URBAN AIR MOBILITY USE CASE

UAM OPERATIONS OVER 5G NETWORKS

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Contents

SUMMARY

In this document, we provide an overview of the Urban Air Mobility (UAM) use case and summarize the key fifth generation (5G) cellular communication requirements to support UAM.

Description

The rapid development of novel multi-rotor vertical takeoff and landing aircraft enables a new era of air transportation, making flights within urban settings technically and economically possible. Advanced Air Mobility (AAM) is a mechanism comprising physical and digital infrastructure that supports the movement of people and cargo, by way of aerial vehicles, between local, regional, intraregional, and urban environments. AAM is under development by the private sector as well as the National Aeronautics and Space Administration (NASA) and the Federal Aviation Administration (FAA), as well as other national and international aviation agencies [1–4]. Urban Air Mobility (UAM) is a subset of AAM focusing specifically on novel air transport within urban and suburban environments. The first UAM systems are expected to be deployed in the metro areas of major cities like Los Angeles, New York, and Miami.

For fast rollout, some companies are considering using the top level of existing parking garages, a convenient location to change the modality of transportation between air and ground. In addition to their convenience installing vertiports – takeoff and landing sites for UAM aircraft – using the top of parking garages would make it possible for UAM aircraft to easily reach key downtown destinations in most major cities.

For this use case, we assume that UAM aircraft are operated between vertiports within a metro area, with flights taking place over a dense urban environment. Based on the Urban Mobility Concept of Operation [3], we assume that cruising UAM aircraft are operating in UAM corridors that are above 400 feet and with a typical cruising altitude between 1,500 and 4,000 feet above ground level (AGL). These flight corridors have designated UAM rules and requirements. Typical flight distance will be between a few miles to a few dozen miles. The typical distance will become shorter as the technology and deployment matures, as aircraft will become smaller and emit less noise dense operation in populated area will become acceptable. In corollary, the density of UAM corridors, the number of vertiports, and the frequency of UAM flights increases. Furthermore, we assume a cruising speed between 50 and 140 knots for UAM aircraft operating in UAM corridors. An overview of the UAM use case is illustrated in **Figure 1**.

Initially, the UAM aircraft will be operated by a pilot onboard. Over time, however, the pilot will be remote, operating the aircraft from a vertiport or another remote location on the ground utilizing video and telemetry data transmitted from the aircraft. Ultimately, UAM systems will reach fully automatic operation. In this use case, we assume that the pilot is remotely operating or supervising the aircraft. The UAM aircraft will need to support (i) command and control and telemetry data, as well as pilot video for the flight operation, and (ii) on-demand cabin video streams for safety and security monitoring of the internal passenger cabin of the aircraft. In addition to the baseline operational communication needs, passengers will likely expect the availability of Internet connectivity while onboard the UAM aircraft for work and entertainment. Note that no assumptions are made that all these communications are transported over the same radio link.

We assume that a single UAM aircraft will be able to transport one to nine passengers. It is expected that passengers will want to use their regular mobile phones and subscriptions while onboard and en route in the UAM aircraft. Hence, we see the need for a requirement that passengers' mobile equipment should work onboard the aircraft and support voice and Mobile Broadband (MBB) communication without affecting UAM aircraft operation. The support of passenger cellular communication is disjointed from the support of UAM communications for the scenarios described below (i.e., the UAM communication solutions are not used to enable the passenger communications).

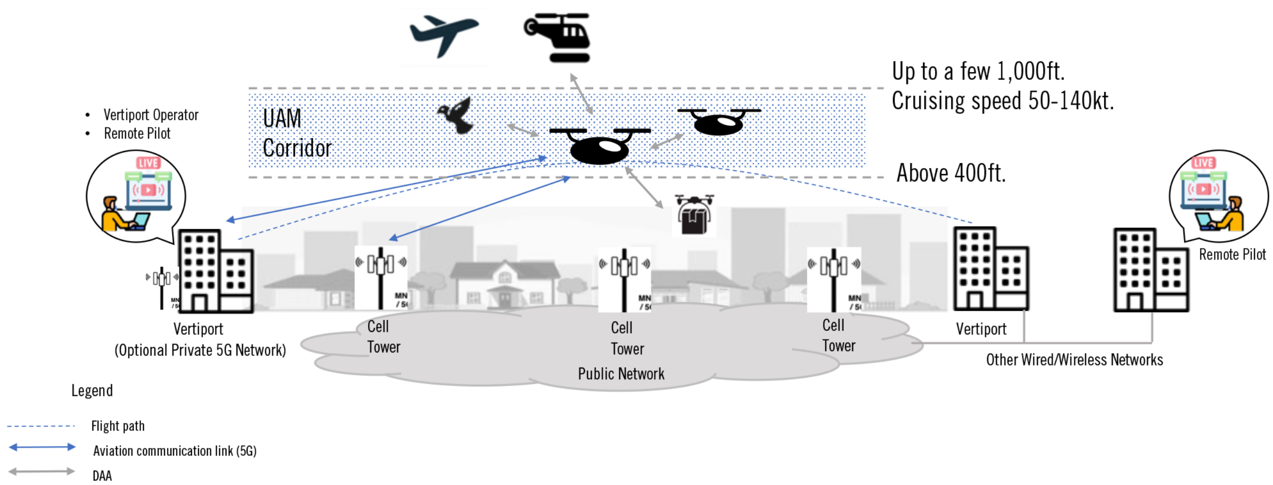

FIGURE 1. OVERVIEW OF UAM USE CASE

Stages of UAM Evolution

We will consider two stages of UAM system density that match well with the envisioned evolution of UAM services from near- to long-term deployment.

Intra-metro air transfer stage

At this stage, the UAM vertiports are located at major transportation hubs within the metro area (e.g., connecting ground transportation terminals and airports). Larger UAM aircraft are operating between the hubs carrying three to nine passengers. Typical UAM operations follow regular schedules. There is a sparse UAM corridor network over the metro area. We assume that the metro area corresponds to a typical larger city like Los Angeles or New York, and for initial deployment we can consider UAM corridors between local major metro airports and the downtown area of the city. The expected statistics of this stage are shown in **Table 1**.

Number of passengers	3–9
Number of vertiports in a metro area	10 - 50
Flight altitude	400ft–4,000ft AGL
Flight distance	10s of miles
Number of UAM aircraft	100s of UAM aircraft in a metro area
Number of UAM operations	10s of UAM aircraft flying simultaneously in a metro area

TABLE 1. EXPECTED STATISTICS OF THE INTRA-METRO AIR TRANSFER STAGE [2]

It is well-recognized that 5G since Release 15 has had its security challenges [4]. These threats are well-understood, and their mitigations—which are not covered by subsequent releases—have been proposed by the industry, by operator forums such as the Global System Mobile Association (GSMA), and by various researchers.

Ubiquitous air taxi stage

At this stage, UAM operations are widespread, with many vertiport locations scattered in the metro area. A dense UAM corridor network connects the vertiport sites. The typical UAM operations are on-demand, utilizing much smaller UAM aircraft to meet individual transportation needs, similar to typical ground ride-hailing operations today. The expected statistics of this stage are shown in **Table 2**.

Number of passengers	1–4
Number of vertiports in a metro area	100-300
Flight altitude	400ft–4,000ft AGL
Flight distance	From a few miles to 10s of miles
Number of UAM aircraft	10,000s of UAM aircraft in a metro area
Number of UAM operations	1,000s of UAM aircraft flying simultaneously in a metro area

TABLE 2. EXPECTED STATISTICS OF THE UBIQUITOUS AIR TAXI STAGE [2]

We consider two UAM aircraft automation levels to account for near- and long-term scenarios. In both scenarios, the pilot is remotely operating the aircraft. The UAM aircraft automation level determines the level of necessary involvement of the remote pilot in command (RPIC) operating the aircraft. At a low level of automation, the RPIC is always in direct control of the automation systems. This stage is referred to as human-within-the-loop (HWTL) [3]. When the full level of automation is reached, the RPIC is only informed of the operation and only passively monitors the system. The RPIC is notified only by exceptions that cannot be addressed by the system. This level is referred to as human-over-the-loop (HOVTL) [3].

Example Operation Overview

The following operation example describes communication, surveillance, navigation, and Uncrewed Aircraft System (UAS) Traffic Management (UTM) data services supporting UAM operation.

Pre-Flight Plan and Move UAM Aircraft from Gate to Vertiport Takeoff Pad at Class D Airport

- The Vertiport Operational Control Center Automation System confirms vertiport safety, resource availability, and operational status and shares that information with fleet operators and Providers of Services (PSUs) for UAM via the PSU Network. Fleet operators and PSUs acknowledge receipt of the message from the Vertiport Operational Control Center Automation System to confirm that they possess the safety, resource availability, and operational status of the vertiport prior to beginning operations.
- The remote pilot creates a flight plan, which includes the operation volume. The remote pilot receives airspace authorization from a Low Altitude Authorization and Notification Capability-like service for the operation conducted within controlled airspace.
- According to the flight plan, the UAM aircraft takes off from a departure vertiport at a Class D airport and transports passengers to an arrival vertiport.
- The flight plan includes flight 4D trajectory intent, relevant aircraft sizing, and performance characteristics.
- The remote pilot submits the flight plan to the PSU. The PSU publishes the flight plan to the PSU Network, which is a network shared by all the PSUs to exchange information. The flight volume information is successfully published to the UTM-like Discovery and Synchronization Service (DSS). The PSU strategically deconflicts traffic to avoid 4D overlap of operations. The remote pilot uses voice channel to communicate with Air Traffic Control (ATC), which issues the clearance.
- The remote pilot uploads any updates to the flight route to the UAM aircraft Flight Guidance System (FGS) via command and control (C2) link.
- The ground crew confirms via a communication link with the remote pilot that the UAM aircraft is ready for departure.

Vertical Takeoff and Departure from Vertiport

- The remote pilot contacts ATC via voice communication for departure clearance. The ATC tower issues departure clearance via voice communication. The remote pilot acknowledges the clearance. Note: For this use case scenario, the remote pilot communicates with ATC via voice relayed through the ATC Very High Frequency (VHF) radio on the UAM aircraft and exchanged over the C2 link between the UMA aircraft and the remote pilot.
- The remote pilot turns on the onboard steerable sensor sending imagery for pilot situational awareness to the Ground Control Station (GCS). The sensor sends information about terrain obstacles as well as airborne proximity traffic.

- The onboard sensor provides real-time imagery of airborne and terrain obstacles that were not previously charted (e.g., a mobile crane, wires, birds) during the flight. This imagery is relayed to a computer located at the 5G tower to compute the detected obstacles, combine the computed information with digital twin information of the terrain environment (e.g., building contours), and send the combined information to the remote pilot.

Follow Revised Departure Path to Designated UAM Corridor

While the UAM aircraft is following its departure path, ATC issues updated clearance via voice communication to change the entry point into the UAM corridor. The remote pilot acknowledges the instructions and uploads the waypoint changes via C2 link to the UAM aircraft.

While the UAM aircraft is on its revised departure path, the ground-based surveillance system detects a UAS that is a potential traffic conflict, and a Detect and Avoid (DAA) Remain Well Clear (RWC) warning alert and maneuver guidance is sent via ground-to-ground communication to the ground control stations (GCS) and displayed to the remote pilot. The remote pilot issues commands to the UAM aircraft to make a left turn to avoid conflict, and informs ATC of the maneuver. Once the conflict is resolved, ATC issues instructions to the remote pilot to return to course. The remote pilot acknowledges the instructions and uploads navigation commands to the UAM aircraft to return to course. The remote pilot monitors the UAM aircaft for conformance.

The UAM aircraft enters the UAM corridor. The UTM DSS provides a capability for the PSU to maintain a common operating picture sharing with other PSUs and UAM operators. Examples of the common operating picture information include:

- Traffic trajectory intent and state data
- National Airspace System (NAS) configuration (e.g., runway configuration, approach-in-use) dynamic hazards
- Landing facility status
- Shared resource capacity
- Weather hazard, terrain, obstruction, wind, and temperature predictions and measurements

Passenger Event

While onboard the UAM aircraft, a passenger presses an emergency call button to report a disruptive co-passenger event. A passenger cabin camera system records and streams imagery to the remote pilot. The remote pilot turns on the video call to the UAM aircraft cabin to respond and provides associated safety instructions to the passengers. The communication between the remote pilot and the UAM aircraft is carried over a 5G communication link.

Change Waypoints while En Route

During transit within the designated UAM corridor, an unplanned weather event shared on the DSS is displayed to the PSU manager. The PSU manager notifies the remote pilot of the weather hazard and recommends a route change to the remote pilot. The remote pilot acknowledges the recommendation and sends new navigation commands to the UAM aircaft for a route change. The remote pilot receives confirmation from the UAM aircraft that the change was accepted, and the remote pilot continues monitoring the UAM aircraft for conformance.

The DSS provides a capability to share the route constraint to the PSUs on the PSU Network. The PSU managers send the constraint information to the remote pilots.

Reroute and Return to Departure Vertiport

While en route, a passenger requires urgent medical care. Another passenger presses an emergency call button to report the emergency medical event. A passenger cabin camera system records and streams imagery to the remote pilot. The remote pilot turns on the video call to the UAM aircraft cabin to respond and provides associated safety instructions to the passengers. The communication between the remote pilot and the UAM aircraft is carried over a 5G C2 link.

The remote pilot submits a change in the route to ATC for a return flight to the nearest vertiport. The PSU strategically deconflicts traffic to avoid 4D overlap of operations for the return route. ATC issues an amended clearance to the remote pilot, who sends the amended route to the PSU. The remote pilot uploads the amended route to the UAM aircraft FGS via C2 link. The remote pilot receives confirmation from the UAM aircraft that the change was accepted and continues monitoring the UAM aircraft for conformance.

The PSU publishes the amended route for the return flight to the UTM DSS, and thus to other PSUs and operators on the PSU Network.

Traffic Conflict while Enroute

While enroute returning to the vertiport, another General Aviation aircraft operating under Visual Flight Rules (VFR) flies too close to the UAM aircraft flight path and there is a potential loss of well clear (see 14 CFR 91.113). The ground-based surveillance system detects intruder aircraft, and a DAA RWC warning alert message is sent via ground-to-ground communication to the GCS and displayed to the remote pilot. The remote pilot contacts ATC via voice communication relayed through the C2 link about the alert and seeks instructions. ATC provides separation guidance, and the remote pilot uploads commands to the UAM aircraft to execute the guidance. The UAM aircraft FGS automatically executes the avoidance maneuver and sends messages to the remote pilot that the DAA event is resolved. The remote pilot contacts the PSU to notify it that the UAM aircraft is clear of the conflict. The UAM aircraft returns to the previous route and previous flight plan.

Note: Aircraft-to-Infrastructure or Aircraft-to-Aircraft (A2A) direct communication can provide DAA RWC information in lieu of using a ground-based surveillance system.

The PSU publishes the traffic conflict and resolution to the UTM DSS, and thus to other PSUs and operators on the PSU Network.

Descent and Arrival Approach to Vertiport at Class D Airport

As the UAM Aircraft reaches the end of the UAM corridor, the remote pilot notifies via a data communication link to the vertiport controller and contacts ATC for authorization to enter Class C airspace. ATC issues the remote pilot a transponder code and holds instructions to deconflict the approach, then later issues the approach clearance to the Class C airspace. The remote pilot complies with the instructions. The remote pilot also contacts the vertiport manager via a communication link for assurance that the vertipad is clear of hazards.

As the UAM aircraft approaches the Class C airport, ATC issues headings and altitude instructions to sequence the aircraft for the approach. Once sequenced and deconflicted, the controller clears the UAM aircraft for approach to the vertiport. The remote pilot acknowledges via voice communications the ATC instructions and commands the UAM aircraft to comply with the instructions. Once cleared for approach, the remote pilot issues a navigation command to the UAM aircraft to execute the instrument approach procedure. The remote pilot notifies the PSU of the UAM aircraft approach clearance.

Changes to air traffic conditions near the vertiport cause ATC to notify the remote pilot to execute a missed approach procedure to the missed approach holding point. The remote pilot sends commands to the UAM aircraft to execute the missed approach procedure, observes the UAM aircraft's conformance, and awaits ATC instructions. The issue is resolved. ATC issues instructions to re-sequence for the approach. The remote pilot ensures the UAM aircraft complies with the instrument approach procedure. The remote pilot notifies the PSU of the UAM aircraft approach procedure.

Landing at Vertiport

As the UAM aircraft turns to final approach for landing, the remote pilot confirms, via a communication link, the arrival with the UAM ground crew. The remote pilot observes the UAM aircraft executing an automated landing on their display.

Changes to conditions at the vertipad cause the remote pilot to execute hover in place. The remote pilot notifies the ATC of the aborted landing and awaits ATC instructions. The issue is resolved, and ATC issues another clearance to land.

Shutdown and Post-Flight

The UAM aircraft conducts a shutdown of the propulsion system. The ground crew moves the UAM aircraft to the gate while the remote pilot continues to monitor the UAM aircraft systems. At the gate, the remote pilot notifies mission completion to the PSU. The remote pilot transfers control of the UAM aircraft to the ground crew and the paramedics offload the sick passenger to an ambulance to go the nearest hospital. The C2 link connection is terminated.

Figure 2 depicts this UAM aircraft operation example.

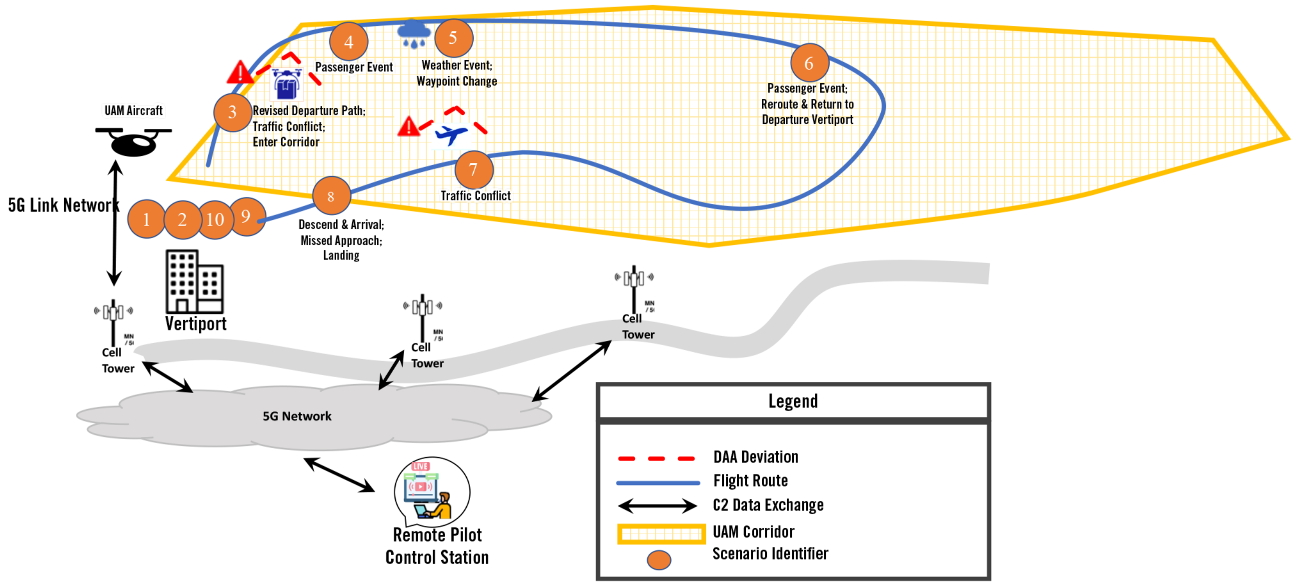

FIGURE 2. UAM AIRCRAFT OPERATION EXAMPLE

Communication Requirements

UAM requires communication technologies that can support high-density operations in urban environments and efficiently address various line-of-sight issues specific to urban environments. Furthermore, the communication solution needs to support aircraft-to-aircraft, aircraft-to-vertiport, and command and control to a remote pilot station, remote identification, and aircraft-to-UAM operator communication, as highlighted by Advanced Air Mobility [1]. For the purposes of the Open Generation 5G Consortium, we assume that only communications supported by cellular technologies (e.g., Vehicle to Everything (V2X) side link and 5G networked connections) are used.

UAM communication performance requirements specific to C2 for HWTL and HOVTL scenarios are highlighted in **Table 3** and **Table 4**.

	Sub-Category	Direction	Data Rates	Round Trip Time (RTT) (ms)	Reliability – Packet Error Rate (PER)	Priority
C2	Waypoints based (HWTL and HOVTL)	Both	35 kbps	500 [6]	1e-5	Very high
C2	Control of UAM aircraft automation systems in case of HWTL operation	Both	35 kbps	500 [6]	1e-5 and, depending on overall system design, may be up to 1e-9	Very high
C2 Video	For remote piloting	To GCS	4–9 Mbps (720p–1,080p)	500 (same as C2 link)	1e-5 and, depending on overall system design, may be up to 1e-9	Very high
Security System Data (Video/Audio) (Payload)	Safety/security monitoring of the passenger cabin	To a ground monitoring center	4–9 Mbps uplink	500	1e-5 and, depending on overall system design, may be up to 1e-9	Very high
DAA **	Aircraft-to-aircraft For more details, see subsequent section	Broadcast/ Unicast/ Groupcast	35	500	1e-6 up to 1e-7 per DO-377A (link integrity [6])	Very high

TABLE 3. UAM COMMUNICATION PERFORMANCE REQUIREMENTS FOR HUMAN-WITHIN-THE-LOOP SCENARIO [5]

Note: The 3rd Generation Partnership (3GPP) in Technical Specification (TS) 22.125 [5] provides more stringent requirements than what is collected in Table 3 based on the Radio Technical Commission of Aeronautics (RTCA) recommendations in RTCA DO-377A [6]. The 3GPP requirements can also be considered during the experimentation phases of Open Generation 5G Consortium.

	Sub-Category	Direction	Data Rates	Round Trip Time (RTT) (ms)	Reliability – Packet Error Rate (PER)	Priority
MBB Internet and Voice Calls (Payload) *	Passenger entertainment and communication	Both	Regular Internet browsing 1 to 6 Mbps per passenger (typical range, mostly downlink, but bidirectional audio and video streaming is also possible) Optionally up to 25 Mbps for 4k video streaming [7] Voice Over Internet Protocol (VoIP) calls using passenger's regular subscription and passenger devices	500	Best effort 10e-3	Best effort

TABLE 4. OPTIONAL COMMUNICATION REQUIREMENTS FOR PASSENGER ENTERTAINMENT

Note: Although in the Open Generation 5G Consortium we focus on more advanced UAM scenarios with remotely piloted and automated UAM aircraft, some of the requirements listed in **Table 3** and **Table 4** are also applicable to piloted aircraft. Requirements to support passenger communication and entertainment onboard *) are applicable to any piloted aircraft. In addition, new solutions for DAA utilizing cellular technologies **) can also be used on piloted aircraft.

Aircraft-to-Aircraft and Aircraft-to-Ground Using Cellular Communication

Aircraft to aircraft (A2A) and aircraft-to-ground (A2G) include broadcast links. The primary destination for the A2A broadcast data is another equipped aircraft. Each aircraft broadcasts its data independently of any other aircraft's transmissions. Any A2A receivers within range receive and process any data they can decode.

Another possible transmitter and receiver of data is a ground station. An A2G broadcast is a ground station. The data transmitted by the ground station is a broadcast intended to be received and processed by any receiver in the area. A ground station may have additional information, such as traffic information (e.g., Traffic Information System – Broadcast (TIS-B)) or (micro)wind alerts that aid in the safety of the operation.

A2A and A2G links primarily address information needed to support desired Air Traffic Management (ATM) operations [10, 11, 12]. The main goal of the A2A and A2G links is to support the allocation of certain ATM tasks to individual aircraft and their pilots to improve the overall safety and efficiency of operations. There is a long history in aviation of allocating certain traffic management tasks to pilots (e.g., DAA, Traffic Alert and Collision Avoidance System (TCAS), Automatic Dependent Surveillance-Broadcast (ADS-B) situation awareness). As traffic density and complexity increase due to new UAM/AAM operations and automation and digital data sharing becomes more prominent, the ability to allocate more tasks to balance workload and enable user optimization will increase. The information shared over the A2A and A2G links will be a necessary, but not complete, part of enabling that increased allocation of tasks. While there are other operational uses and benefits of sharing information for tasks or situation awareness outside of traffic management operations, these A2A and A2G links primarily focus on information needed to support desired ATM operations.

The key application of the A2A and A2G using 5G is to enable the use of A2A to support DAA and Collision Avoidance. Collision Avoidance is the timeliest and most safety-critical of the ATM operations. Examples of Collision Avoidance operations include:

- **Airborne Collision Avoidance Systems (ACAS):** These systems may work cooperatively or independently to propose maneuvers that will avoid the pending collision. RTCA is currently developing multiple standards of ACAS appropriate for different types of aircraft that are dependent on the exchange of aircraft data. The A2A and A2G links should be designed to satisfy these needs as a critical design consideration.
- **DAA:** These systems are designed as an alternative to a pilot's vision to detect and avoid other aircraft and UAS. The A2A and A2G links should be designed to satisfy the known and projected needs of the DAA functionality.

Example Use Cases of A2A and A2G Enabled by 5G

In one UAM use case scenario, an A2A- and DAA-equipped manned conventional short takeoff and landing (CSTOL) aircraft is taking off while an A2A- and DAA-equipped UAS is landing on the same runway at a non-towered Class G airport. The UA transmits A2A messages. The CSTOL aircraft receives broadcast A2A messages, and its DAA system issues a corrective alert followed by a warning alert and maneuver guidance. The CSTOL executes a left turn avoidance maneuver.

In another UAM use case scenario, an A2A-equipped UAS is eastbound (heading 90°). An A2A-, DAA-, and C2-equipped uncrewed cargo Vertical Take Off and Landing (VTOL) aircraft is traveling southwest (heading 220°) at 100 knots and level at 7,500 feet AGL. The UAS, now crossing 2,000 feet AGL, transmits A2A messages—that include surveillance information such as aircraft state data and trajectory intent—and displays the VTOL aircraft as traffic on its traffic display; however, the traffic is not indicated as a factor, as it is not yet predicted to cross into the DAA corrective hazard zone. The UAS and VTOL aircraft are now about 3 nautical miles (NM) separated, but on a converging course. The VTOL aircraft receives broadcast A2A messages, and its DAA system issues a corrective alert followed by a warning alert and maneuver guidance. The VTOL aircraft C2 link downlinks the DAA messages to the GCS. The remote pilot of the VTOL aircraft issues a right turn avoidance maneuver, which is uplinked to the VTOL aircraft. The UA and VTOL aircraft pass about 1.5 NM separated and approximately the same altitude at the closest point of approach.

Other Network Connectivity Considerations

Cellular Network Connectivity

Various cellular network deployment/configuration options can support UAM communication. Each of these has specific trade-offs. Note that from the use case perspective, there is no requirement for a specific combination. Only the traffic performance requirements listed in Table 3 need to be satisfied.

In the consortium we are considering the following scenarios of cellular network connectivity.

First, the UAM aircraft can be connected to the public terrestrial cellular network. All communication that is not specific to aircraft-to-aircraft is relayed through the public network.

Second, the density of UAM aircraft will be high in the vicinity of vertiports, requiring more communication resources. Therefore, vertiports may deploy a local private network, sidelink solutions for aircraft-to-ground communications, or additional antennas and base stations to extend the public communication network.

Third, the density of vertiports may make it possible to deploy a dedicated private communication network supporting flight operations between vertiports. This network deployment can be optimized for airborne communication.

Cabin Safety and Security Monitoring

In all scenarios, it is envisioned that the passenger cabin is monitored by a camera system that relies on the UAM communication system. This video may be locally recorded and/or streamed to a remote security system. The monitoring systems may be operated continuously or may be triggered on demand in case of an emergency. In the case of a trigger or emergency, the video stream will need to be delivered to a remote monitoring system in addition to potential local storage. Support for bidirectional communication to enable passengers and on-ground personnel to talk with each other (e.g., a video call) will be required.

Emergency Landing

The UAM aircraft should be able to make emergency landings along the UAM corridors. In emergency scenarios, where the communication system remains operational, some level of available network connectivity near and on the ground will be desired to allow for the remote monitoring and assistance of the passengers. However, the emergency landing operation itself should not be dependent on or restricted by the availability of communication.

Definitions

Availability: With respect to communication, the probability that the communications system between the two parties is in service when needed. Availability is measured as the ratio of the sum of all link interruption lengths divided by the total time [13, 14].

Constraint: One or more 4D volumes that inform PSUs, operators, and other stakeholders about specific time and geographically limited airspace information. A constraint may restrict access to airspace for some or all operations, or it may be informational.

Continuity: With respect to communication, the probability that the transaction will be completed before the Transaction Expiration Time (TET), assuming the communications system is available when the transaction is initiated [13].

Discovery and Synchronization Service (DSS): A service that enables PSUs to discover other PSUs with which data exchange is required and to ensure that PSUs use current and consistent entity data like operational intent and constraint.

Low Altitude Authorization and Notification Capability (LAANC): A collaboration between FAA and industry. It directly supports UAS integration into the airspace. LAANC provides:

- Drone pilots with access to controlled airspace at or below 400 feet
- Awareness of where pilots can and cannot fly
- Air Traffic Professionals with visibility into where and when drones will operate

Operational Intent: A volume-based representation of a UAS operation. Operational intent comprises one or more overlapping or contiguous 4D volumes, where the start time for each volume is the earliest entry time and the stop time for each volume is the latest exit time. Volumes are constructed based on the performance of the UAS and represent the airspace to which a UA must conform to a sufficient degree to achieve a target level of safety for strategic deconfliction.

Provider of Services for UAM (PSU): An entity that supports UAM operators with meeting UAM operational requirements that enable safe, efficient, and secure use of the airspace.

PSU Network: The set of PSUs operating collaboratively in a region.

Remain Well Clear (RWC): The ability to detect, analyze, and maneuver to avoid potential conflict traffic by applying adjustments to the current flight path to prevent the conflict from developing into a collision hazard.

Transaction Expiration Time (TET): The safety-related maximum time for the completion of the operational transaction supported by the link after which the initiator is required to revert to an alternative procedure [13].

UAM Corridor: A procedural route without ATC separation services. It is a performance-based airspace of defined dimensions (vertical, lateral, and time), in which aircraft abide by UAM-specific rules, procedures, and performance requirements. Corridors will have tracks that are directional and can be spaced laterally or stacked vertically depending on corridor dimensions and procedural designs. UAM corridors may transit through different FAA airspace classes; however, they are performance-based airspace structures with defined dimensions and operating rules. UAM corridors would be known to airspace users and governed by their own set of rules that prescribe access and operations. Within UAM corridors, aircraft are separated by actions taken by the remote pilot based on (i) "strategic" conflict management and separation suggestions from the PSU and (ii) "tactical" actions of the remote pilot based on information from the aircraft's navigation and DAA systems. These concepts are based on the FAA UAM ConOps 1.0 [10].

UAS Traffic Management (UTM): A federated set of services operated under regulatory oversight that support safe and compliant UAS operations.

Acronyms

3rd Generation Partnership (3GPP)

Advanced Air Mobility (AAM)

Airborne Collision Avoidance Systems (ACAS)

Aircraft-to-aircraft (A2A)

Aircraft-to-ground (A2G)

Air Traffic Control (ATC)

Command and Control (C2) link

Conventional Short Takeoff and Landing (CSTOL)

Discovery and Synchronization Service (DSS)

Federal Aviation Administration (FAA)

Fifth Generation (5G)

Flight Guidance System (FGS)

Ground Control Station (GCS)

Human-Over-The-Loop (HOVTL)

Human-Within-The-Loop (HWTL)

Low Altitude Authorization and Notification Capability (LAANC)

Mobile Broadband (MBB)

National Aeronautics and Space Administration (NASA)

National Airspace System (NAS)

Nautical Miles (NM)

Providers of Services (PSUs)

Radio Technical Commission of Aeronautics (RTCA)

Remain Well Clear (RWC)

Remote Pilot in Command (RPIC)

Technical Specification (TS)

Traffic Management (UTM)

Transaction Expiration Time (TET)

Unmanned Aircraft Systems Traffic Management (UAS UTM)

Urban Air Mobility (UAM)

Uncrewed Aircraft System (UAS)

Very High Frequency (VHF)

Vehicle to Everything (V2X)

Vertical Take Off and Landing (VTOL)

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