

Urban Air Mobility Command and Control Communications

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Cleveland, Ohio

AIAA Aviation Forum

June 15-19, 2020

Reno, Nevada

OVERVIEW

Urban Air Mobility (UAM), commonly called Air Taxis, is an application of Unmanned Aerial Vehicles (UAV). Unmanned vehicles require a communications system to provide command and control to insure safe operations. NASA Glenn Research Center (GRC) has been researching the Command and Control (C2) portion of NASA's Unmanned Aircraft Systems Integration in the National Airspace System (UAS Integration in the NAS) since 2011.

UAM is a special case of UAS. Whereas UAS operates in open airspace, UAM functions in "closed" urban environments. There will be some crossover to suburban areas and even into the NAS, but the novelty will be in flying within a city (See Figure 1).



Figure 1. Notional UAM Operations

GRC's UAS C2 research encompasses simulations and analysis, laboratory investigations, and test flights of a Control and non-Payload Communications (CNPC) radio designed specifically for UAS operations. This work is in support of the RTCA Special Committee 228 (SC-228) to develop a UAS C2 Minimum Operational Performance Standard (MOPS). The radio is a joint developmental effort between GRC and Collins Aerospace. (NASA Glenn's CNPC Lab, Test Control Room, S3 Viking Test Aircraft and RTCA work are shown in Figures 2, 3, 4 and 5.)



Figure 2. NASA GRC CNPC Lab



Figure 3. NASA GRC UAS Control Room



Figure 4. NASA GRC S3 used for CNPC Flight Tests



Figure 5. NASA GRC's Support in RTCA DO-362 Formulation

The long term UAM vision is for pilotless, fully autonomous vehicles; in other words, UAVs. However, until the autonomy technologies mature to the level of safe operations, the UAM vehicles will take an evolutionary path. The first step, or phase, is likely to be an expert pilot (meaning fully certified) on-board. As experience with UAM is gained and technology improves, a second phase with a skilled pilot (meaning certified to a lower level) could begin. Here again, as experience and technology improvements occur, a third phase, the one with a Remote Pilot in Command (RPIC) may be initiated. (Figure 6 shows the envisioned UAM phases.)

As the phases progress from expert pilot on-board to full autonomy, the communications load will increase. It may seem that communications will be obviated in the full autonomy phase but

the opposite is the case. The more that vehicles will operate on their own, the higher the need for reliable state information to be communicated throughout the system to enable safe operations.

Table 1 – UAM Operational Phase

		Manned		Unmanned	
	Pilot	Phase 1	Phase 2	Phase 3	Phase 4
	Autonomy	Expert Pilot	Skilled Pilot	Ground Pilot	No Pilot
	C2	None	Limited	Partial	Full
		None	Low	Medium	High

Figure 6. Pilot and Communications Phases for UAM Operations

UAM STUDIES

Because GRC’s mandate is unmanned vehicles, the UAM work has concentrated on the RPIC phase. A set of studies have been conducted with the development of a Concept of Operations (Con Ops) as the first step.

Additionally, UAM C2 simulations are being carried out and lab, ground, and air tests for Long Term Evolution (LTE), 4G wireless, are being examined as one possible wireless communications solution in the urban environment. This paper will describe in more detail the various UAM pieces that GRC has been working on.

The C2 UAM Con Ops (NASA/TM-2019-220159) was developed by the same team that has been working on UAS Integration in the NAS. Even though most specifics about UAM operations are unknown, experience in C2 for UAS helps the team anticipate likely UAM C2 needs.

The Con Ops considers the physical (structures, airspace, weather), radio frequency (RF) and policy/regulation challenges unique to urban operations. Policy and regulations are an overarching gap that required the Con Ops to make a number of assumptions. (Figure 7 illustrates some of the urban RF challenges.)



Figure 7. Multipath and Blockage

In an Urban Environment

Regulations may not seem to be part and parcel of a technical Con Ops but in fact are indispensable for understanding what the C2 technologies must deliver. Regulatory questions include, what sort of certification will a UAM pilot require, where in the urban area may a UAM vehicle fly and land, what RF bandwidth and communications security will be necessary, and what kinds of checking will passengers and packages be subjected to are examples of regulatory decisions that are awaited. The answers to those questions will affect the character of the communications system. (Figure 8 refers to one of the regulatory decisions awaited.)



Figure 8. Will Regulations Mandate Corridors?

Taking the above into consideration, the Con OPs includes six use cases of C2 UAM operations. Two of the use cases, Air Taxi Commuter Service and Multi-Package Delivery, are dealt with in more detail. Besides descriptions of these cases, each has an extensive table associated. (Figure 9 shows a portion of such a table.) The table lists the step-by-step events in that use case, which operation requires communications, the source and destination of that communication, the communications system elements involved (ground network or wireless) and then as appropriate, each step is associated with one or more Data Type Category. These

categories include Telecommand, Telemetry, Navigation, Surveillance, Weather, Air Traffic and a few more.

The other use cases are: Metro Air Shuttle Service, Point-to-Point Package Delivery, Life Flight Support and Surveillance Services. The envisioned use cases are not exhaustive but they do represent likely operations types. The common denominator is that they will all require a C2 communications system in order to operate safely.

Flight Operation (Air-Taxi UAM Service)	Operation Requiring Comm	Source - Dest	Comm System Element(s)	Data Type Category										
				Reference Appendix A, Comm Elements for Category Details										
				1	2	3	4	5	6	7	8	9	10	11
Note: ‘‘autoprogram’ used to indicate Autopilot-like system, flight segment, programming. Commanded by PIC to Vehicle as needed.				Commands	Telemetry DL	ATC	NavAids	Surv. Data	Surv. Data	Weather	Video DL	Air Traffic	Air	Vehicle
1) Beginning at 5:30 am, four ‘Airlift’ personal transport vehicles at the Steelyard Commons (SYC) transport VTOL site are prepped and ready for departure to 4 different downtown, VTOL site passenger drop off locations. Transports leave at staggered 10 min intervals from each of the four AirLift pads.	N/A													
2) A PIC is assigned to the 7:45 am flight	N/A													
3) Vehicle Prep A – vehicle at Departure VTOL site														

Figure 9. Portion of a Con Ops Use Case Table

Based on the Con Ops, the UAM Team extracted a number of requirements related to a wireless communications system. In turn, the requirements were translated into criteria by which to assess candidate wireless systems.

The assessment effort stopped short due to a lack of regulations and policies that are needed to perform a thorough evaluation. For example, what traffic altitude and volume will be allowed? Or, what frequency and power level may the UAM communications system use? The plan had been to perform a technology assessment, and based on results of the assessment, identify technology gaps, if any. Instead, the UAM Team itemized which requirements could not be assessed and then identified the information gaps that prevented the assessment.

UAM MODELLING & SIMULATION

Along with the UAM studies – Con Ops, Seed Requirements, Technology Assessment, Information Gaps – GRC is conducting additional UAM work to advance command and control for UAM. Communications simulations with urban models are being run. These simulations look at UAM vehicles operating at various altitudes in a designated urban corridor with C2 antennas located along the route. Power and reception are being calculated to offer a first

level numerical indication of wireless capabilities in an urban environment. (Figure 10 is an example output of the urban communications modeling and simulation.)

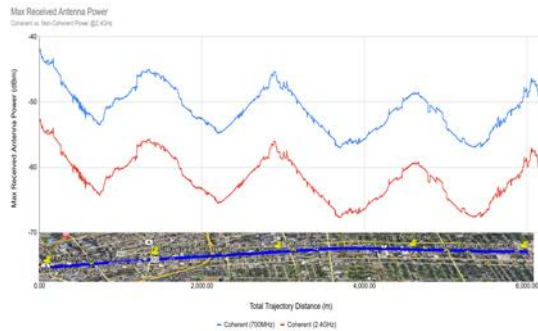


Fig. 10. Results from an Urban Communications Simulation

LTE TESTS

Similarly, the GRC UAM Team has started testing of LTE communications. The first piece consists of “ground truth” tests collected by a vehicle traversing Cleveland area freeways. The purpose of the ground tests is to measure signal availability for comparison with flight measurements. The flight tests will measure signal availability at altitude. (Figure 11 shows the lab setup for the LTE equipment. Figure 12 is a picture of the T34 that will be used for flight tests.)

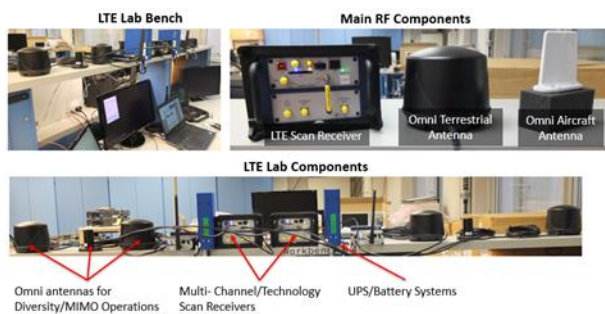


Figure 11. LTE Test Equipment



Figure 12. NASA's GRC T34 Slated for LTE Flight Tests

LTE communications is a potential method for providing C2 support so it behooves us to obtain data from which informed engineering decisions can be made. It is anticipated that the decisions will be preliminary as there are numerous questions outstanding. But this is a bona fide first step that opens up exploration of UAM C2 via LTE.

SUMMARY

The GRC UAM Team has been working on C2 communications studies and tests in order to better characterize and understand the RF and regulatory urban landscape. Through simulations and lab tests, ground and flight investigations, and studies anticipating the technical and regulatory needs, GRC is heavily involved in finding solutions for safe UAM operations.