# Revising the Airspace Model for the Safe Integration of Small Unmanned Aircraft Systems

*This paper describes Amazon's position on the design, management and operations of the airspace for the safe and efficient integration of low-altitude small unmanned aircraft systems. Amazon anticipates this model will be refined over time, and will work in close collaboration with public and private industry on the development of an approach that is safe and efficient for all types of operations.*

## Airspace Design

The development of an air traffic system that fully enables the safe operations of small unmanned aircraft systems (sUAS) in civil airspace, particularly highly-automated vehicles operating beyond line of sight (\LOS), is essential for realizing the enormous benefits of this technology in a safe and responsible manner. A good place to start in creating such a system is to clarify the use of the airspace.

The majority of airspace integration efforts over the past decade have focused on integrating medium or large unmanned aircraft systems into non-segregated civil airspace, i.e. airspace above 500 feet where most civil and military aviation activities occur. However, given the rapidly growing small unmanned aircraft industry, Amazon believes the safest and most efficient environment for sUAS operations—from basic recreational users to sophisticated BLOS fleets—is in *segregated* civil airspace[1] below 500 feet. Segregating the airspace will buffer sUAS operations from current aviation operations. It will also buffer lesser-equipped vehicles from highly-equipped vehicles able to safely perform BLOS missions.

In this proposed model:

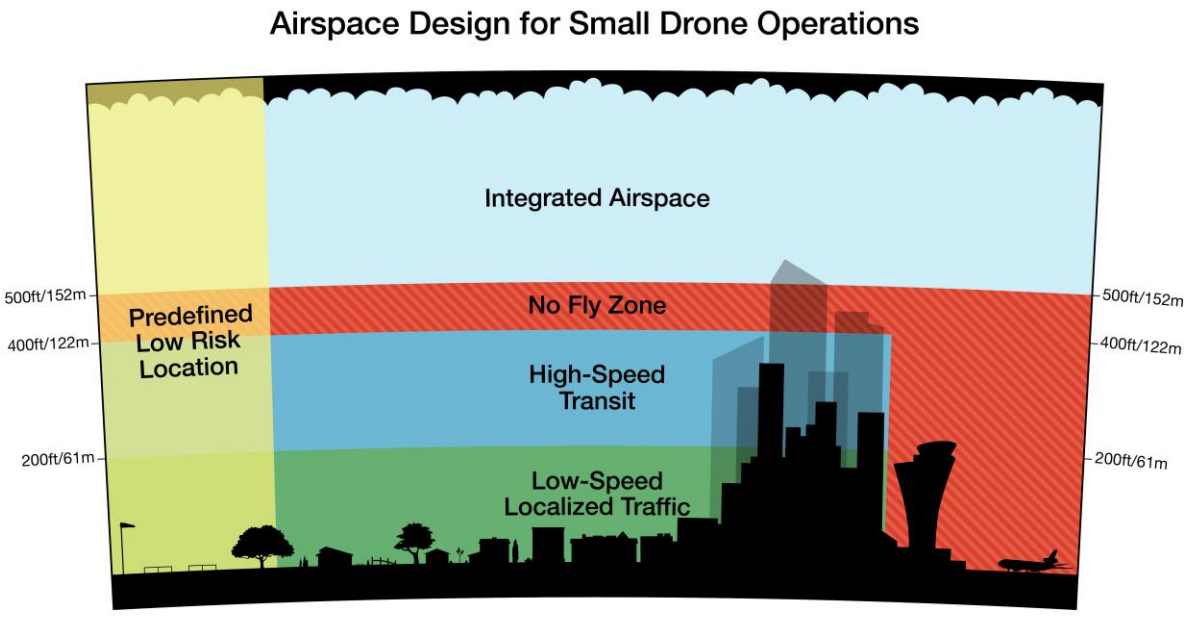
- Airspace below 200 feet, or the 'Low-Speed Localized Traffic' area, will be reserved for (1) terminal non-transit operations such as surveying, videography and inspection, and (2) operations for lesser-equipped vehicles, e.g. ones without sophisticated sense-and-avoid (SAA) technology. Those lesser-equipped vehicles will not have access to certain airspace in this zone, such as over heavily-populated areas.

[1] Segregated airspace is defined as airspace which is restricted to the exclusive use of specific users.

- A 'High-Speed Transit' space, between 200 and 400 feet, will be designated for well-equipped vehicles as determined by the relevant performance standards and rules.
- The airspace between 400 and 500 feet will serve as a permanent 'No Fly Zone' in which sUAS operators will not be permitted to fly, except in emergencies.
- Finally, this airspace model will also encompass 'Predefined Low Risk Locations.' Altitude and equipage restrictions in these locations will be established in advance by aviation authorities. These Predefined Low Risk Locations will include areas like designated Academy of Model Aeronautics airfields, where members will meet pre-established parameters for altitude and equipage.

Amazon believes this segregated airspace model will enable safer overall operations by providing a framework where airspace access is tied to vehicle capability, and by buffering sUAS operations from current aviation operations.

Below is a visual representation of this proposed airspace design model.




## Airspace Management & Operations

Revising the way airspace is managed is also a key factor in the development of a system that will meet future sUAS demands. Today, most of the world's airspace systems and related

training are designed for a single pilot or flight crew per-vehicle concept. More so, in the United States and Europe, air traffic controller workload is the single-greatest functional limitation on airspace capacity [2] [3] [4]. Workload is largely driven by airspace complexity, and controller workload increases linearly as the ratio of UAS to manned aircraft increases[5]. In the United States, for example, there are approximately 85,000 commercial, cargo, military, and general aviation flights every day. This number is likely to be dwarfed by low-altitude sUAS operations in the next 10 years.

As a result of these factors, Amazon believes the current model of airspace management will not meet future sUAS demands, particularly highly-automated, low-altitude commercial operations. A paradigm shift in airspace management and operations is necessary to safely accommodate the one-operator-to-many-vehicle model required by large-scale commercial fleets.

While more research is needed to identify exactly how an air navigation service provider (ANSP) will evolve to support high-volume sUAS operations, it is Amazon's position that the projected industry growth also requires the delegation of responsibility for many traditional air navigation services, such as navigation and air traffic control and communication. There should be a controlling entity that serves a central, offline coordination and auditing function, however, many of these services will be handled in a more distributed and federated fashion where multiple operators cover overlapping areas, each managing their own fleet. Those operators would coordinate by following established protocols, using vehicle-to-vehicle, vehicle-to-service and service-to-service data communication and automation, to safely and efficiently manage the shared airspace.

Highly-equipped sUAS will be capable of navigation, merging and sequencing, communication, maintaining safe self-separation, collision avoidance and deconfliction in congested airspace without operator assistance. Again, while many of the traditional ANSP responsibilities may be delegated, the underlying authority will still reside with the ANSP and/or the civil aviation authority. To help move this model forward, Amazon is collaborating with civil aviation authorities like the Federal Aviation Administration, as well as NASA and others, on research related to delegation and federation.

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[2] Lishuai, L., Hansman, R.J. (2009), Experimental Studies of Cognitively Based Air Traffic Control Complexity Metrics For Future Operational Concepts, MIT International Center for Air Transportation, Cambridge, MA.
[3] Hilburn, B. (2004), Cognitive Complexity in Air Traffic Control: A Literature Review, Eurocontrol Experimental Centre, Brussels, Belgium.
[4] Majumdar, A., Polak, J. (2001), Estimating Capacity of Europe's Airspace Using a Simulation Model of Air Traffic Controller Workload, Transportation Research Record: Journal of the Transportation Research Board, 1744:30-43.
[5] Helleberg, J., Maroney, D. (2010), UAS Operations in the National Airspace System: Human-in-the-Loop Simulation and Experimentation, The MITRE Corporation, Mclean, VA.

Additionally, it is Amazon's view that air traffic management operations should follow a 'managed by exception' approach. This means operators are always aware of what the fleet is doing, yet they only intervene in significant off-nominal cases, e.g. emergencies and national security directives. Automation on the vehicles, e.g. vehicle-to-vehicle communications and SAA, and automation on the control structure, e.g. routing, separation management and optimization, will handle nominal and minor off-nominal cases. This approach will entail a distributed network comprised of local/regional air operations centers and remote vehicle operators. This new system is essential given the highly-automated nature of future sUAS, and it will result in a decrease in operator workload and an increase in both safety and capacity.

## A Path Forward

Modifying the way airspace is used will require close collaboration with multiple stakeholders—aviation authorities, academia, the commercial and recreational sUAS industry, as well as the manned aviation industry. It will also require investment in advanced technologies, like the types of automation discussed above. Amazon believes NASA already has a solid understanding of these technologies through decades of experience in airspace automation, as well as a firm grasp on how they will be used for sUAS through its Unmanned Aerial System Traffic Management, or UTM, program. Amazon applauds NASA's efforts as the technological investment will result in a safer and more efficient use of the airspace, enabling innovation across a wide range of missions and scenarios. To help realize this new airspace model and bring the industry forward, Amazon will actively cooperate with other sUAS stakeholders—large and small, commercial and recreational—in developing equipage and performance standards for sUAS.

In summary, Amazon believes the safest and most efficient model for sUAS with mixed equipage and capabilities is in segregated airspace with a defined structure for operations below 500 feet, alongside federated, highly-automated, highly-available and secure air navigation services. The public and private sUAS industry should work together to realize this new concept of airspace operations if we are to bring the remarkable innovations of sUAS to bear in a safe and responsible way.