WHY **RTCA DO-377** COMPLIANCE IS ESSENTIAL TO ADVANCED AIR MOBILITY

AURA
NETWORK SYSTEMS

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INTRODUCTION

How to Integrate a Command-and-Control Communications System for Certification-Level Uncrewed Aviation Flights

By AURA Network Systems CEO Bill Tolpegin

In the dynamic landscape of modern transportation, the integration of state-of-the-art technologies has given rise to a groundbreaking era in aviation. This transformative period is characterized by the emergence of Advanced Air Mobility (AAM) and uncrewed aircraft systems (UAS), promising enhanced safety and efficiency in transporting people and goods. As we stand at the cusp of a revolutionary paradigm shift, the boundless potential of these innovations invites us to envision a future where the skies are gateways to unprecedented possibilities. AURA exists to usher in this era of unparalleled innovation by providing the pioneering technology to fly in ways we've never flown before.

In the pursuit of safely integrating autonomous and uncrewed aircraft (UA) into controlled airspace, the question of continuous and reliable communication between remote pilots and the aircraft, as well as Air Traffic Control (ATC), becomes paramount, especially in operations beyond visual line of sight (BVLOS). Recognizing this imperative, RTCA DO-377B stands as a beacon, providing a well-charted path acknowledged by the Federal Aviation Administration (FAA) to achieve the requisite levels of connectivity performance to ensure the safe integration of UAS into the National Airspace System (NAS).

Standards pertaining to safety-of-life operations add regulatory certainty and are key enablers in this burgeoning industry. For AAM to be successful, aircraft manufacturers need to obtain FAA certification of their novel aircraft, designed with unprecedented levels of automation. In partnership with them, we must design, develop, and deploy the command-and-control (C2) networks necessary to allow remote pilots to stay in constant control of these aircraft and to talk with ATC. DO-377B is the product of significant research and analysis into the performance requirements of any link that will be used to control an AAM UAS, including availability, continuity, integrity, and latency for all phases of flight and in all types of airspace.

Since we launched our company, AURA has been highly mindful of the regulation and consensus-based standards that govern our industry. Today, we are right where we planned: a Command-and-Control Communications Service Provider (C2CSP) at the center of functional and regulatory solutions, transforming the concept of aviation for both crewed and remotely piloted aircraft.

Our partnership approach is largely why operators focused on achieving FAA certification of airborne elements turn to AURA to support regulatory-centered demonstrations of compliance with RTCA DO-377B performance requirements. Our private commercial and deterministic network is specifically designed to meet such standards.

As we expand in the AAM market, our mission is to deliver an FAA-compliant, nationwide, safety-critical network for C2 communications with UAS operating BVLOS in controlled airspace. Use of such a network will be a common denominator for all UAS applications like air cargo or air taxis, and we are determined to provide what so far have been the missing links for our industry.

RTCA

What is the RTCA?

RTCA (formerly the Radio Technical Commission for Aeronautics) is the aviation industry's nonprofit independent Standards Development Organization focused on aeronautical communication. Started in 1935, the standards set by RTCA are consensus-based documents that are the products of significant studies and analyses used by both industry and government to ensure avionics are safely integrated into aircraft and that aviation communications meet rigorous performance standards.

The most operative RTCA documents are Minimum Operational Performance Standards (MOPS) and Minimum Aviation System Performance Standards (MASPS). As described by the RTCA, MOPS "provide baseline requirements for manufacturers and customers of avionics equipment. A MOPS focuses on the functional performance and avoids being prescriptive to provide manufacturers with the maximum design space while preserving the safety of the airspace." Relatedly, MASPS "define the intended functions of a technology and identify the impacts, good and bad, of integrating that function."

RTCA & AURA: Safer Skies Through Collaboration

In the fall of 2021, the RTCA Program Management Committee (PMC) approved AURA's request to assist in the creation of new Minimum Operational Performance Standards (MOPS) for ultra-high frequency (UHF) C2 links for avionics utilizing AURA's unique aviation-dedicated 450 MHz spectrum.

The RTCA action allowed AURA to draft MOPS for review and approval by RTCA's Special Committee (SC)-228, initially established in May 2013, to develop the standards for C2 links that are critical for controlling UAS and urban air mobility (UAM) aircraft operations within the NAS. Critically, RTCA works closely with the FAA to develop comprehensive, industry-vetted and endorsed recommendations regarding technical performance standards, as well as the operating environment for those standards; these are ultimately utilized as a means of compliance with FAA regulations and other aviation regulatory authorities.

DO-377 FOR OPERATORS: A HIGH-LEVEL OVERVIEW

The next generation of aviation will include uncrewed and autonomous aircraft with a wide range of designs and operational requirements to meet a varied mix of missions and applications. Whether it involves transporting people or cargo, safely navigating such aircraft BVLOS in controlled airspace necessitates regulatory assurances that the C2 communications links are ultra-reliable.

Understanding the likely regulatory landscape is vital for operators focused on achieving FAA certification of airborne elements, along with operational approval of ground elements. Here, we address key issues as AURA works to support regulatory-centric demonstrations of compliance with RTCA DO-377 performance requirements.

Developing action plans focused on DO-377 and its evolutions are critical for operators seeking to attain FAA approvals for BVLOS operations and for C2 of uncrewed and autonomous flights. Attaining compliance with the numerous specifications discussed in the comprehensive document can be a steep mountain to climb for operators – especially for those previously unaware of its centrality to their commercialization plans. DO-377 can seem complex partly because it's best understood not as the usual "standard" that directs a specific action but more as a compendium of criteria that provides guidance to demonstrate a safe C2 ability.

What is DO-377?

First, DO stands for "document," and "377" outlines the ***"Minimum Aviation System Performance Standards (MASPS) for C2 Link Systems Supporting Operations of Unmanned Aircraft Systems in U.S. Airspace."*** This document is fundamental to the safe integration of UAS into the NAS, particularly for any flight in controlled airspace operating BVLOS, which is necessary for all AAM operations to scale. Such operations require robust and reliable C2 Link Systems, including C2, between a pilot and a remotely piloted aircraft (RPA). These links must demonstrate means of compliance with the specifications established in RTCA DO-377.

NOTE: Like other RTCA materials, documents often undergo revisions; e.g., Revision B was published December 14, 2023, and additional updates are expected as the industry continues to evolve.

AURA seeks to onboard operators in a way that ensures they can fully utilize the AURA commercial network as the primary Control and Non-Payload Communication (CNPC) link for FAA-certified BVLOS operations. DO-377 specifically delineates the standards for:

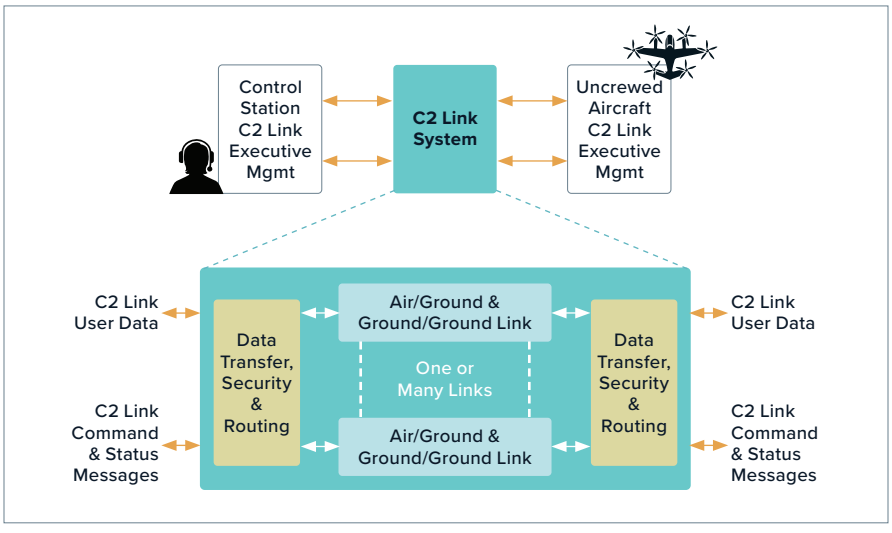
- Operational and functional requirements of the link between the C2 and UA;
- Performance requirements; and
- Internetworking and security requirements.

The following excerpts from DO-377 provide a high-level understanding of the requirements, as well as how AURA's network can support operators in attaining FAA compliance.

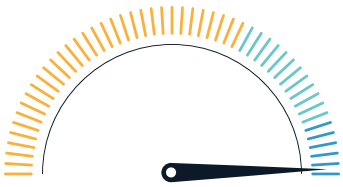
DO-377A: What is the C2 Link System?

Section 3.2.3 of DO-377 (Revision A) provides a definition of a C2 Link System: *The totality of Air/Ground links, Ground/Ground links and Data Transfer, Security and Routing capabilities that support the exchange of C2 Link User Data between the CS and UA C2 Link Executive Management Systems.*

Section 1.2 provides more details:
The C2 Link System is defined as the connection used to send information exchanges between a Control Station (CS) and an Unmanned Aircraft (UA) and to manage the connection between them.



A C2 Link System can have multiple "Links" within it. A "Link" (or "C2 Link") is further clarified in DO-377 as: *The logical C2 connection between the UA and CS for the purposes of safely managing the flight.*



AVAILABILITY
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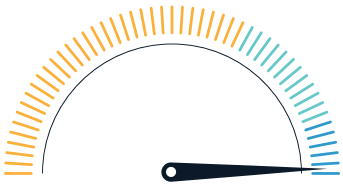

CONTINUITY
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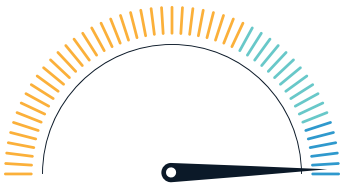
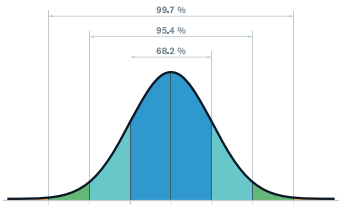


LATENCY
120ms



INTEGRITY

A Sampling of DO-377 Performance Requirements

Note: Important context and discussion of these requirements and how they relate to other considerations can be found in the DO-377A document.

Availability

The C2 Link System Availability, for all interruption lengths, shall ensure an interruption no longer than 3 seconds at a probability of 0.999 per flight hour (surface phase + non-towered airspace)

The C2 Link System Availability, for all interruption lengths, shall ensure an interruption no longer than 3 seconds at a probability of 0.99999 per flight hour (all phases of flight and all airspaces except surface + non-towered)

Continuity

The C2 Link System Continuity shall ensure an interruption no longer than 3 seconds at a probability of 0.999 per flight hour (surface phase+ non-towered airspace)

The C2 Link System Continuity shall ensure an interruption no longer than 3 seconds at a probability of 0.99999 per flight hour (all phases of flight and all airspaces except surface + non-towered)

Latency

The latency of the C2 Link System Status Reporting shall be less than 0.5 seconds

The C2 Link System one-way latency shall be less than 0.155 seconds to support the "communicate" function, including the latency of voice/codec functions (which are outside of C2 Link System)

The C2 Link System one-way latency shall be less than 1.0 seconds to support all functions except for the "communicate" function

Integrity

The C2 Link System Integrity shall ensure the probability of an undetected error in a transaction is less than 1×10^{-7} per flight hour (all phases of flight and all airspaces)

The probability of a Failed C2 Link System Establishment or Termination shall be less than 1×10^{-3} per flight hour

The probability of a Misdirected C2 Link System Establishment shall be less than 1×10^{-7} per flight hour

AURA'S UNIQUE ROLE IN JOURNEYS TO CERTIFICATION

DO-377 defines quantitative performance requirements that are specific to a phase of flight such as departure and arrival, as well as type of airspace. AURA's network is designed to meet the most stringent requirements covering all types of airspace and phases of flight. The network is designed to accommodate the different C2 Link Systems used by a wide array of end-user operators. For example, a C2 Link System specific to an air cargo mission will be different from one specific to air taxis. Regardless, the AURA CNPC link used as one part of that operator's C2 Link System will meet the DO-377 performance requirements specified for the mission critical CNPC link.

WHAT DOES AURA NETWORK SYSTEMS BRING TO THE TABLE?

Spectrum Certainty for the Long Haul

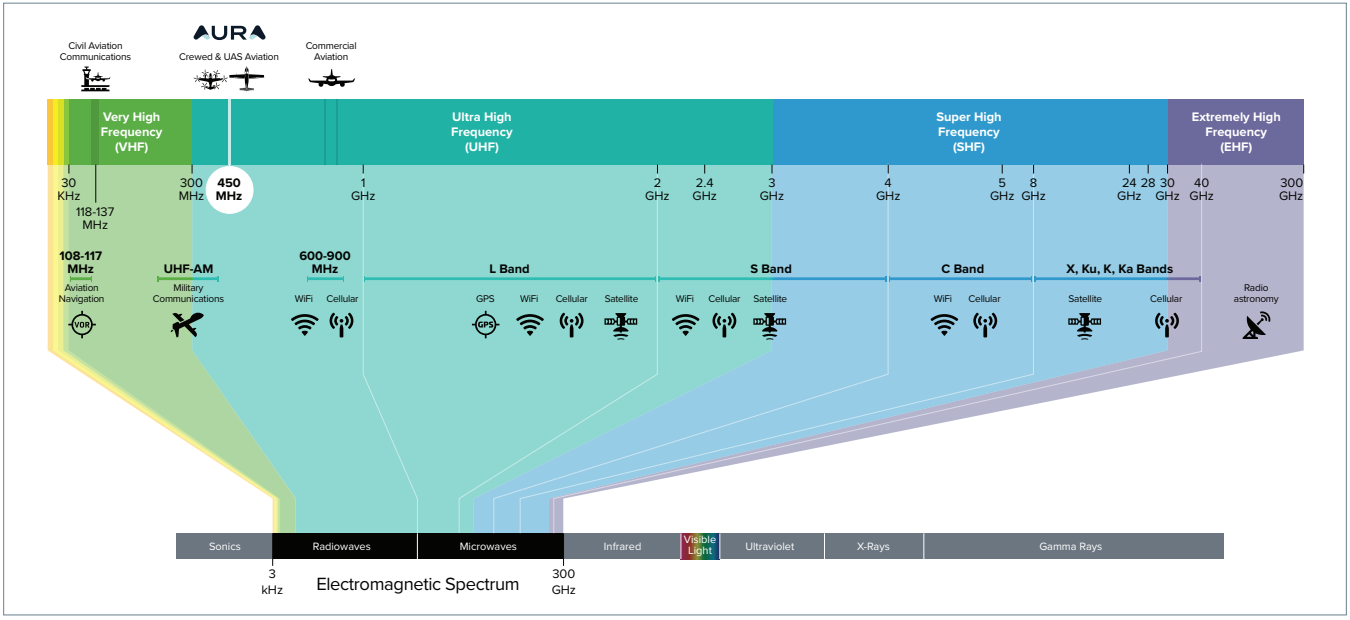
As a C2CSP, AURA is unique in that it is the only operator with licensed, exclusive nationwide use of 450 MHz UHF radio spectrum, which the FCC has authorized for air-ground operations enabling secure voice and data services to UA. Operators using the AURA network will benefit from the immediate and long-term certainty of an existing aviation-allocated license for the transmission of mission- and safety-critical data. AURA's spectrum is ready today to be particularly helpful to industry first movers.

Expertise

AURA's team includes a dynamic mix of experienced industry thought leaders, pilots, visionary technologists, and aerospace, telecommunications, and software engineers whose insights are often sought out by organizations such as RTCA or FAA advisory and rulemaking committees. Collaborative experience with regulators and involvement in the regulatory community's work position AURA strategically at the center of the functional and regulatory solutions integrating UA into controlled airspace. This approach has led to a four-year FAA cooperative R&D agreement and two Space Act agreements with NASA.

Technology

AURA can support organizations by providing all required link- or network-specific hardware and software required to meet their certification process goals. As important, AURA maintains exclusive FCC licenses enabling its robust ground network, along with a nationwide experimental license that can be used to support test flights.



AURA utilizes exclusively licensed nationwide 450 MHz UHF radio spectrum that the FCC has uniquely authorized for UA voice and data services.

Scale

Transmissions in the 450 MHz band are not just ideal for secure and reliable FAA-compliant C2 links. The long-distance propagation characteristics of signals at these frequencies enable users to also benefit from a scalable, cost-efficient network build out.

While today's aviation industry operates along well-established sky routes, AURA's value-add to the UA community is built on the knowledge that future applications will require building additional highways and adapting communications capabilities in existing frameworks. AURA has already built a ground network providing nationwide coverage in anticipation of these new routes. That network will serve as a starting point as AURA builds out collaboration-specific routes.

Designed to meet FAA standards for CNPC links encompassing C2 data, telemetry data, Detect and Avoid (DAA), and ATC voice relay, the AURA network aims to empower aircraft with safe, secure, and reliable links enabling routine BVLOS flight in the NAS.

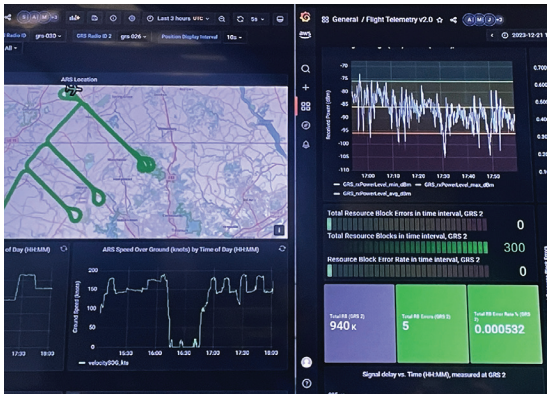
THE AURA COLLABORATIVE ASSESSMENT

Identifying and meeting these standards is why AURA exists.

AURA works with its partners and customers to understand their certification and approval paths and offers its C2 service and aviation expertise to help them along their certification journeys. This begins with a joint understanding of the specific aircraft and the anticipated concept of operations (CONOPS) of any potential project. We then work with our partners and customers to map out their C2 link needs and how our system can help them achieve the necessary level of compliance with DO-377B, including:

- **Expectation for C2 link integrity, continuity, availability, and latency under RTCA DO-377, including any special data-transmission delivery parameters, expected data-framing structure, desired data-update frequency, and other links utilized by the operator's C2 Link System;**
- **Airworthiness requirements of the system in the context of certification plans and any available operational approvals;**
- **Specific collaboration objectives and "measures of success" including flight-specific goals;**
- **Setting points of contact, establishment of potential collaborative evaluation metrics; and**
- **Decision point on advancing beyond initial assessments into the AURA three-phase onboarding plan.**

The assessment process lays the groundwork for a three-phase implementation of collaborative efforts, as described below.



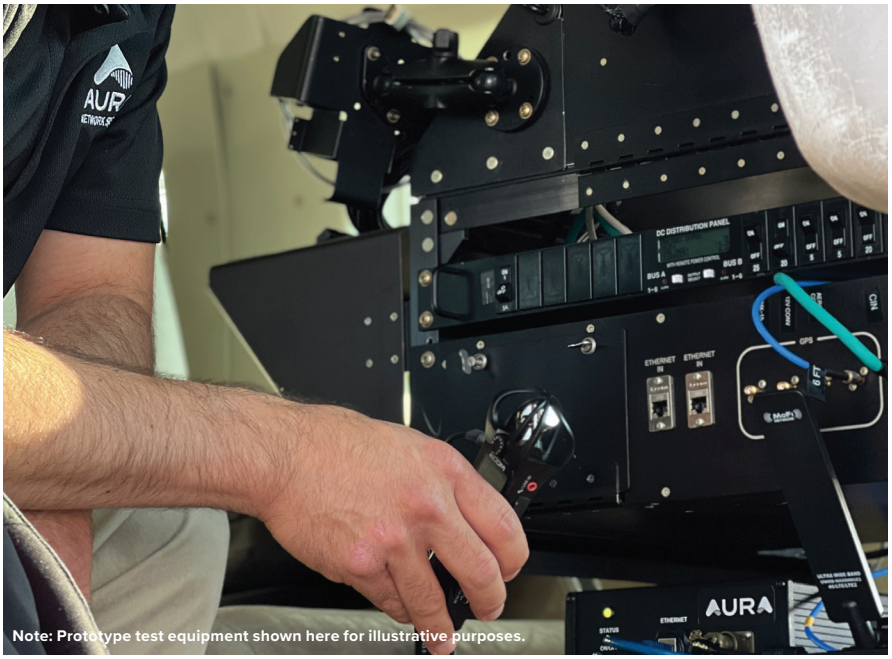
AURA works with its partners to design testing performance metrics that ultimately support FAA certification.

THREE-PHASE IMPLEMENTATION

Phase One:
System Testing, Integration & Flight Demonstrations

Phase one begins with bench testing AURA's ground radio and airborne radio (and associated voice-communications software) with a particular partner's own avionics system to determine the optimal integration architecture. From there, AURA works with the partner to integrate the airborne radio(s) into the partner's aircraft and deploy, as needed, one or more ground stations, whether fixed or temporary, into the existing AURA national network. Once the ground stations are complete and the airborne radio is integrated, AURA will work with the partner to support flight demonstrations using AURA's C2 link. This is designed to demonstrate AURA network functionality, including the following:

- **Safe integration of AURA's technology into the partner's avionics systems;**
- **Seamless data flow through airborne-ground radio station via ground and flight testing; and**
- **Utilization of AURA as a reliable link for incremental flight testing.**



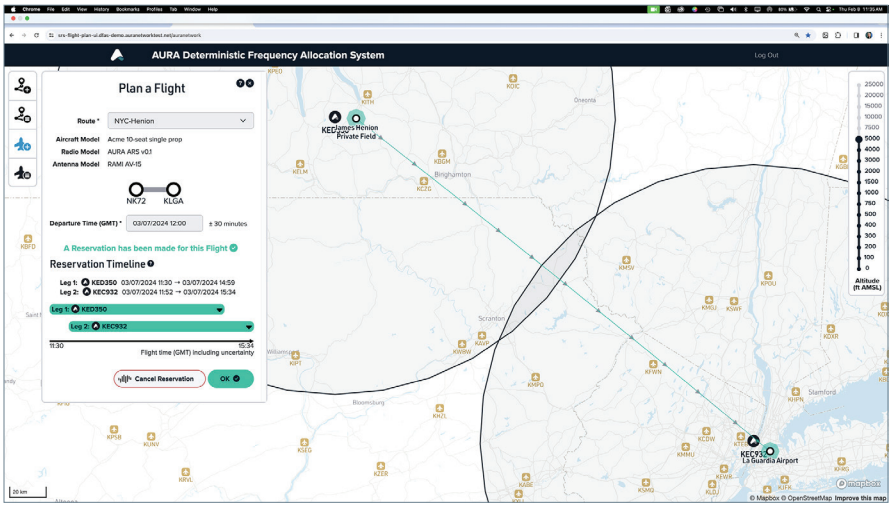
Note: Prototype test equipment shown here for illustrative purposes.

AURA works with its partners to integrate airborne radios into their aircraft for regulatory-centric demonstrations.

Phase Two:

Certification/Approval & Network Planning

AURA will work with partners to develop network modeling for the planned routes used for certification, with further plans to scale from there, along with developing all of the artifacts necessary for certification. AURA will then build any incremental sites necessary to support certification and provide connectivity for all required flights in the certification path, while generating the necessary flight data and helping ensure FAA acceptance of these results as measured against DO-377B.



AURA guarantees operators access to aviation-dedicated spectrum for its flight tests through its Deterministic Frequency Allocation System.

Phase Three:

Network Scaling & Commercial Operations

While certification is underway and pending, AURA will work with its partners to fully design the network necessary to support their planned flight routes, ensuring a deterministic link throughout each required route. AURA will then build any incremental physical infrastructure necessary to support these routes and integrate its frequency reservation system with the particular partner's flight planning and operational interfaces. Once certification is achieved, AURA will provide a highly reliable C2 service on a commercial basis with its new customers, providing full-scale service, including technical support and network monitoring, as they scale their operations.

AURA believes a phased collaborative approach will provide a framework that allows for anticipating specific requirements and supports a pathway to collaborator certification. Ultimately, together we can accelerate the timeline for routine commercial BVLOS flights for UA in the NAS.

ABOUT AURA

AURA Leadership

Chief Executive Officer Bill Tolpegin has over three decades of experience in the communications industry and was instrumental in freeing up a record-breaking amount of C-Band spectrum to advance 5G technologies across the U.S.

AURA Network Ventures President Tamara Casey leads efforts to identify, develop, and implement strategic opportunities that advance AURA's mission. She is intricately involved in the development of standards designed to safely integrate UAS into the NAS.

Chief Legal & Regulatory Officer Brian Regan leads AURA's legal and compliance efforts, where he develops and executes the company's regulatory strategies. He is also responsible for business development.

Chief Network Officer Mike Gagne leads the nationwide network buildout, as well as the company's flight-testing program, to support safe and reliable communications between pilots and aircraft.

Senior Vice President of Software & Infrastructure Ginger McClendon is responsible for product development, spectrum management, core network and IP services, as well as systems and quality engineering.

Senior Vice President of Marketing & Communications Daisy Tong is responsible for AURA's marketing and communications, where she leads strategy development and implementation of the company's branding and marketing initiatives.

Vice President of Finance Heather Samartino is responsible for the company's financial reporting, accounting, and audit management functions. She provides support for operational and financial strategy, as well as budget and financial planning.

Regulatory Affairs Director Jim Williams leads the company's efforts to secure approval to utilize its network services to provide C2 links for UAS and traditional crewed-aircraft applications. He previously served as Executive lead for the FAA's UAS Integration Office.

CONTACTS

Partner with AURA

We welcome the opportunity to facilitate flight testing and documentation to provide communication links over FCC-approved frequencies for remotely piloted aircraft in the NAS. For more information, email us at: inquiries@auranetworksystems.com

Office

AURA Network Systems, Inc.
1765 Greensboro Station Place, 9th Floor
McLean, VA 22102

Online

auranetworksystems.com

linkedin.com/company/aura-network-systems/

@AURAforAviation

Media Contact

Michael Tucker
tucker@auranetworksystems.com