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An Analysis of Information Requirements for Passengers of (Autonomous) Urban Air Mobility Vehicles

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Much effort has been put into examining control/monitoring strategies for semi-autonomous/autonomous urban air mobility vehicles (UAMVs). Less has been done to define information requirements for passengers to facilitate their cognitive comfort. Similarities and differences between driverless automobiles (and transport-category aircraft) and UAMVs will both affect what information is needed and what operational factors influence that need, including; perceived locus of control, shared fate, ambient visibility, familiarity with the area to be traversed, and operational status of the vehicle. Information impacted includes route/progress (location, estimated time of arrival), phase of flight, and system status as well as communications between passenger and vehicle operator/monitor. Some intermediate level of information less than that required for orientation and control will likely suffice to achieve passenger acceptance, and that the level of information required is likely negatively correlated with both the visibility in the external environment and with the perceived safety/reliability of the vehicle/system.

There are, on the near horizon (metaphorically and literally), several interesting means by which people could be conveyed from point to point. We have seen testing of driverless automobiles and use of same to capture street-level photographs for use by Google Maps. We are also now seeing efforts to take this type of approach to the airborne environment in the context of autonomous urban-air-taxi operations. As an example, an electrically powered autonomous passenger-carrying air vehicle has been fielded in China by Ehang (https://www.ehang.com/ehangaav). This vehicle is in advanced testing and has carried occupants on flights. Airbus is testing a similar vehicle in Oregon (Banse, 2019), and Boeing also has activity ongoing, but the FAA is working with as many as 30 manufacturers pursuing vehicle certification (Reichmann, 2021). This type of operation has been discussed at various meetings with emphasis being on (1) system designs to allow operation within safe bounds, (2) infrastructure needed for integration into the existing airspace (or restructure present airspace), and (3) the business case for profitable operations (NASA, 2018). There has been discussion of user acceptance (Edwards & Price, 2020; survey of 2500 potential users) but this has largely been related to safety features and ride quality that would enhance acceptability (see Edwards & Price for full list of issues). There is a separate issue that has not received much attention, and that is what one might label as the "*cognitive comfort*" of the passenger (vaguely labeled "psychological factors" by one source).

Definitions and Analysis

If we consider an operational definition of "cognitive comfort," it might be the condition of the passenger that results in minimal feelings of anxiety. Anxiety can be generated by a number of factors in this situation, which could include but not be limited to (1) perceived (not necessarily actual) safety, (2) degree of perceived control, (3) predictability of vehicle behavior, (4) familiarity with the vehicle environment, etc. For the purposes of this examination, we can restrict the consideration to information that is available to the passenger that allows them to (1) assess vehicle state (normal/abnormal), (2) determine progress towards the destination, and (3) initiate communication with the operator/monitor of the vehicle. In doing this it is assumed that the most important concern of potential passengers, safety (Edwards & Price, 2020), can and will be addressed elsewhere (both the necessary hardware and software systems to achieve a high level of safety and the necessary user education/briefing materials). It should be noted that at this point in time there is little in the regulations that can be used to specify many of the details of what is necessary (trend towards performance-based criteria, attainable in a number of nonspecific ways).

It may not be appropriate to use existing systems as sources from which to generalize passenger needs as there are some aspects of the airborne on-demand system concept that differ from other transportation systems used in the past or presently. The two most relevant ones appear to be that (1) the vehicle is airborne as opposed to being a ground vehicle, ground vehicles being the most common experience for the majority of the population, and (2) there is no onboard operator/pilot (no shared fate). However, it may be appropriate to reuse information sources from those vehicles as they will be familiar to the potential passengers, and thus *familiarity may breed cognitive comfort rather than contempt* (Johnny Carson: "These ARE the jokes…").

Shift of Locus of Control, Shared Fate, and Airborne versus Ground

A feature of autonomous systems that has been a point of issue for potential passengers has been the lack of an onboard pilot or operator (Edwards & Price, 2020, indicate that 75% of those queried had reservations about using autonomous aircraft, and 25% said they would not use such services if they became available). This has been proposed previously for transport-category aircraft, but was not widely accepted by the public. If we look at the ground-vehicle environment and the efforts towards autonomous passenger-carrying vehicles, we collectively have some illusions regarding locus of control. It has been established that drivers of automobiles are not as aware of the true risks involved in operating a car in comparison with flying in an aircraft because, in some sense, they believe that the locus of control in their automobile is internal; they control their vehicle and hence their exposure to risk. However, most do not appreciate their lack of control of the myriad other vehicles that pose hazards. In pubic ground transportation, passengers forfeit control over the vehicle (e.g., bus) to the operator but the environment is similar to that with which they are familiar and in which they believe they have control. Thus, there is the familiarity with the environment, and that may also work to the benefit of autonomous ground vehicles (may have a back-up onboard control option). The notion of a small autonomous air taxi is not something that people in general have acquaintance or familiarity with, and thus there are additional hurdles to overcome to generate cognitive comfort.

People often associate aircraft with more hazard exposure than that in ground vehicles because aircraft leave the ground and it is perceived that they can come back into contact with the ground in an unpleasant manner. Second, in piloted aircraft, the locus of control is, again, transferred to the pilot(s) and is not with the passengers. We all have that experience when we ride in a car with someone else, and the degree of our discomfort is frequently correlated with how closely we are related to the driver (positive correlation?). The difference between this situation and an aircraft is that most people have experience driving a car and thus may compare the driver's actions with what they would have done as the driver. This is not the same in an aircraft as most of the passengers are not pilots, cannot (except when a passenger in a small General Aviation aircraft) see displays showing aircraft performance indices (one can usually see the speedometer in a car even when not driving), and cannot thus make direct comparisons of personal expectations with pilot performance. However, there is the perception that there is an operator on the aircraft who is experiencing the same things as are the passengers, is in the same "boat" so to speak, and also has a vested interest, at the most basic level (survival), in getting the aircraft back on the ground safely (shared fate). In contrast, there is no such pilot/operator onboard an autonomous or remotely-operated aircraft who has a shared fate with the passengers, and thus the remote operator/monitor could be perceived as largely dissociated from the passenger.

Passenger information needs

In discussing this new environment with a number of potential users, and with UAV researchers Kevin Williams and Anthony Tvaryanas at the Civil Aerospace Medical Institute, it was apparent that desired information included (1) indications that the aircraft was continuing to operate safely and within expected parameters, (2) indications that the flight was making progress towards the destination (location, destination, estimated time of arrival; these are not regularly scheduled flights as are scheduled carriers), and (3) indications of deviations from the intended route/destination or schedule. Associated with (1) and (3) was a desire for a means of communicating with the operator/monitor of the flight (to both deliver and receive information). These categories of information were identified as those that would make the potential users feel more comfortable with the vehicle and the flight (again, assuming that all safety issues have been satisfied). Entertainment was not a top issue, particularly as flight durations appear limited by stated ranges of vehicles (power limited: see Table 1). To set a context, three of the four eVTOL (electric Vertical Take Off and Landing) vehicles listed by Bellamy (2021) that had no pilot onboard were limited to 20 minutes or less of operation as a function of stated range and cruise speed.

Table 1. Range and speed, maximum duration of flight based upon range and speed, and number of passengers for 4 eVTOL aircraft without pilots onboard (summarized from Bellamy, 2021).

Name	Company	Range (miles)	Cruise speed (mph)	Calculated max duration, (hrs:mins) @ cruise*	Passengers
The Cora	Wisk	25	100	0:15	2
City Airbus	Airbus	80	75	1:00	4
EH216	Ehang	21	83	0:15	2
Volocity	Volocopter	22	68	0:19	2

*Actual flight durations should be shorter due to power requirements to climb and reach cruise speed

Further examination of the variables that are likely to affect the passenger's need for information can begin with the simplest case where much of the information is received by direct viewing of the contact environment (out-the-window view). We can then look at best and worst possible cases of the environment, and the one case of *transmitting* information from the passenger to the operator/monitor. These should shape the approach to how much and what kind of information needs to be given to the passenger.

1) Communications with operator/monitor (labeled "connectivity with the ground" by Edwards & Price, 2020). Need for this information/function may be influenced by -
    a. Knowledge of how many vehicles the "monitor" is tracking
        i. If the passenger knows it is 1 operator/many vehicles, the passenger may want a dedicated system onboard that is guaranteed, by minimal passenger action, to reach the operator/monitor (may be influenced by experience of having problems contacting someone on 911 in a large metroplex area).
        ii. If the passenger knows it is 1 operator/one vehicle, they may accept a cellphone option or similar means of communication.
    b. Desire to actually "see" an operator and converse in real time (can interface with aft-cabin crew in scheduled-carrier operations)
2) Geographic Orientation (Where am I? Am I making progress towards my destination? When will I arrive?) Need for this information is likely influenced by -
    a. Level of landmark detail that can be seen out the window (NOTE: presently there appears to be a belief amongst the potential operators that these vehicles are not likely to use airspace at altitudes greater than 3,000 feet AGL regularly; as such, terrain and cultural features would be visible as long as there were no impediments to visual acquisition)
        i. Geographic operating environment
            1. Need lower in areas with prominent cultural or geographic features
            2. Need higher in areas without prominent terrain or with few cultural features
        ii. Meteorological operating environment
            1. Need lower when visibility is high (daytime, no atmospheric obscuration)
            2. Need higher when visibility is low (nighttime, precipitation, cloud cover, haze, fog)
    b. Familiarity of passenger with flight area (terrain, cultural features)
        i. Need lower in areas with which passenger is familiar
        ii. Need higher in areas with which passenger is unfamiliar
3) Visibility of vehicle to other vehicles/operators (this is really connected with "safety" to a large degree)
    a. Can other operators of similar aircraft and of piloted aircraft see/detect this one?
        i. Visual-detection-enhancement devices on aircraft (lights; presence, strobes, beacons)
        ii. Electronic presence (tracking) indicators (ADS-B, radar, etc.)
4) Operational status of the vehicle
    a. Knowledge of the current state of the vehicle by category
        i. Operating within expected parameters
        ii. Operating safely but with limitations on performance/duration.
        iii. Deviating to "safe" landing site to avoid exceeding operational limits (or partial failure)

From these we can construct a “worst-possible-case” situation. Table 2 presents the worst-possible factor levels with the required information required under those conditions and possible means of information presentation. The design approaches one could follow would be (a) tailor the interface to automatically provide the minimum information required under the established conditions or (b) provide information at all times that supports worst-possible-case conditions. Selection of means/formats should likely lean towards formats that would be most familiar to the user/passenger and thus more likely to support cognitive comfort as a function of their familiarity and little need for learning how to interpret the presentation.

Table 2. Environmental/flight condition, required information, and possible means of presentation.

Condition	Information/function required	Possible means of presentation*
Many-to-one vehicle-to-monitor configuration	Direct link with flight monitor	Call button, in-vehicle two-way audio-video; cell-phone-based video (e.g. FaceTime)
Minimal topographic and cultural features in area	Vehicle location and reference points	Plan-view electronic map; voice messaging with progress/location data+
Low visibility (night or meteorological obscuration)	View of outside world	Forward-looking synthetic vision (dash-mounted display or head-worn appliance); sensor-based forward view; plan-view electronic map; voice messaging with progress/location information
Geographical area unfamiliar to passenger	Vehicle location and reference points	Plan-view electronic map; voice messaging delivering progress/location information
Vehicle entering “recovery” mode, nearest landing site	Status of vehicle and relative locations of vehicle and landing site	Plan-view electronic map; voice messaging delivering progress/location information; status indicator showing phase/mode of flight

*Listing most likely and user-familiar means; list is not all-inclusive or exhaustive
+ Consistent with current PA announcements by crew in scheduled carriers

Information display/communication link

It is also of interest to providers to determine how best to bring this information into the vehicle. Ehang advertises that they are using 4G-5G networks to provide communication with and control of their vehicles. This suggests that an in-vehicle display would make sense for providing information regarding status and progress as well as audio-video communication with the flight monitor, and Ehang’s document (Xu, 2020) depicts an in-vehicle display (Figure 1). The display appears to have attitude and airspeed indications in the upper left quadrant, some kind of vehicle status information in the upper-right quadrant, other undecipherable (at this resolution) vehicle related information and temperature (C) in the lower left quadrant, and an apparently forward-looking-camera image in the lower-left quadrant (does not appear to be synthet-

Figure 1. Example in-vehicle display (from Xu, 2020)

ic vision). Lacking a detailed explanation in the source document as to intent/use of this format, it is difficult to conclude much about this set of displays. However, it does illustrate that there is sufficient graphical-display real estate to present information of passenger interest. Unfortunately, there is little information available at this time for any of the proposed vehicles regarding interior displays or communication systems for passengers. It is also possible that a Bluetooth or USB connection could be provided by which a passenger could connect their personal electronic device, use an app provided by the service provider, and have these same data/functions provided on their cell phone or tablet. The disadvantage of the latter is that the passenger loses this information if the device battery goes down unless power can be drawn from the aircraft (USB; communications AND device charging at the same time). Ehang is proposing an app for scheduling rides (the Uber model), but Ehang shows the in-vehicle display.

Conclusion & Prospectus

This effort was originally intended to be an analysis/survey/simulator experiment study, but the latter phases were temporarily delayed by Covid 19 and by retirement, both of which occasioned a reduction in resources and loss of simulator-study participants. As such, we have to be temporarily satisfied with suggesting what information may be useful to and needed by passengers of autonomous airborne vehicles. The survey portion, to validate the analysis/identification of factors, is in progress now. However, it may remain for a later time, hopefully soon, to conduct the simulation experiment with appropriate displays and manipulation of levels/formats of information display and environmental conditions to determine if potential users' stated preferences align with their actual responses in a quasi-realistic environment (the oft-observed dissociation between preference and performance). The limitation of the approach is, of course, that the vehicle will be "simulated," and that the passenger will not actually be potentially exposed to any real hazard, and thus the potential difficulty of observing any true variation in perceived anxiety. Hopefully validation of the analysis will produce reasonable recommendations for creating a harmonious environment for future passengers in these systems.

References

Banse, T. (2019). In the Skies Of Eastern Oregon, An Autonomous Robo Taxi Takes Flight. Retrieved from https://www.opb.org/news/article/pacific-northwest-oregon-drone-air-taxi-airbus-test-flights/.

Bellamy, W., III (2021). 10 eVTOL Development Programs to Watch in 2021. Aviation Today, Febr4uary-March 2021. Retrieved from: file:///Volumes/NO%20NAME/ISAP_2021/First%20FAA%20Type%20Certification%20for%20Advanced%20Air%20Mobility%20Aircraft%20Could%20Come%20This%20Year%20-%20Aviation%20Today.htm.

Edwards, T. and Price, G. (2020). eVTOL Passenger Acceptance. Alexandria, VA: National Technical Information Service, NASA/CR—2020–220460. (also available at http://ntrs.nasa.gov)

NASA (2018). Urban air mobility market study. Retrieved from https://www.nasa.gov/sites/default/files/atoms/files/uam-market-study-executive-summary-v2.pdf

Reichman, K. (2021). First FAA type certification for Advanced Air Mobility Aircraft could come this year. Aviation Today, January 26, 2021. Retrieved from: file:///Volumes/NO%20NAME/ISAP_2021/First%20FAA%20Type%20Certification%20for%20Advanced%20Air%20Mobility%20Aircraft%20Could%20Come%20This%20Year%20-%20Aviation%20Today.htm.

Xu, E. (H.) (2020). The Future of Transportation: White Paper on Urban Air Mobility Systems. Ehang. Retrieved from https://www.ehang.com/ehangaav.