NEXT GENERATION FIRST RESPONDER
CASE STUDY
DATA INTEGRATION

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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 and 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 enhance emergency communications, increase operational coordination, improve responder safety and augment 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 data integration between technologies that were used in the OpEx and discusses how nationwide public safety agencies could implement data integration to enhance operational situational awareness, collaboration and communication.

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 applied open standards data integration to bring new 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 maintain enhanced situational awareness 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: Data Integration." This document provides public safety agencies with an overview of how DHS S&T implemented data integration 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 data during the NGFR – Harris County OpEx, taking real-time data from numerous sensors 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 data integration solutions 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 emergency medical services (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 that 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 used Nightjar handheld, wearable and vehicle-mounted flammable gas sensors. These devices can detect a wide range of volatile substances in a single sensor and deliver that data over the Nightjar network to existing situational awareness applications used by incident command.

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., land mobile radio [LMR], long-term evolution [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.

Intrepid Connect (Moxtra)

Moxtra, powered by Intrepid Networks, provides robust team collaboration with rich multimedia sharing, whiteboarding, task management and secure text communication.

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.

National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory

AUDREY – Assistant for Understanding Data through Reasoning, Extraction and Synthesis

AUDREY is a state-of-the-art human-like Artificial Intelligence (AI) system designed to assist first responders in reducing the data overload problems and providing life-saving actionable intelligence by automatically analyzing relevant sensor data and synthesizing high-level situational awareness information while at the scene of an emergency.

WAMS – Wearable Alert and Monitoring Systems

WAMS provides front-end processing for AUDREY, enabling AUDREY agents to efficiently receive personalized sensor data, alerts and events and supporting voice-to-text conversion. NASA Jet Propulsion Laboratory was funded by DHS S&T for these technologies.

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.
- Participation by IS4S was considerably delayed due to contracting issues; they were unable to participate in integration work until a few weeks before the OpEx. This significantly limited the number of systems that were integrated for data routing through the Communication Hub.
- Due to time limitations, the sensor data for each responder was consolidated at the server level instead of the on-body (controller) level as recommended in the NGFR Integration Handbook. This expedited the configuration of the data flow from each type of sensor but made the matching of sensor data to the appropriate responder more complex.

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 architecture. This established the foundation for the OpEx architecture, as well as ensured consistency with the expectations and needs of participating public safety organizations, as shown in Figure 4.

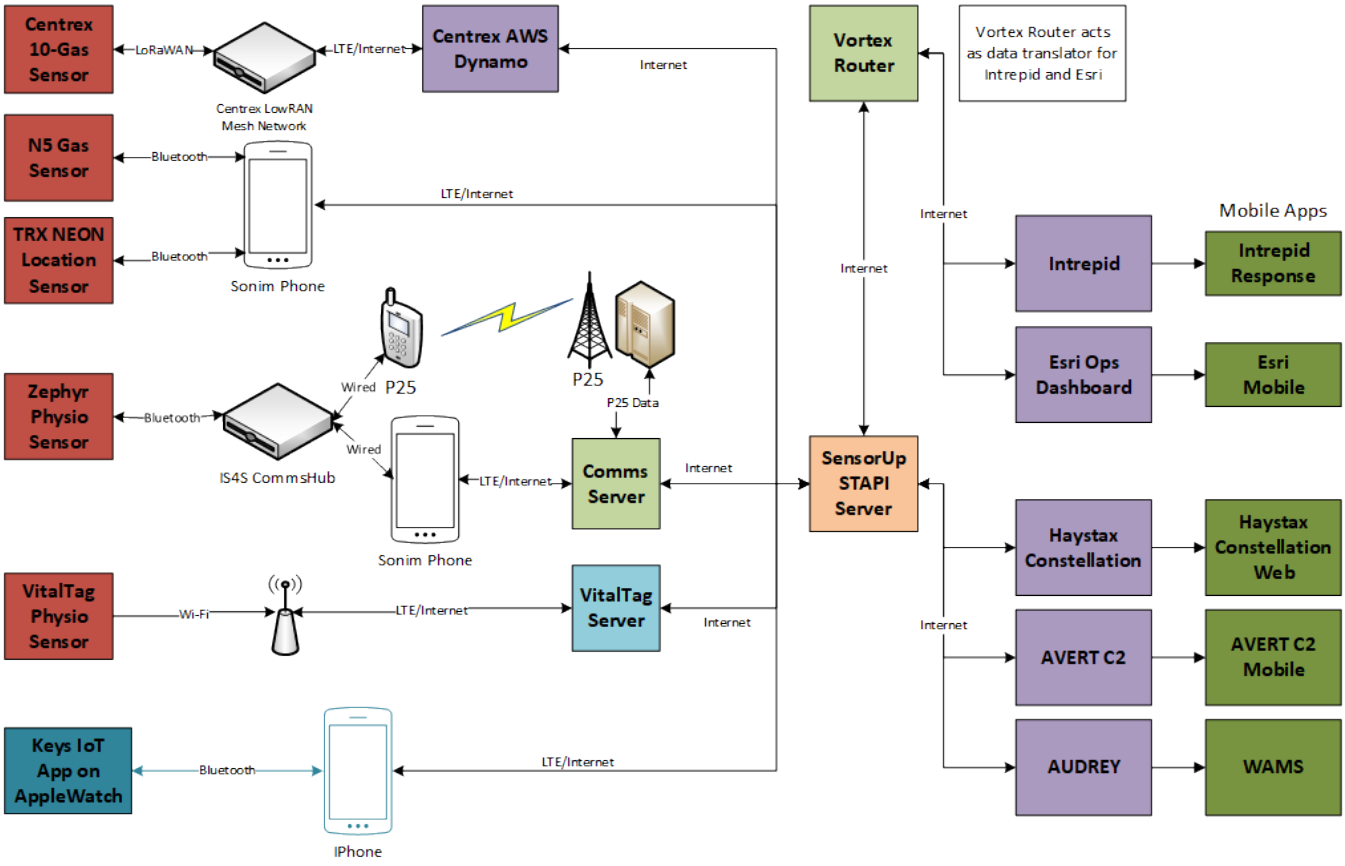

Figure 4. OpEx Communications Architecture with Central SensorUp Data Integration Point

Implementing Data Integration Solutions

Over the span of the NGFR Apex program, identifying data integration needs became a key part of the NFGR Integration Handbook, ensuring it is a useful guide for vendors to create modular on-body sensor and communications solutions. DHS S&T and partners provided data and alert standards to support the OpEx that incorporated OGC Sensor Things API and MQTT standards to facilitate communications between systems.

Figure 5. The DHS S&T OpEx Team Monitors the AVERT C2 Dashboard During the OpEx

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. Data integration is 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.

Data Integration Requirements

Achieving enhanced situational awareness requires data integration. The OpEx data integration requirements are derived from the situational awareness requirements, which spell out the situational awareness systems (data destinations), sensors (data origins) and data characteristics. To effectively develop and implement a first responder enhanced situational awareness solution, DHS S&T and participating public safety agencies assessed their mission needs for the situational awareness systems and arrived at the following requirements:

- The situational awareness system that receives data from first responder sensors shall include AVERT C2 (for the Port of Houston) and both Intrepid Response and Haystax Constellation (for Harris County);
- The situational awareness system shall incorporate and display the sensor data from gas sensors, physiological sensors, location sensors, and video analysis and alerting; and
- The situational awareness system shall associate the sensor data with the corresponding responder and display any alerts for sensor readings that exceed configurable parameter.

Baseline Assessment of Existing Capabilities

Participating public safety agencies did not have baseline data integration capabilities for real-time sensor data, nor an existing environment capable of passing sensor data on to their situational awareness applications without additional development. Harris County did not have any active sensors deployed that could connect to their existing situational awareness tools and therefore no existing data integration requirements. The Port of Houston did not have any active sensors deployed that could connect to their existing situational awareness tools and therefore no existing data integration requirements.

OpEx Sensors

Participating public safety agencies prioritized location, physiological and chemical sensors based on their operational needs, and DHS S&T worked to integrate the following sensor types for the OpEx:

Location Sensors

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

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

The TRX NEON devices were used as the primary location data source, but provisions were made to allow for the selection of alternative sources of location data if they were available. Each of the devices used different communications paths to return their data as shown in Figure 4.

Gas (Chemical) Sensors

There were two different gas detectors providing environmental readings during the OpEx:

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

The N5 sensors used Bluetooth to pair with a smartphone or Single Board Computer (SBC) for transport back to the sensor data collection point. The Centrex sensors worked in conjunction with the Centrex Nightjar LoRaWAN mesh network and an internet gateway to return data for distribution to collection servers.

Physiological Sensors

There were three different physiological sensors used for tracking responder and patient physiological status during the OpEx:

- VitalTag, PNNL
- Zephyr, Medtronic via IS4S
- AppleWatch, Keys Net

The AppleWatch and Zephyr sensors were used to monitor responder health, and they each used different communications paths as shown in Figure 4. VitalTag sensors were used to monitor patients as they went through triage, and status information was sent via Wi-Fi for distribution to the collection point.

OpEx Communications Networks

Given the variety of sensors, there were several communications networks used to support the OpEx. The Sonim XP8 phones were used to support some sensors over FirstNet LTE network as shown in Figure 4. The IS4S CommsHub provides a mechanism to direct traffic as available to both LTE and Project 25 (P25) networks and provided Zephyr physiological sensor data. Wi-Fi networks were provided by 4K mobile broadband kit (MBK) devices and hotspots provided by Sonim XP8 phones as needed. The LoRaWAN network was part of the Centrex suite of equipment.

OpEx Data Collection Points

A significant challenge DHS S&T managed was how to input the sensor data coming from the devices carried by the responders and transmit the data—still associated with the specific responder—to the situational awareness platforms. Because there is no sensor payload standard, the OpEx team of industry partners and NGFR staff worked to develop documented payload standards for use by the sensor providers and SensorUp in transmitting sensor data and alerts to the situational awareness platforms. These topics are explored further in the Harris County Case Studies: "NGFR Case Study: Enhanced Situational Awareness," "NGFR Case Study: Sensors," and "NGFR Case Study: Data and Alerting Standards." For more information, see the References and Recommended Reading section of this document.

Because of the disparate collection of sensors and the proprietary nature of the evolving IoT sensor environment, DHS S&T needed a point at which to merge the data streams for them to appear as a single data stream as envisioned by the NGFR Integration Handbook. It became apparent that the SensorUp data collection servers would be the most logical point to normalize the data for transmission to the situational awareness systems. Figure 6 provides the initial notional view of how data would be collected and aggregated. Figure 7 represented the final implemented configuration required to support the NGFR – Harris County OpEx.

For the NGFR – Harris County OpEx, the DHS integration team was unable to closely follow the NGFR Integration Handbook data architecture standards regarding where sensor data was aggregated on the on-body controller. Instead, the team fed sensor data from the sensors via various routes to individual SensorThings API servers, the output of those servers was then consolidated by the central SensorUp server, at which point the data was matched with the appropriate responder and sent on to the situational awareness platforms.

OpEx Data Integration Solution

Figure 6 shows the notional view of the connections among the various sensors, communications networks, individual data servers, the SensorUp SensorThings API server and the various situational

awareness platforms. This view complies with the data integration as put forth by the NGFR Integration Handbook, but was not how the final data integration was accomplished for the OpEx.

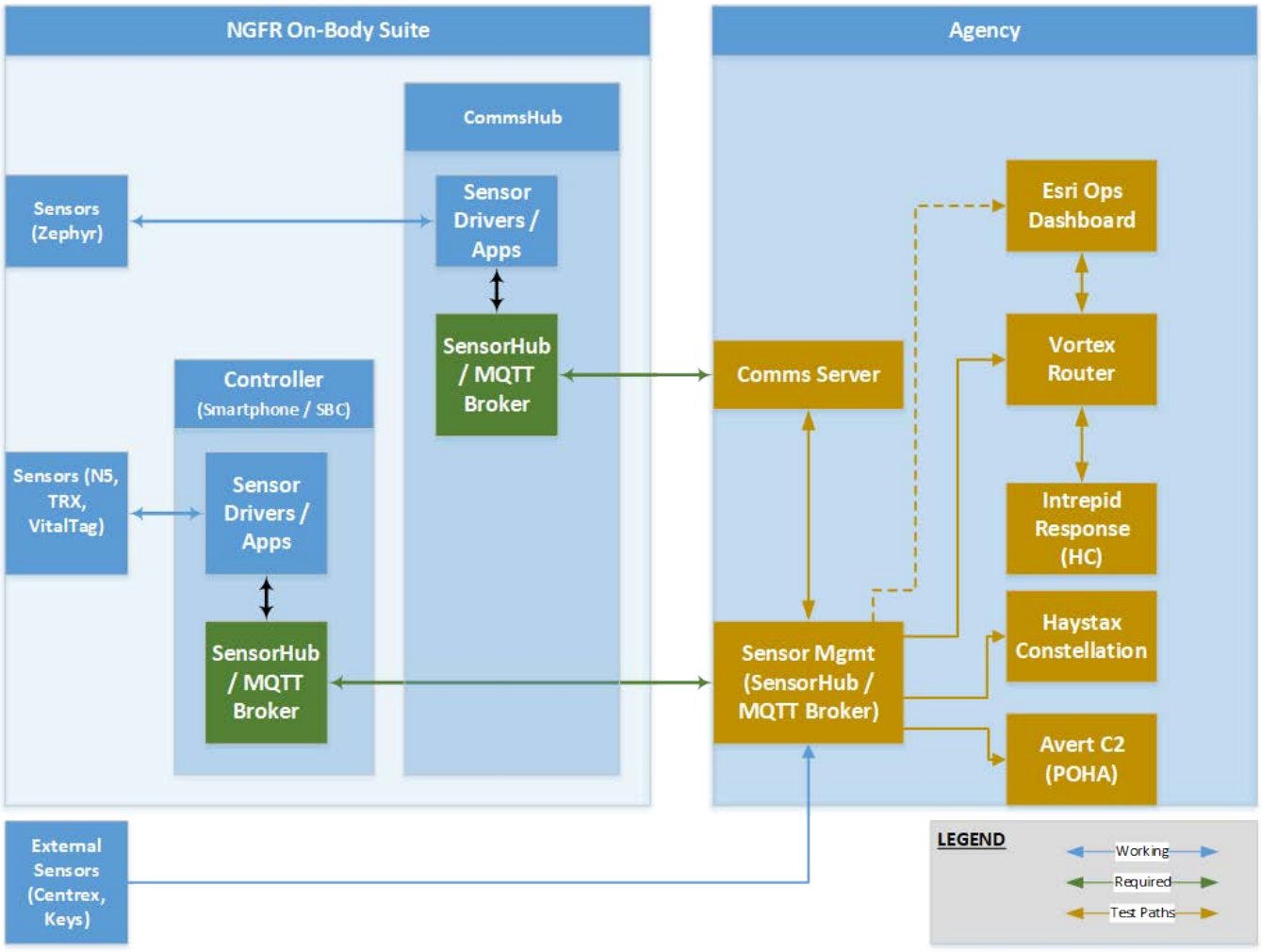

Figure 6. Harris County Notional Data Collection

The OpEx technical team had to develop an approach that would create data streams in a manner to allow the viewing of data as if being sourced from an individual controller (responder) but adapted to the uniqueness and lack of standardization caused by the unique data streams coming from the various sensors.

Using Data Integration Solutions During the OpEx

Figure 7 represents the working architecture used for the Harris County OpEx. It was necessary to develop this design to provide a single stream of sensor data associated with the corresponding responder to pass on to the situational awareness platforms. Ultimately, the goal would be to consolidate the data stream within the on-body controller as per the NGFR Integration Handbook and, from the Controller, output a single, known format data stream to the situational awareness platforms.

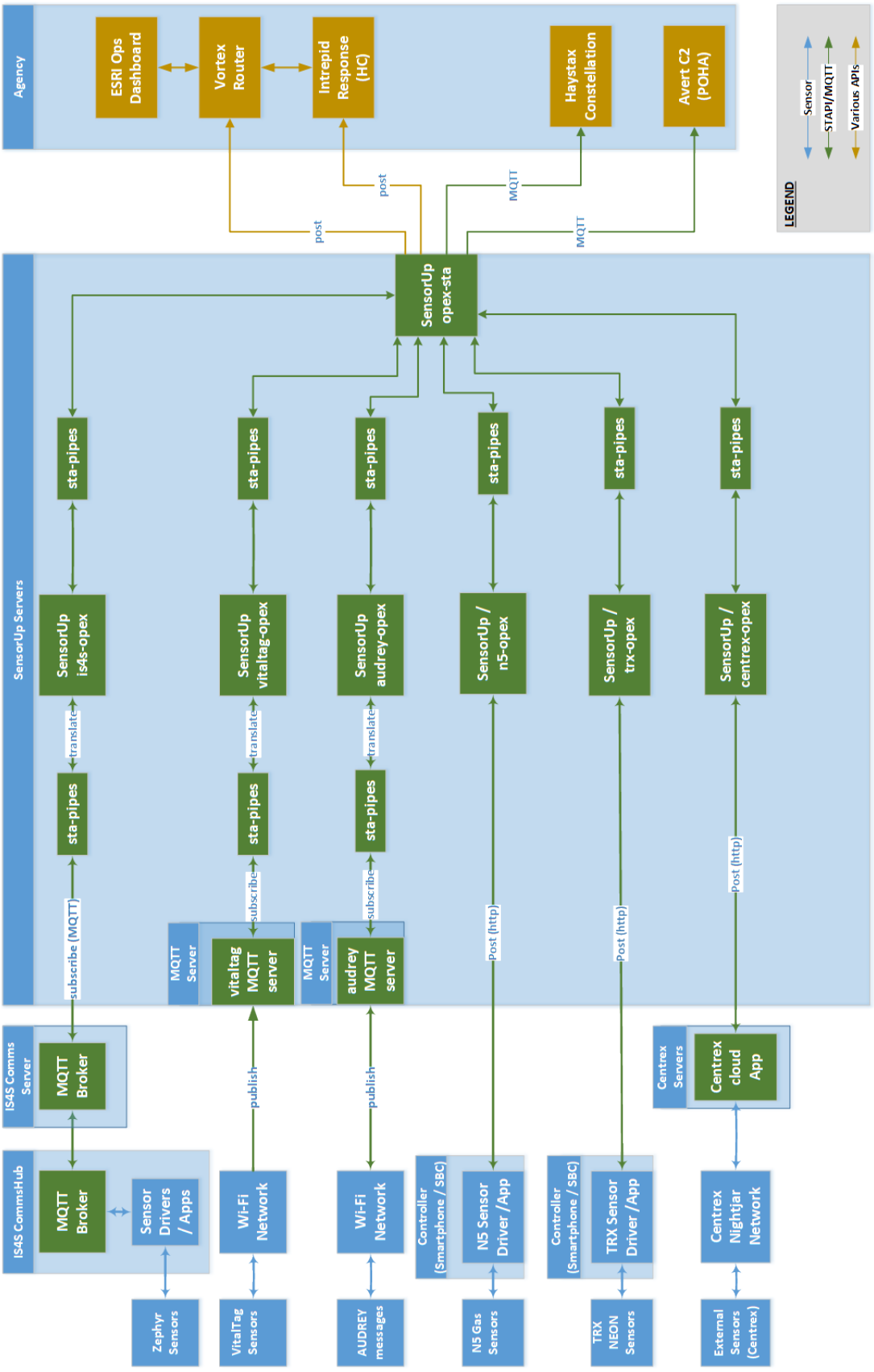

Figure 7. Harris County OpEx Sensor Data Collection

To implement sensor and alerting data message requirements that would align with broader industry implementations, MQTT was selected as the transport layer protocol. The SensorThings API was selected as the data framework and SensorUp provided the data aggregation server. To keep data messages as compact as possible, the JavaScript Object Notation (JSON) data format was chosen. With this framework, a consistent standard was developed that would facilitate the interchange of data. The various data paths in Figure 7 are:

- The IS4S CommsHub communicates with the IS4S CommsServer to convey sensor and other telemetry for monitoring using MQTT and a proprietary data set. SensorUp subscribed to the IS4S CommsServer via a SensorThings API (STA)-pipes server, which performed data preprocessing and passed it along to the IS4S-OpEx server. The IS4S-OpEx server connected through a STA-pipes server (for data processing) to the OpEx-STA server where the aggregated data stream was created.
- The VitalTag Sensors connect via Wi-Fi to the VitalTag MQTT server. SensorUp subscribed to the VitalTag MQTT Server via an STA-pipes server, which performed preprocessing and passed it along to the VitalTag-OpEx server. The VitalTag-OpEx server connected through a STA-pipes server (for data processing) to the OpEx-STA server where the aggregated data stream was created.
- The TRX and N5 sensors connect via Bluetooth to a Sonim XP8 phone equipped with TRX and N5 apps to pair and forward their data to their respective SensorUp servers using POST messaging. The TRX and N5-OpEx servers are connected through a STA-pipes server (for data processing) to the OpEx-STA server where the aggregated data stream was created.
- The Centrex Gas Sensor connected via LoRaWAN to a Centrex Nightjar mesh network where data is delivered to the Centrex cloud app server. Data is moved from the Centrex cloud server to the Centrex-OpEx server via POST (http).
- STA-pipes, an important component of Figure 7, are components that perform Extract, Translate, and Load (ETL) functions. The STA-pipes were essential in manipulating the data streams so that they could ultimately be combined into the desired single stream output. As previously noted, this is not the ideal configuration due to its non-compliance with the NGFR Integration Handbook, but provided the desired outcome given the time constraints of the OpEx.

Implementation Limitations to Consider

It is important for an agency to understand what the integration points are for the sensor data and understand what interfaces are available on the systems where the sensor data is required. It is also critical to understand the security policies in place and make sure the sensor data collection system can meet the agency's data security requirements. Many solutions are cloud-hosted and need to be evaluated to determine if this is an acceptable solution for agency use. Agencies should also consider Freedom of Information Act (FOIA) requirements, privacy needs, evidentiary standards and data storage requirements.

OpEx RESULTS

The OpEx successfully demonstrated both the advantages of data integration solutions 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 data and alerts from first responders on their smartphones and tablets. 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 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 the DHS NGFR website and available upon request from NGFR@hq.dhs.gov.

IMPLEMENTATION FOR YOUR AGENCY

During the NGFR – Harris County OpEx, DHS S&T deployed a standards-based data integration approach to bring real-time data from IoT devices to situational awareness platforms that enabled 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.

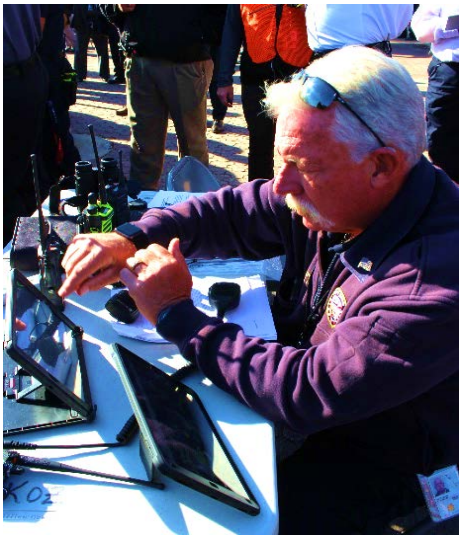

Figure 8. Port of Houston Fire Command Staff Views a Dashboard

One of the most important features of the NGFR – Harris County OpEx was getting the 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 data integration.

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 data integration. However, DHS S&T believes that these questions will help guide your agency and partners towards implementing and deploying data integration solutions that are right for your community.

Determine Data Integration Requirements

The first step for your agency is to assess your data integration 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 a data integration solution? Another way of asking this question is: are there other users in the municipality that may have use of the sensor data via situational awareness platforms? Public safety answering point (PSAP) and Dispatcher? Incident Commander? Other command staff? Frontline first responders? 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 information do your responders and commanders need real-time access to in order 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 the data integration 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 platform and sensor options are nice to have versus necessary, and how does your agency and partners prioritize the possibilities?
- **Where**: Where is a data integration solution needed? Will this data be provided to a CAD system only or will it be needed by situational awareness platforms, Geographical Information System (GIS), and/or Emergency Operations Center (EOC) systems? 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 PSAP or station house? Will the capabilities be easily deployable for significant multijurisdictional incidents or mutual aid situations?
- **When**: Does your agency need a data integration solution 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 Data Integration Capabilities

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

- What legacy systems do you have in operation that could use sensor data to improve situational awareness? Do these systems support interfaces that would allow them to use data from the sensor systems? Think of systems in the PSAP and in the field that provide real-time information about your personnel, resources, environment and hazards.
- What sensors are currently in use by your or other participating agencies? 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.
- What systems (e.g., smartphones, tablets, situational awareness applications) does your agency have that can send alerts to first responders? Are these systems capable of supporting data traffic as necessary? What are the interfaces these systems support?
- Does your agency have the capability to host or contract with a server-provider to integrate the sensor data?
- Given your current capabilities, which of your previously-identified requirements remain unmet?

Identify Data Integration Solutions

Once your agency has determined your data integration 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? 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?)

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; and
- 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:

- Are there solutions that could be deployed within your agency's existing infrastructure?
- Are there cloud-based solutions that could be integrated into your agency's existing infrastructure while meeting security and privacy guidelines?
- 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?
- Where will the data integration server reside, whether hosted by your agency or hosted by the server vendor?
- Does your agency have adequate technical support staff for set-up, device management and troubleshooting?

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 data integration solutions, 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 the implementation of data integration capabilities 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 data integration solutions.

Figure 9. OpEx Director Sridhar Kowdley Describes How OpEx Technologies are Deployed

If your agency finds this NGFR case study useful for improving your data integration 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.

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 the DHS NGFR website 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 the DHS NGFR website 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: Enhanced Situational Awareness, expected February 2020 (will be posted on the DHS NGFR website 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 the DHS NGFR website 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 the DHS NGFR website 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 the DHS NGFR website and available upon request from NGFR@hq.dhs.gov)

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

NGFR Case Study: Sensors, expected February 2020 (will be posted on the DHS NGFR website and available upon request from NGFR@hq.dhs.gov)

This document describes various sensors used during NGFR – Harris County OpEx.