NAB Broadcast Engineering and Information Technology Conference

PROCEEDINGS 2025

A collection of papers from the 2025 NAB Broadcast Engineering and Information Technology (BEIT) Conference

NEXTGEN Incident Response Communication System – Using ATSC 3.0

Fred Engel
Device Solutions Inc
Morrisville, North Carolina, United States
fengel@device-solutions.com

Tim Bagnall
Mosaic ATM
Leesburg, Virginia, United States
tbagnall@mosaicatm.com

Mark Corl
Triveni Digital
Princeton, New Jersey, United States
mcorl@trivenidigital.com

Chris Pandich, Don Smith
PBS North Carolina
Research Triangle Park, North Carolina, United States
cpandich@pbsnc.org; dsmith@pbsnc.org

Jim Stenberg
Over The Air RF Consulting, LLC
Portland, Maine, United States
jim@otarf.com

Dan Wesely
Mosaic ATM
Leesburg, Virginia, United States
dwesely@mosaicatm.com

Tony Sammarco, Chris Lamb
Device Solutions Inc
Morrisville, North Carolina, United States
tsammarco@device-solutions.com; clamb@device-solutions.com

Abstract – This paper provides a timely description of a National Aeronautics and Space Administration (NASA) research project investigating the use of a mobile ATSC 3.0 datacasting station to help support wildland fire management operations. We will discuss a proposed innovation called the NextGen Incident Response Communication System (NIRCS). NIRCS is a rapidly deployable, mobile, long-range broadcast communications system using ATSC 3.0 technology – the digital terrestrial broadcast system built on the internet protocol (IP) – to enable one-way datacasting of IP-compatible

data, including ultra-high-definition video, high-fidelity audio, and other types of data packets (e.g., aircraft position messages).

The Problem – Applications of Uncrewed Aircraft Systems (UAS) in Wildland Firefighting Efforts Are Limited Due to Poor Situational Awareness

Over the last few years, the NASA Aeronautics Research Mission Directorate (ARMD) has successfully investigated capabilities that help support management of wildfires. One ARMD project in particular, the Advanced Capabilities for Emergency Response Operations (ACERO), focuses on the use of uncrewed aircraft systems (UASs) and other advanced aviation technologies to improve wildland fire coordination and operations. With many valuable applications that remove humans from harm's way, UASs are

increasingly being used in wildland firefighting. Applications range from real-time intelligence gathering, including photography, video, and thermal mapping to aerial ignition (Figure 1 [1]). In aerial ignition, UASs safely start prescribed burns without having to overly endanger front-line personnel.

FIGURE 1. UAS AERIAL IGNITION OPERATION.

Although UASs show great promise to significantly improve wildland firefighting operations, they have not yet reached their full potential. A significant roadblock impeding their more widespread application is the lack of situational awareness about the real-time position of UASs by airborne pilots operating nearby in crewed wildland firefighting aircraft. Airborne pilots simply do not know enough about the active location of UAS. Without precise and continuous UAS location data, the many aircraft supporting the operation must maintain a high degree of separation, forcing UASs to operate in areas displaced from the nexus of the firefight where they have less impact. The ATSC 3.0 innovation proposed here aims to remedy this issue, improving crewed aircraft situational awareness of UAS positioning and helping to expand the applications of UASs in the wildland firefight.

Proposed Innovation – The NextGen Incident Response Communication System

The proposed innovation – the **NextGen Incident Response Communication System (NIRCS)** – is a rapidly deployable, mobile, long-range ATSC 3.0 datacasting communications system, as envisioned in Figure 2. The innovation directly addresses one of the NASA ACERO project's critical technological needs: a reliable, resilient, and secure data communication system for quick data dissemination to support effective decision-making. By addressing this ACERO need, NIRCS solves the problem of wildland firefighting pilots not knowing the real-time location of UASs.

FIGURE 2. A RENDERING OF THE NEXTGEN INCIDENT RESPONSE COMMUNICATION SYSTEM DATACAST STATION.

Mosaic ATM and Device Solutions Inc researched and refined the NIRCS concept during a six-month Phase I Small Business Innovation Research project for the NASA Langley Research Center in support of the NASA ACERO project. The first phase of the project concluded in early February 2025. The team hopes to continue the project in a second phase beginning in the Summer of 2025 to produce a prototype NIRCS system and demonstrate the technology in a formal flight test program.

NIRCS uses ATSC 3.0 technology, a digital terrestrial broadcast system using the internet protocol (IP) that enables one-way communication of IP-compatible data, including ultra-high-definition video, high-fidelity audio, and other types of data packets (e.g., real-time aircraft position messages). Table 1 lists the key features of NIRCS.

NIRCS, as a general-purpose digital datacasting system, can send a variety of data to suit many aviation purposes:

- Vehicle position and operational volume data
- Temporary flight restrictions (TFRs)
- Notices to Airmen (NOTAMs)
- Airspace procedures, structure, and adaptation
- Weather information
- UAS surveillance video
- High-fidelity audio

Feature	Description
Protocol	Internet Protocol
Radio Freq.	Ultra-High Frequency (UHF) broadcast 470 to 608 MHz
Throughput	Bit rates vary from 1 to 10 MB/s depending on broadcast settings.
Direction	One-way
Range	• Up to 60 nm for simple data packets (e.g., aircraft position reports) • Less for high-definition video and high-fidelity audio data packets
Encryption	Compatible with standard IP encryption protocols, like IPsec
Distributable Content	Compatible with any content that can be sent over IP (e.g., text messages, documents, audio, and video)
Benefits	**General** • Expands broadcast coverage area • Reduces data dissemination latency • Allows for encryption to protect proprietary and sensitive information • Interoperates with existing devices **Wildland Firefighting Specific** • Facilitates coordination of airspace operations • Significantly reduces the voice communication burden currently placed on aircraft operators • Allows for expansion of UAS operations in the firefighting effort, day and night • Allows wildfire incident aircraft to operate more efficiently and effectively

TABLE 1. NIRCS KEY FEATURES.

Illustration of the NIRCS Wildland Firefighting Use Case

Though NIRCS, as a general ATSC 3.0 datacasting solution, has numerous applications, in this section we focus on a wildland firefighting use case to illustrate its potential.

Figure 3 shows an operational view of this NIRCS wildland firefighting use case where NIRCS broadcasts the UAS's position data, operational volume data, and surveillance video to crewed aircraft at long ranges as well as fire line personnel on the ground. Source datacast content originates with a UAS operating near and over the fire. The UAS continuously relays its 3D position and velocity information (i.e., latitude, longitude, altitude, speed, and heading) and surveillance video to a linked ground control station where the remote pilot is stationed. Collocated with the UAS ground control station is the NIRCS mobile datacast station which rapidly ingests and broadcasts this stream of UAS data throughout the coverage area. Crewed aircraft and other users within range and equipped with a compatible NIRCS receiver and tablet, hosting an end user software application, are then able to receive and review important and timely mission information.

Figure 4 shows a typical NIRCS cockpit configuration with a NIRCS receiver affixed to the cockpit's interior windshield and a tablet positioned approximately where it would sit strapped to a pilot's knee. These pieces of technology, coupled with the tablet's software application, provide the two crewed firefighting aircraft – the air tanker and helitack – significantly enhanced situational awareness. Not only do they each have access to surveillance videos about the state of the fire, but each also knows the real-time location of the UAS, allowing the crewed aircraft to operate more safely and efficiently to the UAS.

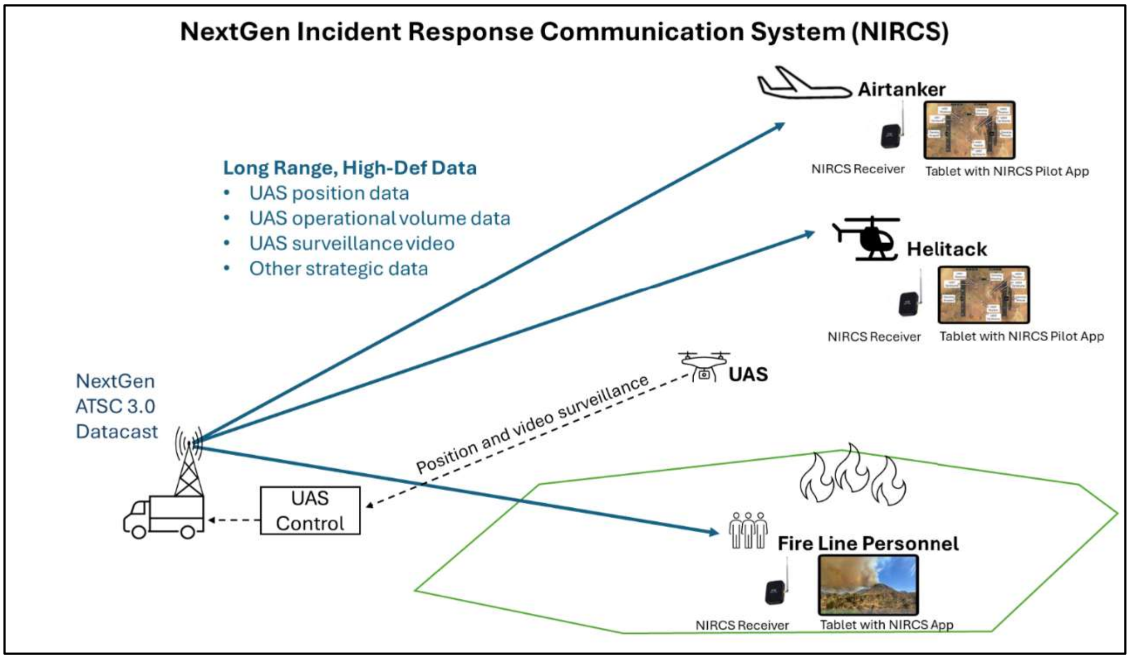

FIGURE 3. NIRCS ENABLES LONG-RANGE BROADCAST OF UAS POSITIONS, UAS OPERATIONAL VOLUMES, AND UAS SURVEILLANCE VIDEO.

FIGURE 4. NIRCS COCKPIT CONFIGURATION.

The figures below further illustrate the NIRCS wildland firefighting use case, showing screenshots from conceptual end user software applications which enhance the user's situational awareness of the operation and fire. One figure shows a display specifically for pilots and the other shows a more general display applicable to many NIRCS end users participating in the firefight.

NIRCS Pilot Application

Figure 5, a screenshot adapted from an existing Mosaic ATM software application, shows a concept for the NIRCS pilot application. Mosaic ATM developed the application during a previous NASA research effort called the small UAS Collision Avoidance System (sUCAS). As the name implies, sUCAS helps pilots avoid collisions with UASs. The sUCAS leverages the NASA Langley Research Center's DAIDALUS software, a reference implementation of RTCA's DO-365 Detect and Avoid standard [2]. The application serves a number of aviation purposes, including flight planning, tracking, and scenario simulation to support education and training.

In the flight tracking mode, the application dynamically follows the pilot's aircraft as it travels through airspace. The user may select from several different backgrounds, including aerial imagery, VFR charts, streets, and terrain. Aerial imagery background is shown in Figure 5. The application also conveys the real-time location of other nearby air traffic in a display commonly known as a cockpit display of traffic information (CDTI). Though Figure 5 is a snapshot, in practice, it looks more like a video as aircraft move throughout the airspace.

To describe the NIRCS pilot application, we use the California York fire that occurred in the summer of 2023 in the Mojave Desert. The underlying aerial imagery seen is near Hart, CA. The scenario features four aircraft consisting of an air tanker and three UAS all performing wildland firefighting operations. The NIRCS software application is explained from the perspective of the air tanker pilot.

The position of the air tanker – termed "ownship" – is denoted by the blue chevron at the center of the figure. At this moment in the scenario, ownship is traveling at a speed of 105 knots with a heading of 0 degrees and at an altitude of 4600 feet. Three UASs, shown with white chevrons, are operating in the vicinity of ownship: "Drn01," "Drn02," and "Drn03." The concentric circles around ownship and the numbers above each UAS symbol allow the pilot to quickly ascertain the relative horizontal and vertical distances from ownship. The first, second, and third concentric circles around ownship, respectively, are 1.25, 2.50, and 5.00 nautical miles away from ownship horizontally. The numbers above each UAS symbol reveal the relative vertical distance to ownship, in hundreds of feet (e.g., +06 means the aircraft is 600 feet above ownship, -03 means the aircraft is 300 feet below ownship). Besides denoting the location of aircraft, the chevrons also reveal the compass direction the aircraft is travelling (e.g., "Drn02" is traveling due east). The magenta hexagons convey the operational volume for each UAS, letting the pilot know their potential operational ranges.

The display can also convey collision risk to the pilot and suggestive guidance on how to reduce that risk. In the notional scenario of Figure 5, of the three UAS, "Drn03" presents the largest risk to ownship at approximately 1.25 nautical miles away from and only 200 feet above ownership. A small yellow band along the heading compass – stretching from 55 to 90 degrees – indicates headings that ownship should avoid to remain a safe distance from "Drn03." Suggestive guidance bands like this one on the heading compass are also shown on the speed and altitude tapes when the dynamics of the encounter call for it. Band coloring changes depending on the associated risk level, with red coloring indicating higher relative risk to yellow coloring (no red banding is shown in the figure).

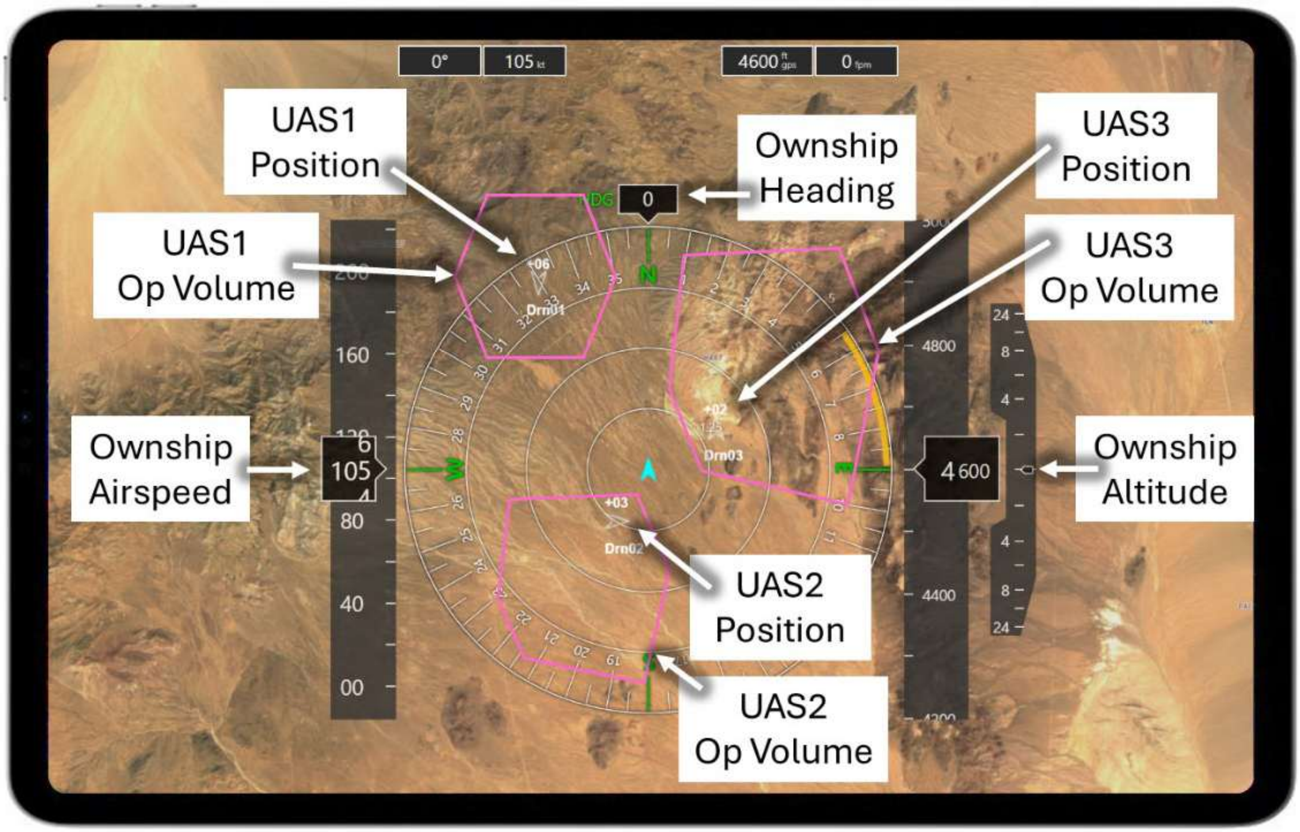

FIGURE 5. NIRCS PILOT APP. THE NIRCS PILOT APP ALLOWS PILOTS TO SEE NEARBY UAS POSITIONS, OPERATIONAL VOLUMES, AND UAS SURVEILLANCE VIDEO.

NIRCS Video Application

Figure 6 shows a more general-purpose software application. Here, the NIRCS video application functions like a typical video viewer application with capabilities to watch live video, pause live or recorded video, and rewind and replay recorded video. Embedded within the application is a channel guide so the user can review information about available ATSC 3.0 broadcasts and tune to the most appropriate channel. Figure 6 assumes that the user has selected "DRN01" from the same York fire scenario and is watching live surveillance video captured by the UAS.

FIGURE 6. NIRCS VIDEO APP. THE NIRCS VIDEO APP ALLOWS PILOTS AND OTHER USERS TO WATCH HIGH-DEFINITION ATSC 3.0 VIDEO IN REAL TIME OR ON DELAY.

Regarding the Collision Between a Civilian Drone and a Canadian Air Tanker During Los Angeles Firefighting Operations in January 2025

On January 9th, 2025, during firefighting operations on the Palisades fire in Los Angeles, a Canadair CL-415 Super Scooper air tanker collided with a civilian drone. Fortunately, the air tanker landed safely after the incident but was taken out of service for several days, depleting the available firefighting resources that were already stretched thin.

FIGURE 7. WING DAMAGE SUFFERED BY A CANADAIR CL-415 SUPER SCOOPER AFTER COLLISION WITH CIVILIAN DRONE DURING LOS ANGELES FIREFIGHTING OPERATIONS IN JANUARY 2025.

By the time of the incident, the Federal Aviation Administration (FAA) had imposed a temporary flight restriction (TFR) for the area which prohibited civilian drone operations. While the FAA investigation is ongoing and it is still too early to say definitively whether NIRCS could have helped prevent the incident, it is this team's expert opinion that it had the potential to help. In a relatively new rule known as Remote Identification (aka Remote ID, or RID), the FAA now requires most civilian drones to continuously broadcast their identity and real-time position and velocity information. Though not depicted explicitly in Figure 3, the NIRCS datacast station design includes RID receivers to collect nearby drone RID broadcasts and include them in the NIRCS broadcast. Consequently, the pilot display shown in Figure 5 would not only have conveyed real-time positioning of official UAS participating in the firefight but also civilian drones complying with the FAA's RID rule.

It is important to note that there have been reports that the civilian drone involved in the incident was below the FAA's RID weight threshold of 0.55 pounds, meaning the drone may not have had to broadcast RID. If the drone was not broadcasting RID or outside the range of NIRCS's RID receiver, NIRCS would have been unable to help prevent the incident. Unofficial and prohibited drone operations near firefighting operations continue to adversely impact wildland firefighting, sightings of which force authorities to temporarily ground firefighting aircraft. The authors urge all civilian drone operators to use their drones responsibly and in accordance with federal regulations.

ATSC 3.0 Background

ATSC 3.0, also known as NEXTGEN TV, is the next generation of digital television, a system that utilizes advanced modulation technologies within the traditional 6 MHz television channel. Developed by the Advanced Television Systems Committee (ATSC) and approved for voluntary use in the United States by the FCC in 2017, ATSC 3.0 has been introduced into over 80 markets in the US and internationally in South Korea, Jamaica, Trinidad and Tobago, and, most recently, Brazil.

ATSC 3.0 is built utilizing Internet Protocol (IP) and can merge the best of over-the-air broadcasting with internet delivered content and applications on connected "smart" TVs. For viewers, whether internet connected or not, it provides better video quality, immersive sound, advanced emergency alerting and informing, and is easily adaptable for future technologies [3].

ATSC 1.0, the current broadcast technology in the US, South Korea, and Canada, was developed in the 1990s and is based on an 8-level vestigial sideband (8VSB) modulation scheme [4] with MPEG 2 video encoding and has fixed capacity of 19.3Mbits/sec [4]. An example of a typical broadcast configuration is shown in Figure 8.

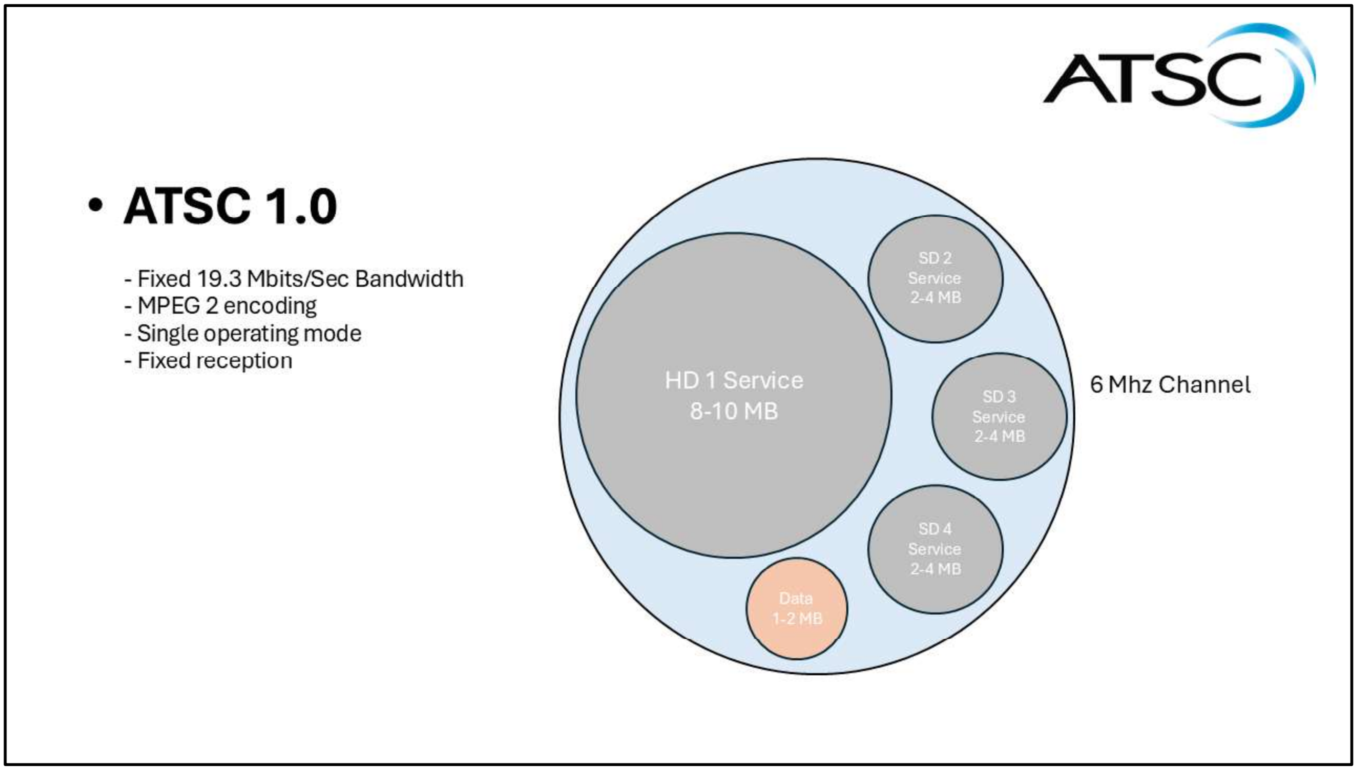

FIGURE 8. ATSC 1.0 TRANSPORT STREAM WITH MULTIPLEXED SERVICES

In this configuration, one high-definition channel service and three standard definition channel services consume most of the bandwidth. Leftover or unused "null bits" are made available for other purposes, in this case for datacasting services shown in orange.

The single carrier used in the 8VSB transmission system makes ATSC 1.0 susceptible to multi-path reception issues where reflections from objects (buildings, water towers, etc.) arriving at a later time than the primary signal, causing significant receiver challenges. For fixed location receivers, buffers within the receiver can be implemented to compensate for multipath interference. However, reliable mobile reception is not possible.

ATSC 3.0 utilizes a very different modulation scheme, Orthogonal Frequency-Division Multiplexing (OFDM) [5][5]. OFDM utilizes a large number of mathematically related low bandwidth subcarriers. As a result, a more spectrum-efficient signal with a higher overall data rate can be achieved. An OFDM signal is also better at compensating for multipath than an 8VSB signal since some subcarriers can be lost and the signal still recovered. Properly configured, the ATSC 3.0 system results in very reliable mobile reception.

The ATSC 3.0 signal can be configured with multiple physical layer pipes (PLPs). Each PLP can be configured with different modulation schemes and data capacities depending on the use case for that PLP. In Figure 9, PLP 1 can be configured to carry video program services and have a similar overage area to an 8VSB signal while PLP 0 can be configured to carry emergency responder or NIRCS data and be more robust, making reception with mobile devices easier and more reliable.

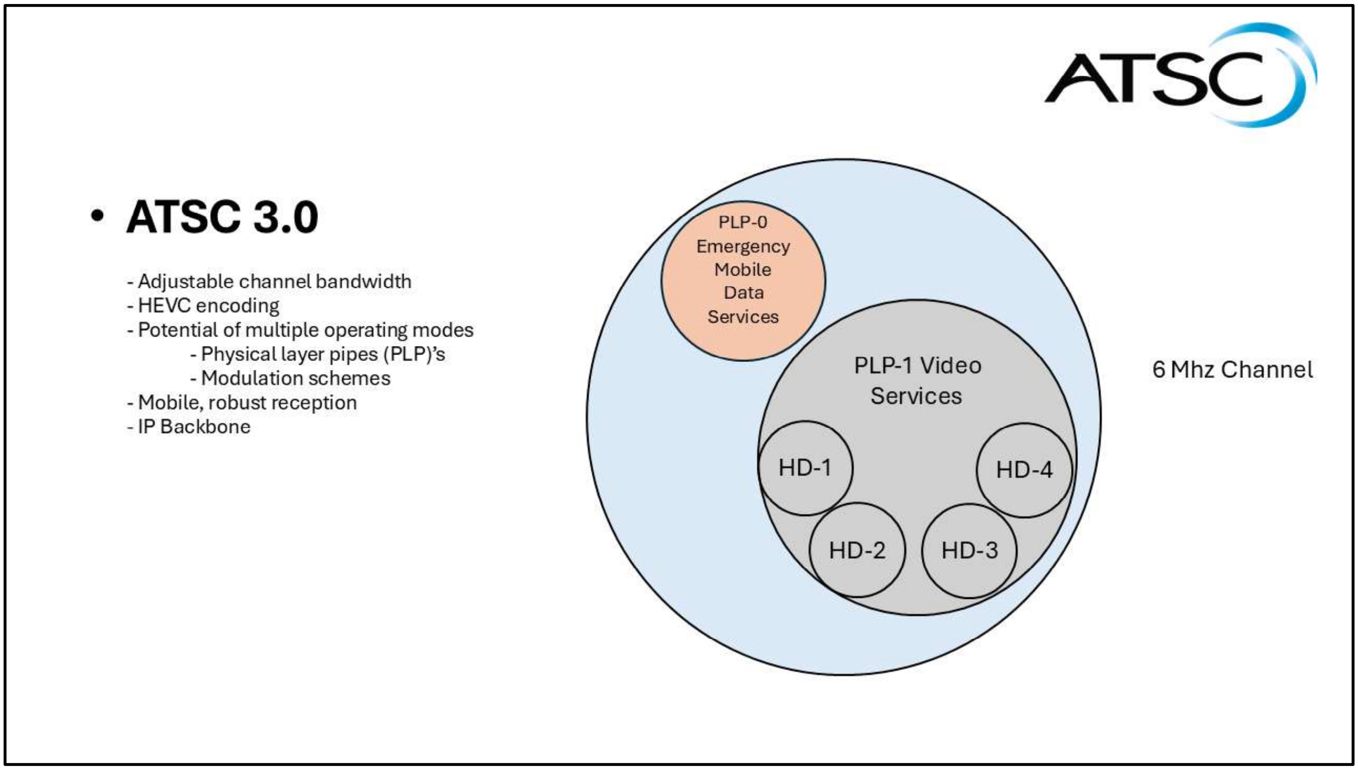

FIGURE 9. ATSC 3.0 PHYSICAL LAYER PIPE CONCEPTUAL DIAGRAM.

ATSC 3.0 and Video Encoding

ATSC 3.0 offers enhanced video and audio quality, improved signal reception, and new interactive services. One of the key features of ATSC 3.0 is its use of H.265 HEVC (High-Efficiency Video Coding) [6] video compression [6]. HEVC provides significant improvements over previous codecs, allowing broadcasters to transmit higher resolution video and HDR (High Dynamic Range) content while using less bandwidth. This coding efficiency creates capacity within the broadcast spectrum, making it possible to deliver other data services without impacting video quality.

As a living standard, the ATSC 3.0 standard can also be amended to implement new technologies as they are developed. In addition to HEVC, the recent approval of H.266 VVC (Versatile Video Coding) encoding by the ATSC [7] holds promise for even more efficient compression, further optimizing bandwidth usage. In the future when this codec is used more widely, improved video compression will allow broadcasters to deliver even higher-quality video or use its freed-up data capacity for additional services. The adoption of ATSC 3.0 with its improved codecs and efficient compression, paves the way for a more versatile and robust broadcasting ecosystem.

ATSC 3.0 and Datacasting

Wireless data broadcasting, or datacasting, is how many types of communications are transmitted. Cellular communications, wi-fi, Bluetooth, broadcast television and many other wireless delivery systems deliver digital data. ATSC 3.0 is an ideal platform for data delivery beyond the audio and video streams used by viewers. Due to its multiple customizable PLPs and highly effective error correction, large volumes of data can be delivered robustly.

A prime example of this is described in the paper submitted by PBS North Carolina, Device Solutions Inc, and Triveni Digital at the 2022 National Association of Broadcasters, Broadcast, Engineering and IT Conference - "ATSC 3.0 as a Use Case for Public Safety Communications – Development Milestones" [8]. The paper discusses the problems associated with existing emergency paging services and how ATSC 3.0 broadcast can provide a cost-effective solution with higher reliability, greater collaboration across jurisdictions, more cost-efficient pagers, and reduced response times.

Many fire and EMS services across the United States still rely on analog VHF paging technology to communicate emergency incident information to first responders. The infrastructure for these paging systems is typically owned, operated, and maintained by the local government or agency to ensure coverage includes as close to 100% of the jurisdiction as possible.

In their paper, Device Solutions Inc and Triveni Digital prove how ATSC 3.0 IP datacasting is well-suited to address the current challenges found within existing analog voice emergency paging. Because TV infrastructure already exists - the transmitter equipment, towers, antennas, power, and spectrum are already in use supporting broadcast television – ATSC 3.0 can be easily adopted and integrated into public safety paging as a redundant method for critical data communication. The footprint of this Public Safety Datacast Paging system would be far greater than current paging systems, which would increase interoperability, reliability, and dependability. Similarly, many Public Safety Answering Points (PSAPs), which provide the information needed by public safety responders, already support the export of such information to their existing paging system. Having a centralized paging system available to several PSAPs in the same geographic area will also increase the ease of providing backup dispatch services between jurisdictions.

Through the support of a DHS SBIR funded Phase II contract, Device Solutions Inc, PBS-NC, and Triveni Digital collaborated to build an end-to-end working prototype emergency paging system. Device Solutions Inc developed a prototype ATSC 3.0 emergency paging receiver. A new dedicated PLP was defined for emergency service for use on PBS-NC's public ATSC 3.0 broadcast infrastructure, and new APIs were defined for use by Triveni Digital's Transport Encoder.

Phase II proved that ATSC 3.0 IP Datacasting provides an opportunity to advance public safety paging to a new level. IP Datacasting provides a redundant method for critical data distribution over a wider area to serve the paging needs of public safety. The ability to alert multiple responders will only take milliseconds using a datacast digital format, which is considerably faster than today's analog paging format. Unlike a cellular service which can only support a limited number of devices in a given area, IP Datacasting is a one-to-many broadcast; the number of simultaneous receivers is unlimited. By delivering the emergency dispatch information in a digital format over datacasting, the technology can support over 2000 dispatches at the same time it would take an analog system to perform a single dispatch.

This demonstrates how IP Datacasting via ATSC 3.0 can provide solutions to unique problems with clear advantages in cost, speed, and public safety.

Technology and Regulatory Considerations

Receiving any large bandwidth data signal with an airborne receiver isn't without challenges. Most airborne communications and data systems utilize low bandwidths and rely on transmission systems designed for reception at high speed, low and high altitude, over long distances. On the other hand, current ATSC 3.0 broadcast infrastructure deployments are optimized for terrestrial ground-based reception where the intended user is stationary with an outdoor antenna or is using a handheld receiver inside a building or in a relatively slow-moving vehicle. While ATSC 3.0 airborne reception in aircraft exceeding 200mph and up to 5000 ft above ground level is certainly possible, fresh thinking about optimizing the transmission variables is required for NIRCS implementation. Utilizing existing broadcast infrastructure presents both technical and regulatory challenges. This section presents some ideas on what is needed and possible to optimize NIRCS for its intended mission.

Reception at High Speed

The NIRCS mission requires reception in both slow- and fast-moving vehicles. Fixed wing aircraft operate in an envelope of speed from roughly 100mph (160kph) (87knots) to 250mph (402kph) (217knots) while rotorcraft typically operate from hovering to 150mph (241kph) (130knots). This defines the primary challenge for the ATSC 3.0 system and sets upper limits on the available capacity of the transmission channel since higher speeds require much more significant coding overhead to ensure they are received properly. The ATSC 3.0 A/322 physical layer specification document [9] describes the various features of modulation and coding within the standard and the A/327 recommended practice document [10] gives information on typical settings and their effects. A dizzying array of variables are available to provide decoding of the signal in a multitude of user scenarios from high capacity/low robustness to low capacity/high robustness on channels with multipath, doppler effects, burst noise, and fading to both fixed and mobile receivers.

The primary physical layer variables in the standard that influence mobile reception are:

1. Formatting of the “bootstrap” signaling
2. Modulation rate and constellation
3. Number and configuration of PLPs
4. Error correction settings including:
    1. Channel estimation
    2. Code length and depth
    3. Echo and doppler protection
    4. Data interleaving type and depth

While numerous drive tests have shown that an ATSC 3.0 signal can be received while traveling over 65mph (105kph), few have looked at speeds significantly above this level. Detailed mathematical simulations and laboratory tests were, however, conducted to understand the performance of various ATSC 3.0 signal combinations and reported in reference [11]. This report gives us an excellent base upon which to build and configure NIRCS although the testing only examined speeds up to 300kph (186mph) (162knots) since this was envisioned as a top speed for ground-based trains.

To obtain robust reception at these high speeds, heavy amounts of error coding must be used along with reduced modulation rates, deeper interleaving, and careful echo cancellation settings. The authors also point out that further optimization of other features may be beneficial to high-speed operations. They found that reception at 300kph was possible for data rates below approximately 3.5MB. One tested combination which was capable of 300kph resulting in 2.14MB data capacity, consisted of Quadrature Phase Shift Keying (QPSK) modulation with 4/15 code rate, 3/2 pilots, 64k code length, 16k frame and preamble FFT lengths, and resulted in a signal to noise ratio of approximately 2.2dB. While this is excellent performance, we hope with further testing that the performance can be further optimized at even higher speeds. To date, we are not aware of any real-world tests at these types of speed.

Transmit System Considerations

The NIRCS vehicle is assumed to be located close to and either above or at the elevation of the theater of operation to provide the highest signal levels to the aircraft and be able to collect local UAS information. This location presents conditions which are quite different from a typical television transmission system.

The resulting recommendations for an optimum vehicle mounted transmission system include:

1. Omnidirectional or configurable sector azimuth coverage. Most locations would likely use an omnidirectional configuration, but it would be advantageous to allow the antenna pattern to be varied at each site dependent on the vehicle's location relative to the operation. For instance, if the vehicle has tall mountains directly behind it, a directional pattern to the front would be advantageous.
2. Coverage from slightly below the horizon to directly above the vehicle with the highest signal levels required in the first 10 degrees of elevation above the horizon (corresponding to greater than 5.5 miles for an aircraft at 5000ft AGL) since the aircraft will be approaching and receding from the theater of operations at these angles and the lowest signal levels when directly overhead since they will be quite close to the vehicle. These values correspond to a relatively moderate elevation gain antenna pointed at the horizon but with reduced values below the horizon as compared to above the horizon in a typical broadcast TV antenna.
3. Vertical polarization to deliver the highest signal levels to short whip antennas located in or on the aircraft. Most whip antennas can be easily mounted to receive vertical polarization and are the de facto standard in vehicles instead of horizontal polarization used on most TV broadcast transmit antennas.
4. Frequency agile operation on any unused UHF TV channel (14 to 36) in the location of the vehicle. This also needs to include ensuring mask compliance for the transmitter on all channels since there will frequently be high power stations on directly adjacent channels.
5. Variable effective radiated power (ERP) levels to allow for expansion and reduction of the total covered area based on; the scale of the fire, the particular interference criteria on the channel of operation at the location, the safety of ground personnel from radiation exposure, and the configuration of the antenna pattern.

Using Existing TV Transmission Systems

Current television broadcast facilities are designed for reception by terrestrial ground-based receivers and typically utilize high elevation gain antennas to focus the signal on the horizon and reduce the output power needed from the transmitter. Gain is achieved by making the antenna longer and by reducing the amount of signal transmitted above the horizon. This is at odds with the recommendations above.

A hypothetical full power station operates on channel 25 at 200 kW ERP using a 28-bay slotted UHF pylon type antenna with an antenna height of 1000 feet. Its elevation pattern shown in Figure 10 is skewed toward the ground so the most powerful portion of the signal is focused below the horizon, not above it. In this case the antenna has 1 degree of downward beam tilt built into the antenna. Figure 10 shows the resulting nulls in the elevation pattern at -1.3, -3.0, and -5.7 degrees.

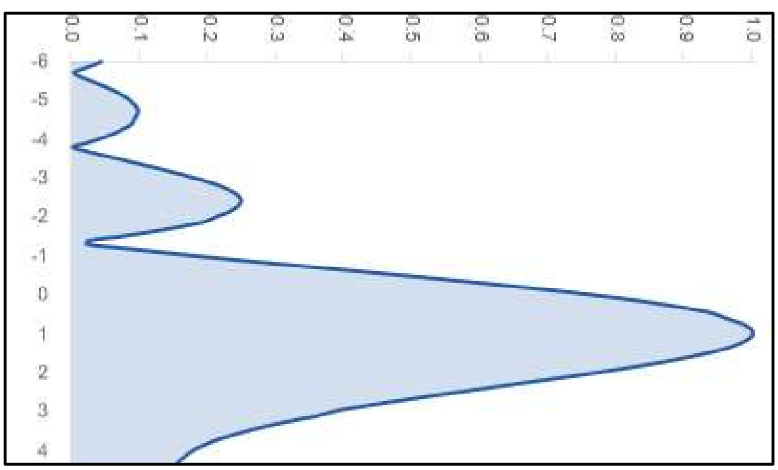

FIGURE 10. TYPICAL 28-BAY UHF SLOTTED PYLON ANTENNA ELEVATION PATTERN.

Low Power (LPTV) and Class A television stations are limited to 15 kW ERP on UHF and tend to use lower gain antennas. A hypothetical low power station operates on channel 25 at 15 kW ERP with an 8-bay slotted pylon antenna with an antenna height of 400 feet. The antenna has 1.75 degree of downward beam tilt built into it since the pattern is much wider than the high gain antenna above. Figure 11 shows a null in the elevation pattern at -5.5 degrees.

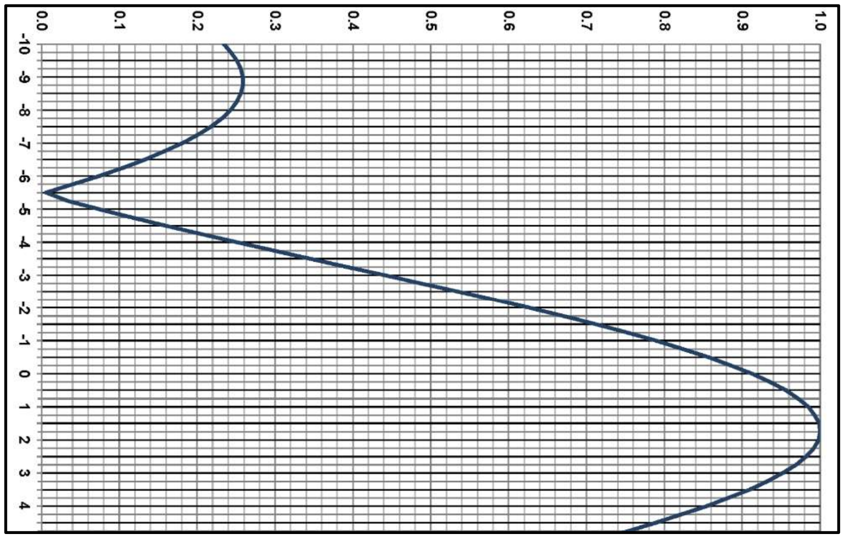

FIGURE 11. 8-BAY SLOTTED PYLON UHF ANTENNA ELEVATION PATTERN.

Taking these typical patterns and calculating the resulting ERPs, Table 2 below shows values toward an aircraft flying at 4600 feet above ground level at certain distances from a transmitter site (Based on a flat earth model). Note that negative angles refer to degrees ABOVE the horizon.

Distance (mi)	Full Power Station			Low Power Station		
	Angle	Field Ratio	ERP (kw)	Angle	Field Ratio	ERP (kW)
6.8	-5.7	0.003	0.002	-6.7	0.158	0.375
8.3	-4.7	0.097	1.882	-5.5	0.006	0.001
10.0	-3.4	0.021	0.088	-4.5	0.160	0.384
30.0	-1.3	0.022	0.077	-1.5	0.712	7.600

TABLE 2. ERP TOWARD AIRCRAFT AT CERTAIN DISTANCES.

The values in Table 2 demonstrate that typical TV systems offer very little capability to provide meaningful signal levels to aircraft without modification.

Regulatory Considerations

We foresee at least these three potential implementations of NIRCS transmission systems:

1. A stand-alone remote operation from a self-contained vehicle that includes a mast with an antenna(s) and a transmitter-like Figure 2 above that operates on an unused UHF channel at a given site.
2. The stand-alone vehicle above operating as an SFN type node within the coverage area of an existing UHF TV station.
3. NIRCS data sent from a modified main antenna of an existing UHF TV station as an ancillary PLP.

The first implementation would require a new licensing/permitting regime and cooperation from the FCC to allow its use. We note that utilizing unused channels, vertical polarization, and minimizing the signal below the horizon as recommended above would help minimize interference to existing TV operations. We see this as an excellent way to implement the system at many sites since they are often rural and in terrain sheltered areas. Use of an experimental authorization could provide a methodology for operation on unused channels. A blanket use allowance from the FCC within some agreed upon parameters would of course be the preferred arrangement. This would require that some level of study be done before each operation and could mean a potential lack of flexibility in movement options. The second and third implementations would be less ominous as far as regulations since they could be covered under existing rules. The SFN operation would be more likely to be quickly approved since the hosting station would be accepting the potential interference upfront to serve the public good. Where the theater of operation is in an urban area (i.e., Los Angeles) this may be the only available option since finding an unused channel may be very difficult. Since the NIRCS operation is only temporary and no ground disturbance is required, there should be very few limitations on potential locations of the vehicle and we do not foresee issues with other permits. The third implementation, using an existing broadcaster's main facility, has the issues discussed above regarding signal levels. However, where those do not present an issue (i.e., stations that are on very tall mountains and the theater of operations is below that horizon), NIRCS could be quickly and easily implemented as an ancillary stream. Each of these implementations requires further study and coordination with the FCC and other stakeholders.

Conclusion

With wildfires and other natural disasters causing increased fatalities, infrastructure damage, and recovery costs, it is imperative to continue investigating new and improved means of communication to support first responders and the public. ATSC 3.0 broadcast technology has been proven to provide wide area and robust data delivery to address these needs. While questions still need to be answered regarding RF propagation patterns, high-speed mobile reception quality, and FCC authorization, the initial work of Mosaic ATM and its technology partners, Device Solutions Inc, Triveni Digital, and other consultants shows NIRCS is a worthy effort to continue to explore and fund.

References

[1] National Interagency Fire Center, "Fire mission photos," [Online]. Available: https://uas.nifc.gov/fire-mission-photos. [Accessed: Feb. 1, 2025].

[2] NASA LARC DAIDALUS, "daidalus," [Online]. Available: https://nasa.github.io/daidalus/. [Accessed: Jan. 22, 2025].

[3] Advanced Television Systems Committee, "NextGen TV," [Online]. Available: https://www.atsc.org/nextgen-tv/. [Accessed: Feb. 1, 2025].

[4] "ATSC Digital Television Standard, Part 1 – Digital Television System", Doc. A/53 Part 1:2013 7 August 2013.

[5] Chang, R. W. (1966). "Synthesis of Band-Limited Orthogonal Signals for Multi-Channel Data Transmission", *Bell System Technical Journal,* December 1966.

[6] International Telecommunications Union, ITU-T H.265 High Efficiency Video Coding, July 7, 2013.

[7] Advanced Television Systems Committee, A/345 VVC Video Candidate Standard, November 25, 2024.

[8] PBS North Carolina, Device Solutions Inc, and Triveni Digital, “ATSC 3.0 as a Use Case for Public Safety Communications – Development Milestones,” NAB BEIT Proceedings April 2022.

[9] Advanced Television Systems Committee, A/322:2024-09, “Physical Layer Protocol” September 13, 2024.

[10] Advanced Television Systems Committee, A/327:2024-12, “Guidelines for the Physical Layer Protocol” December 3, 2024.

[11] Sungjun Ahn, Sung-Ik Park, Jae-Young Lee, Bo-Mi Lim, Sunhyoung Kwon, Namho Hur, Yiyan Wu, Liang Zhang, Wei Li, and Jeonchang Kim, “Mobile performance evaluation for ATSC 3.0 physical layer modulation and code combinations under TU-6 channel”, IEEE Transactions on Broadcasting, Vol. 66 #4, December 2020.

Acknowledgement

The authors and contributors to this paper would like to thank Kyrsten Mougey, Executive Assistant at Device Solutions Inc, for her assistance in editing this document.