ENABLING COMMUNICATIONS FOR ADVANCED AIR MOBILITY: TECHNOLOGIES, SERVICES, AND POLICIES

AURA
NETWORK SYSTEMS

EXECUTIVE SUMMARY

Advanced air mobility (AAM) represents a generational leap in aerospace, with significant economic, societal, and environmental benefits. To capture these benefits, the Government should craft comprehensive policies that support investment in AAM, the development of new technologies and services, and ultimately, safe operations. This includes the ecosystem of Enabling Communications that are necessary for AAM to succeed.

Enabling Communications refers to the full suite of communications technologies, networks, and services that will be necessary to support AAM across all concepts of operation. Communications means any transmission of data between two points, one of which is outside of an aircraft. The technologies include Command and Control (C2) wireless links; radar; resilient position, navigation and timing; detect and avoid (DAA); vehicle to vehicle communications; and other protocols and infrastructure necessary to provide a communications function to an aircraft. The networks include all of the ground, air, or space networks necessary to provide a communications link to an aircraft, and to the ground when necessary. And the communications service providers offer a communications service to an AAM operator.

AURA is building a full stack technology solution to enable crewed, uncrewed, and remotely piloted aircraft to safely navigate through controlled airspace, including beyond visual line of sight, using licensed aviation-designated spectrum for safe, reliable, standards compliant C2, essential to safe flight. As an industry leader in the Enabling Communications for AAM, AURA created this white paper to provide a comprehensive view on the full suite of Enabling Communications technologies and services, the spectrum they require, and the policy considerations necessary for them to flourish. This white paper also provides a detailed concept of operations for the most critical Enabling Communications, including C2, DAA, and air traffic control voice.

AURA offers policymakers two recommendations to improve spectrum access for Enabling Communications and three recommendations for regulations to facilitate Enabling Communications. With respect to spectrum, first AURA recommends that through its AAM strategy, the Administration task the Federal Communications Commission (FCC) in coordination with the National Telecommunications and Information Administration to, in short order, identify all the bands that it believes it can make available to support all Enabling Communications over the next decade. Second, AURA recommends that the FCC create a policy that provides clarity around the process for private sector efforts to repurpose spectrum and the subsequent rule changes that may be necessary to support an Enabling Communications function.

With respect to regulatory facilitation, AURA recommends: 1) a comprehensive plan for spectrum access with a path toward improved repurposing, as discussed above; 2) continued interagency coordination on spectrum requirements and other policies necessary to facilitate Enabling Communications; and 3) a clear Federal Aviation Administration approval process for third-party services supporting AAM, including for C2.

With these suggestions, the U.S. can stimulate the development and deployment of the Enabling Communications necessary to ensure the successful and safe integration of AAM into the U.S. airspace.

TABLE OF CONTENTS

INTRODUCTION

In this white paper, AURA Network Systems Inc. (AURA) provides a comprehensive view on the importance, role, and regulatory framework for the communications technologies, networks, and services that enable advanced automation crewed aircraft, and beyond visual line-of-sight (BVLOS) Uncrewed Aircraft Systems (UAS) concepts of operations (CONOPs), envisioned under the general term advanced air mobility (AAM).[1]

Government and industry have articulated various frameworks for AAM CONOPs, most of which focus on the aircraft and flight operations. These frameworks do not fully address the third-party services necessary to support AAM; this oversight leaves a hole in the consideration of all the elements necessary to ensure U.S. leadership in AAM. In this white paper, AURA articulates its view on the communications architectures and regulatory structures for AAM. In doing so, AURA offers the umbrella concept—Enabling Communications—which encompasses all communications technologies, networks, and services necessary for AAM within all CONOPs. Within *Enabling Communications*, we further break down the prevailing communications technologies and systems across CONOPs —with a focus on Command-and-Control (C2)—and offer a comprehensive framework to facilitate their development.

This white paper begins by describing the imperative for a comprehensive strategy to facilitate AAM and ensure U.S. global leadership, and AURA's role. The white paper then discusses the concept of Enabling Communications, which includes C2, detect and avoid (DAA), vehicle to vehicle (V2V), and air traffic control (ATC) voice, along with the relevant spectrum bands, the standards, and policy considerations for each. We then provide a more detailed view on C2 as the top-level requirement in the hierarchy of Enabling Communications, followed by regulatory and spectrum considerations, and state and local government facilitation.

BACKGROUND: THE AAM OPPORTUNITY AND AURA'S ROLE

Below, we articulate the key attributes and benefits of AAM and some of its sub-sectors. Within this context, we explain AURA's business model, technology, and place within the AAM ecosystem as a precursor to the following section on Enabling Communications.

A Comprehensive View of AAM

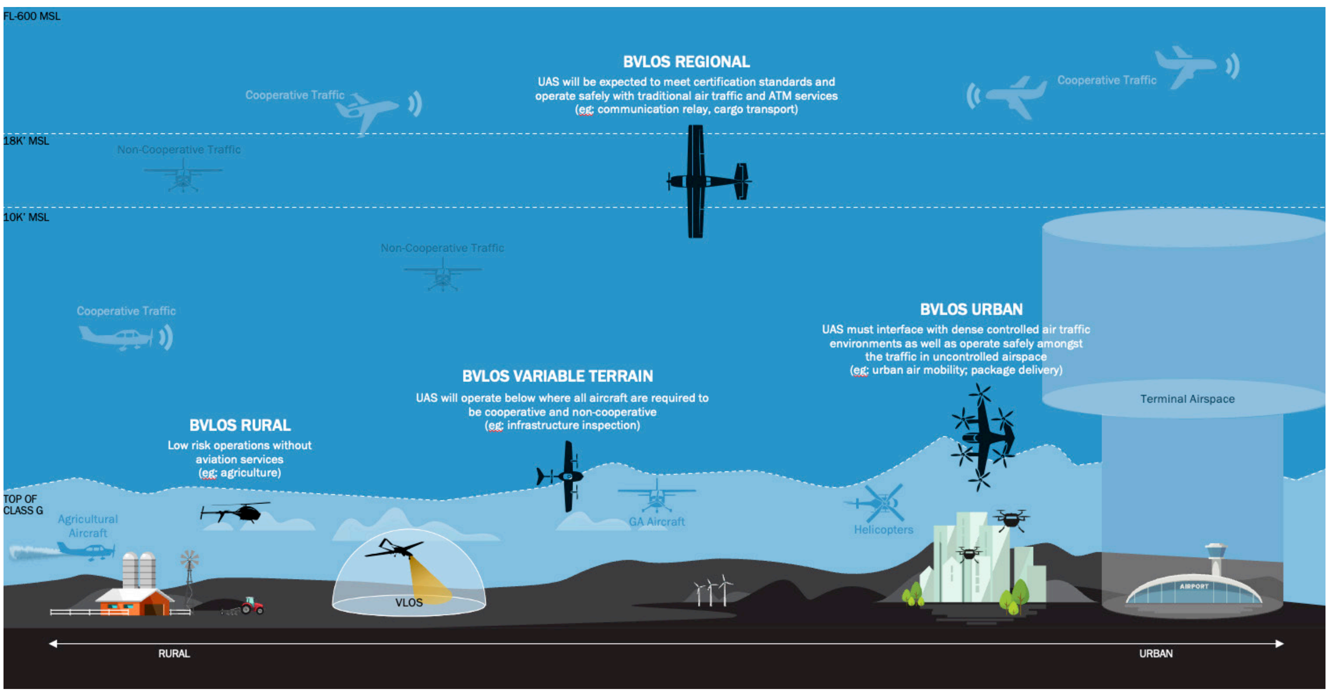
AAM is an umbrella concept that encompasses a range of CONOPs that utilize aircraft of a variety of sizes traveling over short distances, regionally, or nationally with different levels of automation and human intervention. The aircraft can include existing aircraft that have been modified to support remotely piloted/uncrewed operation, new aircraft that use electric propulsion systems and execute conventional or shortened takeoff and landing, and new electric vertical take-off and landing (eVTOL) aircraft that are crewed or uncrewed. Uncrewed flights will generally take place beyond visual line-of-sight from the operator of the aircraft. Within AAM, there are two prevailing near term use cases: Regional Air Mobility (RAM) and Urban Air Mobility (UAM).

RAM involves flights that are mid-distance, generally 50 miles to 500 miles.[2] This is a largely unserved market by current passenger aircraft—data shows that only 1.6% of trips in this range are completed by air.[3] Regional air cargo delivery over the middle mile is the current primary RAM use case, which generally involves flights between a hub and a more remote location to which it's more economical or efficient to cover over air versus ground transportation. RAM has the potential to significantly transform regional travel by offering new flight options for passengers, especially in more remote areas, and new, more efficient, cargo transportation.

RAM flights can include traditional aircraft that have automation modifications or new, autonomous aircraft.[4] These flights can leverage existing regional air infrastructure—there are more than 5,000 regional public-use airports, most of which are underutilized today.[5]

UAM, in contrast, involves flights that are shorter distances, generally under 50 miles.[6] UAM is targeted at improving urban mobility by leveraging direct flights between suburbs and cities, or within suburbs and cities. UAM can more efficiently connect passengers to destinations using primarily electric aircraft, thereby reducing local carbon emissions without a significant increase in noise.[7] This will fundamentally change the way people and goods move within urban and suburban centers across the U.S.

UAM aircraft will primarily consist of new, cutting edge eVTOLS with varying levels of automation, including full autonomy. In the near term, they may include existing rotorcraft with autonomy or incremental fuel improvements.



Near Future UAS Airspace Environment

The Opportunity for Societal Change, Economic Growth, and Global Leadership

As the U.S. Department of Transportation (DOT) recently recognized, AAM "could provide new levels of accessibility, convenience, and connectivity for people and cargo—and thus transform our nation's transportation system to provide enhanced mobility for the traveling and shipping public."[8] AAM represents no less than the transformation of an entire transportation ecosystem.

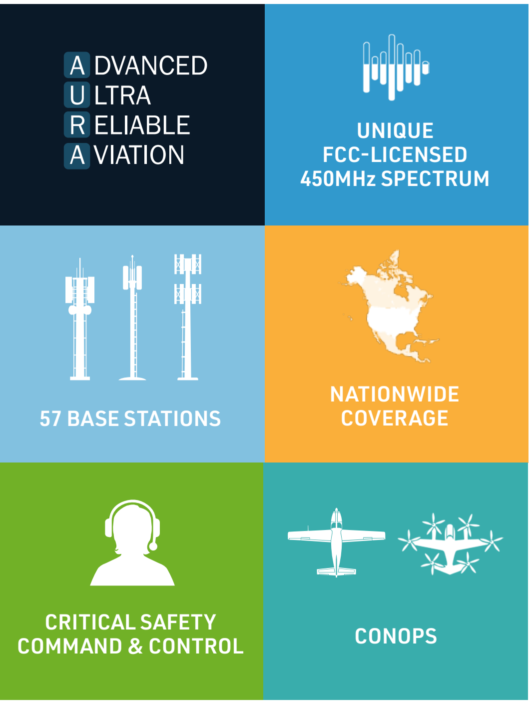
Although the industry is still nascent—aircraft and operations are still being developed and some are in the early stages of certification and approval—

the potential benefits of AAM are extensive. These benefits broadly include the "[long-range] inspection of towers, pipelines, and buildings, aerial photography, mapping, surveillance, deliveries . . . [of] critical medical supplies, and support for emergency operations like . . . post-hurricane recovery and wildfire response."[9] AAM "has the potential to reduce urban congestion, shorten commuting times, speed cargo delivery, and provide lifesaving medical transportation to remote areas . . . ."[10]

As the industry continues to evolve, it will provide myriad additional benefits. For example, in conjunction with developments in clean-fuel aircraft and eVTOL technologies, AAM can "be faster, cheaper, and produce fewer CO2 emissions than conventional aircraft, enabling same-day shipping over very long distances" and and improve businesses' logistics.[11] Similarly, UAM will revolutionize the movement of people and goods in traffic-plagued regions.[12]

The UAS industry is growing rapidly. The total UAS market is expected to grow to more than $63 billion by 2025—up from $5 billion in 2018.[13] The broader AAM market is expected to increase to $115 billion by 2035, creating more than 280,000 jobs.[14] Much of this growth will come from larger scale commercial and industrial UAS applications in the near term, followed by UAM applications.

AAM has global implications, and multiple countries and regions are striving to capture the benefits this widespread transportation transformation. To lead, the U.S. must open its airspace for AAM operations through thoughtful regulatory changes that promote development of the infrastructure and the third-party services necessary to support and facilitate AAM operations, including a variety of communications technologies, networks, and services, as detailed below.



AURA's Important Role as an AAM Enabler

AURA's network is designed to enable crewed, uncrewed, and remotely piloted aircraft to safely navigate through controlled airspace, including BVLOS, using licensed aviation-designated spectrum for safe, reliable, standards compliant C2, essential to safe flight. The McLean, Virginia-based company received Federal Communications Commission (FCC) approval to expand its C2 network and service beyond crewed applications to UAS, at all altitudes across the U.S., in 2021.[15] The company's mission remains the delivery of a Federal Aviation Administration (FAA)-complianct, secure, and reliable network. AURA utilizes its exclusive 450 MHz band spectrum, which has optimal propagation charecterics for control-and-non-payload communications (CNPC), to deliver C2 data, telemetry, and ATC voice relay.

AURA holds numerous patents for its technology, including its innovative and proprietary spectrum reservation and management systems, and the company serves both crewed and uncrewed aircraft (UA) across a range of designs and operational requirements. Whether it involves transporting people or cargo or inspecting powerlines in remote areas, safely navigating the National Airspace System (NAS) necessitates regulatory approval, including C2 links that are ultra-reliable.

In addition to its FCC licenses and authorizations, the FAA and AURA entered into a cooperative agreement to research performance standards for ATC voice communications supporting UAS within the NAS. The company was selected for two Space Act agreements with the National Aeronautics and Space Administration (NASA) for its AAM National Campaign, as well as RTCA approval for the company's request to create performance standards for C2 avionics links utilizing its conflict-free, dedicated spectrum.

AURA's purpose-built, deterministic network provides nationwide coverage, including include Alaska, Hawaii, and several U.S. territories. Its collaboration with industry and government stakeholders to construct ground stations for operators' flight testing is focused on achieving FAA certification of airborne elements, informed by RTCA DO-377A, *Minimum Aviation System Performance Standards (MASPS) for C2 Link Systems Supporting Operations of Unmanned Aircraft Systems in U.S. Airspace*. To AURA's knowledge, no other entity is designing and building a terrestrial, standards compliant C2 communications network to support AAM operations.

AURA MILESTONES

JAN 2021

The FCC issued a ruling that allowed AURA to expand its network beyond crewed applications to UAS operations, at all altitudes across the nation via licensed spectrum approved for aviation-grade communications.[16]

JUN 2021

The FAA selected AURA for the rulemaking committee tasked with empowering BVLOS autonomous flight, as well as how to operate other UA. That same month, the FAA chose AURA leadership for the committee's third-party services working group.[17]

JUL 2021

NASA selected the company as a National Campaign partner to work toward integrating air taxis, cargo-delivery aircraft, and revolutionary air-vehicle concepts into the NAS.[18]

SEP 2021

RTCA approved AURA's request to create performance standards for C2 avionics links utilizing the company's FCC-approved aviation spectrum.[19]

JAN 2022

RTCA named AURA Regulatory Affairs Director Jim Williams as co-chair of its Special Committee (SC)-228, the group charged with developing standards for C2 links critical to the safe operations of UAS and UAM aircraft operations within the NAS.[20]

SEP 2022

AURA and the FAA announced a four-year research and development agreement to research performance standards for ATC voice communications supporting UAS within the NAS. The research is designed to inform RTCA DO-377A Minimum Aviation System Performance Standards (MASPS) for voice relay between UAS pilots and FAA voice-switch ATC positions.[21]

JUL/AUG 2022

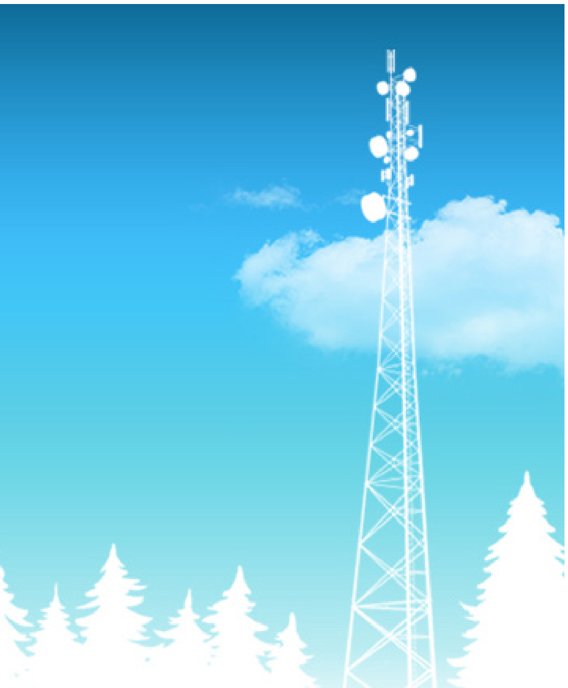
AURA successfully demonstrated its critical communications links to assure safe operations of remotely piloted commercial BVLOS flights. The Western Maryland and Springfield, Ohio testing utilized AURA's proprietary air interface and confirmed the company's deterministic network is capable of meeting federal requirements assuring safe operations of remotely piloted aircraft in controlled airspace.[22]

FEB 2023

AURA and Federated Wireless announced the joint development of a spectrum management system for AURA's nationwide aviation network. The partnership leverages AURA's frequencies and advanced technologies to deliver low latency, reliable, and secure connectivity and to enable commercial BVLOS flight in controlled airspace.[23]

JUL 2023

AURA Director of FAA Regulatory Affairs was selected to serve on the RTCA Inc. Advisory Board. "The Advisory Board serves as an important link between the members of RTCA and the organization's policy development activities by establishing RTCA policies and programs. Individuals from RTCA member organizations are elected to serve on the Advisory Board."[24]



THE COMPREHENSIVE VIEW OF AAM ENABLING COMMUNICATIONS

To date, much of the policy analysis surrounding AAM has focused on the vehicles and CONOPs of crewed and uncrewed flights. These are part of a new era of aviation and need to be integrated into controlled and uncontrolled airspace safely. They also require billions of dollars in new capital investment and years of research and development to create new technologies, new business plans, and new ways of operating and monetizing aircraft and operations.

Along with these new aircraft and CONOPs, new enabling technologies and industries need to be created to realize this transformation of aviation. In today's NAS, third parties offer weather forecasts, updated maps, airport diagrams, in-flight passenger services, crew assignment planning, and maintenance services. Under AAM, third-party service providers are envisioned to also offer flight planning, planned flight route deconfliction, and communications services. These enabling technologies and third-party services will also require significant new research and development, and billions of dollars in capital investment. Ultimately, the aircraft, operational plans, and all the enabling technologies and services need to be considered holistically to maximize the likelihood of AAM's success, and to enable the U.S. to capture all the benefits of AAM.

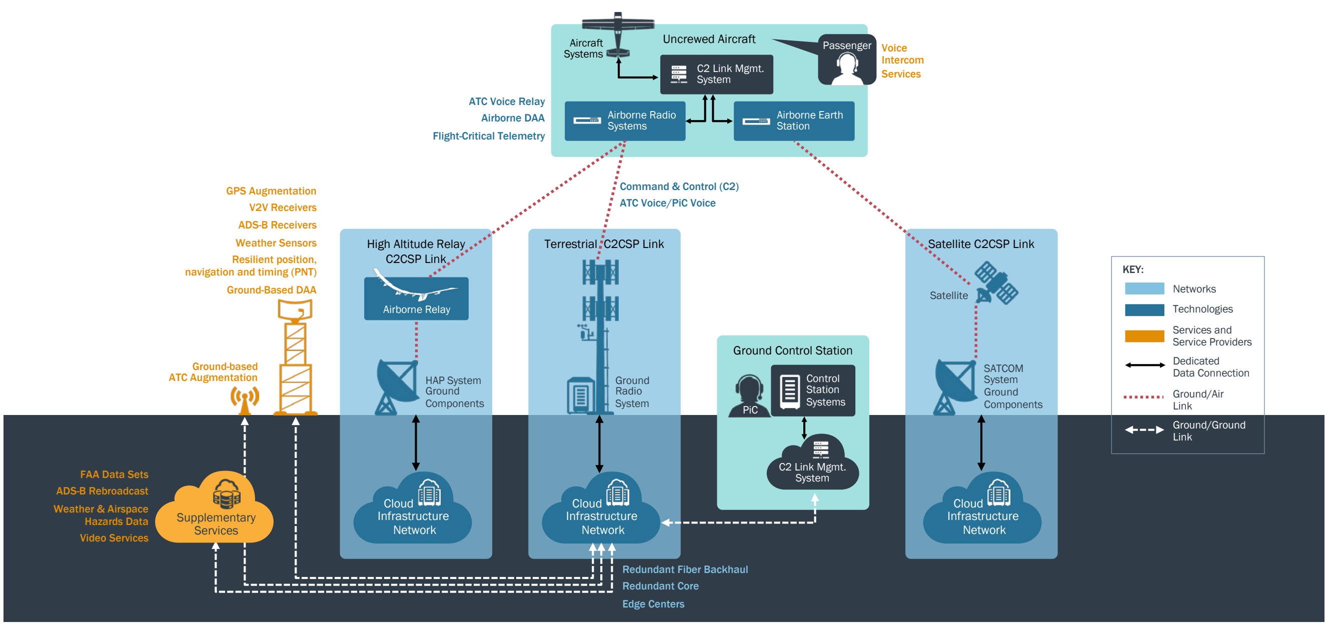
This white paper focuses primarily on the suite of communications technologies that AAM requires as one of the most critical third-party services enabling AAM—referred to throughout as Enabling Communications—and the steps the government can take to maximize their utility as part of a comprehensive and effective AAM strategy.

Enabling Communications

The phrase Enabling Communications refers to the full suite of communications technologies, networks, and services that will be necessary to support AAM across all CONOPs. *Communications* is used in the broadest sense to mean any transmission of data between two points, one of which is outside of an aircraft.

In AAM CONOPs to date, communications are referred to either too narrowly or too broadly: narrowly as a specific service offered (C2, for example); or broadly bucketed within the context of third-party services or UAS traffic management (UTM). These approaches oversimplify the extensive communications ecosystems necessary to enable AAM.

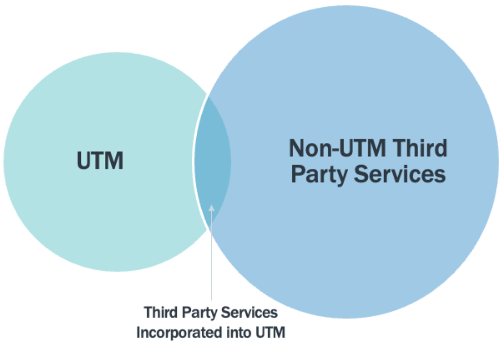
The graphic below visualizes some of the possible Enabling Communications necessary for AAM operations.



Enabling Communication for AAM

We also want to draw a distinction between the technologies, the networks, the services, and the service providers.

The *technologies* include C2 wireless links; radar; resilient position, navigation and timing (PNT); DAA; V2V communications; and other protocols and infrastructure necessary to provide a communications function to an aircraft. For AAM, this will include a combination of existing and new technologies.



The *networks* include all of the ground, air, or space networks necessary to provide a communications link to an aircraft, and to the ground when necessary. For AAM, C2 communications include ground-based multipoint networks that are interconnected elements with their own suites of technologies and sub-services. For instance, many networks will utilize fiber backhaul services to connect network end points.

The *communications service providers* offer a *communications service* to an AAM operator. Importantly, a technology developer may be distinct from a network operator, which may be distinct from a service provider. Some firms may provide one or more of these services within Enabling Communications. For example, a firm may sell communications technology, but not build a network or offer a service. Or a firm may offer a communications service but rely in whole or in part on another firm's network or technology. And there may be many different combinations.

All of these pieces are interrelated, creating a complex marketplace of Enabling Communications. Regulators must be cognizant of the full suite of enabling technologies and associated communications in an AAM CONOPs and take steps to enable the development and deployment of these technologies, networks, and services.

Lastly, AURA distinguishes between Enabling Communications, and UTM. As defined by the FAA, UTM is "the manner in which the FAA will support operations for UAS operating in low altitude airspace."[25] Further, it is "a community-based traffic management system, where the Operators and entities providing operation support services are responsible for the coordination, execution, and management of operations."[26] UTM is therefore an umbrella concept that combines a variety of services that are necessary to integrate UAS operations at low altitudes into the NAS. A UTM is not required for all CONOPs. UTM may include other third-party services, but it is not a blanket term for all third-party services that may be provided to AAM operators. In other words, a third-party service like C2 and the other Enabling Communications described in this white paper can and will exist fully outside of UTM.[27] This reality has implications for the functionality of these technologies, how they are provided, and how they are approved.

With the concept of Enabling Communications established, the following subsections describe the basic communications technologies that are a part of Enabling Communications for AAM including C2, PNT, DAA, V2V and ATC voice.

Command and Control

Concept and Architecture: C2 refers to communications related to commanding the aircraft or controlling it, carried over links between the pilot on the ground and the aircraft. C2 systems are required for all advanced highly automated aircraft operating in the NAS. C2 must be reliable (highly available, with continuity, integrity, and security) to a level that is commensurate with the risk of the aircraft losing the link with the remote pilot and operating autonomously. The requirements for availability, continuity, integrity, and security are determined for each aircraft type based on the airspace it operates in and the missions it performs. Each C2 network can utilize one or several C2 links between the ground radio and the aircraft radio. In practice, especially in the near term, a federation of C2 services will likely be necessary to meet the reliability requirements established in RTCA DO-377A. This combination currently is envisioned as a terrestrial-based link and a satellite-based link.

AAM will require larger scale networked C2 architectures that consist of multiple ground stations that can communicate with multiple aircraft simultaneously and that provide sufficient coverage to manage handoff of C2 links between ground station sites as the UA fly along their flight paths. These sites will need to be interconnected with fiber backhaul and will need to be highly resilient. The backhaul traffic will be directed over networks and transmitted to pilots on the ground. This full architecture needs to be low latency, secure by design, and physically resilient.

Industry Standards: The methodology for determining the requirements for C2 to support UAS is contained in the industry consensus standard RTCA DO-377A, *Minimum Aviation System Performance Standards for C2 Link Systems Supporting Operation of Unmanned Aircraft Systems in U.S. Airspace*. This standard describes the link quality requirements for any wireless system providing C2 communication links between the remote pilot and the aircraft, in any band, for larger aircraft.

Relevant Terrestrial Spectrum Bands: C2 for AAM generally requires exclusively licensed spectrum to ensure availability, continuity, integrity, and security. AURA currently holds general aviation air-ground licenses providing an exclusive nationwide footprint in the 450 MHz band under the existing Air-ground Radio Telephone Service. These licenses allow it to provide C2 and voice services to aircraft, with a pending rulemaking to permit data communications and services to UA, consistent with a waiver granted to AURA.[28]

In addition, at the 2012 World Radio Conference (WRC-12), member countries identified the 5030-5091 MHz band (C-band) as a target to support C2 communications for UA. The FCC recently issued a Notice of Proposed Rulemaking seeking comment on service and licensing rules for the band.[29]

Lower altitude UAS operations can also utilize existing mobile cellular spectrum and networks, assuming such operation does not cause harmful interference, the FCC permits such use, and the networks and services meet aviation safety requirements.

Unlicensed bands may be used to support some UA, including the 5 GHz and 2.4 GHz bands, but they lack the guaranteed channel availability and guaranteed access necessary to support safety of flight for most AAM operations.

No other bands have been specifically identified for C2.

Policy Considerations: Because C2 is necessary for all BVLOS uncrewed and remotely piloted aircraft system operations, the government must quickly act to create rules to allow commercial uses of existing bands and finalize rules for new bands. Without spectrum access, C2 service suppliers cannot provide this required functionality to operators, and operators cannot complete their operational approval processes. Government action includes allowing the use of mobile wireless bands to support lower-altitude flights, adopting rule changes to allow AURA to provide service to UA in the 450 MHz band, finalizing the C-band rulemaking proceeding, and seeking broad comment on additional bands that could be used to support C2.

Position, Navigation, and Timing

Concept and Architecture: PNT technologies provide up to date information about an object's location in space, with timing information that can be used to synchronize a variety of different systems, from communications systems to UAS platforms. Generally, PNT for commercial purposes is provided by Global Positioning Satellites (GPS). GPS is a legacy technology that is effective at providing reliable information, but GPS signals can be blocked, jammed, or spoofed, causing failures to a variety of systems.[30] In addition, precision navigation systems such as Real Time Kinematics, and Differential Ground-Based Augmentation Systems that are used to navigate to within 10 centimeters of the desired path, require GPS signal reception to function. Resilient PNT technologies, deployed terrestrially, in space, and on-board aircraft should be considered a critical back-up capability to provide higher reliability for emerging aviation CONOPs.

Industry Standards: GPS is maintained by the U.S. Government, which establishes the GPS standard positioning service performance standard.[31] PNT technologies for aerospace are addressed in RTCA standards DO-235C (LI interference environment), DO-292A (L4 interference environment), DO-373 (GNSS dual frequency antenna MOPS), GNSS (SBAS) L1/L5 MOPS (GPS/Galileo/SBAS MOPS), BeiDou White Paper (white paper on including BeiDou), and GNSS (GBAS) L1/L5 MOPS (GPS/Galileo/GBAS MOPS).

Relevant Spectrum Bands: GPS currently operates in the L-band. Precision navigation systems that broadcast corrections to enable greater accuracy operate in VHF, UHF, and L band spectrum. The VHF band broadcast is allocated as flight-critical aviation-reserved spectrum, for the existing differential systems.

Policy Considerations: Resilient PNT has been a critical focus for the DOT and Department of Defense for many years.[32] The DOT should bring all research to bear in considering the requirements for this aspect of communications, navigation, and surveillance infrastructure deployment. A combination of advanced technologies, a diversity of systems operating in diverse bands, strong interference enforcement policy, and development of receiver performance standards should all be pursued. This should include a study to determine the feasibility and risks of using other jurisdictions' global positioning capabilities and a resolution of ongoing FCC action regarding performance standards for receivers.[33] Ultimately, diversity of capabilities will be essential to ensuring the availability of robust and ultra-reliable PNT for future CONOPs.

Detect and Avoid

Concept and Architecture: In short, DAA is the replacement for the pilot's ability to see and avoid hazards from onboard the aircraft. Safety is ensured in the NAS by overlapping means. FAR 91.113 requires pilots to ensure safe separation using see and avoid. In addition, ATC instruction provides separation assurance when visibility and aircraft speed require augmentation on top of see and avoid. Since 1989, an additional layer of safety is required for aircraft with more than 30 seats—the Traffic Alert and Collision Avoidance System (TCAS). TCAS works on a cooperative interrogation basis (detects other aircraft also carrying TCAS), while DAA works for cooperative and noncooperative aircraft alike. In DAA, radar, electro-optical/infrared sensors, and ground-based surveillance systems are used to detect other aircraft. The DAA processor provides avoidance advisories to the aircraft or pilot on the ground, as appropriate to the specific pilot-aircraft delegation of separation duties and the available equipment. Active avoidance is designed to work within 4,000 feet of range for operations above 400 feet above ground level, meaning that the system operates within the separation distance that an air traffic controller would normally apply. DAA provides a single-layer collision avoidance capability for UA in uncontrolled airspace.

Industry Standards: DAA systems are described in RTCA standards DO-365 (airborne DAA), DO-366 (Air to Air radar), DO-387 (EO/IR sensor systems), and DO-381 (ground-based DAA surveillance). Some of the eight classes of DAA systems can incorporate traffic information from automatic dependent surveillance broadcasts, and TCAS and its next-generation systems, for a combined surveillance picture. A DAA processor has both a pilot-alerting mode and an automatic mode in cases in which a collision is imminent and pilot action would not be timely.

Spectrum Bands: While RTCA Standard DO-366A Appendix A lists possible bands for Air to Air Radar, there are currently no spectrum bands identified for DAA that utilize wireless link-based technologies. Radar-based DAA can operate in K- and X-bands. When a ground based DAA system communicates with an aircraft, it is presumed to do so over the C2 link, as do the aircraft DAA systems to the remote pilot.

Policy Considerations: DAA is essential functionality to support AAM. While some existing radar bands may be used, there are no dedicated spectrum bands to support this functionality. This should be further explored in the context of identifying additional bands to support AAM.

Vehicle-to-Vehicle

Concept and Architecture: As NAS operations grow more complex in terms of types of aircraft, variety of vehicle ability, level of traffic, and the addition of performance-based airspace volumes, there is an increasing need for information coordination and communication between aircraft. Knowledge of aircraft intent (future path) and maneuvering capabilities is important to smoothly deconflict traffic by coordinating routes, speeds, and altitudes of vehicles that cross or occupy the same airspace. Crewed aircraft can equip with ADS-B, ADS-B-R, UAT, and TIS-B to assist in locating other aircraft to efficiently avoid conflicts for airspace. UA are prohibited from using ADS-B when not under ATC control and are thus blocked from using a potentially important tool to detect and avoid. Crewed aircraft may not see UAS on their ADS-B or UAT-based traffic displays, leaving crewed and UA with only see and avoid (eyeballs) and DAA methods to avoid conflicts. For this reason, industry has proposed introduction of a V2V communication device that could be common across crewed and UA.

At a minimum, under V2V an aircraft would broadcast its aircraft type, an identifier, position, and intent. This minimum set is similar to the original TCAS and ADS-B message sets, also used for deconfliction and increasing efficiency in air traffic flows. Other potentially useful data include emergency contingency flight plans, maneuvering class of the aircraft, required time of arrival for corridor operations, and wind or weather data. The greater the quantity of data broadcast, the more spectrum that is needed to carry the broadcasts. Additional proposals include a direct V2V coordination messaging capability, "vehicle-to-company" communication of propulsive health and energy levels, and the ability to relay messages over an airborne network. The basic V2V concepts endorse a low-cost, voluntarily equipped, broadcast radio with a lower power (for short range), exclusively for air-to-air transmissions. Such air signals could be picked up by ground receivers in a passive listening mode to provide an aircraft situation picture for ground monitors such as the FAA, which is an incremental but not necessary component. As AAM traffic density increases, V2V may become required equipment on vehicles operating at reduced separation in performance-based service volumes.

Industry Standards: The General Aviation Manufacturers Association (GAMA) published a concept paper describing V2V in 2021.[34] This paper was followed up with a lengthier 2022 RTCA white paper in greater technical detail, further defining the minimum message set.[35] RTCA DAA and ACAS standards have incorporated V2V as a contributing avionics package, and work continues in RTCA to define the V2V message set. Defining the message set is expected to allow capacity studies that will identify the amount of spectrum needed to support the proposed randomized transmissions over the range of transmission. This in turn leads to a recommendation for specific bands and coding protocols for broadcast.

Spectrum Bands: There are currently no spectrum bands identified for V2V communications.

Policy Considerations: V2V represents incremental functionality that will become necessary at higher AAM flight densities, and policymakers need to create the path toward its successful implementation. These technologies will necessarily require dedicated spectrum to allow communications between onboard systems. Although some have argued that the FCC should take up to one-third of the spectrum identified for C2 in the C-band proceeding, this would inhibit the core C2 functionality needed to enable all AAM, which is a first order need. Instead, as described below, the FCC along with other federal and industry stakeholders, should develop a comprehensive roadmap and action plan to fully identify the spectrum needs of AAM and the bands that might be used.

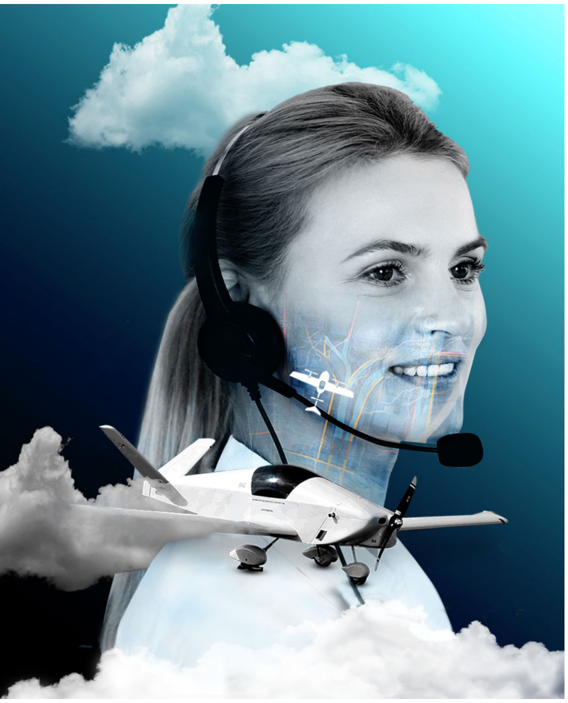
ATC Voice

Concept and Architecture: Currently, UA operations in controlled airspace require the use of instrument flight rules (IFR), which in turn require the use of voice radios for communications between the remote pilot and air traffic controllers.[36] All IFR aircraft are required by the FAA airspace rules to maintain two-way voice communications with ATC while operating in controlled airspace (*i.e.*, Classes A, B, C, D, and E).[37] Consequently, all UAS flights conducted under Part 91 rules and in controlled airspace require the ability to communicate via voice with air traffic controllers.

The FAA maintains a complex system of voice radio stations across the U.S. and territories that support FAA ATC conducting two-way communications in all controlled airspace. The voice communications service is provided with very high reliability using multiple radios and redundant connectivity with a minimum latency threshold.[38] The FAA ground voice communications service is considered safety-critical, so the service must be at least dual redundant and have a minimum availability of 0.99999.[39]

Voice radio communication systems used by UAS operators must allow the remote pilot to conduct voice radio communications with an ATC facility and other aircraft in the vicinity of the UA using a voice radio located on the UA. These systems include one or more VHF voice radios and antennas on the aircraft that are compliant with the FAA standard for voice radios used to communicate with ATC. Compliance with current standards requires there to be a control system on the UA that allows the remote pilot to command a frequency change on the voice radio on the aircraft.[40] Both the remote pilots' voice communications and the radio frequency change commands are carried on the C2 link, as described in the C2 section above. Hardware and software are also required to convert the analog voice information from the voice radio into compressed digital data that is routed to the remote pilot on the C2 link. This architecture, in which the pilot on the ground communicates to the UA using a C2 frequency, that the UA converts to VHF and transmits on aeronautical VHF channels to ATC, is generally referred to as ATC relay.

Industry Standards: RTCA DO-186A, *Minimum Operational Performance Standards for Airborne Radio Communications Equipment Operating within the Radio Frequency Range 117.975-137.000 MHz* governs the minimum operational performance standards for airborne radio communications in the aeronautical VHF band.



C2, DAA, AND ATC VOICE CONOPS

AURA is a market leader in C2 technologies, networks, and services, and has developed a comprehensive CONOPs for C2 and associated technologies and functionality that it supports, specifically ATC voice and DAA. Below we provide a detailed explanation of this CONOPs. We begin by briefly referencing the primary relevant AAM aircraft and CONOPs and then describe the core elements of the C2, DAA, and voice architecture.

AAM CONOPs Requiring C2

Aircraft flying in controlled airspace are required to have a pilot in control. For UA, this requirement can be met with a remote pilot on the ground. These pilots, the information they receive from the aircraft, and their commands to the aircraft, are carried over dedicated, standards based C2 networks. As such, C2 is currently required functionality for advanced uncrewed or automated aircraft flying in the NAS. For the purposes of describing a C2 CONOPs, this white paper largely focuses on architectures and technologies necessary to support BVLOS flights in the NAS.

Larger UAS need ADS-B Out and ATC voice radios to comply with the regulatory requirements of controlled airspace. While the flight guidance system of the aircraft may be automated, these aircraft are connected to a remote pilot with a C2 link, so that a pilot can respond to ATC and, if necessary, alter the flight route. Longer flight routes introduce greater variability in obstacles and hazards such as changing weather conditions. These UAS may be equipped with both DAA and an advanced ACAS. Strategic deconfliction in controlled airspace is provided by ATC and filed flight plans; but at present there is no means of strategically reserving a slot in uncontrolled airspace above the Low Altitude Authorization and Notification Capability 400-foot ceiling, and all aircraft conflicts in that airspace are resolved with onboard avionics and/or with remote pilot involvement. These large UAS have a variety of airframe configurations ranging from rotorcraft and powered lift to fixed-wing retrofits (*e.g.*, Cessna Caravans), and are large enough to warrant airport landing and take-off. Their primary navigation is GPS; many have precision satellite-based GPS and may use cameras to assist in landing and taxiing.

C2 is essential to the safe operation of the large UAS. Many of these UAS will launch with a remote pilot on the ground. Automated flight guidance performs many of the formerly onboard pilot's functions. To handle the many contingencies that can arise during flight, a pilot remains connected via a C2 link system.

C2, Voice, DAA CONOPs

C2 systems connect the ground control pilot and station to the aircraft with an intermediate air-ground component.

At its simplest in a point-to-point configuration:

1. The aircraft avionics send telemetry, position, health, and sensory information to the onboard radio, which frames, encodes, and encrypts the digital data.

2. The aircraft-mounted radio transmits this information to a ground radio receiver.

3. The ground radio receiver processes the information, keeping track of lost information and received signal strength.

4. The information is routed through fiber backhaul networks to a service provider's network core (usually in one or more data centers), and then back onto a fiber connection and routed to the pilot in control.

5. Any required transmission from the ground station to the aircraft follows a similar path in reverse.

In practice, AAM requires large, interconnected ground networks that provide full coverage across an operator's planned flight routes, with extended coverage for off nominal situations.[41]

This simple picture grows more complex for AAM flights over medium distances and with increased AAM flight density:

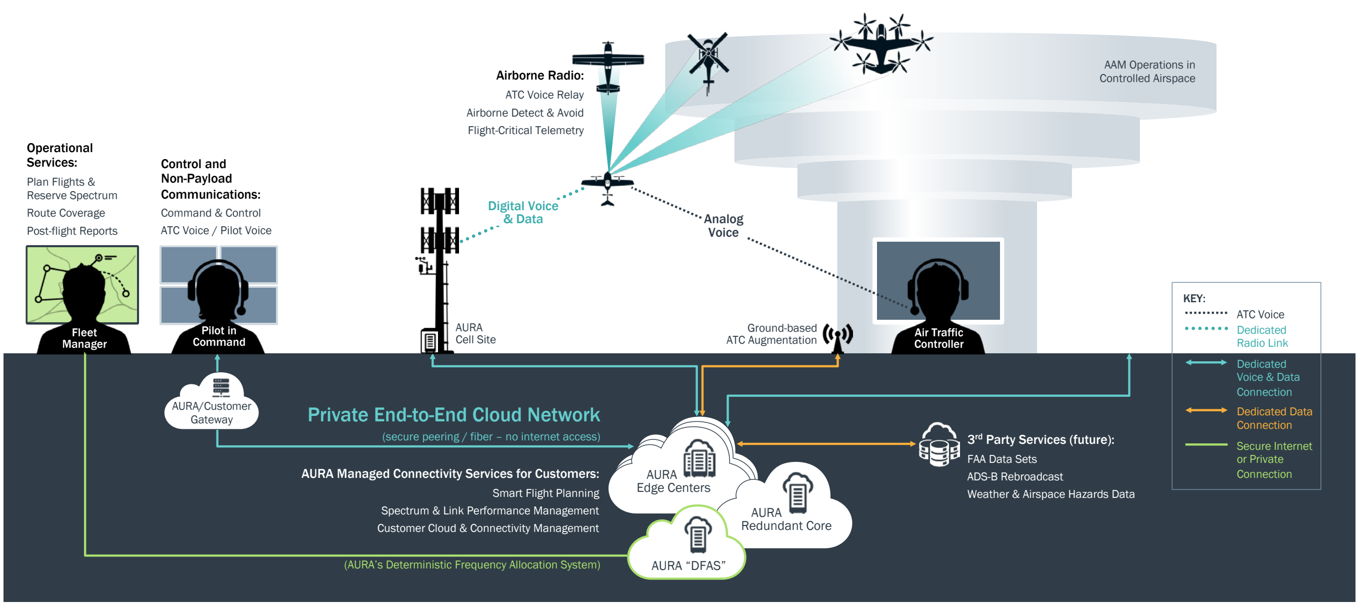
1. The service provider needs to use sophisticated radio frequency propagation prediction tools with a high degree of precision to plan and model the routes that it serves. This coverage provides sufficient overlap at altitude to hand off a flight from ground station to ground station, while also managing adjacent channel interference between sites.

2. The service provider models the fiber backhaul and long haul necessary to interconnect the sites with each other, with redundancy in cloud services for the service provider's core network.

3. Once the modeling is complete, the service provider then builds the sites, leveraging existing vertical infrastructure (towers) as much possible to keep construction costs and timelines reasonable. It must also lease and/or construct the fiber backhaul and long haul.

4. In parallel, the provider will have built a robust core network infrastructure, which is the software necessary to run and manage the network. It must also develop sophisticated network management tools to monitor the network and reserve dedicated channels to ensure a sufficient connection is available for each.

5. This end-to-end system needs to be sufficiently resilient and manage the low latency to allow a pilot to adjust the aircraft.



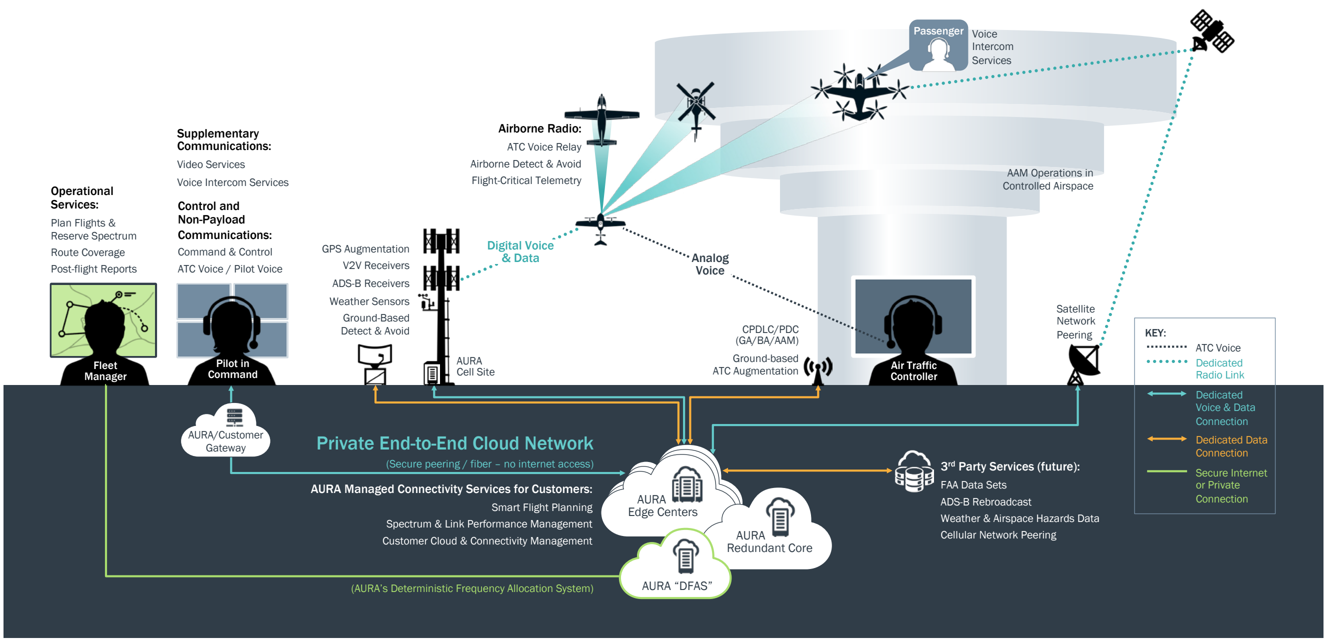
Enabling Communications Architecture

These C2 ground networks will need to be able to manage multiple flights connected to the same sites simultaneously. AAM at scale will involve many flights over the same routes with close spacing. Notably, this level of sophisticated network technology and architecture requires dedicated companies focused on building and deploying these technologies and networks. C2 providers need to work collaboratively with AAM operators to maximize coverage over planned routes and to provide actionable user interfaces for pilots on the ground.

With the C2 link CONOPs established, there are two other Enabling Communications technologies that will rely on these C2 links to transmit information to and from the aircraft.

First, ATC voice communications are sent from the pilot on the ground, through the C2 network as described, to the aircraft. The hardware and software on the aircraft will receive the voice communications, decode it, and reencode it to be transmitted over the aeronautical VHF band to ATC on the ground. The same process runs in reverse for ATC voice communications back to the pilot on the ground: ATC voice is carried over aeronautical VHF to the aircraft, which receives the signal, decodes it, reencodes it, and transmits it back to the pilot on the ground through the C2 network as described.

Second, DAA systems themselves can have different architectures. Radar is perhaps the simplest architecture, where a large powerful radar system tracks objects in flight. A system or a pilot (or other human) will interpret the data and provide commands to the aircraft to adjust its flight pattern as necessary to avoid an unforeseen object. This is the reverse path of the C2 link described above: when DAA information requires an action, that information is transmitted through the ground network to the ground station to which the aircraft is currently connected and then to the aircraft itself. Other DAA architectures that are not onboard will operate in largely the same way.



C2 Architecture for UA in Controlled Airspace

These core Enabling Communications will be required for most AAM flights in controlled airspace, with C2 playing the central role as the communications tether between the aircraft and the ground.

SPECTRUM REQUIREMENTS FOR ENABLING COMMUNICATIONS

Enabling Communications require electromagnetic spectrum across a variety of bands, making spectrum and telecommunications infrastructure availability essential to the development of AAM in the U.S. The FCC recently stated that "because a UA, to the extent its route is not pre-programmed, must be operated remotely, the operator depends critically on wireless communications to send commands to the aircraft and to receive telemetry and other data from it."[42] And Boeing recently noted that "as the [UAS] industry continues to develop, the need for aviation safety spectrum will become even more critical."[43] In short, there can be no AAM industry absent spectrum and communications infrastructure to support the myriad operations performed by UA.

The FCC has correctly noted, however, that "currently, no spectrum is licensed in the United States exclusively for UAS communications and operators have generally relied on unlicensed operations or experimental licenses," which do not meet operators' need for the "greater reliability that interference-protected licensed spectrum provides for control-related and other safety-related communications."[44] The FAA has initiated a practice of requiring licensed spectrum for BVLOS operations in controlled airspace due to the fact that unlicensed spectrum lacks interference protection and guaranteed access under FCC rules, which is insufficient for safe operations.[45]

Spectrum is foundational for all Enabling Communications. Spectrum reallocation, re-farming, and assignment is a complicated process that involves detailed administrative procedures, as well as a wide range of industry stakeholders and government interests. Given these complexities, it can take the FCC years to bring new spectrum bands to market, even in relatively easy scenarios.

Therefore, AURA recommends the U.S. Government take two actions:

First, AURA recommends that through its AAM strategy, the Administration task the FCC in coordination with NTIA to, in short order, identify all the bands that it believes it can make available to support all Enabling Communications over the next decade. The FCC should begin by identifying bands it believes may be available or useful even if the current allocation or existing rules do not support a UAS use case, and it should present its compelling case for the equities in support of such a reallocation or reassignment. The FCC should also look at any unutilized spectrum bands that may be available. Once the target bands are identified, it should solicit industry feedback on its analysis, with a focus on very detailed technical analysis and cost-benefit analysis relative to the highest needs first with respect to the criticality of a system for supporting AAM.

Second, AURA recommends that the FCC create a policy that provides clarity around the process for private sector efforts to repurpose spectrum and the subsequent rule changes that may be necessary to support an Enabling Communications function. Some of the spectrum necessary to support Enabling Communications may already be licensed under a different set of rules. However, to the extent private sector users develop a higher and better use for that spectrum and acquire the rights, the FCC should expeditiously update the relevant rules to enable such use, balancing the public interest benefits of its actions.

In response to this recognized obstacle to the growth of AAM in the U.S., the FCC appropriately has begun to address the spectrum needs of the UAS industry.

Specifically, as noted above, the FCC in 2021 granted AURA a waiver of certain rules governing the general aviation Air-Ground Radio Telephone Service to allow AURA to utilize its 450 MHz licenses to provide additional, non-general aviation air-ground radiotelephone services, such as CNPC, to UAS over AURA's existing network.[46] As required by the Waiver Order, AURA subsequently filed a Petition for Rulemaking seeking to make the rule waivers permanent.[47] The Petition is pending and the FCC has stated that it "expect[s] to address the AURA/A2G Petition . . . ."[48]

More recently, after consultation with the FAA and NTIA, the FCC in early 2023 issued the C-band NPRM, in which the agency proposed “to adopt a band plan and service rules in the 5030-5091 MHz band to enable UAS operators to use interference-protected CNPC links.” Numerous commenters, including AURA, supported the FCC’s proposal in concept, and offered constructive input toward maximizing the use of the band for C2.[49] The C-band is valuable for CNPC use in part because it is globally harmonized spectrum—an important move initiated by the United States.[50]

This proceeding reflects the need for incremental spectrum to support UAS. While the band offers 61 megahertz and is already specified for C2 and safety of life operations, the record reflects requests from the satellite industry, V2V, DAA, and terrestrial mobile for access to the same spectrum. This band cannot support all these use cases, highlighting the need for the FCC, in consultation with the FAA, to create a roadmap.

Together, these two FCC proceedings are important initial steps in ensuring spectrum availability for UAS CNPC and work on them should continue without delay, in combination with additional analyses to identify the full scope of spectrum bands that may be used to support Enabling Communications.

FACILITATING REGULATION

AAM by nature is in a heavily regulated space. The U.S. Government has a compelling mandate to protect the public by ensuring that these new operations do not pose additional risks to safety of life or property, and regulators need to take appropriate actions to ensure that is the case. Regulators also need to consider that these technologies, services, and entire new industries cannot launch, let alone succeed, without their proactive work to create the right rule structures for them to flourish.

Although the industry is highly regulated, that does not necessarily mean that regulation needs to be an obstacle to success—instead, regulators should take an active role in crafting regulations that facilitate the industry's growth.

AURA highlights the current regulatory environment and offers suggestions specifically focused on regulatory structures that can more rapidly support technology development and deployment to support large scale AAM operations across the U.S.

Specifically, AURA urges regulators and policymakers to address three key areas:

1. a comprehensive plan for spectrum access with a path toward improved repurposing, as discussed in the prior section;

2. continued interagency coordination on spectrum requirements and other policies necessary to facilitate Enabling Communications;

3. a clear FAA approval process for third-party services supporting AAM, including for C2.

Below AURA provides its suggestions with respect to the second and third focus areas.

With respect to the second focus area, as the Administration and Congress appropriately recognize, ensuring that AAM both succeeds and does so safely requires a significant multi-agency approach. The existence of the

DOT Advanced Air Mobility Interagency Working Group (IWG) is a welcome start to this process and reflects the broad agency engagement that will be required.[52] Specifically with respect to Enabling Communications, cross agency collaboration is necessary to leverage relevant agencies' expertise to help create the right set of policies to facilitate the rapid development and deployment of Enabling Communications.

This includes continued coordination on spectrum policy with a specific interaction between the DOT and FAA providing their expertise to the FCC and NTIA to help scope the spectrum needs of all Enabling Communications for AAM, with industry input.[53] The FCC is the expert agency in spectrum, but its mandate cuts across all sectors, and it will require sector expertise on the unique needs and use cases of AAM. This will help inform the spectrum identification process that AURA recommends above. AURA commends the work of the IWG subgroup on Infrastructure Development as a meaningful start.

Lastly, interagency coordination and engagement is necessary in the standards arena and international policymaking bodies. Like the commercial wireless industry, aerospace relies on standards bodies to establish both the technical and operational requirements of wireless systems, including the full suite of Enabling Communications. Frequently, the FAA relies on these standards as the basis for its certifications and approvals. To date, however, these standards bodies have not engaged in a comprehensive manner with the FCC with respect to broader spectrum policy, and the FCC may be insufficiently staffed to participate in these bodies on a full-time basis. This creates the risk of technical externalities, where standards may not reflect the current or future policy prerogative of the FCC or the Administration across all areas related to wireless and spectrum.

In the area of standards development, ASTM, RTCA, and SAE are active in writing industry-based standards to form the basis for common equipment and processes. In the area of AAM, the FAA provides authority for approval of equipment meeting standards that have passed an inspection and validation process for performance and interoperability (when applicable). RTCA has long held the position of writing standards for equipment that uses sensors and radio frequencies in aircraft. Many of the technologies discussed in this white paper have been described in standards written by RTCA. A manufacturer is able to seek FAA approval for components that meet the standard and demonstrate to the FAA that the component meets the function described in the standard, and validates that performance through testing described in that standard. This method of creating a common reference spreads a great deal of the start-up certification cost across the industry rather than placing all the cost on the first mover.

With respect to the third focus area, third-party service providers are going to provide Enabling Communications to AAM operators in most cases. The FAA has a clear process for certifying the equipment that is placed on the aircraft but does not have an established process for reviewing and approving the communications services themselves. This creates uncertainty and unpredictability about the process and standards by which the FAA will review and approve these services.

Third-party service providers need to develop new technologies, new network architectures, and new service models to provide Enabling Communications services to AAM operators. AAM operators in turn need to have confidence not only that the third-party services on which they rely work as intended, but also that the FAA will ultimately approve the use of such services. This lack of clarity regarding how third-party services will be approved presents risks to technological development and new capital investment into these essential services.

AURA therefore recommends that the FAA, in the near term, publish a process by which the FAA will review and approve third-party services and service providers, including references to industry standards to the extent they exist. This process can be variable by the type of Enabling Communications technology or system, or the operations they support, but should be as uniform as possible to drive predictability. To be clear, AURA does not suggest altering the FAA's existing certification and approval frameworks, but rather adding to them to support the continued development of robust third-party services, including Enabling Communications.

STATE & LOCAL GOVERNMENT FACILITATION

Much of this white paper focuses on policy recommendations for federal policymakers and regulators, but AAM's success will require collaboration across all levels of government, including state and local. AAM will transform the aviation and transportation industries, making the U.S. more globally competitive by providing new mobility options for the movement of people and cargo.[54] These options will enable greater accessibility, convenience, and productivity for the nation's businesses and citizens. The U.S. Government, in part through the IWG, can play a leadership role in aligning federal, state, and local government agencies to ensure a common vision and raise awareness of the societal, economic, environmental, and global benefits enabled by this new mode of mobility.[55]

While the FAA regulates the NAS and is responsible for ensuring safety of life aviation operations, both state and local governments have the duties to protect and ensure their constituents' quality of life. States and many local jurisdictions also have transportation departments responsible for administering intrastate, county, and city transportation networks to ensure safety and efficiency. AAM has the potential to reduce congestion of the ground network and increase the flow of commerce and the mobility of people across these networks. As the DOT stated: "State Departments of Transportation . . . are at the heart of planning, design, construction, and operations and maintenance projects across all travel modes."[56]

In accordance with Title VI of the Civil Rights Act of 1964, state DOTs are required to assess the benefits and adverse impacts of transportation activities among diverse population groups. As a result, it is imperative to ensure—from the outset—that policy and decisionmakers from state and local DOTs are engaged. Without that support, getting AAM operations off the ground will be challenging.

Many states are already embracing the AAM industry, recognizing the opportunities for new job creation and economic growth, new sustainable modes of transportation, increased access to critical goods and services—such as medical supplies—and overall improved safety and security of citizens.

Several states, including California, Florida, Michigan, New York, North Carolina, North Dakota, Ohio, Oklahoma, and Utah are advancing programs and deploying infrastructure funding in support of AAM operations. These disparate initiatives are in support of federal programs addressing AAM infrastructure requirements and funding.

As an example, the Ohio DOT, in partnership with The Ohio State University, secured Federal Highway Administration and state funding to build out a BVLOS UAS corridor and area of operation, which includes the research, planning, and deployment of surveillance and other sensor systems, as well as an AAM operations center for airspace awareness and monitoring. Ohio DOT's intent is to support the development of the AAM industry in its state by providing shared-use safety-critical infrastructure for deconflicting uncrewed and crewed aircraft operations, while providing real-time data and information necessary to perform safe, economic, and at-scale operations. Although this model may be the right approach—it is critical to consider its scalability nationwide. Federal regulators must establish programs that address the role of state and local authorities in enabling AAM operations and establish a common operational framework, including the enabling infrastructure performance requirements (such as the key components highlighted in this white paper), that can be extended to state and local authorities with AAM interests for their communities.

CONCLUSION

This white paper offers a comprehensive view on the Enabling Communications for AAM, the spectrum it requires, and the recommended regulatory actions needed to facilitate Enabling Communications.
To support the safe integration into the NAS and provide certainty for investments in AAM, AURA recommends a comprehensive plan for spectrum access, continuing interagency coordination on policies to facilitate Enabling Communications, and a clear FAA approval process for third-party services supporting AAM, including C2. These regulatory initiatives will directly contribute to maintaining the safety and success of the U.S. aviation industry, ensuring the nation's position as a leader in the rapidly evolving and transformative world of AAM.

APPENDIX A: SUMMARY OF RELEVANT SPECTRUM BANDS, USE CASES, AND STANDARDS

ENABLING COMMUNICATION	SPECTRUM BANDS FOR AAM	STANDARDS REFERENCES
Command and Control	450 MHz Air-ground Radio Telephone Service (under waiver with rulemaking pending); 5030-5091 MHz (rulemaking pending)	RTCA DO-377A
Positioning, Navigation, Timing	Primarily the L-band, with supplemental corrections in UHF and VHF	U.S. Department of Defense, Global Positioning System Standard Positioning Service Performance Standard; RTCA DO-235C (LI interference environment); RTCA DO-292A (L4 interference environment); RTCA DO-373 (GNSS dual frequency antenna MOPS); RTCA GNSS (SBAS) L1/L5 MOPS (GPS/Galileo/SBAS MOPS); RTCA BeiDou White Paper (white paper on including BeiDou); and RTCA GNSS (GBAS) L1/L5 MOPS (GPS/Galileo/GBAS MOPS).
Detect and Avoid	Radar-based DAA can operate in K- and X- bands; non-radar ground based DAA does not have existing allocations or assignments	RTCA DO-365; RTCA DO-366; RTCA DO-387l; and RTCA DO-381.
Vehicle to Vehicle	No existing allocations or assignments	GAMA White Paper (Vehicle-to-Vehicle Datalink Communications: Enabling Highly Automated Aircraft and High-Density Operations in the National Airspace); RTCA White Paper No. 302-22/PMC-2350.
Air Traffic Control Voice	117.975-137.0 MHz	RTCA DO-186A

ENDNOTES

1. As the U.S. Department of Transportation notes: "AAM operations will typically start as piloted flights" but "are expected to . . . incorporate highly automated, unpiloted aircraft." 88 Fed. Reg. 31593, 31594 (May 17, 2023).

2. NASA, Regional Air Mobility at 4 (Apr. 2021) (NASA RAM Report) https://ntrs.nasa.gov/api/citations/20210014033/downloads/2021-04-20-RAM.pdf

3. *Id.*

4. *See, e.g.,* Reliable Robotics, https://reliable.co/; Xwing, https://xwing.com/; BETA, https://www.beta.team/.

5. NASA RAM Report at 4.

6. NASA, Urban Air Mobility (UAM) Market Study at 86, (Nov. 2018), https://ntrs.nasa.gov/api/citations/20190001472/downloads/20190001472.pdf.

7. *Urban air mobility: A comprehensive review and comparative analysis with autonomous and electric ground transportation for informing future research,* Laurie A. Garrow, Brian J. German, Caroline E. Leonard, Transportation Research Part C: Emerging Technologies, Volume 132, 2021, 103377, ISSN 0968-090X, https://doi.org/10.1016/j.trc.2021.103377.

8. DOT RFI p. 31594.

9. *Wireless Telecommunications Bureau Seeks to Refresh the Record on Unmanned Aircraft Systems Use of the 5 GHz Band*, Public Notice, 36 FCC Rcd 12706, at 1 (WTB 2021).

10. U.S. Government Accountability Office, *Transforming Aviation: Stakeholders Identified Issues to Address for 'Advanced Air Mobility'*, Report to Congressional Committees at 1 (May 2022), https://www.gao.gov/assets/gao-22-105020.pdf.

11. DOT RFI p. 31594.

12. *Wireless Telecommunications Bureau Seeks to Refresh the Record on Unmanned Aircraft Systems Use of the 5 GHz Band*, Public Notice, 36 FCC Rcd 12706, at 1 (WTB 2021).

13. U.S. Government Accountability Office, *Transforming Aviation: Stakeholders Identified Issues to Address for 'Advanced Air Mobility'*, Report to Congressional Committees at 1 (May 2022), https://www.gao.gov/assets/gao-22-105020.pdf.

14. *Id.*

15. AURA Network Systems OpCo, LLC and A2G Communications, LLC Request for Waiver, WT Docket No. 20-185, DA 21-58, Order (rel. Jan. 14, 2021) *(AURA Waiver Order).* AURA has a Petition for Rulemaking pending before the FCC for permanent rule changes that are necessary to enable the use of the band to support uncrewed flights. See AURA Network Systems OpCo, LLC and A2G Communications, LLC to Permit the Transmission of Data in Air-Ground Radio Telephone Automated Service Channels Between 454.675-454.975 MHz, RM-11912, Petition for Rulemaking (filed Feb. 16, 2021) *(AURA Petition).*

16. *See AURA Waiver Order.*

17. See UAS Beyond Visual Line-of-Sight (BVLOS) Aviation Rulemaking Committee Membership, https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/BVLOS%20ARC%20Members%20FINAL_12-3-2021.pdf

18. Newton, L. (2021, July 8). NASA's National Campaign Adds Partners. NASA. https://www.nasa.gov/centers/armstrong/features/national-campaign-adds-partners.html; Advanced Air Mobility National Campaign. (n.d.). Advanced Air Mobility National campaign. NASA. https://www.nasa.gov/aamnationalcampaign

19. AURA Network Systems (2021, September 16). *AURA—Big news: we're approved to develop a MOPS*. AURA. https://auranetworksystems.com/news/big-news-were-approved-to-develop-a-mops.

20. AURA Network Systems (2022, January 10). *AURA—National Standards Organization names AURA Exec as Co-Chair to develop C2 links critical for UAS*. AURA. https://auranetworksystems.com/news/national-standards-organization-names-aura-exec-as-co-chair-to-develop-c2-links-critical-for-uas; RTCA, Inc. (2023, July 10). SC-228 - RTCA. RTCA. https://www.rtca.org/sc-228/

21. AURA Network Systems (2022, February 1). *AURA—AURA to research critical communications in national airspace.* https://auranetworksystems.com/news/faa-and-aura-to-support-critical-communications-in-national-airspace; RTCA, Inc. (2019, March 21) RTCA DO-377 - Minimum Aviation System Performance Standards for C2 Link Systems Supporting Operations of Unmanned Aircraft Systems in U.S. Airspace. https://standards.globalspec.com/std/13301563/RTCA%20DO-377

22. AURA Network Systems (2022, July 26). *AURA—AURA successfully demonstrates critical communications links to assure safe operations of commercial flights beyond visual line of sight.* https://auranetworksystems.com/news/aura-successfully-demonstrates-critical-communications-links-to-assure-safe-operations-of-commercial-flights-beyond-visual-line-of-sight

23. AURA Network Systems (2023, February 24). *AURA—Federated Wireless Partners with AURA Network Systems to Advance Autonomous Aviation with Spectrum Management in the 450 MHz Band.* AURA. https://auranetworksystems.com/news/federated-wireless-partners-with-aura-network-systems-to-advance-autonomous-aviation-with-spectrum-management-in-the-450-mhz-band.

24. RTCA Inc. Website: https://www.rtca.org/about/governance/

25. Federal Aviation Administration, NextGen, *Concepts of Operations v 2.0: Foundational Principles, Roles and Responsibilities, Scenarios and Operational Threads for Unmanned Aircraft System Traffic Management* at xi (Aug. 2022).

26. *Id.*

27. NASA researchers are now working on concepts for extensible traffic management (xTM), which generalizes the requirements of UTM to be adaptable to more diverse use cases and altitudes. See NASA, Jaewoo Jung, Joseph Rios, Min Xue, Jeffrey Homola, Paul Lee, *Overview of NASA's Extensible Traffic Management (xTM) Research (Jan. 2021).*

28. See *AURA Waiver Order.*

29. *See Spectrum Rules and Policies for the Operation of Unmanned Aircraft Systems, Petition of AIA for Rulemaking to Adopt Service Rules for Unmanned Aircraft Systems Command and Control in the 5030-5091 MHz Band,* WT Docket No. 22-323, RM 11798, Notice of Proposed Rulemaking, FCC 22-101 (rel. Jan. 4, 2023) (*C-band NPRM*).

31. U.S. Department of Defense, Global Positioning System Standard Positioning Service Performance Standard, 5th Edition (Apr. 2020), https://www.gps.gov/technical/ps/2020-SPS-performance-standard.pdf.

32. See U.S. Government Accountability Office, *GPS Disruptions: DOT Could Improve Efforts to Identify Interference Incidents and Strengthen Resilience*, Report to the Committee on Transportation and Infrastructure, House of Representatives (December 2022), https://www.gao.gov/assets/gao-23-105335.pdf.

33. See *Promoting Efficient Use of Spectrum Through Improved Receiver Interference Immunity Performance,* ET Docket No. 22-137, Notice of Inquiry, FCC 22-29 (rel. Apr. 21, 2022). *See also, Principles for Promoting Efficient Use of Spectrum and Opportunities for New Services, ET Docket No. 23-122, and Promoting Efficient Use of Spectrum Through Improved Receiver Interference Immunity Performance,* ET Docket No. 22-137, Policy Statement, FCC 23-27 (rel. Apr. 21, 2023).

34. General Aviation Manufacturers Association, *Vehicle-to-Vehicle Datalink Communications: Enabling Highly Automated Aircraft and High-Density Operations in the National Airspace,* GAMA EPIC Data Communications Ad-hoc Committee Concept Paper Version 1.0 (Dec. 17, 2021), https://gama.aero/facts-and-statistics/consensus-standards/publications/gama-and-industry-technical-publications-and-specifications/.

35. RTCA, *Vehicle to Vehicle Communications White Paper*, SC 228, RTCA Paper No. 302-22/PMC-2350 (Dec. 15, 2022), https://www.rtca.org/wp-content/uploads/2023/01/V2V-White-Paper-Final.pdf.

36. 14 CFR, Part 91, §91.183.

37. 14 CFR Part 91 §91.126-131, and §91.135.

38. FAA studies have shown that excessive latency in the ATC voice system can result in excessive simultaneous transmissions (known as "step ons") that can hinder the ATC specialist's ability to manage the traffic flow. Consequently, the FAA has established an end-to-end latency requirement for all ATC voice communication systems of 250 ms average, 300 ms 95% of the time, and a not to exceed (NTE) value of 350 ms. The current FAA position is that, for successful integration of UAS into U.S. airspace, all UAS must meet the same communication requirements as those for crewed aircraft. National Airspace System Requirements Document, U.S. Department of Transportation, Federal Aviation Administration, August 11, 2014, NAS-RD-2013

39. FAA National Airspace System Requirements Document, NAS-RD-2013.

40. *See 14* C.F.R. §§ 91.123; 91.205(d)(2).

41. Large UAS flying BVLOS may also connect to ground pilots using satellite-based networks. In this architecture, the radio signal from the aircraft is transmitted to a satellite before being routed down to a ground radio station and on to a pilot. This additional hop introduces additional transmission time or latency, meaning that a satellite link alone is insufficient to meet latency requirements, particularly for ATC voice requirements, as described above.

42. *C-band NPRM* at para. 4.

43. Comments of The Boeing Company and Wisk Aero LLC, FCC 22-101, at 4.

44. *C-band NPRM* at para. 4.

45. *See FAA*, Part 107 Waiver Section Specific Evaluation Information at 5, https://www.faa.gov/sites/faa.gov/files/uas/commercial_operators/part_107_waivers/Part-107-Waiver-Section-Specific-Evaluation-Information.pdf.

46. *AURA Waiver Order.* A2G Communications, LLC, the predecessor licensee of AURA's 450 MHz licenses, assigned a number of those licenses to AURA subsequent to the Waiver Order. *See Application of A2G Communications, LLC and AURA Network Systems OpCo, LLC for Consent to Assign Licenses*, ULS File No. 0009752785 (filed Oct. 13, 2021, consented to June 3, 2022, and consummated July 22, 2022).

47. *AURA Petition*

48. *C-band NPRM* at fn. 3.

49. *C-band NPRM* at para. 11.

50. *See, e.g.,* Comments of AURA Network Systems, Inc., FCC 22-101, at 4 ("AURA strongly supports the Commission's efforts to promote the growth of the UAS industry by making available licensed spectrum for UAS."); Comments of Florida Power and Light Company, FCC 22-101, at 1 ("Having long sought a protected spectral home for its unmanned aircraft system ("UAS") program, FPL commends the Commission for taking this initial step towards establishing a more permanent regulatory framework for UAS."); Comments of the Choctaw Nation of Oklahoma, FCC 22-101, at 3 ("The FCC's proposal to make dedicated, exclusive-use spectrum available for Network Supported Service ("NSS") UAS operations will help move the UAS industry forward.").

51. *See C-band NPRM* at para. 5 ("Consistent with the United States proposal, the 2012 World Radiocommunication Conference allocated the 5030-5091 MHz band internationally to the AM(R)S on a primary basis in all Regions.").

52. See DOT, Advanced Air Mobility Interagency Working Group, https://www.transportation.gov/mission/office-secretary/office-aviation-and-international-affairs/advanced-air-mobility/advanced. IWG member agencies include: DOT, Department of State, Department of Defense, Department of Justice, Department of the Interior, Department of Agriculture, Department of Commerce, Department of Labor, Department of Energy, Department of Veterans Affairs, Department of Homeland Security, NASA, Office of Management and Budget, Council of Economic Advisors, National Security Council, Office of Science

53. Outside of Enabling Communications, this can also include ongoing coordination and collaboration on receiver performance standards. In the context of aviation communications, there is a large installed base of receivers that may have different performance characteristics than commercial wireless receivers, and on an ongoing basis, continued coordination is necessary to ensure new services and equipment have sufficiently robust receiver performance to avoid the creation of interference externalities in adjacent services.

54. National Aeronautics Science & Technology Priorities, Aeronautics Interagency Working Group of the National Science and Technology Council, (March 2023), https://www.whitehouse.gov/wp-content/uploads/2023/03/032023-National-Aeronautics-ST-Priorities.pdf.

55. State and Local Regulation of Unmanned Aircraft Systems (UAS) Fact Sheet, FAA, DOT, (July 14, 2023) https://www.faa.gov/sites/faa.gov/files/State-Local-Regulation-of-Unmanned-Aircraft-Systems-Fact-Sheet.pdf.

56. State DOT's Responsibilities, U.S. Department of Transportation, https://www.transportation.gov/civil-rights/civil-rights-awareness-enforcement/state-dots-responsibilities (last updated January 5, 2016).