 4-5, 2018, at the Port of Houston. Participating agencies included Harris County (Fire Marshal's Office, Sheriff's Office Marine Unit, Office of Homeland Security and Emergency Management, Central Technology Services, and Community Emergency Response Team), the City of Houston (Fire Department, Police Department Marine Unit, and Information Technology Services), Port of Houston Authority (Emergency Management, Fire Department, Police Department), SouthEast Texas Regional Advisory Council, Cy-Fair Volunteer Fire Department,

Atascocita Fire Department, U.S. Coast Guard Sector Houston-Galveston, DHS Federal Emergency Management Agency's Integrated Public Alert and Warning System Office, and DHS Cybersecurity and Infrastructure Security Agency's Emergency Communications Division.

The goal of this OpEx was to integrate and demonstrate a variety of cutting-edge responder technologies, assist Houston-area response organizations in incorporating them into their daily operations, gather responder feedback to help improve both individual DHS-funded and industry technologies, and demonstrate the value of the NGFR Apex program. During the OpEx, Houston-area responders and federal partners used integrated responder technologies to enhance their mission capabilities in a HAZMAT and mass casualty incident response scenario in the Houston Ship Channel. Together, responders and DHS S&T evaluated how selected S&T-developed and commercial technologies integrated with existing public safety systems using open standards and how those integrated capabilities enhanced emergency communications, increased operational coordination, improved responder safety and augmented situational awareness.

Purpose of this Case Study

This case study describes how DHS S&T integrated sensors during the NGFR – Harris County OpEx, taking real-time sensor data and displaying it on unified situational awareness applications to give the Incident Commander, command staff and first responders the right information at the right time. It provides an overview of the systems used, the challenges encountered and the solution implemented for the OpEx, as well as considerations that any public safety agency should think through if they intend to implement IoT sensors for their organization.

OpEx OVERVIEW

OpEx Objectives

DHS S&T hosted the OpEx to validate and advance the Next Generation First Responder Apex program, as well as benefit Houston-area public safety and technology provider partners. The OpEx integrated NGFR technologies to support an operationally-relevant, mission-based scenario centered on HAZMAT and mass casualty response operations. The goal of this OpEx was to demonstrate the capabilities of new technologies and provide a proof of concept to participating responders to illustrate how the technologies could be incorporated into daily operations and existing systems. By gathering feedback from first responders on the technologies and how they did or did not augment public safety emergency response capabilities, the NGFR Apex program seeks to better ensure new technologies fully meet responder needs.

Figure 2. Atascocita and Cy-Fair Paramedics connect physiological sensors to an OpEx "patient" prior to transport

OpEx Requirements

Initial discussions with Harris County resulted in the identification of the following technology requirements for the OpEx:

- Geo-location of first responder personnel in three dimensions on map displays provided to the Incident Commander, the command staff and on smartphones carried by responders.

- Capability to monitor patients' physiological condition and send the data wirelessly to the Incident Commander and command staff for viewing using a visual "dashboard" on a monitor and/or smartphone.
- Remote monitoring of HAZMAT using body-worn gas sensors transmitting alerts to the Incident Commander and command staff.
- Integration of all sensor feeds into one data feed provided to multiple situational awareness applications, especially the two existing applications in place or planned for use by Harris County and the Port of Houston (Intrepid Response and AVERT C2, respectively).

DHS Core Capabilities Alignment

The NGFR – Harris County OpEx was shaped around critical requirements identified by operational partners from Harris County, the City of Houston, Port of Houston Authority, U.S. Coast Guard, SouthEast Texas Regional Advisory Council, Cy-Fair Volunteer Fire Department and Atascocita Fire Department. These requirements included helping fill gaps identified during the response to Hurricane Harvey in 2017, particularly gaps around information sharing and multi-jurisdictional coordination. The planning process included joint identification of OpEx objectives and targeted DHS Core Capabilities, which included:

- Operational Communications;
- Operational Coordination;
- Environmental Response/Health and Safety;
- Intelligence and Information Sharing;
- Access Control and Identity Verification;
- Mass Search and Rescue Operations;
- On Scene Security, Protection and Law Enforcement;
- First Responder Safety; and
- Situational Awareness.

OpEx technologies were selected to meet these Core Capabilities and the scenario was developed to test the technologies and the associated operational capabilities.

Figure 3. A DHS Data Collector Observes the Harris County HAZMAT Team During the OpEx

OpEx Scenario

The OpEx 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 to improve the participating technologies. The evaluation team was able to verify that the NGFR system architecture implemented and configured at the Port of Houston was easy to install, easy to use and provided capabilities that were valued by the first responders.

The NGFR – Harris County OpEx consisted of an operational scenario divided into three vignettes:

- **Vignette A**: A HAZMAT spill occurs on USCGC Hatchet and the resulting gas cloud also affects the civilian vessel, the M/V Sam Houston, following in its wake. The vessels moor across Buffalo Bayou and HAZMAT teams are activated from the Port of Houston, Harris County, and the City of Houston, as well as EMS units from the City of Houston, Atascocita Fire Department and the Cy-Fair Volunteer Fire Department. Harris County and the City of Houston marine units respond, as well as the Port of Houston Fireboat 1 and a USCG Response Boat Small (RB-S). All HAZMAT

and marine units arrive on scene at the Sam Houston Pavilion and the Battalion Chief from the Port of Houston establishes Incident Command to evaluate the situation.

- **Vignette B**: The Harris County HAZMAT crew sets up a decontamination station at the Sam Houston pavilion, boards the M/V Sam Houston, and starts evaluating the passengers and crew. HAZMAT crews from the Port of Houston and City of Houston board Fireboat 1 and are transported across the bayou to USCGC Hatchet. They board the vessel to evaluate the crew and identify the source and nature of the HAZMAT spill. They also note that one of the crewmembers is unaccounted and is assumed to have fallen overboard prior to mooring.
- **Vignette C**: Victims from civilian vessel M/V Sam Houston undergo technical decontamination, triage and treatment, and are prepared for transport. Victims from USCGC Hatchet undergo gross decontamination and are then transported by Fireboat 1 over to the pavilion, where they undergo technical decontamination, triage and treatment. The USCG crew and a helicopter search for and find the missing crewman in the bayou, the RB-S crew retrieves him and returns him to the pavilion for decontamination, triage and treatment.

OpEx Technologies

DHS S&T worked with federal, industry and on-contract performers to provide 23 technologies, many of which were integrated to increase information sharing and situational awareness during the OpEx. DHS S&T and partners used data and alert standards to facilitate technology integration, including the Sensor Things server running their Open Geospatial Consortium (OGC) standard Application Program Interface (API), and Message Queuing Telemetry Transport (MQTT). Full descriptions of all OpEx technologies are available in the NGFR – Harris County OpEx Playbook and After Action Report listed in the References and Recommended Reading section. Note that the following descriptions were current as of the NGFR – Harris County OpEx in December 2018, and that throughout this document, technologies are frequently referred to by the name of the company rather than the name of the technology. OpEx technologies relevant to this case study include:

Ardent Management Consulting, Inc.

Vortex Router with the Esri Ops Dashboard

The Esri Ops Dashboard is an Esri-based situational dashboard which uses Esri Portal and ArcGIS awareness to display and help visualize the data collected in the Vortex Router from both personnel and vehicles for use in emergency situations. The Vortex Router aggregates and translates messages encoded with the Emergency Data Exchange Language (EDXL) Distribution Element (DE) standards and uses a REST API to allow for easy third-party integration and to encourage interoperability. Ardent Management Consulting, Inc. (Ardent MC) was funded by DHS S&T for this technology.

ARES Security Corp.

AVERT C2

AVERT C2 is an intelligent command and control platform that provides collaborative situational awareness by allowing each user to view and share the information sources and layers they need to understand and manage events as they unfold. AVERT C2 ingests and visualizes data from virtually any sensor—including chemical sensors, biometric sensors, cameras, radar, access control and alarm systems—to manage all security and response information through a single user interface.

Centrex Solutions LLC

Nightjar

The Nightjar Platform connects devices with systems and people, over a variety of long-range, low-power wireless technologies, allowing connectivity beyond cellular coverage areas. During the OpEx, first responders will be using Nightjar handheld, wearable and vehicle-mounted flammable gas sensors.

Haystax, a Fishtech Group Company

Haystax Constellation

Haystax Constellation for safety and security helps first responders prepare and respond with confidence, using a cloud-based platform for early threat detection, situational awareness and information sharing. Haystax Constellation gives first responders advanced analytics to automatically score the highest-priority threat signals and rapidly deliver them to the right people at the right time and provides a tightly-integrated ecosystem of web and mobile apps that enables users to manage their critical assets and respond effectively to incidents and natural hazards.

Integrated Solutions for Systems, Inc. (IS4S)

Communication Hub

The Communication Hub (CommsHub) is a body-worn, smart router that interconnects multiple communications systems (e.g., LMR, LTE, FirstNet) with the variety of sensors and electronics (e.g., location, vitals) worn or carried by the user. It intelligently, efficiently, securely and resiliently routes data between first responders and commanders using the best available communication link, removing the burden of handling increasing amounts of data, so first responders can focus on the task at hand. IS4S was funded by DHS S&T under the Small Business Innovation Research program for this technology.

Zephyr™ Performance Systems

IS4S brought this commercial-off-the-shelf product, which is produced by Medtronic, to the OpEx to test out additional physiological monitoring capabilities. The Zephyr physiological monitoring sensor is attached to the responder via a strap around the chest, which can monitor core body temperature, body positioning and stress levels.

Intrepid Networks, LLC

Intrepid Response

Intrepid Response is a mobile application that enables enhanced situational awareness by providing live responder locations and static locations of interest with a simple user interface. Open API architecture provides integration capability for higher level command and control tools or other platforms.

Keys Net LLC

Keys Internet of Things (IoT) Watch App

With the Keys IoT Watch App, first responders can leverage the devices they already own to provide location, heart rate and other sensor data into their current operational systems, as well as receive incident alerts (visual/audio/vibration), select sensor data and view an incident/team map from their smart watch. Keys IoT Watch App is a software-based solution that utilizes mass-market consumer wearables (such as the Apple Watch) to both send and receive location, sensor data, and alert notifications. Keys Net LLC was previously funded by DHS S&T for this technology.

N5 Sensors, Inc.

Compact Multi-Gas and Particulate Matter Detector

A compact, low-cost gas and particulate detector leveraging N5's patented chip-scale nanoengineered gas sensor technology. It provides real-time detection of multiple toxic and fire gases along with particulate matter counts in a wide range of environmental conditions. N5 Sensors, Inc. was funded by DHS S&T under the Small Business Innovation Research program for this technology.

Pacific Northwest National Laboratory (PNNL)

VitalTag

VitalTag is a small, disposable suite of sensors that securely detects and communicates vital sign data in real-time to first responders. This information helps first responders more effectively triage, treat and transmit patients during a mass casualty event. PNNL was funded by DHS S&T for this technology.

SensorUp, Inc.

SensorThings

SensorUp provides the Internet of Things platform for customers who rely on geospatial in their IoT Implementations. SensorUp helps make sense of data, combining all different sensors into one easily-managed visualizer and get the bigger picture. SensorThings technology rapidly aggregates and coordinates disparate sensors and IoT systems transforming them into actionable insights. SensorThings provides the primary sensor integration platform for the OpEx by connecting and aggregating various sensors and providing that actionable information to situational awareness tools. SensorUp, Inc. was funded by DHS S&T through a subcontract for this technology.

TRX Systems, Inc.

NEON® Personnel Tracker and NEON® Command

NEON Personnel Tracker delivers ubiquitous location indoors and out, improving operational efficiency, command effectiveness and safety for security, public safety and industrial applications. NEON Personnel Tracker is an Android application tightly integrated with the NEON Location Service where a suite of patented algorithms fuse inertial sensor data. NEON Command is a PC based visualizer used to view location data remotely in real-time. TRX Systems, Inc. was previously funded by DHS S&T for indoor tracking solutions under the Firefighter Accountability and Proximity Systems project.

OpEx Constraints and Limitations

The identified constraints and limitations for the OpEx event include:

- Most of the technology providers were identified through a Request for Information process and worked under Cooperative Research and Development Agreements (CRADAs) with DHS S&T, which did not include funding. This constrained the scope of their participation.
- DHS S&T could not interface with existing Computer Aided Dispatch (CAD) systems for the City of Houston, Port of Houston or Harris County, so the sensor feeds had to be aggregated, normalized and sent to situational awareness applications entirely outside of the local CAD systems.
- The primary situational awareness solutions used—AVERT C2, Intrepid Response and Constellation—were selected because they were already in use (or planned for use) by Harris County and the Port of Houston.
- Standards for data payloads, alerting messages and SensorUp to the situational awareness platforms had to be developed and implemented for the integration solution to work.

OpEx Communications Architecture

Based upon site visits, a baseline technology assessment of all participating agencies and ongoing collaboration with Harris County and other participants, DHS S&T developed a notional communications architecture. This established the foundation for the OpEx architecture, and ensured consistency with the expectations and needs of participating public safety organizations, as shown in Figure 4.

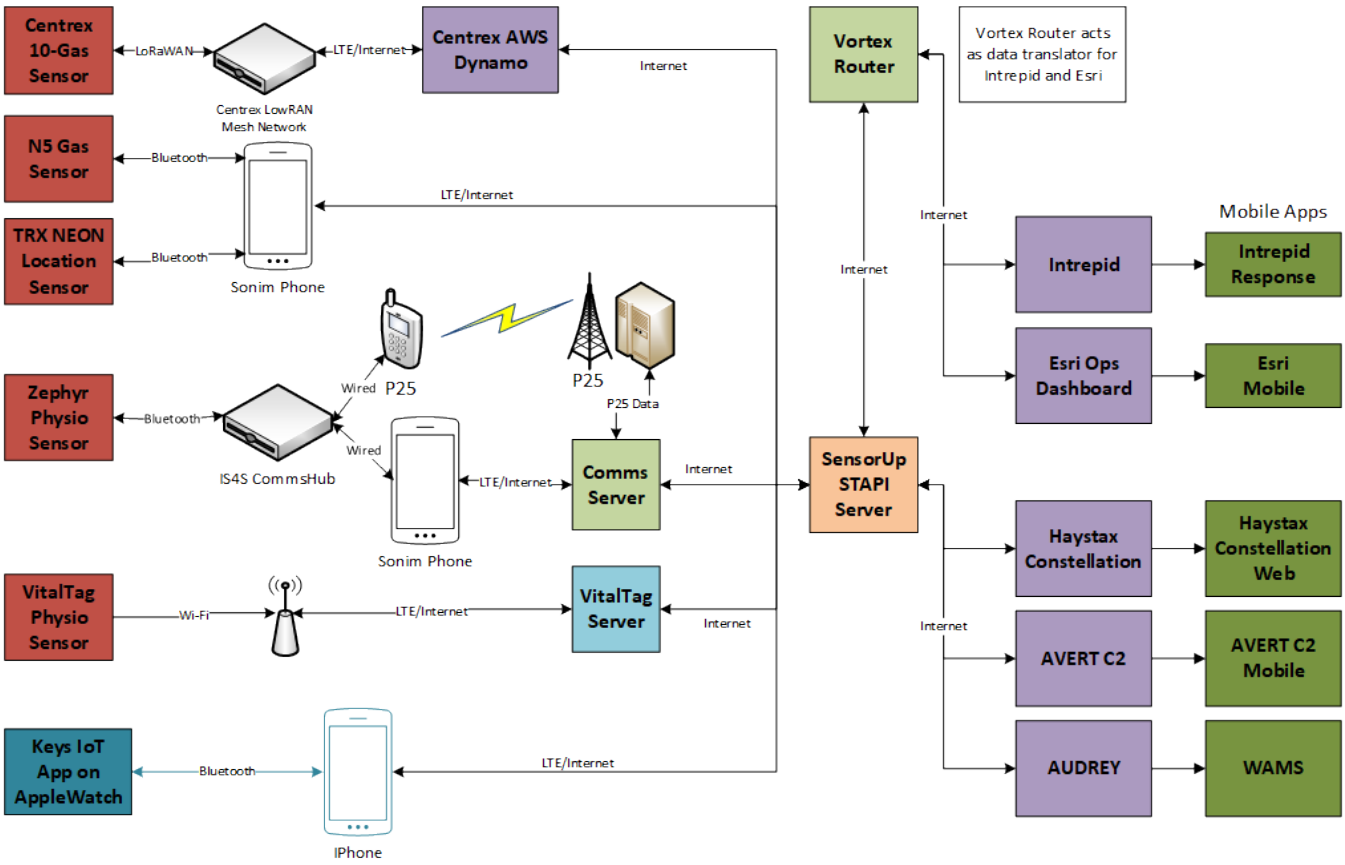

Figure 4. OpEx Communications Architecture with Central SensorUp Data Integration Point

Implementing Sensor Solutions

It is crucial for public safety agencies to maintain effective real-time situational awareness in the execution of their various law enforcement, emergency medical care and fire safety missions. IoT sensors are an essential part of enabling situational awareness, including providing the location of first responders, their physical condition and any exposure to HAZMAT. This awareness helps command staff make informed decisions that both protect first responders and improve their effectiveness in serving their communities. To establish a complete situational awareness system with sensor integration, public safety agencies must assess and understand the types of sensors, communications networks, data collection servers and back office systems they are planning to incorporate into their enterprise architecture and be able to identify integration and data exchange points for that data traffic.

Sensor Requirements

In order to effectively develop and implement a first responder sensor integration, NGFR and Harris County assessed their requirements for sensors and arrived at the following sensor requirements:

- Geo-location of first responder personnel (both in-building and outside) in three dimensions on map displays provided to the Incident Commander, command staff and on smartphones carried by first responders.
- Capability to monitor patients' physiological condition and send the data wirelessly to the Incident Commander and command staff for viewing using a visual "dashboard" on a monitor.
- Remote monitoring of HAZMAT using body-worn gas sensors transmitting alerts to the Incident Commander and command staff.

Baseline Assessment of Existing Capabilities

Participating public safety agencies did not have any wireless sensors deployed, nor an environment capable of passing sensor data on to their situational awareness applications without development.

OpEx Sensors

Participating public safety agencies prioritized location, chemical and physiological sensors based on their operational needs. These sensors, which were worn or carried by participating first responders, were intended to provide real-time data and alerts to the Incident Commander and command staff. DHS S&T integrated the following sensors for the OpEx:

Location Sensors

There were several devices that provided location data during the OpEx:

- NEON Personnel Tracker, TRX Systems
- XP8 Smartphone, Sonim
- Communication Hub, IS4S
- Nightjar, Centrex Solutions
- AppleWatch with Keys IoT Watch App, Keys Net

For responders who were equipped with multiple location sensors (e.g., NEON Personnel Tracker, Comms Hub, AppleWatch), the integration system was configured to use only one source for the location of the responder. This prevented overlapping or disparate locations for the same responder displayed on situational awareness platforms used by Incident Command.

NEON Personnel Tracker, TRX Systems

NEON Personnel Tracker delivers both indoor and outdoor location data using their NEON Tracking Unit, shown in Figure 5, coupled with an Android smartphone. Sonim XP8 smartphones were used during the OpEx. NEON Personnel Tracker provides real-time, 3D location calculated at every step, utilizing sensor fusion, map data and ranging technologies, delivering latitude/longitude, altitude, floor level, error estimate and building outline data. The NEON Location Service uses the inertial data from the TRX Tracking Unit and combines that with known information in the environment (building models, beacon ranges, etc.) to compute location.

Figure 5. TRX Systems' NEON Tracking Unit

The sensor data from the TRX system was sent via the integration service to the situational awareness platforms to display the location of each responder. Other sensor data could be associated with the location and identity of the specific responder as well. For displaying the responders' locations in three dimensions, TRX provided NEON Command, a 3D visualizer, to the Incident Commander. With this system, the

Incident Commander was able to determine the location and floor level of the TRX-equipped responders, including those on-board the USCGC Hatchet and the M/V Sam Houston.

Communications Hub, IS4S

Figure 6. Four IS4S Communication Hubs, Two with Tethered Radios

The IS4S Communication Hub is an intelligent, body-worn smart router that interconnects multiple communications systems (e.g., LMR, LTE, Bluetooth, Wi-Fi) with a variety of sensors (e.g., location, chemical, physiological) worn or carried by the user. The CommsHub identifies the communications path with the best connectivity to send on-body sensor data to the data aggregation point for integration. During the OpEx, the IS4S Communications Hub, shown in Figure 6, was used to demonstrate connectivity between sensors and the situational awareness platforms, via both LTE and LRM connectivity to the IS4S communications server.

Due to time limitations leading up to the OpEx, IS4S was only able to integrate the Communication Hub location data into the overall OpEx architecture, and therefore only provided responder location for the OpEx. IS4S also brought the Zephyr physiological monitoring system, which had been previously integrated with their system, for use as a responder physiological monitoring sensor. The data from the Zephyr sensors demonstrated the data path that would have been established with other participating sensors had they had additional integration time prior to the OpEx.

Gas (Chemical) Sensors

There were two different gas detectors providing chemical gas detection, identification and alerting during the OpEx:

- Compact Multi-gas and Particulate Matter Detector, N5 Sensors
- Nightjar, Centrex Solutions

Compact Multi-gas and Particulate Matter Detector, N5 Sensors

Figure 7. N5 Gas Sensor

The N5 gas sensors are chip-scale gas sensors manufactured using standard semiconductor microfabrication processes, typically used for making integrated circuits. These low-power chips with multiple sensors are able to detect different gases present in the air and are used for both indoor and outdoor air quality and personal exposure monitoring in varying humidity and temperature conditions. The N5 gas sensors did not require heating like other Micro-Electro-Mechanical Systems-based sensors; instead they use low-power UV LEDs (off-chip) for detection of different gases with high selectivity and fast response and recovery. Figure 7 shows an N5 sensor as used in the OpEx.

The N5 sensors were used to detect HAZMAT during the OpEx. The sensors were worn by selected members of the HAZMAT team as they entered the area where the HAZMAT had been released (simulated). The OpEx planners selected the HAZMAT gas to be methyl bromide for response scenario purposes, but the gas sensors were triggered using test bottles of methane, since the participants did not want to release even small test samples of methyl bromide into the atmosphere.

Nightjar, Centrex Solutions

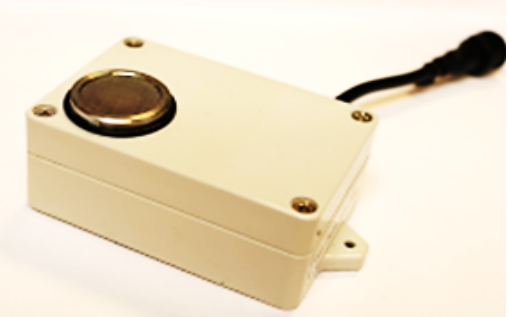

Figure 8. Nightjar Gas Sensor

The Centrex Nightjar gas sensor was a portable system developed for gas detection and identification. The gas sensor provided accurate measurements of 10 other flammable gases, including methane and hydrogen, as well as mixtures of those gases without user-applied k-factors. The sensor was low-power and operated in the field for long periods of time. Nightjar is intrinsically safe, robust, extremely poison-resistant and calibrated for all gases. Nightjar gas sensors, shown in Figure 8, were worn by selected HAZMAT responders and were triggered by the same methane gas as the N5 gas sensors.

The Nightjar gas sensor was fully integrated into the Nightjar LoRaWAN Mesh Network. The portal from the network to the internet was set up to backhaul the information to the Amazon Web Services cloud. From there, it interacted with various other data providers via MQTT or APIs. The platform also provided easily customized dashboards for users to view the gas sensor data. The Nightjar gas sensors were sensitive enough that they were triggered by atmospheric methane at the exercise venue, possibly vented by the ships or storage tanks along the waterway. Centrex adjusted the alert levels for the sensors to help eliminate the false positives.

Physiological Sensors

There were three different physiological sensors used for monitoring the health status of responders and patient during the OpEx:

- VitalTag, PNNL
- Zephyr, Medtronic via IS4S
- AppleWatch with Keys IoT Watch App, Keys Net

VitalTag, PNNL

VitalTag is a lightweight, low-cost, disposable solution for monitoring trauma patients. During the OpEx, VitalTag sensors—pictured in Figure 9—were strapped to HAZMAT-contaminated patients that were evacuated from the USCGC Hatchet and the M/V Sam Houston. The VitalTag suite connects to a patient's chest with other sensors attached to the ear and index finger. The device then collects and broadcasts the patient's vital signs to the emergency medical services team's mobile devices, allowing the team to prioritize their attention to those in need of the most urgent care at the triage site.

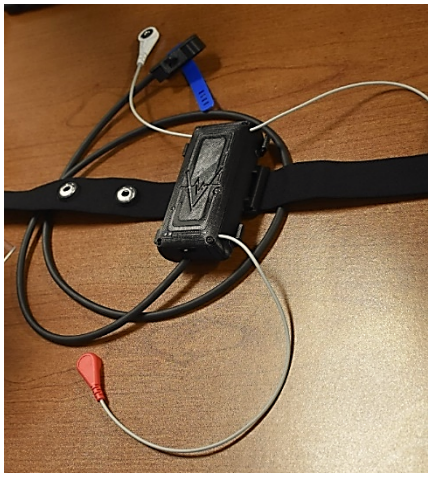

Figure 9. VitalTag Physiological Sensor

However, because the VitalTag was at the time undergoing FDA approval trials, the sensors used during the OpEx replayed stored vital sign data from an internal file, instead of providing real-time patient readings. This stored information was transmitted via Wi-Fi hot spot to the VitalTag dashboard for viewing by the EMS medical supervisor. The information was also sent to the data integration service that forwarded the data to the situational awareness displays for viewing by the Incident Commander. The VitalTag devices had GPS receivers and were able to transmit patient location information; however, the accuracy and refresh rate for that information proved to be of minimal use to the EMTs.

VitalTag monitors numerous vital signs in real-time, including systolic blood pressure, heart rate, shock index, dissolved oxygen, ECG and respiration rate. Patients were assigned stoplight colors to indicate their triage status (green is minor, yellow is delayed and red is immediate) to the EMTs as they monitored the triage area. This data is then broadcast via MQTT to DHS-based local area networks (LAN) for display on the VitalTag dashboard shown in Figure 10.

Figure 10. VitalTag Patient Data Dashboard

The EMTs were pleased to be able to monitor the vital signs of their triage patients on the iPad DHS S&T provided for their use. They held discussions with the PNNL staff and provided feedback to the dashboard developer on the first day of the OpEx. The developer modified the VitalTag dashboard accordingly and the new version was used for the second day of the OpEx. The EMTs were able to track the patients as they were evacuated from USCGC Hatchet, across the bayou and into the triage area, but once the patients were in triage the location information was unnecessary.

Zephyr, Medtronic via IS4S

The Zephyr physiological monitor is a small, Bluetooth-enabled chest-band sensor that was used to sense responder heart rate, respiration rate and skin temperature, and transmit the data wirelessly to the IS4S CommsHub during the OpEx. The CommsHub then passed the data to situational awareness servers that displayed the data and created an alert if the data readings fell outside the set parameters. This enabled the Incident Commander and command staff to know when a responder was in physical distress. Figure 11 shows the Zephyr sensor.

Figure 11. Zephyr Physiological Monitoring Sensor for Responders

AppleWatch with Keys IoT Watch App, Keys Net

The Keys IoT Watch App was a software-based solution that utilized mass-market consumer wearable computing and biometric platforms (such as the AppleWatch during the OpEx) to both send and receive location, sensor data and alert notifications. The solution used non-proprietary, platform-independent and royalty-free open standards (SensorThings, MQTT, etc.) for communication to enhance interoperability and compatibility and reduce costs. It accommodates both organization-provided and user-provided (Bring Your Own Device) implementations, allowing first responders and incident commanders to leverage the devices they may already own. The application enables the watch to transmit location, heart rate and other sensor data into their current operational systems, as well as receive incident alerts (visual/audio/vibration), select sensor data, and view an incident/team map, all from their smart watch.

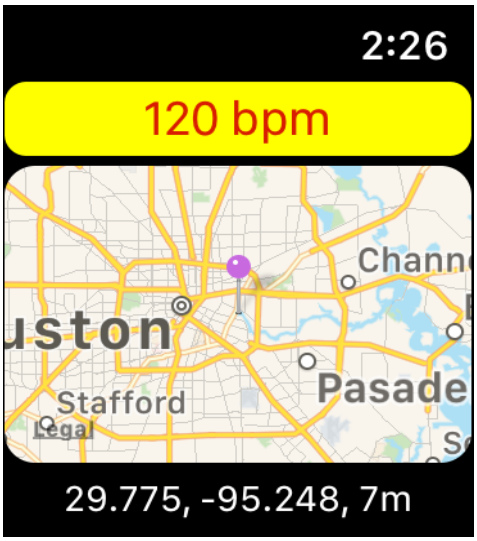

Figure 12. Keys IoT Watch App on an AppleWatch

Keys Net provided multiple AppleWatches running the Keys IoT Watch App, as shown in Figure 12, to act as location and physiological sensors, collecting sensor data (heart rate, position, movement) from the watch's integrated hardware and publishing to the data integration service (SensorThings/Incident Scene SensorHub). The App received MQTT/SensorThings alerts and data from the SensorHub, enabling the AppleWatch to display both notifications and sensor data. In addition, the App sent alerts based on configurable rulesets (heart rate over X beats per minute, watch battery at 20%, etc.) to the SensorHub for display on multiple situational awareness platforms.

Connectivity for the Keys IoT Watch App was provided using multiple technologies, carriers and network topologies. Some AppleWatches utilized a consumer LTE network connection as well as Incident Scene Wi-Fi. Others utilized Bluetooth Low Energy to relay data through paired iPhones, which in-turn connected to the SensorHub via Wi-Fi, commercial LTE or FirstNet.

The AppleWatches used in the OpEx were worn by the Incident Commander and HAZMAT responders from three different agencies to capture their location and physiological data.

Implementation Limitations to Consider

It is important for an agency to understand the security policies in place and make sure the sensor data collection system can meet the agency's data security requirements. Agencies should also consider FOIA requirements, privacy needs, union requirements, evidentiary standards and data storage requirements.

OpEx RESULTS

The OpEx successfully demonstrated both the advantages of IoT sensors and their shortfalls as currently implemented. All of the requirements were fulfilled with the delivered capabilities, but with varying degrees of success. The feedback from participating first responders was overwhelmingly favorable.

The Incident Commander and first responders were very pleased to be able to monitor real-time sensor data and alerts from first responders on their smartphones and tablets. The HAZMAT team supervisor was able to receive alerts when one of them encountered a higher-than normal gas reading (triggered by the methane bottle). In addition, the Port of Houston and Harris County dispatchers who provided dispatcher services for the event were able to see the location of each first responder and their sensor data across the incident area, which the OpEx data integration work made possible. It was particularly important that they

could see data from multiple response agencies and multiple jurisdictions in one place, which met several local requirements identified during the 2017 Hurricane Harvey after action review.

Additional information can be found in sources listed in the References and Recommended Reading section. A complete Harris County OpEx After Action Report is under development and will be posted at www.dhs.gov/NGFR and available upon request from NGFR@hq.dhs.gov.

IMPLEMENTATION FOR YOUR AGENCY

During the NGFR – Harris County OpEx, DHS S&T integrated IoT sensors with situational awareness platforms to provide public safety decision makers with real-time incident information. How can your agency apply this case study and best practices to improve your capabilities? DHS S&T has developed the following questions to help your agency and/or all of the public safety agencies in your community determine data integration requirements, current capabilities, target capabilities and implementation considerations.

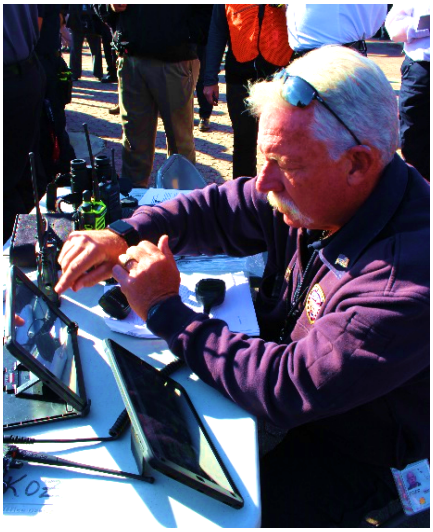

Figure 13. Port of Houston Fire Command Staff Views a Dashboard

One of the most important features of the NGFR – Harris County OpEx was getting the sensor data for responders from different agencies and jurisdictions integrated into a unified situational awareness platform. If your agency regularly responds to multijurisdictional incidents, you would likely benefit from a similar unified multi-agency approach to data integration. Even if different agencies own different brands of equipment, with NGFR integration approaches, the data can be shared through common situational awareness platforms. To plan for multijurisdictional interoperability, bring your regular public safety partners to the table when using this guidance to define your approach to sensor implementation.

Due to the significant differences between agencies and their capabilities around the country, there is not a one-size-fits-all approach for public safety sensors. However, DHS S&T believes that these questions will help guide your agency and partners towards implementing and deploying sensor solutions that are right for your community.

Determine Sensor Requirements

The first step for your agency is to assess your IoT sensor requirements. DHS S&T recommends involving a variety of responders at different levels of command in your requirements discussion to ensure all perspectives are considered. Discussion topics include:

- **Who**: Who needs the sensors? Will different types of responders need different types of sensors? Does every responder at an incident scene need a sensor (may depend on type) or is one sensor per incident adequate? Think through all stages of an emergency from 9-1-1 call through conclusion and think about the different types of information each of these roles need at each stage of response.
- **What**: What sensors do these users need? What information do your responders and commanders need real-time access to make better decisions about responder and community safety? What types of sensor information best aligns with the high impact or high probability threats your community faces (e.g., HAZMAT sensors for cities with chemical manufacturing factories)? What is the scope of sensor solutions that your agency requires and has budget for (types of sensors, situational awareness platforms)? This could be as narrow as Automatic Vehicle Location (AVL), or a full complement of physiological, environmental, traffic and video. Which sensor and platform options

are nice to have versus necessary, and how does your agency and partners prioritize the possibilities? Which sensor types would be body-worn on first responders versus fixed on response vehicles?

- **Where**: Where will the sensors be employed? If first responders are wearing sensors in the field, what durability and environmental requirements will the devices need to meet (i.e., heat resistance for firefighter sensors)? Are there other agencies or jurisdictions that could benefit from the data? Will it be deployed to the edge (incident scene) or mostly used by command at a public safety answering point (PSAP) or station house? Will the sensors and situational awareness platforms be easily deployable for significant multijurisdictional incidents or mutual aid situations?
- **When**: Does your agency need sensor solutions on a full-time or part-time basis? Is it a surge capability for major incidents, used to manage everyday incidents, or both?

Identify Current Sensor and Infrastructures Capabilities

The second step is for your agency to determine your current sensor capabilities. Discussion topics include:

- What sensors are currently in use by your or other participating agencies? Are they able to send data wirelessly? Think of networked and non-networked sensors, such as handheld HAZMAT detectors. Also think of other types of sensors that might provide useful incident information, such as traffic cameras, in-building sensors and weather stations.
- How are those sensors currently deployed by your or other participating agencies? How is the sensor data currently used?
- Does your agency have the network infrastructure needed to pass sensor data to your existing or planned situational awareness platforms?

Determine if your agency's current infrastructure can provide the necessary LTE coverage and if you have the right hardware:

- Is there adequate LTE connectivity coverage?
- Does your agency have access to LTE, Wi-Fi or LMR capability? (entire jurisdiction, parts of jurisdiction, limited hot-spots)
- Do first responders have access to smartphones and/or tablets? (issued by agency or personal)

Identify Sensor Solutions

Once your agency has determined your sensor requirements and current capabilities, you need to identify which solutions can fulfill those gaps. Your agency should follow internal guidance to evaluate the costs of and functionality provided by each solution to determine which one(s) to select.

First, determine which types of sensors are necessary based on your requirements:

- Physiological sensors (For responders, patients or both?)
- HAZMAT sensors (Chemical gas and substance sensors? Biohazard sensors? Radiation sensors?)
- Environmental sensors (Flashover heat levels? Weather conditions, including wind direction? Floodwater depth and current sensors?)
- Location sensors (2D or 3D? Indoor/outdoor or just outdoor? Person, vehicle or both?)
- Gunshot detectors
- Fixed, mobile or body-worn cameras (for both photos or videos)

Your agency then needs to identify legacy (or new) situational awareness platforms that you wish to integrate into, considering:

- CAD systems
- Map-based situational awareness applications
- Collaboration and messaging applications

Finally, your agency needs to consider the technical requirements of implementing a situational awareness system with real-time sensor integration onto situational awareness applications. Discussion topics include:

- What are the technical capabilities of agency-provided or bring-your-own-device smartphones, tablets and computers (ruggedization, storage, network access, data plans, processing power)?
- What are the technical capabilities of internet access in the field, including bandwidth for pushing steady streams of sensor data and/or large packets of video and voice data?
- Does your agency have adequate technical support staff for set-up, device management and troubleshooting?

Note: for a more complete review of data integration requirements, please see the "NGFR Case Study: Data Integration," referenced in the References and Recommended Reading section.

Implement Solutions

Once your agency has selected the sensor, situational awareness and data integration solution(s), you should develop an implementation plan for the system(s). The plan would include processes for:

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

After implementing and testing IoT sensors, your agency will be able to send and receive real-time sensor data and alerts to first responders and command staff, allowing them to make better-informed decisions during everyday response and major incidents.

SUMMARY

This NGFR case study provided an overview of the NGFR – Harris County OpEx, with a focus on implementing IoT sensors to augment mission response through information sharing and common operating pictures. It also provided a discussion guide that may help your agency determine requirements, current capabilities, target capabilities and implementation considerations for sensor solutions.

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

Figure 14. OpEx Director Sridhar Kowdley Describes How OpEx Technologies are Deployed

REFERENCES & RECOMMENDED READING

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

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

NGFR Integration Handbook (https://dhs.gov//science-and-technology/ngfr/handbook)

This three-part document provides technology developers with a standards-based architecture for developing and integrating interoperable first responder technologies.

NGFR – Harris County OpEx Playbook, expected February 2020 (will be posted on https://dhs.gov/ngfr and available upon request from NGFR@hq.dhs.gov)

This document is the guide that was used to execute the NGFR – Harris County OpEx.

NGFR – Harris County OpEx After Action Report, expected March 2020 (will be posted on https://dhs.gov/ngfr and available upon request from NGFR@hq.dhs.gov)

This document thoroughly describes the planning, execution and results of the NGFR – Harris County OpEx.

NGFR Case Study: Data Integration, expected February 2020 (will be posted on https://dhs.gov/ngfr and available upon request from NGFR@hq.dhs.gov)

This document describes sensor data integration during NGFR – Harris County OpEx.

NGFR Case Study: Enhanced Situational Awareness, expected February 2020 (will be posted on https://dhs.gov/ngfr and available upon request from NGFR@hq.dhs.gov)

This document describes situational awareness applications during NGFR – Harris County OpEx.

NGFR Case Study: Mobile Device Management, expected February 2020 (will be posted on https://dhs.gov/ngfr and available upon request from NGFR@hq.dhs.gov)

This document describes mobile device management during NGFR – Harris County OpEx.

NGFR Case Study: Patient Monitoring, expected February 2020 (will be posted on https://dhs.gov/ngfr and available upon request from NGFR@hq.dhs.gov)

This document describes patient monitoring applications during NGFR – Harris County OpEx.

NGFR Case Study: Sensor and Event Alerts, expected February 2020 (will be posted on https://dhs.gov/ngfr and available upon request from NGFR@hq.dhs.gov)

This document describes standard formats for sensor and event alerts during NGFR – Harris County OpEx.