Life-Saving Innovation: ATSC 3.0 in Public Safety Communications

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EXECUTIVE SUMMARY

Many emergency services across the United States, including fire, medical, and law enforcement, rely on analog VHF paging technology to communicate emergency incident information to responders in the field. However, the current paging system involving voice pagers and analog radio channel relies on outdated technology that is slow at delivering emergency information and can hinder response by public safety agencies.

FirstTech, a program within the North Carolina Department of Information Technology that helps public safety agencies utilize advanced technology, is partnering with government, nonprofit, and industry partners to deliver emergency dispatch paging information over digital television signals. This method, called datacasting, can meet the challenges of analog voice paging and provide a redundant method to distribute critical public safety paging data over a wide area. Datacast public safety paging can speed emergency response by delivering more than 2,000 dispatches in the same time that an analog system can perform a single dispatch.

FirstTech and its partners have developed a prototype broadcast system with a custom paging receiver and miniature antenna encoder that uses the new digital broadcasting standard, Advanced Television Systems Committee (ATSC) 3.0. The emergency paging system over ATSC 3.0 utilizes a different delivery scheme that is far more robust and useful for mobile applications, can carry significantly more data, and can be reliably received by mobile devices, even when moving.

A paper describing this development milestone in the use of ATSC 3.0 in public safety communications received the best paper award at the 2022 National Association of Broadcasters (NAB) Broadcast Engineering and Information Technology Conference, and an update titled "Demonstration of an TSC 3.0 Solution for Emergency Paging" won the NAB Technology Innovation award for 2023. The prototype has since entered field testing with live broadcast of emergency paging dispatches over a public broadcaster's ATSC 3.0 signal in eastern North Carolina. Leveraging the significant advantages of the digital broadcast spectrum over the current VHF paging system, this datacasting prototype for emergency services paging has the potential to establish a national model that can lead to cost-sharing, higher reliability, greater cross-jurisdiction collaboration, and reduced response times.

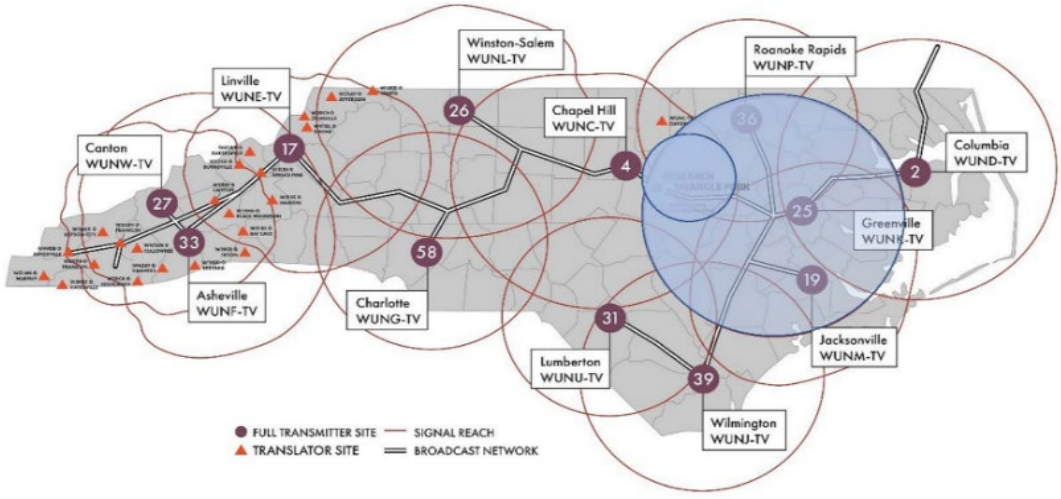

Figure 6 - WUNK-TV Coverage Map

PBS NORTH CAROLINA
POWERED BY THE UNC SYSTEM

IDEA

First Responder Emerging Technologies (FirstTech), a program housed within the North Carolina Department of Information Technology (NCDIT), aims to assist all public safety agencies throughout North Carolina to seamlessly and securely communicate using advanced technology. In collaboration with government, industry, and nonprofit partners, FirstTech explores emerging technological solutions and promotes their adoption across public safety disciplines, from law enforcement and emergency dispatch to fire and emergency medical services.

FirstTech is partnering with PBS North Carolina, the Wireless Research Center (WRC) of North Carolina, Device Solutions, and Triveni Digital in researching digital broadcasting applications as a solution to meet the challenges of analog voice paging for public safety response. Many fire and EMS services across the United States still rely on analog VHF paging technology for public safety answering points (PSAP) to communicate emergency incident information from 911 callers to responders in the field. Local governments or agencies typically own, operate, and maintain these paging systems' infrastructure. It is not viable to rely on commercial paging or cellular services for this mission-critical communication, and industry best practices do not recognize such systems because they are not controlled by the agency or a governmental partner and may rely on unsecured, best-effort methods.

However, the current paging system involving voice pagers and analog radio channel presents significant drawbacks. The voice pager is based on outdated technology that is slow at delivering emergency information. When multiple groups of responders need to be paged, each group's audible tone, up to 2 to 3 seconds long, must be transmitted sequentially before any of the verbal dispatch information, which can also take 20 to 40 seconds. Throughout this process, other emergencies are queued, waiting for the paging transmitter to become available. Other disadvantages of this system include low-quality audio, a restricted ability to replay messages, a lack of updates sent over the paging channel, and the complexity of sending data via computer-aided dispatch software and third-party servers. These issues are particularly problematic in rural, volunteer-oriented departments, which cannot afford to equip their responders with modern, digital radios costing $3,000 or more.

FirstTech, along with its partners, is developing and testing the delivery of emergency dispatch information over the new digital broadcasting standard, Advanced Television Systems Committee (ATSC) 3.0, often called NextGen TV, which has features and capabilities far beyond the current digital television system. ATSC 3.0 utilizes a different delivery scheme that is far more robust and can be reliably received by mobile devices, even when moving. Digital television can deliver more data using the same amount of spectrum as an analog transmission. The delivery of emergency paging services over these digital TV signals – called datacasting – can provide a redundant method for critical data distribution over a wide area to serve the paging needs of public safety.

The infrastructure for datacasting — transmitting equipment, towers, antennas, power, and spectrum – is already in use by broadcast television and offers a coverage footprint and in-building penetration unmatched by any other current technology. Many PSAPs can export the data to their existing paging system. A centralized paging system available to multiple PSAPs will have a far greater footprint, increasing interoperability, reliability, and dependability, and supporting PSAPs' ability to provide backup dispatch services between jurisdictions.

Datacast paging can enable more timely public safety service delivery. Whereas cellular service supports only a limited number of devices in a given area, datacasting serves an unlimited number of receivers and can alert multiple responders in only seconds, literally a thousand times faster than analog paging. Datacast paging can deliver more than 2,000 dispatches in the same time it takes an analog system to perform a single dispatch.

FirstTech approached PBS North Carolina, which has North Carolina's largest broadcast network covering nearly the entire state, to explore applications using the public broadcaster's ATSC 3.0 signal for an emergency dispatch paging service. FirstTech and its partners have developed a prototype system with a custom ATSC 3.0 paging receiver and miniature antenna encoder for use on the public broadcaster's NextGen TV signals. Initial field testing with live dispatches transmitted by PBS North Carolina's WUNK- TV, an ATSC 3.0 station in eastern North Carolina, has begun to determine the optimum performance configurations and will continue throughout 2023.

Leveraging the significant advantages of the digital broadcast spectrum over the VHF paging system, this datacasting prototype for emergency services paging has won national recognition as a model for public safety, which can lead to cost-sharing, higher reliability, greater cross-jurisdiction collaboration, and reduced response times. A paper, "ATSC 3.0 as a Use Case for Public Safety Communications - Development Milestones," coauthored by FirstTech, PBS North Carolina, Device Solutions, and WRC, received the 2022 Broadcast Engineering and Information Technology (BEIT) Conference Proceedings Best Paper Award at the 2022 National Association of Broadcasters (NAB) BEIT Conference, and an update titled "Demonstration of an TSC 3.0 Solution for Emergency Paging" won the NAB Technology Innovation Award for 2023.

IMPLEMENTATION

FirstTech joined with PBS North Carolina and the WRC in 2019 to develop and operate a public safety research center, initially evaluating and analyzing the potential of innovative applications for NextGen TV to improve public safety response. FirstTech focused on public safety initiatives and government interactions, WRC on research design, execution and data science, and PBS North Carolina on strategy, operations, technical talent and training.

The partners presented a white paper on the concept of an emergency services paging system using ATSC 3.0 and a public broadcaster at the 2019 NAB BEIT Conference. In 2020, FirstTech submitted the topic as a Small Business Innovation Research (SBIR) grant from the U.S. Department of Homeland Security to develop a new emergency digital paging system over public television. The topic was selected, and a SBIR grant has been carried out in three phases: identify small businesses that could prove their ability to address the issue, develop prototypes to prove the concept, and bring the product to market.

Datacast Paging Progress in North Carolina

The first phase of the SBIR was to identify small businesses that could prove their ability to address the issue. The second phase was to expand that work to develop prototypes to prove the concept. The third phase is to bring the product to market. Device Solutions Inc., an engineering firm based in Morrisville, N.C., that qualifies as a small business, along with the WRC, won the Phase 1 SBIR award to describe how they would address this challenge. Device Solutions and the WRC advanced to phase 2 to build a prototypes device and have partnered with PBS North Carolina and Triveni Digital to demonstrate a working broadcast solution system.

Phase 1 goals included:

- Provide responders and incident commanders with improved pager coverage and capacity, quicker dispatching, and messaging content for increased situational awareness
- Develop a proof-of-concept digital paging system and receiver for emergency responders using public television (Figure 1)

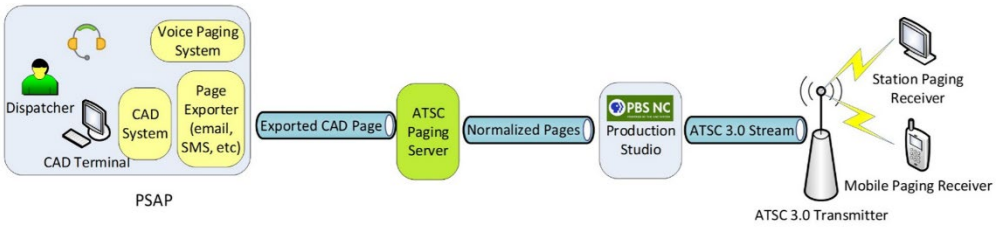

Figure 1- Proof of Concept

Phase 2 goals included:

- Develop a prototype ATSC 3.0 paging receiver that displays the computer aided dispatch (CAD) information normalized and sent from the ATSC paging server to the ATSC 3.0 transmitter or forwards it to other Bluetooth-capable devices
- Optimize the ATSC 3.0 delivery chain for delivery of emergency pages
- Deliver results from performance modeling and testing of ATSC 3.0 receptibility in a controlled environment for anticipated paging receiver design (e.g., a small body-worn device on a belt)

- Prototype two different paging receiver designs, one based on a stand-alone model and the other based on a smartphone integration with the ATSC 3.0 information passed along to a smartphone application
- Provide a practical demonstration of the capability with at least 10 receivers located with different first responder organizations representing different jurisdictions within the state, from urban to rural, career to volunteer, mountainous to coastal

To fully appreciate the benefits and requirements, it is helpful to review how emergency calls are handled in many jurisdictions. When someone dials 9-1-1, it is automatically routed to the nearest PSAP or 9-1-1 call center. Once sufficient information is received from the caller, the operator alerts the first responders via a VHF transmitter and belt-worn audio pagers (Figure 2). The received audio quality is often limited by the low quality of the device speaker, poor use of the microphone by the dispatcher, dispatcher speech accents, local noise at the receiver or other factors. If the first responder does not clearly hear and remember all the relevant details, the pager may have limited ability to replay the message, and the responder may have to use a cell phone or two-way radio to request details from the PSAP. Furthermore, in many jurisdictions, updates are not always transmitted over the paging channel – resulting in delayed responses and responders arriving at the incorrect address.

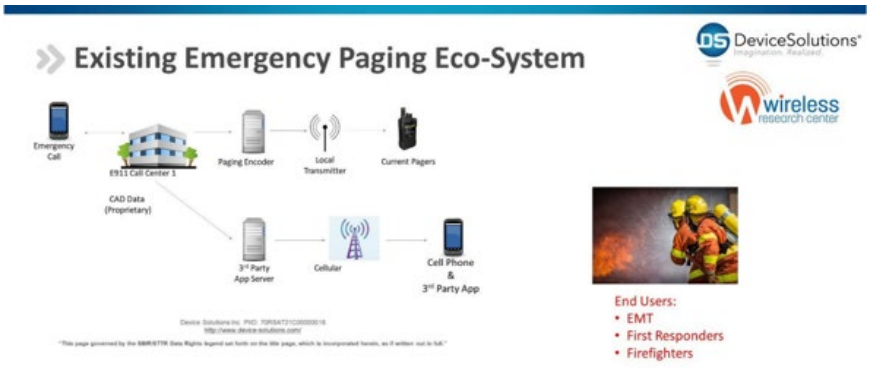

Figure 2 - Existing Emergency Paging Eco-System

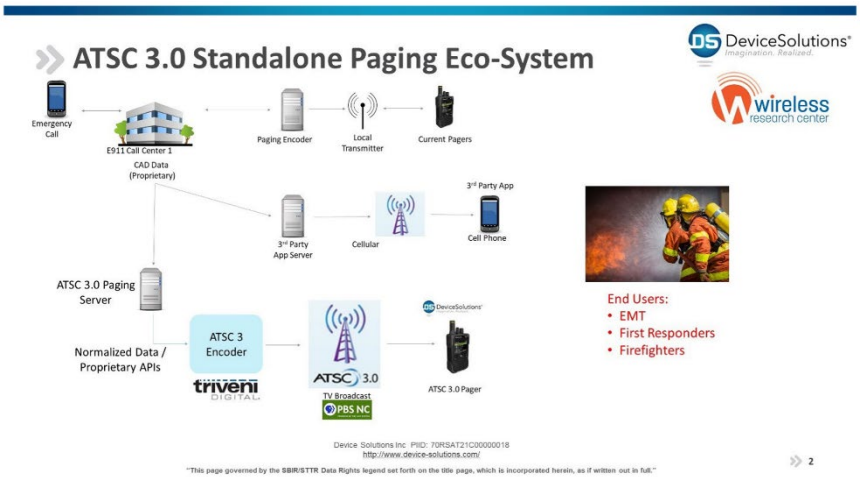

Figure 3 - ATSC 3.0 Standalone Paging Eco-System

Most PSAPs utilize CAD software to input the details of an emergency and track the status of responding units, among other features. Each PSAP may have its own vendor and instance of CAD in use for its operations. In many cases, the CAD data is also exported and directly sent, often via email and SMS, to users or to third-party application servers for delivery to the first responder. Third-party application servers work to normalize the data from multiple PSAP/CAD feeds and deliver it in consistent formats, sometimes decreasing the usability of the message. Adding to the complexity of handling these exported CAD messages – each dispatch center uniquely formats its exported data– and thus of a statewide deployment, this project proposes integrating a normalization function into the ATSC paging server to ensure consistent broadcast format and content and to potentially augment it with additional geographic information systems (GIS) content. These issues are particularly problematic in rural, volunteer-oriented departments which cannot afford to equip the majority of their responders with modern, digital radios, which can cost $3,000 or more.

In the prototype system, a custom page normalization function has been developed as part of the ATSC paging server, which transfers standardized messages to the ATSC 3.0 broadcast system with a few simple APIs, implemented by Triveni Digital (a business partner), over secure IP connections (Figure 3).

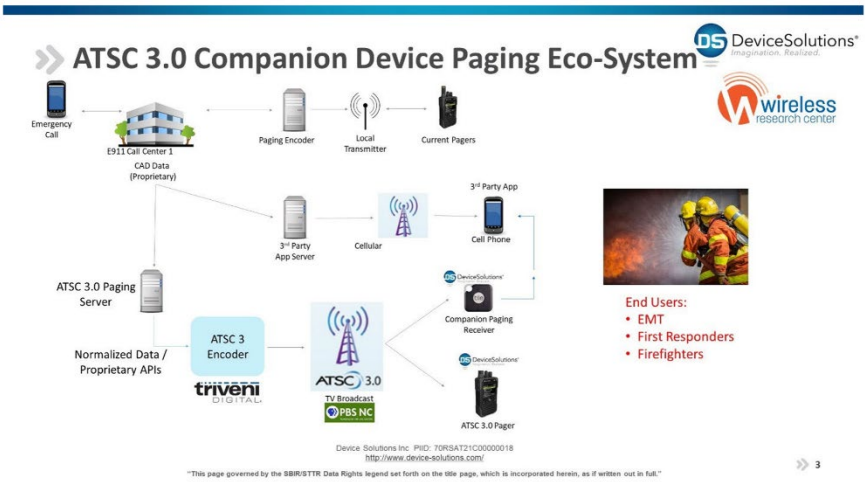

Figure 4 -ATSC 3.0 Companion Device Paging Eco-System

Additionally, as shown below, the paging receiver can be further minimized by connecting to a standard cell phone over Bluetooth to provide all the user interface functionality and providing a redundant data path to existing phone applications (Figure 4).

Technical Details of the ATSC 3.0 Broadcast

The ATSC 3.0 standard is based on IP protocols, meaning that all the connections from the video encoders to the transmitter are all IP based. The only coax cable in the lab is used in conjunction with the inputs to the video encoders and the RF output of the exciter modulator.

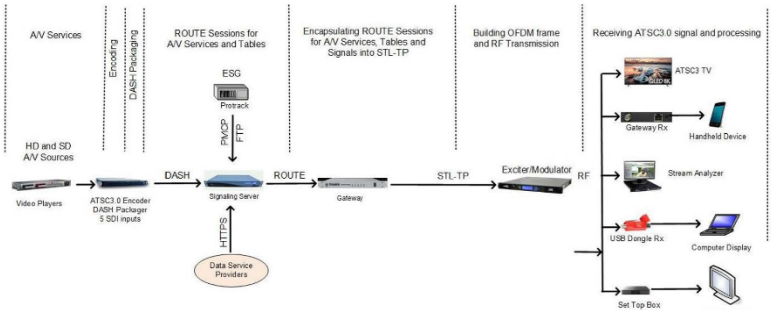

Figure 5 - PBS NC ATSC 3.0/NEXT GEN TV Research Lab

–Going left to right across the diagram in Figure 5, the signal flow starts with video sources feeding an HEVC video encoder system that generates IP video streams. This output, using the dynamic adaptive streaming over HTTP (DASH) protocol, feeds a signaling server. The signaling server is an IP signal aggregator. It can receive a variety of data feeds from various sources, such as the output from the video encoders, programming guide information, and other data feeds such as those from emergency services, Emergency Alert System (EAS), and other sources. This is where the paging data is input into the transmission path. The signaling server assembles the various IP streams and uses the route protocol to send that data to the gateway. The gateway then packages the data and creates an IP output using the STL TP protocol, which is then used to send the data to the exciter modulator. The STL TP protocol enables several functions, including the ability to introduce forward error correction to minimize data loss during transport to the transmission site. It also embeds the mod cod information, so the transmitter's exciter can create the RF signal with the desired physical layer pipe (PLP). Security signing is also part of the STL TP protocol. This prevents man-in-the-middle attacks from being successful against the station. In other words, the transmitter will only broadcast what its operator sends it and not information from another party. In the PBS lab, the exciter modulator is a transmitter exciter, which was donated by GatesAir. The output of that exciter feeds a multi-port RF splitter, which feeds a wide variety of receivers as well as other RF test devices.

PBS North Carolina operates 12 full-power, UHF stations (see Figure 6). All facilities are ATSC 3.0 capable. All the transmit antennas are also elliptically polarized. PBS North Carolina currently has two stations operating with an ATSC 3.0 broadcast signal. The first station is WUNC-TV Chapel Hill, which began operation as a guest station on Capitol Broadcasting's host station WNGT-CD. This signal is also shared by Capitol's other two Raleigh stations WRAL-TV, an NBC affiliate, and Fox 50, WRAZ. The signal is on channel 23 with a power of 15 kW ERP using a circularly polarized directional antenna at a height of 1040 feet, and it serves the Raleigh-Durham area. The second station is an over-the-air research lab station, WUNK-TV Greenville North Carolina. No guest stations currently share the WUNK signal. The station operates on channel 25 with 1000 kilowatts ERP using an elliptically polarized nondirectional antenna. That antenna provides a 500 kilowatt vertically polarized signal, as well as the 1000 kilowatt horizontally polarized signal. The antenna height is 1142 feet, and the station serves the Greenville-Washington-New Bern area of eastern North Carolina.

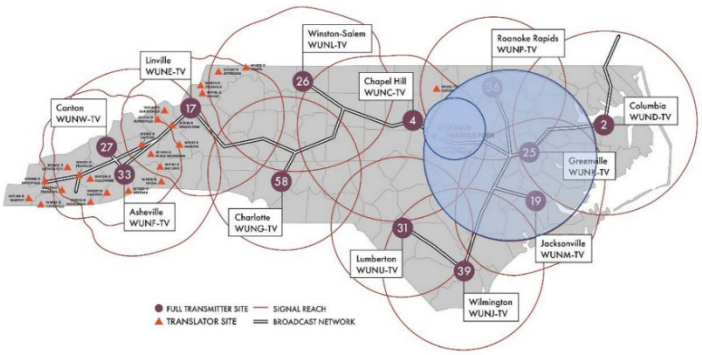

Figure 6 - WUNK-TV Coverage Map

In cooperation with partners WRC and Triveni Digital, Device Solutions and PBS North Carolina conducted field testing with the WUNK transmitter and live dispatches from multiple counties, using second-generation prototype paging receivers. Optimization of the RF performance and battery life of these devices and survey signal propagation with a dedicated, highly robust PLP is continuing. These pagers were also deployed with other public safety departments in the mountains and Piedmont areas for end-user testing in late 2022.

IMPACT

Public safety has used tone-and-voice paging for decades, but this technology delivers emergency dispatches at a slow pace compared to today's digital world. Datacasting presents a unique opportunity to send emergency notifications to first responders in a more efficient manner, over a greater distance, and with better coverage than ever before. It is not viable to rely on commercial paging or cellular services for this mission-critical communication, and industry best practices do not recognize such systems as they are not controlled by the agency or a governmental partner and may rely on unsecured, best-effort methods.

FirstTech has played an integral role with its partners in developing an emergency digital paging system prototype that uses a custom ATSC 3.0 paging receiver and miniature antenna encoder to broadcast live dispatches on a public broadcaster's NextGen signal in eastern North Carolina. This system overcomes many technological disadvantages of the analog VHF paging technology that emergency services across the United States often still rely on to communicate emergency incident information to responders. These disadvantages include slower delivery of emergency information and low-quality audio, which can create queues of emergency notifications awaiting transmission and delay adequate response by public safety agencies.

The emergency paging system over NextGen TV utilizes a different delivery scheme that is far more robust and useful for mobile applications, can carry significantly more data, and can be reliably received by mobile devices, even when moving. The digital emergency paging system enables more timely delivery of public safety notifications to first responders. The datacasting formatting serves an unlimited number of receiving devices and can alert multiple responders in seconds – literally a thousand times faster than analog paging. Digital datacasting can deliver more than 2,000 dispatches in the same it takes an analog system to perform a single dispatch.

This solution, now under live field testing, can deliver the following benefits that improve first responders' ability to ensure public safety in both North Carolina and throughout the United States:

- Digital delivery of information greatly increases the speed of reception, thus decreasing response times.
- Datacasting capacity allows for sending dozens of separate dispatches within seconds.
- A centralized paging system serving a large region can decrease mutual aid requests.
- A larger coverage footprint allows departments to notify members outside their jurisdiction.
- Transmitting infrastructure is already in place.
- Receivers can also support live audio streaming, video, data files, maps, and sensor data.

The solution has gained recognition as a national model for the use of ATSC 3.0 broadcast signals in public safety communications, as demonstrated by the 2022 BEIT Conference Proceedings Best Paper Award received at the 2022 NAB BEIT Conference and further recognized with the NAB 2023 Technology Innovation Award. FirstTech and PBS NC was also invited to present the solution at the 2022 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting event in Spain, where it also won the 2022 Best Paper Award. In the year since, the solution has been put to the test in field trials with great success. Leveraging the significant advantages of the digital broadcast spectrum over the current VHF paging system, FirstTech and its partners have demonstrated that an emergency digital paging system in partnership with a public broadcaster can provide a redundant method to serve public safety paging needs over a wide area. The solution leverages infrastructure for datacasting that is already in use by broadcast television, can be used by many PSAPs to export data to their existing paging systems, and offers a coverage footprint and in-building penetration unmatched by any other current technology.

This technology trial shows how ATSC 3.0 can replace paging systems for public safety communications more robustly and with faster delivery times than other methods. This use case can be easily replicated for many wide-area, secure, emergency notification applications, which can sit on a local, trusted public broadcaster's ATSC 3.0 transmission signal. Use of this prototype datacasting system for emergency dispatch paging service can lead to cost-sharing, higher reliability, reduced response times, and greater collaboration across jurisdictions.