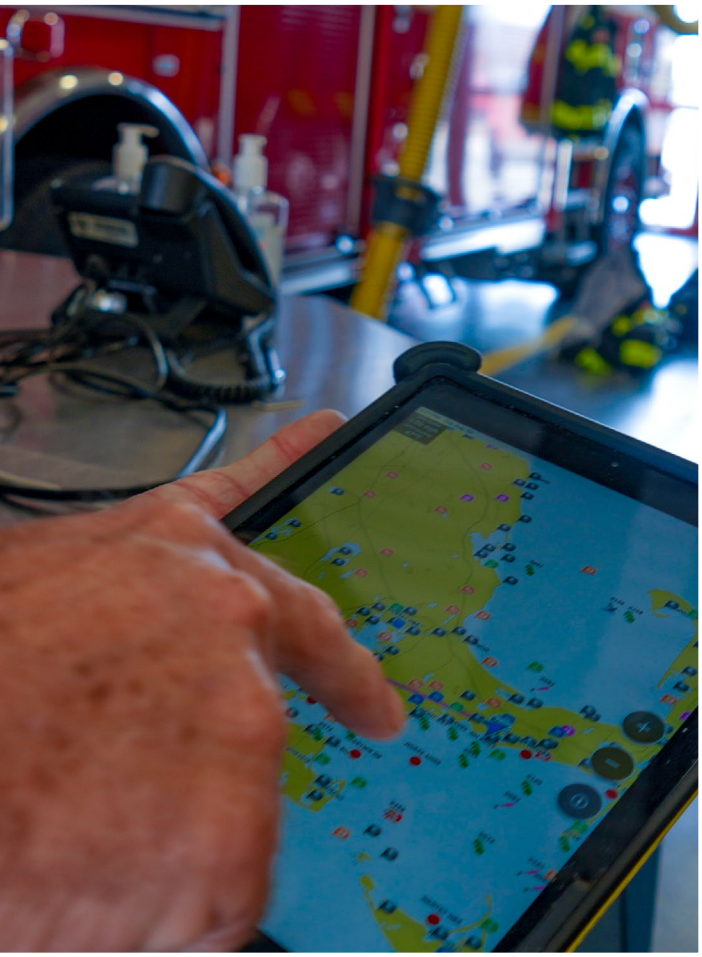
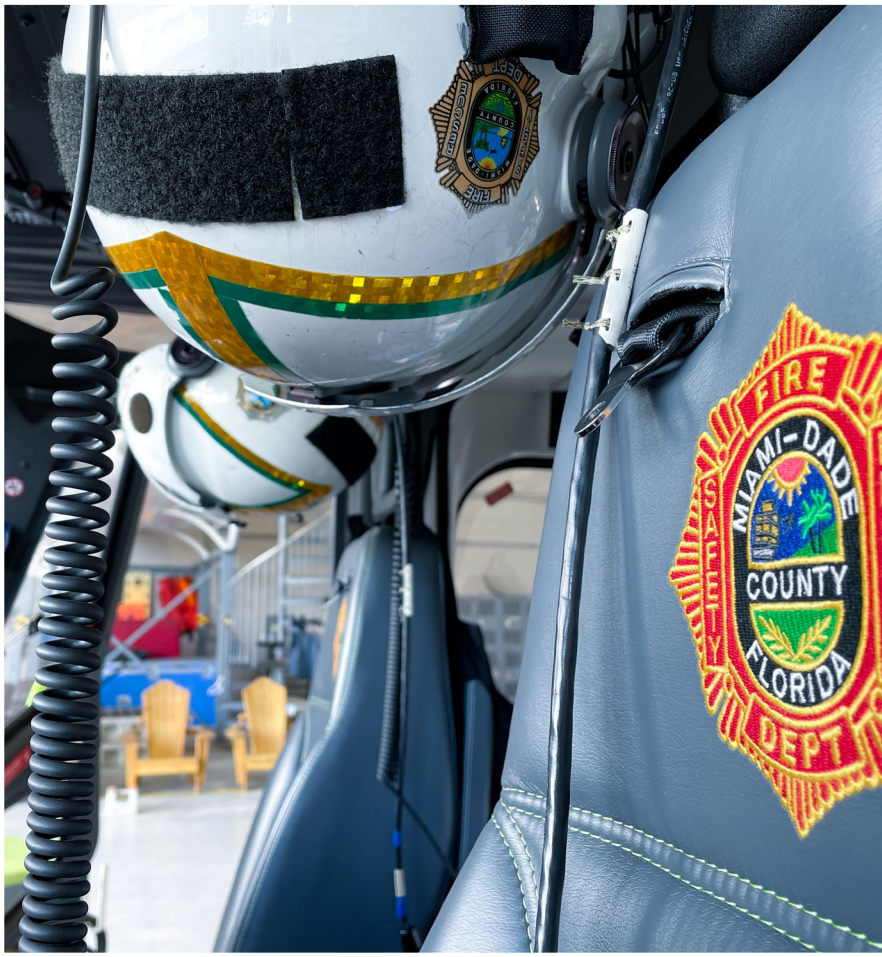
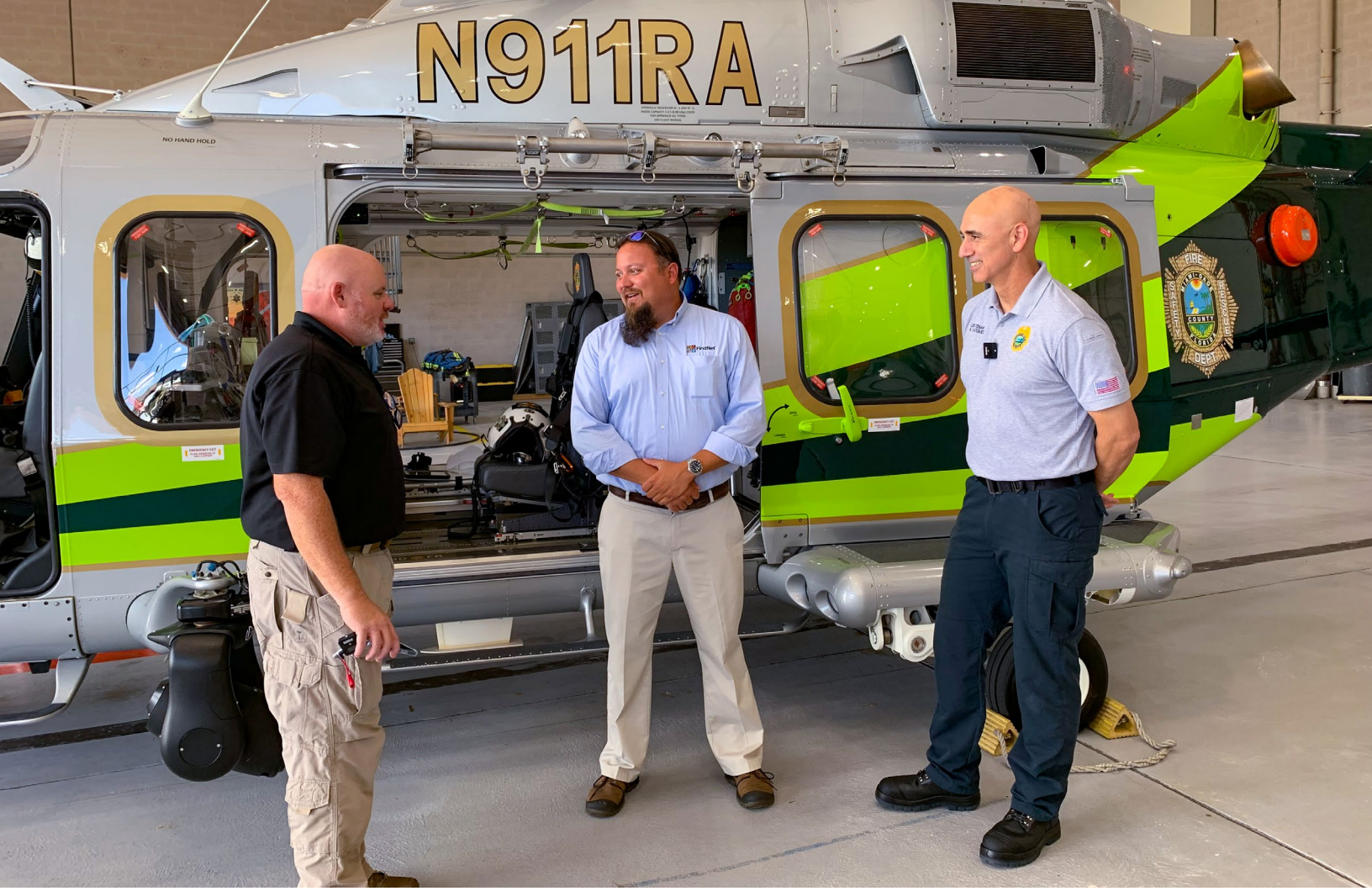




PUBLIC SAFETY AVIATION AND MARITIME CASE STUDY

July 2023

FirstNet® Authority



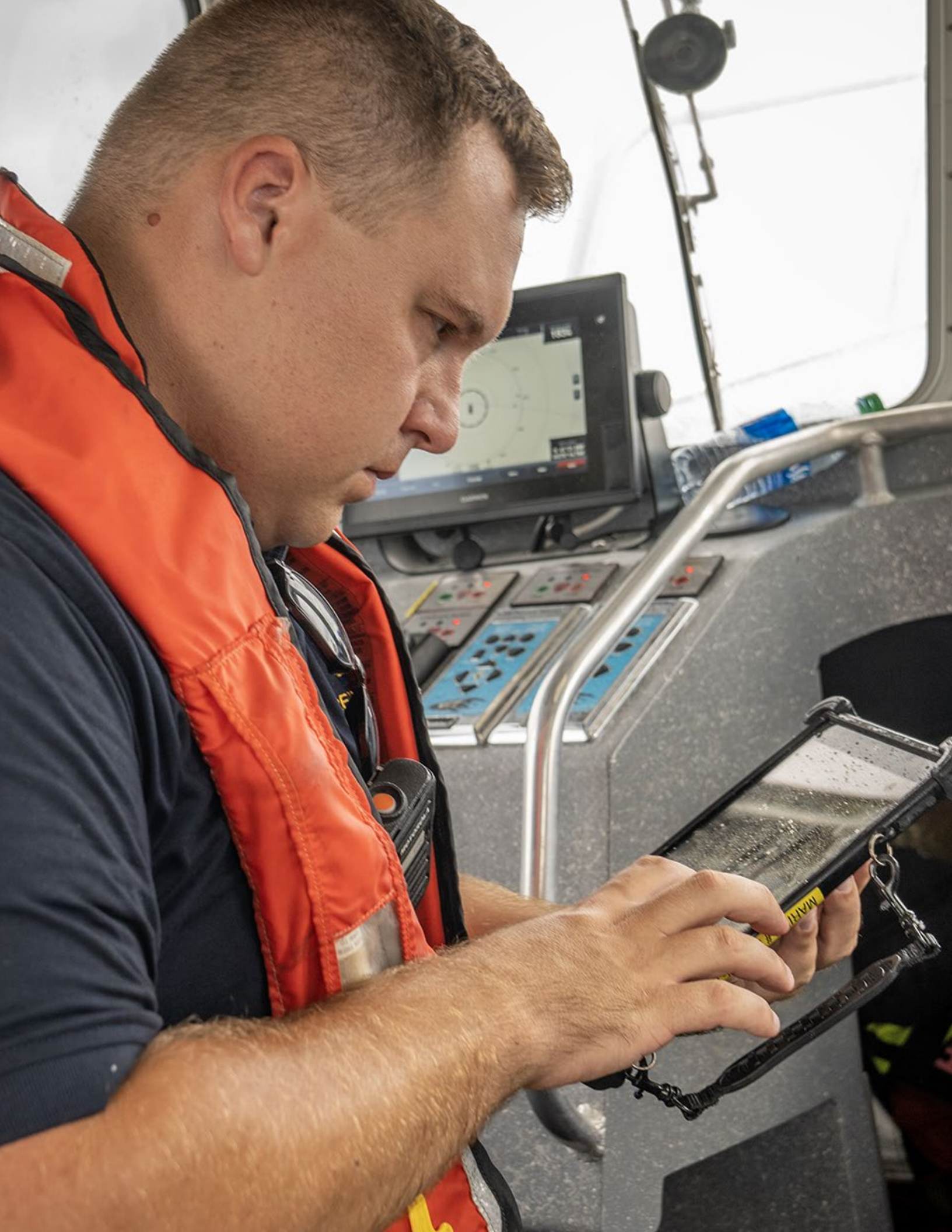
FirstNet Authority staff members meet with Miami-Dade Fire Rescue.

FirstNet® Authority

The FirstNet Authority was established in light of 9/11 to lead the creation of a dedicated nationwide broadband network using spectrum set aside for the public safety community (Band 14). Through a combination of government, commercial, and public safety partnerships, we are committed to delivering a network and supporting ecosystem of apps, devices, and capabilities that are innovative, reliable, accessible, and secure. By modernizing public safety communications with our partners, we can help responders keep America safe—every day and in every emergency.

To learn more, visit **FirstNet.gov**.

CONTENTS



EXECUTIVE SUMMARY

In January 2022, the First Responder Network Authority established a cross-functional working group to study and understand public safety's current use of broadband communications in aerial and maritime environments. Current cellular mobility systems are designed and built for terrestrial use and thus are not optimized to support aerial and maritime use cases. As such, the goal of this study was to identify the key operational challenges the public safety community experiences using FirstNet, the nationwide public safety broadband network (NPSBN), while conducting aviation and maritime missions. The study also aimed to identify the device and software technologies currently used in these two environments and gain a greater understanding of how the FirstNet network will be used during these missions in the future.

Between March and September 2022, the working group conducted a series of virtual engagements with 20 public safety aviation programs (14 of which also included an uncrewed aircraft system [UAS] component) and 12 public safety maritime units. The group also conducted on-site engagements with two aviation units and two maritime units. The group identified commonalities across engagements and defined high-level themes from the aviation, UAS, and maritime discussions. For example, some aviation programs are leveraging multiple wireless broadband providers for redundancy and bandwidth needs. Additionally, distance from shore and sea/weather conditions impact maritime users' experiences, and maintaining connectivity is challenging along varied coastlines.

> *"…to solve those horizontal, vertical issues is not going to be simple. Can you fly low, can you fly slow, and can you fly level to be able to connect and make it work? Absolutely, we do it today; it just depends on what the mission is. To use it mainstream and solve these other technical issues, that's an engineering thing."*
>
> STATE AVIATION AGENCY

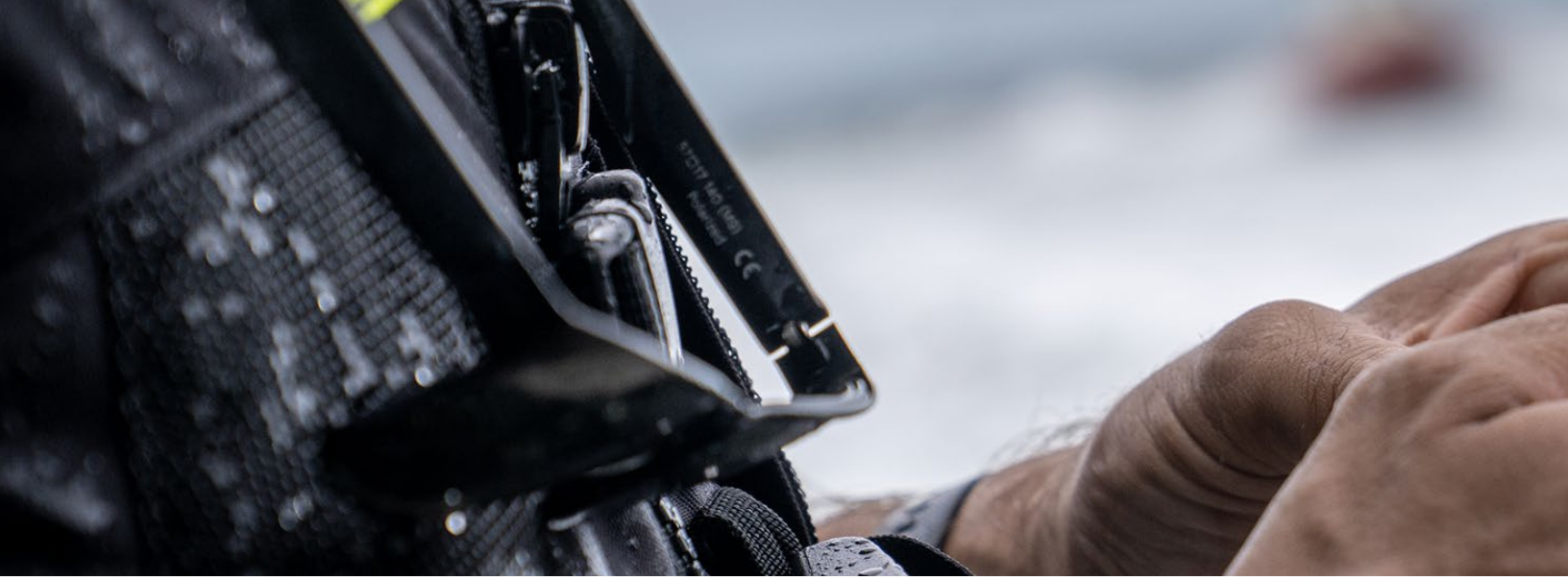
While those interviewed relayed the use of many different communications tools, this study focused specifically on broadband use. Some public safety entities are actively incorporating broadband connectivity and data use into their aviation operations using portable devices, such as tablets and smartphones, and by leveraging various applications and software. UAS programs today are primarily using broadband connectivity to stream video or pictures from the UAS hand controller on the ground, not the UAS itself. Some maritime units are leveraging broadband connectivity and data use for maritime operations using portable devices, while others are hesitant given past experiences or assumptions about current maritime coverage availability.

Interviewees provided examples of how they would like to leverage broadband connectivity in the future for aviation and UAS programs, as well as maritime operations. Across the engagements, the described use cases primarily reflected two overarching mission requirements:

- Providing enhanced situational awareness, which refers to the ability to create a common operating picture for all those supporting an incident to facilitate more informed, data-driven decision-making, and
- Supporting aerial (e.g., search and rescue; intelligence, surveillance, and reconnaissance; fire detection and suppression; patient transport) or maritime operations (e.g., search and rescue, drowning recoveries, law enforcement assistance, tows, firefighting).

Almost unanimously, the interviewees identified the need to both provide aviation *and* maritime units with enhanced situational awareness and to obtain information (e.g., video, photos) from aircraft, UAS, and marine vessels to provide enhanced situational awareness to ground units.

Through these engagements, the working group developed a thorough picture of the current use of broadband and other communications tools in fixed-wing and rotor aircraft, on maritime vessels, and for UAS, as well as public safety's future anticipated mission requirements.

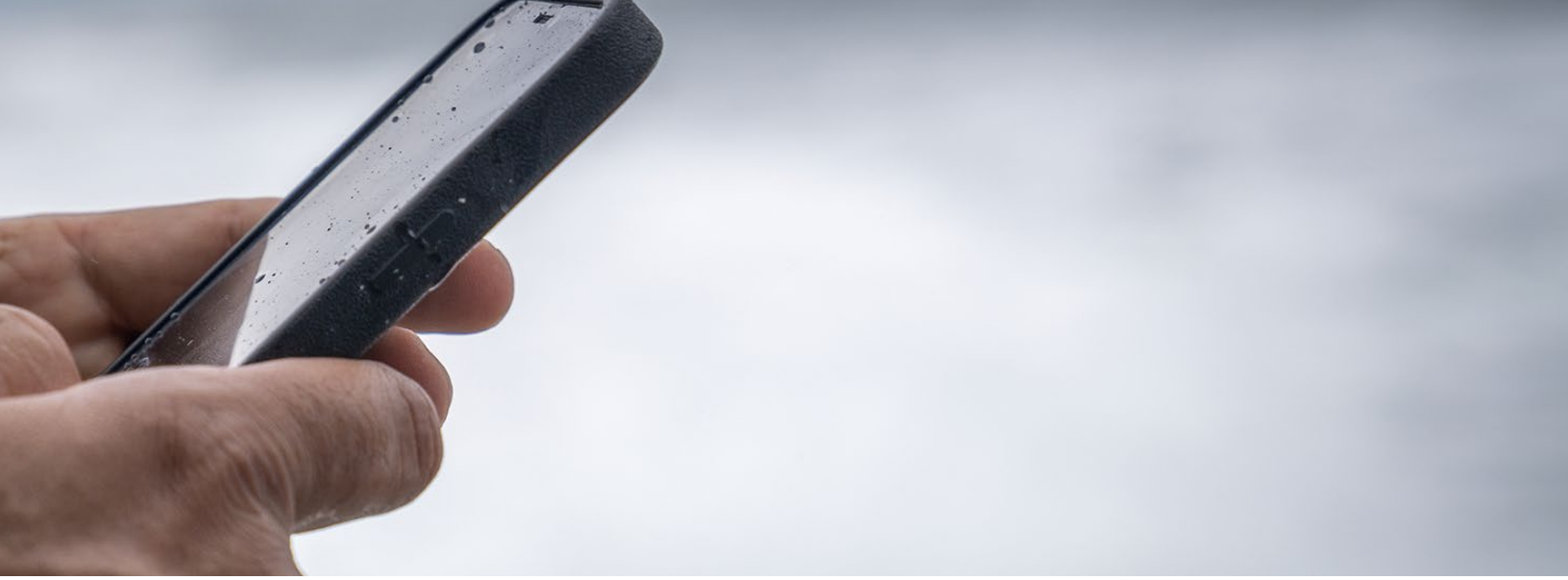


Examples of Desired In-Flight Broadband Usage

- Make phone calls, send/receive text messages, and access the internet
- Consistently stream full-motion, high-quality video to ground-based or marine units
  - For example, one fire agency wants to livestream video of the fireline to increase responder safety.
  - Another agency seeks to stream video directly from the aircraft to their video management server for distribution using FirstNet.
- Send and receive responder and asset location data to then visualize and track
  - For example, one fire department expressed an interest in sharing asset locations between aviation and marine units, as well as location breadcrumbs (e.g., past search patterns).
- Secure communications between the aircraft and ground-based units (e.g., incident command)
  - For example, some air ambulance providers stated they want the ability to have air-to-ground communications with the hospital for transport scenarios or when bringing in an acute patient.
- Access agency or department computer aided dispatch (CAD) systems in real time with the same user experience as vehicle-based mobile data terminals
- Transmit flight tracking data, engine systems data, and other aircraft-related data via broadband rather than satellite
- Access geographic information system (GIS) maps and all available layers
- Share patient telemetry with emergency departments or trauma centers while in flight
- Leverage airborne platform as a communications gateway connecting teams using land mobile radio and broadband devices
- Access regional or national interoperable push-to-talk over cellular channels
- Transmit Band 14 or commercial bands from the aircraft to provide coverage to the ground

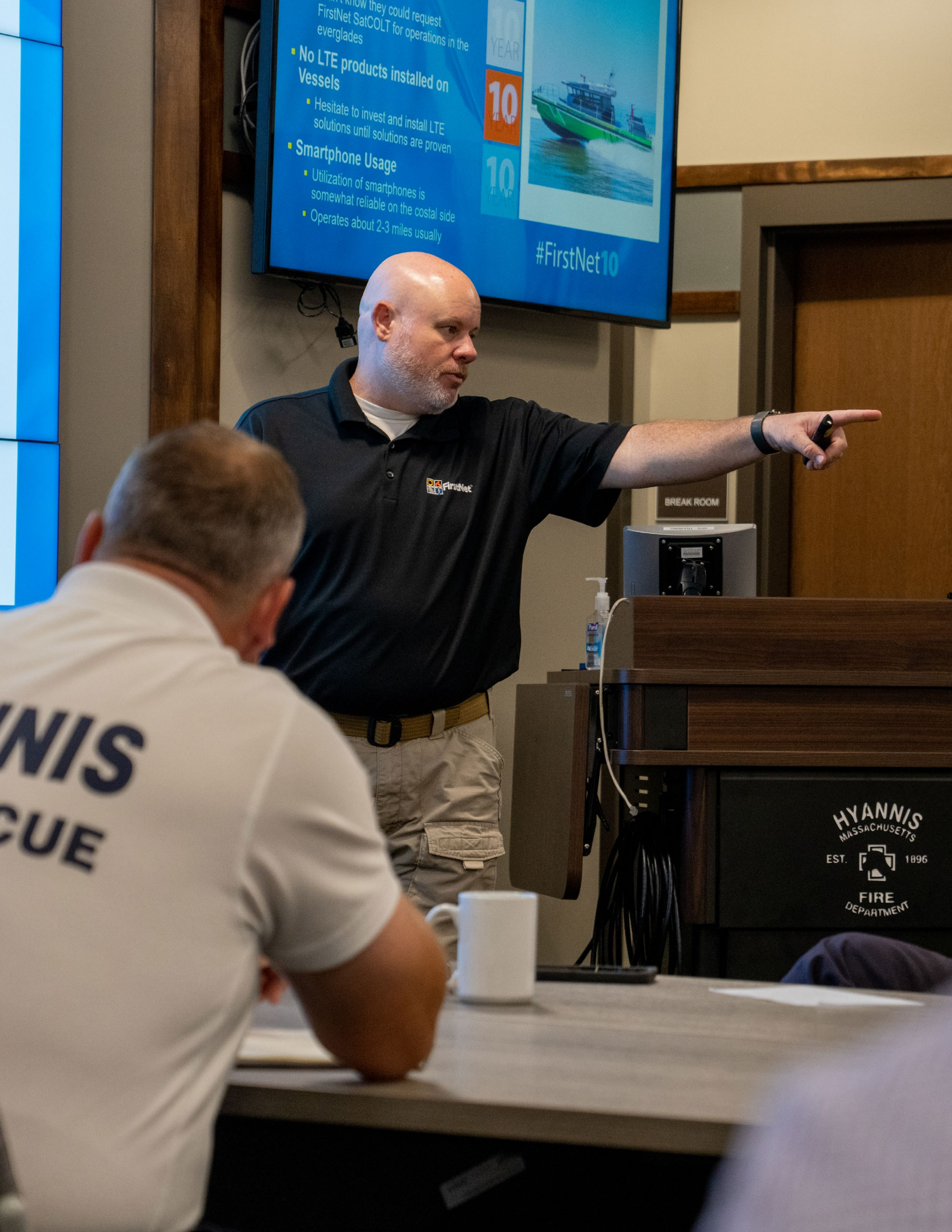
Examples of Desired UAS-related Broadband Usage

- Stream video directly from the UAS via broadband to various solutions beyond simply the hand controller
- Transmit data and share it on multiple platforms simultaneously
- Establish a redundant command and control broadband data link
- Leverage a broadband connection to the UAS to further enable Beyond Visual Line of Sight (BVLOS) and "Drones as a First Responder" capabilities



Examples of Desired Maritime Broadband Usage

- Make phone calls, send/receive text messages, and access the internet
- Reliably communicate with staff and land-based units, as well as other marine units
  - For example, a fire department described the desire for an alternative, broadband-based means of communicating with the U.S. Coast Guard for response operations.
- Send and receive responder and asset location data to visualize and track
  - For example, a fire department expressed it wants to share asset locations between aviation and marine units, as well as location breadcrumbs (e.g., past search patterns).
- Access CAD systems and records management systems, as well as email and messaging applications
- Complete reports and ticket violations in real time
- Stream video and/or conduct real-time video calls
- Operate a small cell on the marine vessel to provide both commercial and Band 14 FirstNet access
- Support autonomous underwater vehicle missions, including asset tracking
- Use of FirstNet high power user equipment (HPUE) devices for improved user experience at the cell edge


know they could request
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everglades
No LTE products installed on Vessels
Hesitate to invest and install LTE solutions until solutions are proven
Smartphone Usage
Utilization of smartphones is somewhat reliable on the costal side
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INTRODUCTION

In January 2022, the First Responder Network Authority's (FirstNet Authority) Market Engagement Office Stakeholder Collaboration Division established a cross-functional working group to study and understand public safety's current use of broadband communications in aerial and maritime environments. Through a series of virtual engagements and in-person discussions, the Public Safety Aviation and Maritime Working Group developed a thorough picture of the current use of broadband and other communications tools in fixed-wing and rotor aircraft, on maritime vessels, and for uncrewed aircraft systems (UAS), as well as public safety's desired operational requirements of the nationwide public safety broadband network (NPSBN).

Purpose

The goal of this study was to identify the key operational challenges the public safety community experiences using the NPSBN, also known as the FirstNet network, while conducting aviation and maritime missions. The study also aimed to identify the device and software technologies currently used in these two environments and gain a greater understanding of how the FirstNet network may be used during aviation and maritime missions in the future. These goals are consistent with the FirstNet Authority Strategic Plan for fiscal years 2023 to 2027, which includes a strategic objective to "identify and promote public safety's needs in support of network evolution planning."

Study Rationale: Growing Public Safety Need

Data is becoming an integral part of public safety operations and response. However, not all response takes place on land; first responders are increasingly looking for data capabilities as they take to the air or sea to respond to emergencies. Current cellular mobility systems are designed and built for terrestrial use; they are not optimized to support aerial and maritime use cases. The 2021 research paper, *A Survey of Wireless Networks for Future Aerial COMmunications (FACOM)*, notes "our match study on the communication technologies versus aerial use cases shows the lack of a unified networking solution to meet all the connectivity demands of the use cases."[1] And yet, public safety aviation and maritime units have used the existing terrestrial coverage for many years, to the extent possible, to provide solutions in support of mission requirements.

> *"Uninterrupted connectivity has long been a requirement for government aviation, and for today's military and other non-commercial government aircraft, demand for faster broadband communications at high data rates has never been greater."*[2]

In fiscal years 2021 and 2022, the FirstNet Authority Market Engagement Office conducted more than 3,500 engagements with public safety stakeholders. Approximately five percent of these engagements included discussions around the use of or need for wireless broadband communications capabilities in aerial or maritime environments. Through these engagements, the Market Engagement Office team captured direct feedback from public safety. For example, one stakeholder identified a desire for FirstNet service to be accessible in the air from helicopters specifically in the 1,000 to 3,000 foot range. An emergency medical services (EMS) stakeholder emphasized, "FirstNet connectivity is important especially when live streaming from [our] drones on the DroneSense application." Many fire service stakeholders advocated for live streaming from fixed-wing aircraft to provide situational awareness for wildfires, while others sought the ability to deliver photographs in real time rather than having to wait for the aircraft to download content.

While they continue to seek wireless broadband-based solutions, agencies have devised alternative solutions to achieve these mission requirements. For example, one west coast fire department uses a video management system in combination with an existing mesh network system to push down newsworthy quality video from a rotor aircraft to command staff's personal devices to facilitate real-time decision-making.

1 Baltaci, Aygun, Ergin Dinc, et. al. "A Survey of Wireless Networks for Future Aerial COMmunications (FACOM)." Institute of Electrical and Electronics Engineers. Available online: **https://arxiv.org/pdf/2111.04175.pdf**.

2 Air Force Technology. "FlexAir: At the cutting edge of broadband communications for aircraft." September 2, 2020. Available online: **https://www.airforce-technology.com/sponsored/flexair-broadband-communications-for-aircraft/**.

Maritime Communications Challenges on September 11, 2001

When the World Trade Center towers collapsed on September 11, 2001, the normal transportation routes off the island of Manhattan were closed, including all tunnels, bridges, and mass transit. Citizens fled to the water's edge along the New York Harbor to escape the island. Evacuations started small with local ferry boats, but quickly the number of people outnumbered the boats available. Seeing the influx of people, the U.S. Coast Guard—which oversees all marine traffic in the harbor—placed a general marine band call for all mariners to assist in the evacuation. Tugboats, fire and police boats, commercial ferries and barges, pleasure craft, and commandeered cabin cruisers answered the call by the hundreds. Some boats transported evacuees off the island while others distributed water to waiting civilians or ferried emergency supplies to the island.

It became the largest maritime evacuation conducted in the history of the United States. The entire operation was coordinated through overloaded marine radio channels, limited cellular service coming from New Jersey, cardboard signs, and hand signals. The heroes of this rescue are rarely remembered, but they successfully evacuated more than 500,000 civilians from Manhattan to New Jersey or other locations in New York. This real-life example illustrates the importance of extending broadband coverage to public safety operations in maritime environments.

Band 14: FirstNet Differentiator

Band 14 is nationwide, high-quality spectrum set aside by the government specifically for the FirstNet network. Band 14 may provide public safety with the broadband connectivity needed to operate in aerial and maritime environments. There are two unique elements of policy that make Band 14, and therefore the FirstNet network, a viable potential candidate for aviation and maritime mission-critical communications.

> *"We have great interest in all things FirstNet, especially this aviation piece. I know the technology works. It is time to solve the FirstNet problems that are critical for public safety air operations."*
>
> WEST COAST FIRE DEPARTMENT AVIATION UNIT

First, the Federal Communications Commission (FCC) prohibits the use of cellular telephones by the public while aircraft are airborne. Under FCC regulations, "Cellular telephones installed in or carried aboard airplanes, balloons or any other type of aircraft must not be operated while such aircraft are airborne (not touching the ground)."[3] However, Part 90 of the FCC's rules, which covers public safety communications (including FirstNet Band 14) states, "mobile stations…may be operated aboard aircraft for air-to-mobile, air-to-base, air-to-air and air-to-ship communications subject to the following: (1) operations are limited to aircraft that are regularly flown at altitudes below 1.6 km (1 mi) above the earth's surface."[4]

Second, the FCC authorized the transmission of Band 14 at a higher power, and the 3rd Generation Partnership Project Release 11 defines the maximum power to be 1.25 watts. This means responders operating near the cell edge, such as in a maritime environment, using high power user equipment (HPUE) MegaRange® devices will have improved uplink data speeds and more reliable use of the coverage area.

Methodology

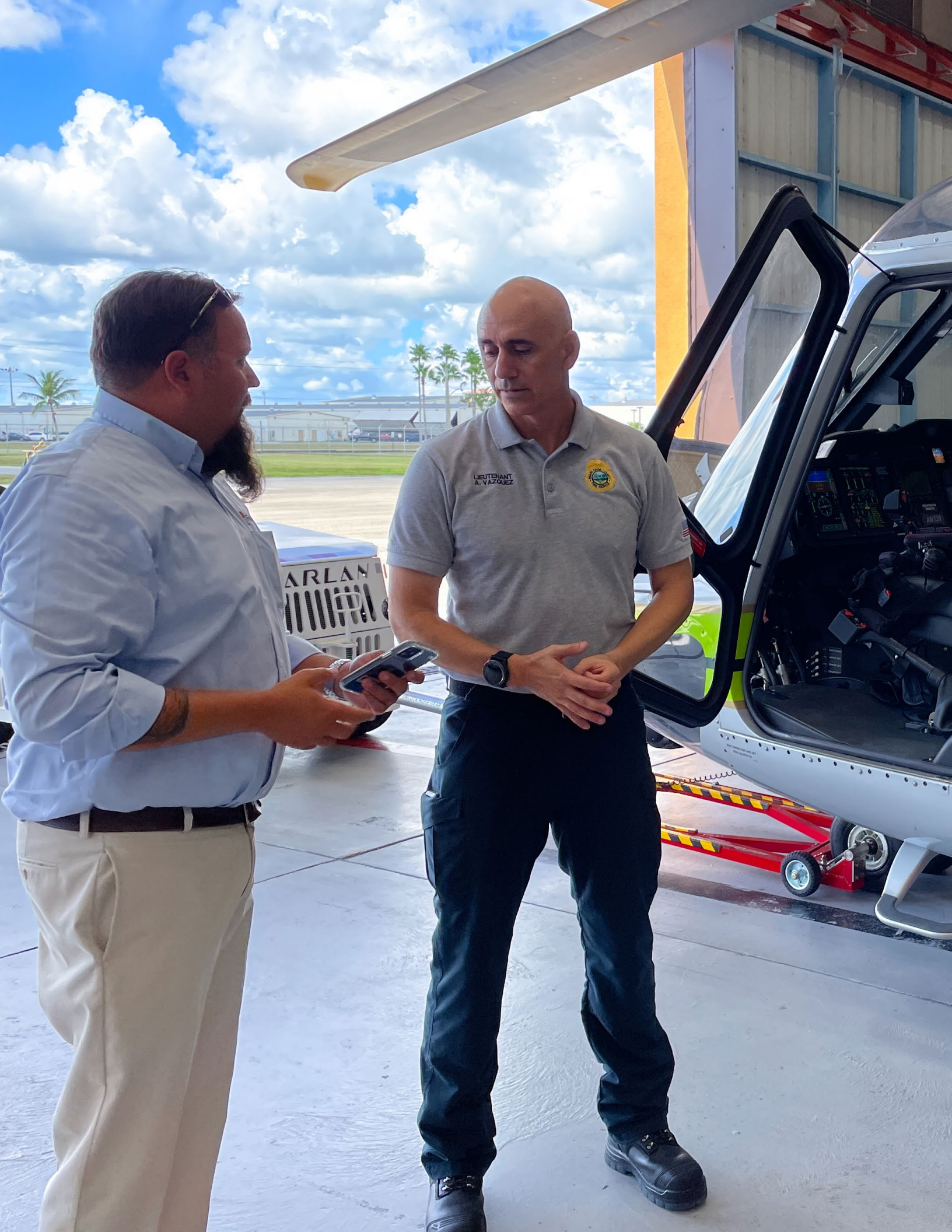
The Public Safety Aviation and Maritime Working Group members represented several FirstNet Authority mission units, including the Market Engagement Office, Office of the Chief Network and Technology Officer, Roadmap Development Division, and Executive Operations Division. The members were selected based on their various areas of expertise and experience, including aerial operations, UAS operations, fire service, network design, and public safety operations, among others. The working group had two subcommittees—Aviation and Maritime—for the purposes of developing specific questions for public safety and planning the virtual engagements with public safety entites.

Between March and September 2022, the subcommittees conducted a series of 20 aviation and 12 maritime virtual engagements with various public safety agencies and associations from across the United States. During these engagements, the FirstNet Authority facilitators asked participants about their use of wireless broadband

3 47 C.F.R. § 22.925.
4 47 C.F.R. § 90.423(a).

connectivity in aviation and maritime environments, as well as future mission requirements related to wireless broadband. Notably, 14 engagements also included a UAS component. If a particular agency or association did not use wireless broadband connectivity in its operations, the facilitators solicited information about the current mode(s) of communication used. To gather a first-hand perspective of the technologies discussed during the virtual engagements, the subcommittees conducted two aviation and two maritime on-site engagements with public safety agencies.

After collecting and reviewing the virtual engagement information and participating in on-site engagements, the FirstNet Authority analyzed the information to develop a summary of its findings.


LIEUTENANT
A. VAZQUEZ

AVIATION

The Aviation Subcommittee conducted virtual engagements with 19 public safety entities with aviation programs, plus one organization that actively supports public safety aerial operations. The subcommittee also conducted two on-site engagements with public safety aviation programs. These entities ranged from federal agencies to state law enforcement entities to large urban fire departments. Though each agency or association offered unique perspectives, the subcommittee identified the following seven commonalities and themes for aviation programs:

- Aircraft crews are leveraging FirstNet as a "best effort" today. For example, some agencies have leveraged FirstNet to stream video and upload/download imagery to/from the aircraft.
- Aircraft crews report improved broadband connectivity at lower altitudes, but diverse rugged terrain presents challenges.
- Some agencies are leveraging multiple wireless broadband providers for redundancy and bandwidth needs.
- Some agencies are modifying exterior airframes to accommodate additional antennas, which can greatly improve network connectivity.
- Any wireless broadband equipment added to the inside of the aircraft must be small and lightweight.
- All agencies leverage land mobile radio (LMR) for both air-to-air and air-to/from ground; however, their public safety LMR communications are limited when flying outside their respective jurisdictions.
- Aircraft crews desire the same FirstNet connectivity as ground units while conducting aerial operations. Network connectivity is vital to maintaining situational awareness and the safety of public safety operators.

Entity Summary Information

The public safety agencies that participated in the case study virtual engagements provided details about the makeup of their respective aviation fleets, as well as other information about aerial operations. Table 1 summarizes this information in several areas: types of aviation assets, common operational environments, expectations for multiple assets responding to the same incident, common mission types, applications and software used today, and current communications tools.

Current Broadband Use

Interviewees relayed their aviation units use various communications tools—including broadband in some capacity—both on-the-ground and in-flight for various operations.

The working group noted some public safety entities are actively incorporating broadband connectivity and data use into their respective aviation operations using portable devices, including tablets and smartphones. They are running various applications and software on these devices, including CAD solutions, electronic patient care reporting, maps, weather applications, pre-flight planning, location-based services applications, and situational awareness applications. However, some agencies interviewed, specifically private EMS transport companies, only use wireless broadband connectivity while on the ground versus during operations in the air due to entities' current understanding of Federal Aviation Administration (FAA) and FCC regulations.

Table 1: Aviation Entity Summary Information

Aspect	Description
Assets	Fleets ranged in size from one fixed-wing aircraft (e.g., Cessna Caravans, Super Cub, Beechcraft Super King Air 350) to seven helicopters (e.g., Bell helicopters) to a fleet of 43 aircraft, including both fixed-wing and rotary craft.
Operational Environments	Entities operate their aircraft over terrain ranging from densely populated urban areas to mountains and valleys to vast, rural plains. Some also noted operations over swamps, wetlands, lakes, rivers, and the open ocean.
Simultaneous Operations	Most entities articulated an expectation of multiple assets being active simultaneously over an area during an incident. Participants said the number of assets could range from a little as one aircraft up to 26 aircrafts sharing an airspace, depending on the severity of the mission, like a search and rescue incident or a special event like the Super Bowl.
Common Missions	Missions vary with the agency discipline. Law enforcement agencies listed various missions, including search and rescue; tactical situations; damage assessments; intelligence, surveillance, and reconnaissance work; forest inventory flights; forest health and monitoring flights; counter drug surveillance; and homicide surveillance. EMS entities described patient interfacility transport and patient transports from scenes. Fire service agencies listed search and rescue missions, as well as aerial firefighting, fire detection, and fire suppression flights.
Applications and Software	Agencies listed various applications and software used on mobile devices (e.g., smartphones, tablets) and mobile data terminals in aircraft, as well as on computers in terrestrial facilities to monitor aircraft activity. Some of the applications listed include computer-aided dispatch (CAD) systems (e.g., CentralSquare Field Ops), flight planning and location-based services solutions (e.g., Find My Friends, FlightCell DZMx, Flight Tracker, ForeFlight, SilverEye Aviation), situational awareness solutions (e.g., Android Tactical Awareness Kit [ATAK], FUSUS software), as well as common commercial applications (e.g., FirstNet Enhanced Push-To-Talk [EPTT], WhatsApp, various weather applications, Google Maps).
Communication Type	Aviation program participants noted leveraging various types of communications outside of cellular broadband connectivity, including satellite communications (e.g., Starlink, SKYTRAC, Spidertracks), microwave, Silvus Technologies Mesh Network System, Lower S Band 2205, GPS System, Lynx System, Gogo Air Cell Connection, ICOM radios, Telex radio system, ultra high frequency (UHF) and very high frequency (VHF) radio, radio over Internet protocol (RoIP), 800 megahertz (MHz) radios, and Cobham system.

Examples of On-the-Ground Broadband Usage

- Before Departure
  - Receive call for service via cell phone
  - Review email with call details (e.g., date, time, location, point of contact for the mission)
  - Check weather, route, and closest aircraft via various mobile applications
  - Use commercial application to identify flight crew locations
  - Enter initial coordinates into flight planning application as provided by dispatch or reporting party for a search and rescue mission
  - Load fire location information
- After Landing
  - Upon landing, coordinate for fuel
  - Update dispatch and others on the mission outcomes via phone calls, text messages, or updates on applications

Examples of In-Flight Broadband Usage

- Use aviation applications to enter updated coordinates
- Use LTE network to extend LMR coverage (e.g., Motorola WAVE with RoIP connection to a statewide LMR system, use of FirstNet EPTT when LMR is not available)
- Use broadband to perform "charting" on tablets and check weather radar
- Receive incident updates via text or email
- Exchange texts or phone calls among aircraft during large event support for coordination purposes
- Send photos and damage assessments in real time to the ground
- Contact 9-1-1 callers directly to get additional details or directions
- Maintain situational awareness, including other aircraft locations

Future Desired Capabilities: Public Safety's Vision

Interviewees provided various examples of how they would like to leverage broadband connectivity in the future for aviation and UAS programs. Across the engagements, the described use cases primarily reflected two overarching mission requirements: providing enhanced situational awareness and supporting aircraft operations.

> *"The only way we can get data in the aircraft is to hear it."*
>
> LAW ENFORCEMENT OFFICIAL

Almost unanimously, the interviewed aviation programs identified the need to both provide aviation units with enhanced situational awareness *and* obtain information (e.g., video, photos) from aircraft and UAS to provide enhanced situational awareness to the ground units. Enhanced situational awareness helps create a common operating picture for all those supporting an incident; it also facilitates more informed, data-driven decision-making. For example, programs seek to consistently stream high-quality video and data from aircraft to provide ground units real-time insight to an on-going incident, such as fire conditions or a barricaded suspect location or current search patterns, among other scenarios. EMS programs seek to stream video to emergency departments to inform on-scene patient care, as well as provide situational awareness to the receiving unit. Programs also emphasized a key element of enhanced situational awareness is location information. Many interviewees expressed the need to monitor the location of aerial assets in real time to, for example, coordinate search patterns with ground- or marine-based units, as well as improve responder safety. As noted above, some programs today leverage commercially available applications to monitor aircraft and responder locations, but the opportunity exists to implement public safety-specific solutions to visualize and track assets and responders. Another component of situational awareness in the aircraft is having access to real-time information about a given incident or call; aviation units need and desire the same CAD experience as the ground units to ensure all responders are working from the same information. One interviewee articulated specific frustrations associated with dispatch personnel assuming aviation units have access to identical information as ground units when in reality, they do not. According to interviewees, robust, reliable broadband connectivity in the aircraft would support full CAD instances, which would facilitate an identical experience for aviation units.

Simultaneously, interviewees expressed a desire for broadband connectivity to support various aircraft operations, including search and rescue; intelligence, surveillance, and reconnaissance; and patient transport. These operations require enhanced situational awareness, as mentioned previously, but also increased coordination and communication among disparate responder groups or ground-based units (e.g., hospitals). Aviation programs seek ways to use broadband connectivity to send and receive important information in support of these missions.

Within the context of these overarching mission requirements, interviewees described specific ways they envision using broadband to provide enhanced situational awareness to the aircraft and from the aircraft or UAS to the ground, as well as to support aircraft operations. The following table summarizes program input across interviews and relays the various ways they seek to leverage reliable broadband connectivity in the future. At the core of interviewees' collective responses is the desire for a network that provides unparalleled quality of service but also retains the flexibility to morph and change as public safety expectations continue to grow.

Examples of Desired In-Flight Broadband Usage

- Make phone calls, send/receive text messages, and access the internet
- Consistently stream full-motion, high-quality video to ground-based or marine units
  - For example, one fire agency expressed a desire to livestream video of the fireline to increase responder safety.
  - Another agency seeks to stream video directly from the aircraft to their video management server for distribution using FirstNet.
- Send and receive responder and asset location data to then visualize and track
  - For example, a fire department stated it wants to share asset locations between aviation and marine units, as well as location breadcrumbs (e.g., past search patterns).
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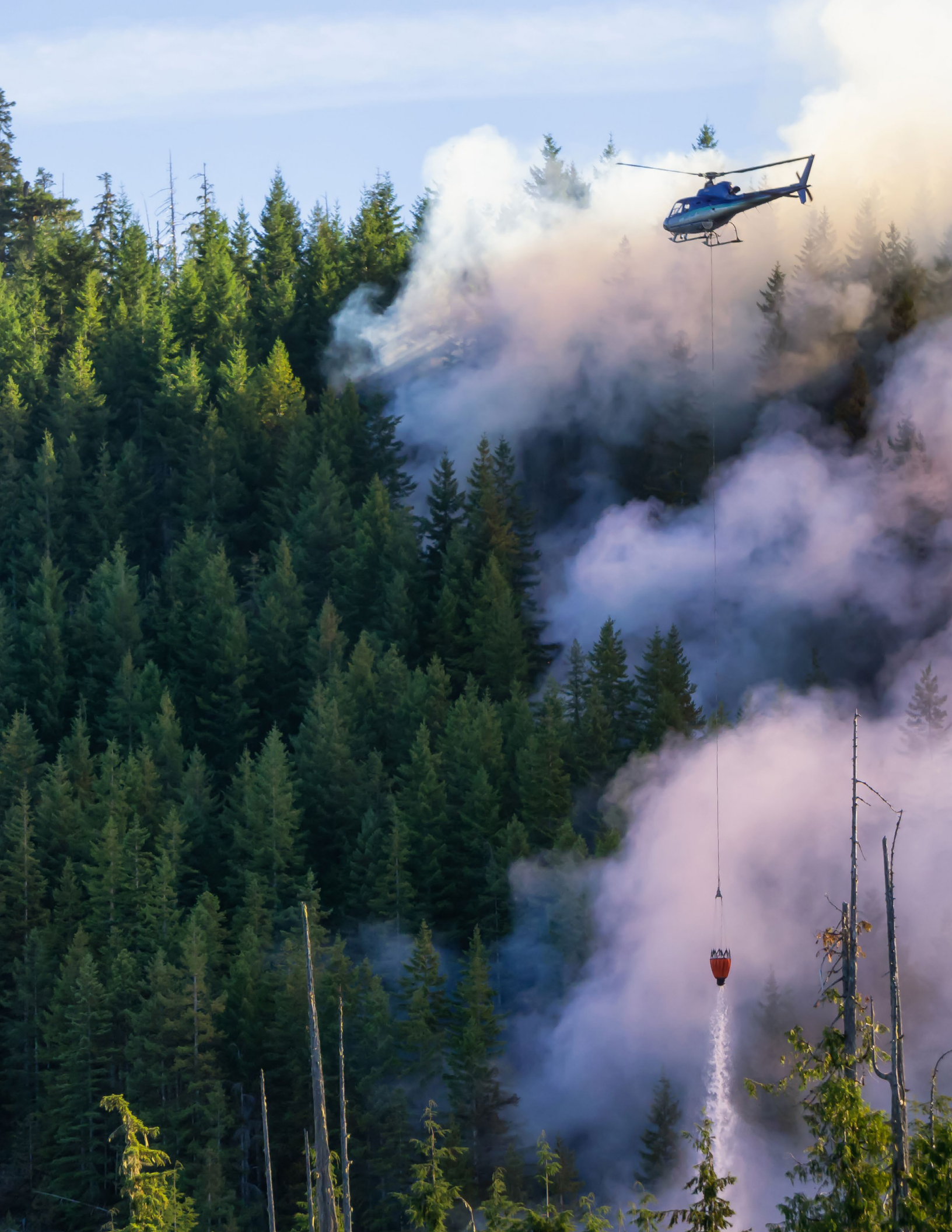
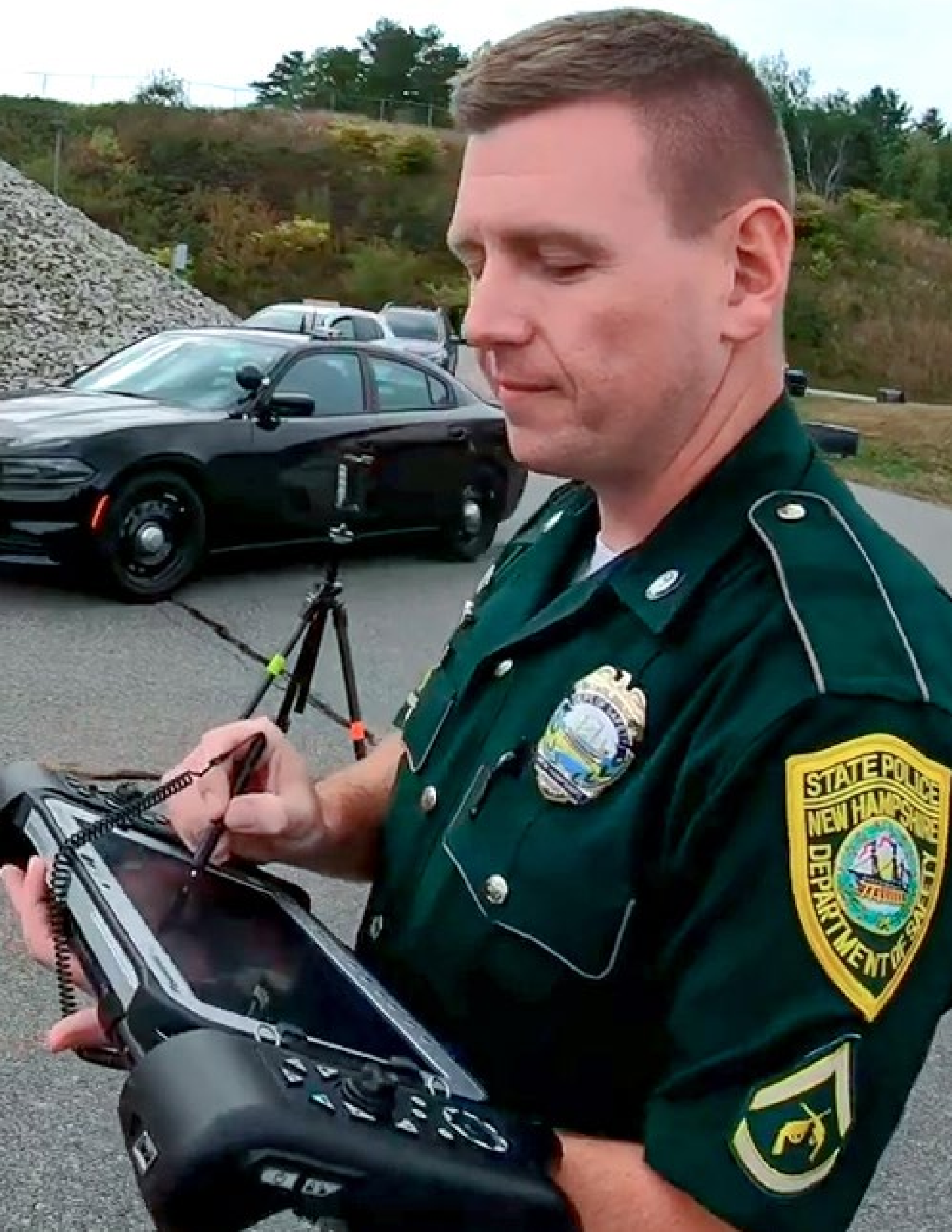
  - For example, some air ambulance providers articulated they want the ability to have air-to-ground communications with the hospital for transport scenarios or when bringing in an acute patient.
- Access agency or department CAD systems in real time with the same user experience as vehicle-based mobile data terminals
- Transmit flight tracking data, engine systems data, and other aircraft-related data via broadband rather than satellite
- Access geographic information system (GIS) maps and all available layers
- Share patient telemetry with emergency departments or trauma centers while in flight
- Leverage airborne platform as a communications gateway connecting teams using LMR and broadband devices
- Access regional or national interoperable push-to-talk over cellular channels
- Transmit Band 14 or commercial bands from the aircraft to provide coverage to the ground




STATE POLICE
NEW HAMPSHIRE
DEPARTMENT OF SAFETY

UNCREWED AIRCRAFT SYSTEMS (UAS)

The Aviation Subcommittee conducted virtual engagements with 14 public safety entities with UAS programs, as well as one association that advocates for UAS operations in public safety environments. Though each agency or association offered nuances and various operational scenarios, the subcommittee identified the following six commonalities and themes for UAS:

- UAS operators leverage wireless broadband to stream video and photos from the UAS hand controller; however, no UAS operator interviewed is streaming from an LTE device on the UAS/drone itself.
- A UAS with an LTE connection would further enable beyond visual line of sight (BVLOS) and "drone as a first responder"[5] capabilities.
- Using multiple wireless broadband providers helps improve an agency's chances of having coverage.
- Maintaining broadband coverage in diverse terrains is challenging.
- Having multiple manned and uncrewed aircrafts in an operational area can be common depending on the incident type or scale.
- Most agencies' UAS operators want cellular broadband connectivity to improve latency when streaming video from UAS for situational awareness.

5 As described by the **Chula Vista (Cal.) Police Department**, drone as a first responder (DFR) programs use drones to proactively respond to emergency calls. "The intent of the program is to get a drone on scene before responding officers arrive. Certified teleoperators can evaluate the situation remotely and relay information to officers and field supervisors. The drone can also feed live-streaming video of the incident to commanders and first responders. This helps personnel determine the best tools, tactics and resources to safely mitigate a problem—often before officers arrive on scene."

Table 2: UAS Entity Summary Information

Aspect	Description
Assets	UAS fleets ranged from several Autel Evos to various DJI products (e.g., M300s, Enterprise Advanced, Phantom 4 Pro, Mavic Pro) to an AEE Mach 4 Drone and Skydio products.
Operational Environments	Entities operate their UAS over terrain ranging from mountainous suburbs to large hills with peaks up to 4,000 to 5,000-feet. Some work over water close to the coastline or within harbor areas while others operate in remote geographies. Most operators noted they do not operate drones beyond their visual line of sight; however, one state agency mentioned they do have a tactical BVLOS waiver that allows them to go behind a building if they are pursuing an adversary.
Simultaneous Operations	Most entities shared an expectation of multiple assets being active simultaneously over an area during an incident. Participants said the number of assets could range from as little as three UAS to dozens of devices, especially for large crime scene incidents like officer-involved shootings or special events with large attendance. Most UAS programs are already used to sharing airspace with multiple UAS from neighboring agencies.
Common Missions	Entities employ UAS for various purposes and listed many use cases, including search and rescue operations, traffic incident reconstruction photography, crime and accident scene documentation, overwatch for law enforcement operations, searches for missing or wanted persons, fires, damage assessments after major incidents or natural disasters, and delivering items (e.g., water) during tactical operations. Other missions included harbor patrol, homeless outreach, and dive operations.
Applications and Software	Agencies listed various applications and software used in the context of UAS operations. Many of the applications are specific to preparing for or coordinating flight (e.g., Aloft for LAANC, UAV Forecast application), operating the aircraft (e.g., DJI Go application, DroneSense, Parrot Anafi application), and gathering or visualizing data (e.g., ATAK, GoPro, Pix4DReact, Responder Air), as well as common commercial applications (e.g., WhatsApp).
Communication Type	UAS stakeholders noted leveraging various types of communications outside of broadband connectivity including the use of TVU Networks Backpacks and Genetec. They also noted using CAPE via a hardwire internet connection.

Entity Summary Information

The public safety agencies that participated in the case study virtual engagements provided details about the makeup of their respective UAS fleets, as well as other information about UAS operations. Table 2 summarizes this information in several areas: types of assets, common operational environments, expectations for multiple assets responding to the same incident, common mission types, applications and software used today, and current communications tools.

Current Broadband Use

Interviewees relayed their UAS programs are primarily using broadband connectivity to stream video/photos from the UAS hand controller on the ground, not the UAS itself. Agencies are using various applications to stream video and provide situational awareness to responders in many locations, including ATAK, DroneSense, Genetec, and Responder Air, as well as solutions like Pix4DReact to create maps.

Examples of Broadband Usage by UAS Programs

- Leverage cellular devices to send images directly from the UAS hand controller to the agency's web portal for easy consumption
- Use cellular devices (e.g., smartphones, tablets) to fly UAS and use applications to stream video from the device to a Government Cloud Server; anyone with a link and credentials can log in and watch the video in real time, providing situational awareness
- Use cellular connection on routers and tablets for flying "drone as a first responder" missions
- Use drones with a network connection with tactical field pilots to perform three-dimensional (3D) mapping and diagraming for incidents (e.g., fatal collisions, major crime scenes); for example, use drones to capture 360 aerial shots to allow responders to later display the layout of the entrances and exits of schools for potential future emergencies
- Use cellular broadband connectivity in combination with different software and hardware solutions (e.g., TVU Networks Backpack) for secure video streaming and data dissemination
- Use messaging applications on smartphones and tablets (e.g., WhatsApp) on the ground to coordinate the number of drones in the operational airspace and create groups within the application to share information

Examples of Desired UAS-related Broadband Usage

- Stream video directly from the UAS via broadband to various solutions beyond simply the hand controller
- Transmit data and share it on multiple platforms simultaneously
- Establish a redundant command and control broadband data link
- Leverage a broadband connection to the UAS to further enable BVLOS and "Drones as a First Responder" capabilities

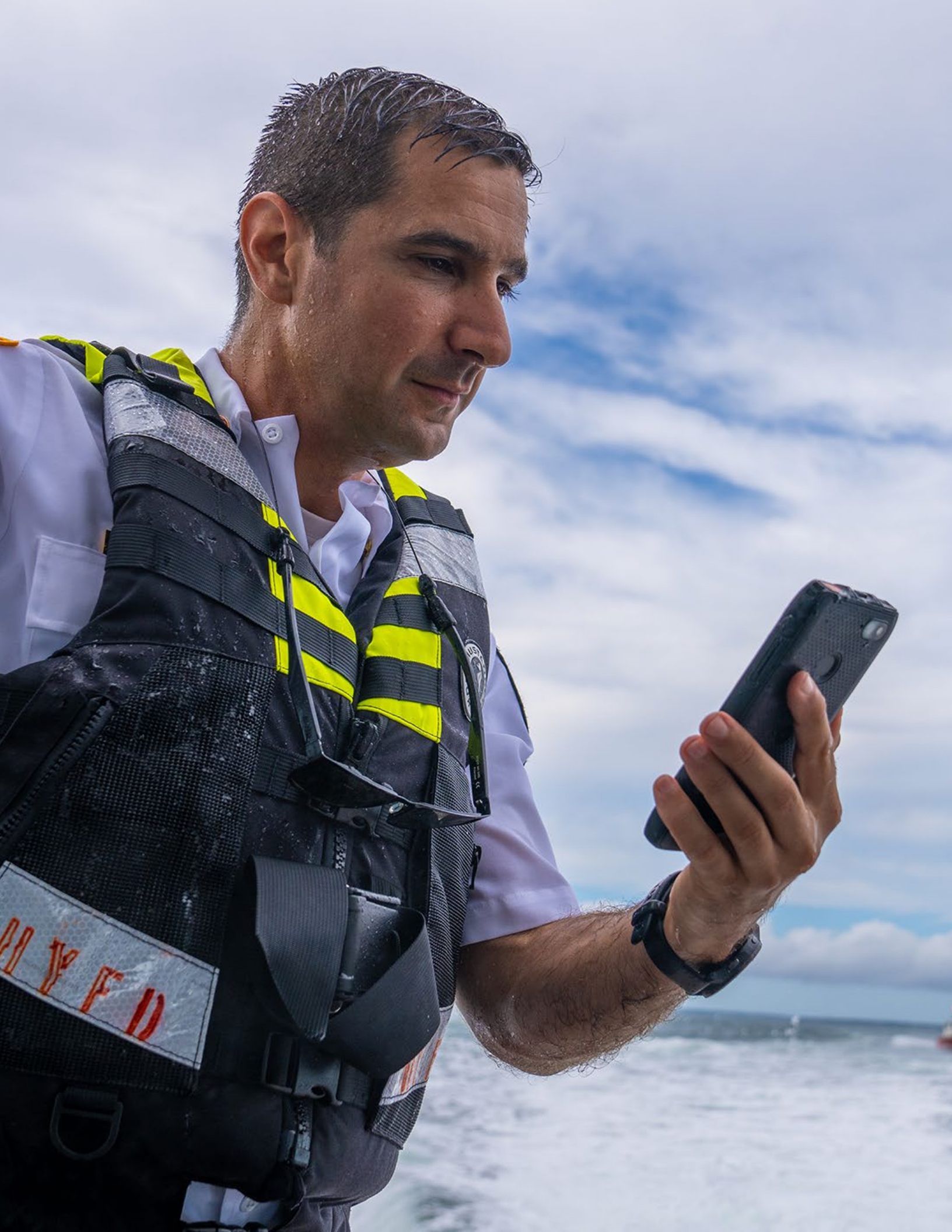
Future Desired Capabilities: Public Safety's Vision

"You will see a continued expansion of drones in the public safety spectrum."

UAS PROGRAM LEAD

The UAS-specific discussions yielded a unique opportunity to leverage broadband connectivity in the future to support UAS programs. Specifically, interviewees discussed the opportunity to use broadband for command and control of UAS for public safety operations. Interviewees indicated most command and control for UAS is conducted on unlicensed spectrum.[6] As such, they described how broadband connectivity, but more specifically FirstNet and Band 14, could help address security concerns related to control of the aircraft itself. The UAS program representatives also expressed the need for broadband connectivity on UAS to support collision avoidance capabilities, which are necessary for widespread BVLOS operations. Additionally, as noted in the aviation-specific *Future Desired Capabilities: Public Safety's Vision*, agencies seek to use UAS to provide enhanced situational awareness to ground units. Table 2 summarizes program input across interviews and relays the various ways they seek to leverage reliable broadband connectivity in the future.

6 This assertion is supported by the FCC. The **Report on Section 374 of the FAA Reauthorization Act of 2018 (Aug. 20, 2020)** states, "While the vast majority of UAS currently operate on unlicensed spectrum, wide-area, secure wireless network connectivity is required to control, track, and manage UAS operations safely and reliably. As UAS become larger and are used for more complex operations, the need for reliable communications necessarily will increase."



MARITIME

The Maritime Subcommittee conducted virtual engagements with 12 public safety entities with marine units and on-site engagements with two of those marine units. While these engagements yielded various use cases and unique perspectives, the Public Safety Aviation and Maritime Working Group identified the following four commonalities and themes for maritime programs:

- Maritime first responders desire a similar "FirstNet Experience," whether operating on land or on the water.
- A limited number of agencies incorporate broadband connectivity into their maritime operations today due to poor past user experiences (e.g., significant existing coverage gaps between islands, dropped calls).
- A crew's distance from shore and sea/weather conditions impact user experience, and maintaining broadband connectivity is challenging along varied coastlines.
- LMR solutions have presented connectivity issues in maritime environments.

Entity Summary Information

The public safety agencies that participated in the case study's virtual engagements provided details about the makeup of their respective marine fleets, as well as other information about maritime operations. Table 3 summarizes this information in several areas: types of marine assets, common operational environments, multiple assets responding to the same incident, common mission types, applications and software used today, and current communications tools.

Table 3: Maritime Entity Summary Information

Aspect	Description
Assets	The marine units described various assets, including Metal Shark boats (e.g., 50 foot Defiant series, 36-foot Fearless series, 38-foot), 46-foot fiber glass lobster style patrol boats, 47-foot motor lifeboats, and various SAFE boats (e.g., 27-foot). Other vessels include smaller Zodiac boats, twin outboard boats, aluminum skiffs, and jet skis.
Operational Environments	Entities frequently operate their vessels on the open ocean up to five miles offshore. Some participants noted operating up to 60 miles offshore, and one state law enforcement agency may go up to 200 miles offshore. Most entities cover inland navigable waterways, open water with some surrounding barrier islands, canals, and marshlands. Some entities operate in navigable waterways inland where they can see both sides of a river, along lake shores, or in coastal areas like harbors and bays.
Common Missions	The public safety entities support various missions, including search and rescue, drowning recoveries, law enforcement assistance (e.g., human smuggling, drug smuggling), tows, surf line rescues, firefighting, pollution responses, boat accidents, special events with high boater traffic, and fishing compliance. Most missions include multiple assets from the same agency, and some missions require mutual aid provided by multiple agencies that may include maritime and aviation assets working in conjunction to meet mission objectives.
Applications and Software	Agencies listed various applications and software used on mobile devices (e.g., smartphones, tablets) and mobile data terminals on vessels, as well as on computers in terrestrial facilities, to monitor marine traffic. Some of the applications listed include i911, RapidSOS, MarineTraffic application, Phoenix G2 application, and CG OneView (pulls together terrestrial and satellite automatic identification system [AIS] data), as well as common commercial applications, such as Google Translate and WhatsApp.
Communication Type	Marine unit interviewees leverage various types of communications outside of broadband connectivity including 800 MHz radios, VHF radios, Garmin inReach, satellite communications (including Push-to-Talk and phones), Rescue 21 contracted towers, and MilSatCom (military satellite communications systems wing).

Current Broadband Use

The working group noted some public safety entities are actively incorporating broadband connectivity and data use into their respective maritime operations using portable devices, including tablets and smartphones, while others are hesitant given past experiences or assumptions about current maritime coverage availability.

"The expansion of coverage and reliability of signal continue to be an issue despite the advances over the past 20 years. There are still some areas where you just drop out of cell service."

MARINE UNIT LEAD

Examples of Broadband Usage by Marine Units

- Before departure: Use LTE-connected tablet to obtain incident information and plug in the incident's latitude and longitude
- Send/receive emails, as well as share documents, photos, fingerprints, and other data elements
- Share search pattern
- Stream data from LTE-based sensors
- Use FirstNet-enabled router with an external antenna to provide connectivity to the agency's CAD system, enabling public safety officials to write reports and ticket violations
- Track location of marine assets via broadband routers and software/applications, such as MarineTraffic AIS, Nautical Alert application, or SmartView
- Use mobile applications (e.g., Phoenix G2) to dispatch marine units and provide basic description of the call and location
- Transmit sonar imagery to assist with search and rescue or recovery missions and to prepare for special events
- Use cellular broadband connectivity for charting applications (e.g., Navionics boating application)
- Use messaging applications on smartphones (e.g., Signal) to create chat groups and easily push information out to relevant responders
- Use video/audio chat platforms such as FaceTime on cell phones to provide incident command with situational awareness during maritime missions

Future Desired Capabilities: Public Safety's Vision

Interviewees provided various examples of how they would like to leverage broadband connectivity in the future for maritime operations. Similar to aviation and UAS, the described use cases primarily reflected two overarching mission requirements: providing enhanced situational awareness and supporting maritime operations. It is important to acknowledge these mission requirements are applicable to both of the distinct environments in which maritime units operate: offshore and in navigable waterways. For both environments, interviewees communicated a desire for broadband coverage to support the mission requirements.

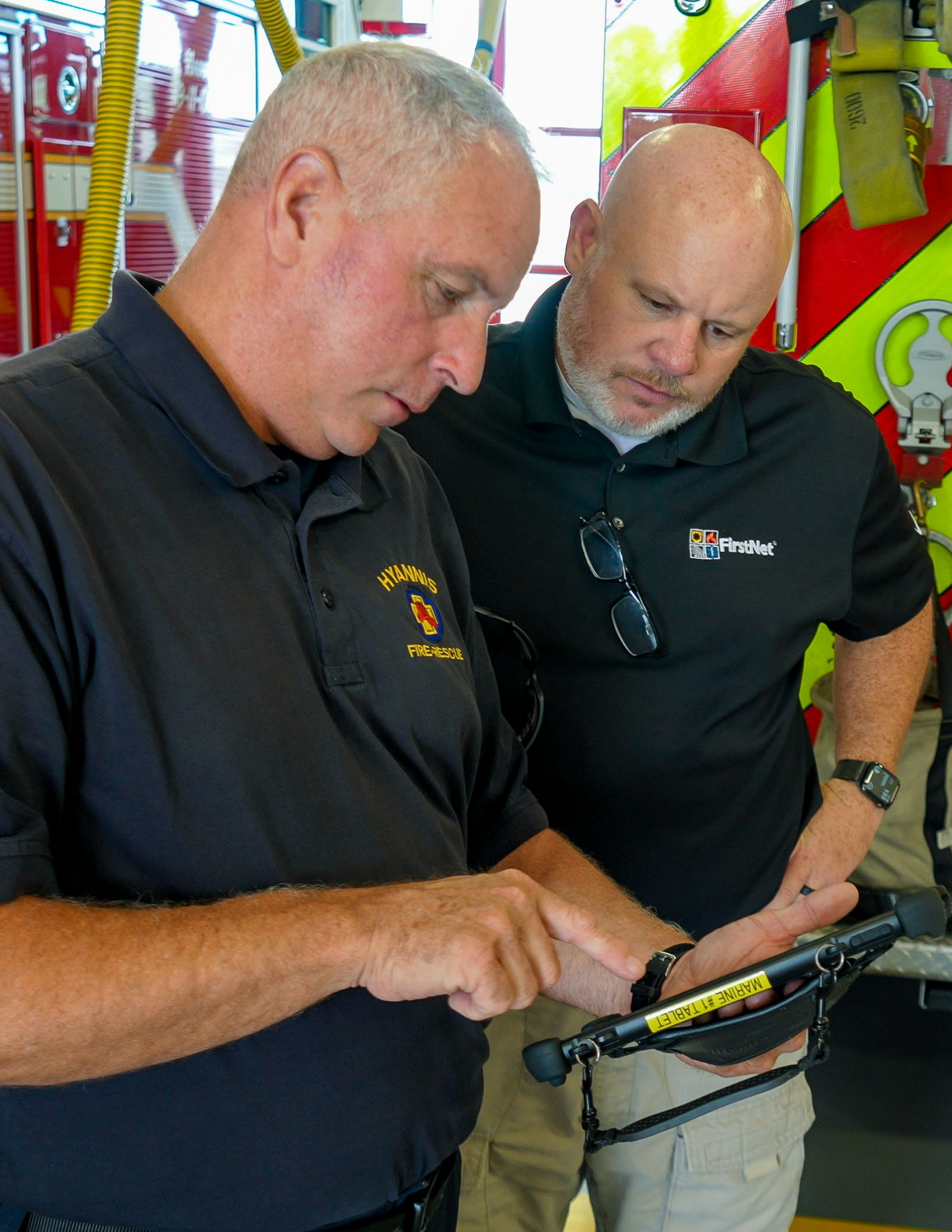
> *"We want to have any sort of communication with marine units when they're sent out. Video streaming is nice, but we first need to be able to communicate with boats out on the water."*
>
> FIRE SERVICE OFFICIAL

Agency representatives often spoke to the need to both provide marine units with enhanced situational awareness, as well as obtain information (e.g., video, photos) from maritime assets to provide enhanced situational awareness to decision-makers. The same elements of situational awareness mentioned for aerial and UAS operations apply to maritime operations as well. Interviewees expressed the need to monitor the location of maritime assets in real time for responder safety and response coordination. They also identified the desire to have access to real-time or updated information about the mission at hand, as well as real-time communications with other responding parties to ensure a coordinated response and limit duplication of effort for maritime operations.

Within the context of these overarching mission requirements, interviewees described specific ways they envision using broadband to provide enhanced situational awareness, emphasizing the importance of information flowing among marine assets, aviation assets, and land-based operations. The following table summarizes program input across interviews and relays the various ways they seek to leverage reliable broadband connectivity in the future. There is some overlap between current broadband use and desired use; current broadband use may only be representative of one marine unit's operations while desired use seeks to capture the broad vision as relayed by the various units.

Examples of Desired Maritime Broadband Usage

- Make phone calls, send/receive text messages, and access the internet
- Reliably communicate with staff and land-based units, as well as other marine units
  - For example, a fire department described the desire for an alternative, broadband-based means of communicating with the U.S. Coast Guard for response operations.
- Send and receive responder and asset location data to visualize and track
  - For example, a fire department conveyed it wants to share asset locations between aviation and marine units, as well as location breadcrumbs (e.g., past search patterns).
- Access CAD systems and records management systems, as well as email and messaging applications
- Complete reports and ticket violations in real time
- Stream video and/or conduct real-time video calls
- Operate a small cell on the marine vessel to provide both commercial and Band 14 FirstNet access
- Support autonomous underwater vehicle missions, including asset tracking
- Use FirstNet HPUE devices for improved user experience at the cell edge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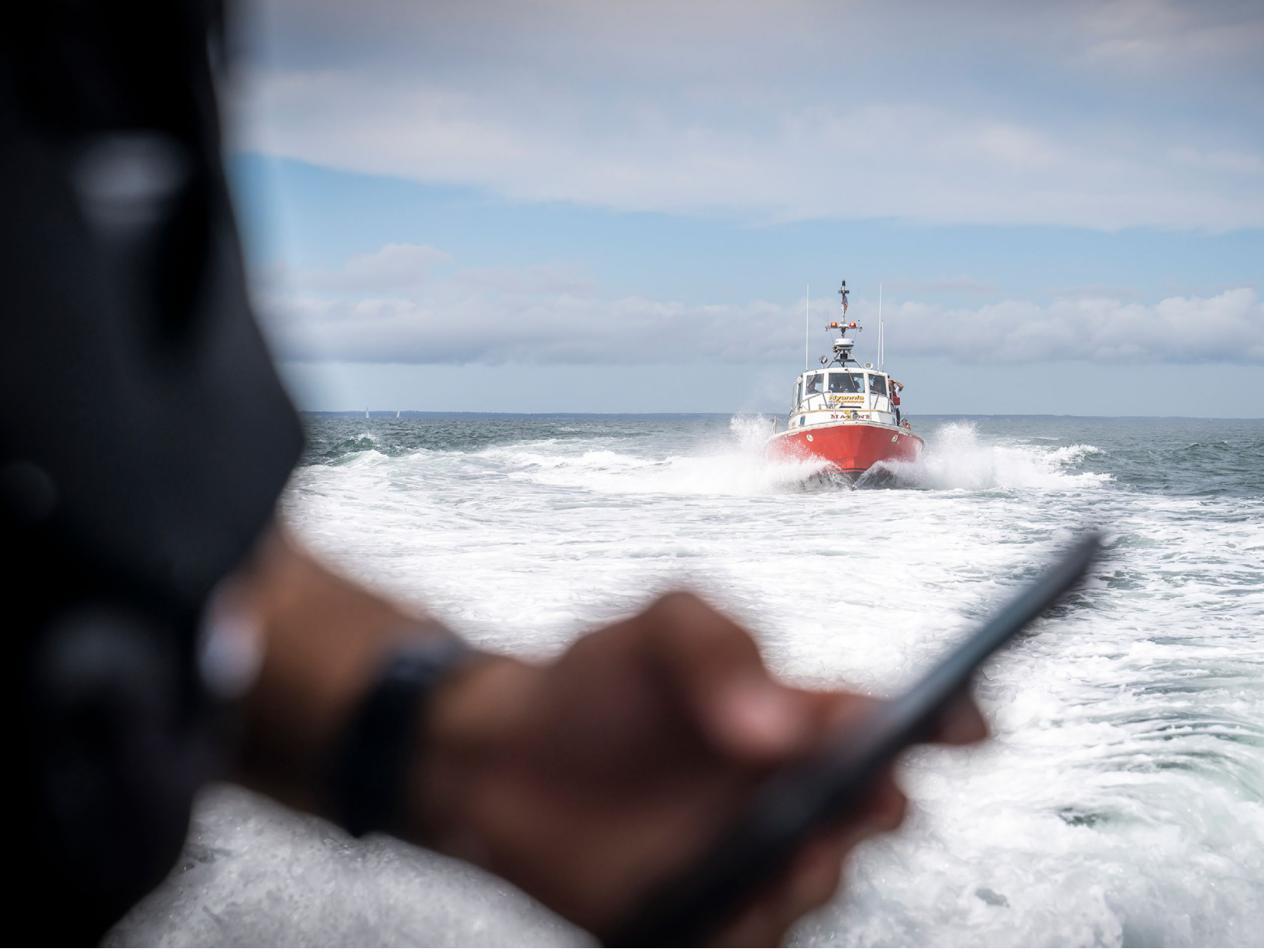
CONCLUSION

The Public Safety Aviation and Maritime Working Group was a cross-functional effort among various FirstNet Authority mission units to determine the extent of public safety's broadband-related needs for aerial and maritime operations. Through the virtual and on-site engagements, the working group developed a thorough picture of the current use of broadband and other communications tools by aviation, UAS, and maritime units, as well as public safety's desired operational use of the NPSBN.

Interviewees relayed examples of how they would like to use broadband connectivity in the future in fixed-wing and rotor aircraft, on maritime vessels, and for UAS. Across the engagements, interviewees described use cases that primarily reflected two overarching mission objectives: providing enhanced situational awareness and supporting aircraft or maritime operations. The interviewees almost unanimously identified a desire to both provide aviation and maritime units with enhanced situational awareness and obtain information (e.g., video, photos) from aircraft, UAS, and marine vessels to provide enhanced situational awareness to the ground units. Enhanced situational awareness helps create a common operating picture for all those supporting an incident, as well as facilitates more informed, data-driven decision-making. Aviation programs seek ways to use broadband connectivity to send and receive important information in support of various missions (e.g., search and rescue; intelligence, surveillance, and reconnaissance), and UAS programs pondered the use of broadband connectivity —specifically FirstNet — to address security concerns related to command and control of the aircraft itself. Maritime units expressed the need to monitor the location of maritime assets in real time for responder safety and to ensure a coordinated response, as well as identified the desire to have access to real-time or updated information about the mission at hand.

This study offered a unique opportunity to gather targeted feedback from public safety agencies across the United States, which will help shape the future of the FirstNet network. Public safety's vision for future broadband use in aerial and maritime environments provides critical insight into public safety's desired uses and applications of the network for the FirstNet Authority and its NPSBN partner, AT&T. The FirstNet Authority will continue to work with AT&T to further enhance and evolve the FirstNet network for public safety.



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