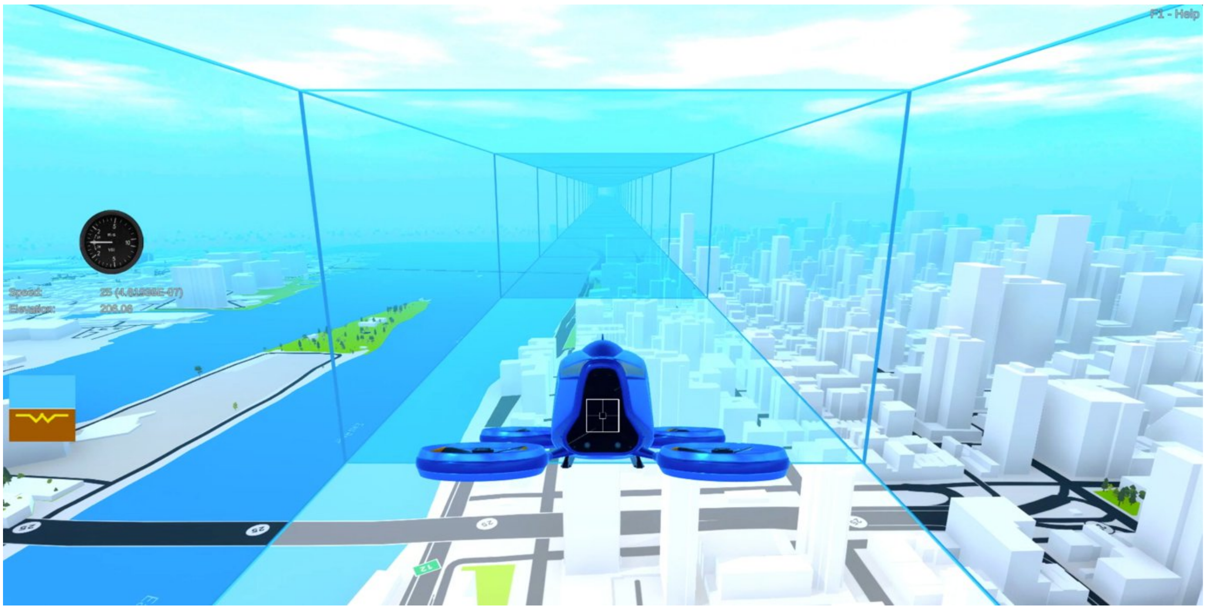
Air Traffic Control
for Urban Air Mobility



White Paper

D3 Technologies

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Abstract

Design and industrial development effort for work drones providing services such as deliveries, surveying, environmental protection etc. is rapidly growing. Larger drones (electric Vertical Take-Off and Landing, eVTOLs) for passenger transport are only a few years away.
With increasing numbers of flight movements, the emerging use of passenger drones will eventually create the need for enhanced air traffic control (ATC) services. Based on elaborate research studies by aircraft manufacturers and consultancy firms, ***D3 sees the inflection point when demand will become highly visible in the timeframe 2026-2028**,* with 1000s of daily eVTOL movements over major metropolitan areas.

Traditional air traffic control service providers act as public administrations and they follow mandatory regulations (usually embedded in legal code). As such, they will most likely not be able to provide cost-effective service and they are too slow to adapt to managing new eVTOL categories, in high density traffic, and at very low altitudes. As a matter of fact, the large Western regulators (FAA and EASA) have already stated that urban air traffic control will not be developed and/or operated by governmental bodies and that they expect to see a new competitive field for urban air traffic management.

The limiting factors of airspace capacity today are air traffic controllers' workload and the cognitive capabilities of pilots on the one hand and the ability to ensure vehicle trajectories to very close tolerances on the other. To make urban air mobility at scale a reality, **a paradigm shift for air traffic management is needed**.

While first concepts and ideas for a future automated air traffic management exist, they are generic in nature and not linked to any technology development.

Systems built for managing non-passenger-carrying **UTM cannot be "upgraded" to reach the safety level required for regulatory certification**.

The D3 Air Vehicle Control System (AVCS) will be a central part of a city's future urban air mobility ecosystem and it will offer access to all stakeholders. D3 is approaching its design task systematically. We are engaged with the regulatory community to monitor and influence the rulemaking process.

Introduction

Design and industrial development effort for work drones providing services such as deliveries, surveying, environmental protection etc. is rapidly growing. Various studies by consultancy firms indicate that larger drones (eVTOLs) for passenger transport are only a few years away ([1], [2], [3]).

With increasing numbers of flight movements, the emerging use of passenger drones will eventually create the need for enhanced ATC services. Based on elaborate research studies done by aircraft manufacturers ([4], [5], [6]) or mobility service operators [7], **D3 *sees the inflection point when demand will become highly visible in the timeframe 2026-2028*,** with 1000s of daily eVTOL movements over major metropolitan areas. Traditional air traffic control service providers act as public administrations and they follow mandatory regulations. As such, they are not prepared to handle a rapid increase in demand for air traffic services, with new aircraft categories, in high density traffic, and at very low altitudes.

First visible “pilot use cases” are likely to appear as soon as 2024. These will be experimental in nature (not certified, however based on certifiable technology) and will be aimed at proving the utility of the urban air transport concept. These could be point-to-point connections in protected air corridors. With regard to pilot cases, companies like Ehang are already today pursuing the options of transporting harbor-pilots to ships in large ports or using drones instead of helicopters as crew-exchange vehicles for drilling platforms.

In order to manage a significant number of vehicles in constricted airspace, a unified method of commanding these vehicles will be required. This is all the more true when assuming that airspace above cities will not be “up for grabs” but will be heavily segregated into flyable and non-flyable zones, which will further increase traffic density and the requirement for control.

Furthermore, it is unclear in which airspace future drone traffic will operate. A lot of regulatory and early commercial activity is invested into various UAS (Unmanned Aerial System) Traffic Management (UTM) concepts. There is a proverbial elephant in the room, a looming unaddressed conflict: the operational requirements of manned and unmanned drones differ substantially. Presently, there seems to be a tacit assumption that the various services proposed for UTM will mature and can be integrated to form a sufficient and complete set of services with corresponding reliability levels that will fulfill the requirements for passenger-carrying flight. ***D3 challenges this assumption*.**

An initial set of regulatory requirements ([8], [9], [10]) and concepts ([11], [12]) for smaller work drones is already available, and further requirements for eVTOLs are under development in the US [13], the EU [14], and for China’s Civil UAS Operation Management System (UOMS). However, the question of how to integrate all types of drones into unsegregated airspace (= airspace not set aside for work drones only) and how to achieve scalability for higher traffic densities remain unsolved.

In the US, the FAA and NASA have recently rebranded the “NASA Grand Challenge” for Urban Air Mobility (UAM) into the “Advanced Air Mobility National Campaign”.

Also, the terms “Urban Air Mobility” is replaced by “Advanced Air Mobility”. We will use both terms interchangeably.

There are considerations to segregate “work drones” from “passenger drones” by airspace, or to create air corridors for passenger drones. ***D3 believes this may be a solution in an interim period while traffic volumes are still low.*** These ideas aim for a separation of types of operation, safety requirements and operating cost through geometrically defined areas. However, competition for airspace and its efficient use will call for an eventual integration. This integration will place an additional financial burden (due to higher safety requirements) on the work drone operators’ current business models, and ***D3 predicts that there will be considerable resistance*.**

D3’s collective experience indicates that a “master-system” will be required, which will reliably integrate diverse services into a coherent whole in order to achieve overall system reliability. Moreover, layered safety mechanisms are required to ensure uniform behavior of air vehicles across the entire system in the event of failures of specific system components in order to contain failure propagation. Systems that conform to this type of requirement are frequently called “safety critical” (systems).

The competition for opening urban airspace to passenger-carrying local transport, delivery drones etc. will be decided by the added value for the general public. ***We believe that passenger-carrying local transport will get a huge piece of the cake*** since it will be considered the higher-value service.
Initially, limitations will not be “scarcity of airspace” but available space for take-offs and landings in densely populated urban environments. These areas will be mandatory for safe and reliable urban air traffic.

Our interaction with members of the ecosystem, conversations with city planners and city officials at numerous industry events, as well as additional own research have clearly shown that cities will be reluctant to set aside resources (e.g. energy supply, civil engineering, planning) if they cannot assume that there will be a tangible public benefit. Cities are aware that nascent technology will take time to mature and to show benefits. While it remains challenging to argue that individual air transport will beat established mass transport (by volume), several of the large actors in the field (e.g. Uber), make good cases showing that decentralized point-to-point options have the potential of efficiently relieving transport hotspots.

D3 suggests that a viable solution for managing air traffic will have to be designed to ***enable cities to have a say in how their airspace is being used***. This way cities can make sure that benefits will be distributed in an acceptable form. Giving cities a say in airspace usage will go a long way toward overcoming a reluctance in adopting this promising opportunity. It will help create an atmosphere of empowerment rather than being “sold out”, and it will support the introduction of this new transportation mode [15].

Barriers to Urban Air Mobility

Apart from other barriers to UAM such as public acceptance or the availability of ground infrastructure, D3 sees the regulatory framework, airspace structure, and a suitable safety architecture as relevant for its solution.

The limiting factors of airspace capacity today are air traffic controllers' workload and the cognitive capabilities of pilots on the one hand, and the ability to ensure vehicle trajectories to very close tolerances on the other. To make urban air mobility at scale a reality, ***a paradigm shift for air traffic management is needed: only a highly automated air traffic management system will be able to scale*** and to meet traffic demand. The currently proposed "first-come-first-served"-approach limits capacity and therefore public value drastically.

New regulatory requirements, technical standards and the corresponding Acceptable Means of Compliance for UAM are still being defined. Regulators in both the US and in the EU appear to be reluctant to change existing airspace structures or to define flight rules in addition to the existing rules for operating air vehicles by visual reference (VFR) on the one hand and by instrument reference (IFR) on the other hand.

Regulators understandably aim to minimize:

- additional workload on air traffic controllers
- additional system infrastructure for air traffic management
- burdens on existing airspace users beyond equitable access to airspace

The safety assurance levels for systems for passenger-carrying air vehicles differ from the current approach especially for smaller unmanned air vehicles (work drones).
The most burdensome solution requirements are those that will enable the certification by safety regulators (required for any system that puts human life at risk). This system needs to show an extremely high safety level (on par with today's aviation) and resilience to disruption.

For small work drones, a Sense-and-Avoid (SAA) system is foreseen as a primary safety layer. This vehicle-centric approach works only as long as there are few participants in the systems. In a higher density environment, contingency maneuvers triggered by an on-board SAA will lead to unacceptable secondary effects and traffic disruptions.

Current industry proposals

As more and more eVTOL manufacturers demonstrate first prototype models, the need for air traffic control concepts to manage this new type of air vehicles becomes more evident.
Among the aircraft manufacturers currently developing eVTOLs, only Airbus [4], Ehang [5] and Embraer [6] have published initial ideas for the integration of UAM traffic into city infrastructures and national airspace systems.

The Airbus Blueprint study mainly provides a high-level vision. It lists different scenarios for airspace and routing concepts, and it suggests the development of a new set of flight rules for UAM traffic, but it does not solve the question how to achieve an automated high-capacity ATC solution for UAM.

The Ehang White Paper proposes a single centralized remote command-and-control system for each city, with eVTOLs travelling along fixed routes in a hub-and-spoke network. This concept would not allow for competition or a federated network of service providers operating in the same city. 4G and, at a later stage, 5G networks are proposed for voice and data communication. The paper suggests a joint industry-government initiative to work out a concept of operations and to agree on technical requirements.

The EmbraerX “Flight Plan 2030” study points to the gaps between UAS traffic management (UTM) and UAM, recognizing that eVTOLs will need separate considerations from those given to small UAS. The study proposes federated systems tailored to the needs of the urban areas they serve. EmbraerX proposes an urban airspace service provider — exclusively in charge of all urban ATM, working with air navigation service providers and UAS service suppliers. The report highlights the importance of collaboration, bringing in stakeholders and community members — who have concerns such as noise — and other airspace users.

None of the major air traffic control systems manufacturers has announced plans for new types of systems yet.

Of the future eVTOL fleet operators, Uber Elevate has published a White Paper on UAM [7] where they say that they will work with partners to build air traffic management systems.

UTM system manufacturers focus only on current business models and on UAS. In our opinion, these concepts will not scale. E.g. the “strategic de-confliction” service envisaged by UAS Service Suppliers in the US is based on a concept where an entire airspace volume is reserved for one flight operation for a given period of time. This concept will allow to keep UAS traffic segregated from other traffic, but it is only suited for very low traffic densities.

Among the large regulators and standardization bodies, in 2019 EUROCAE has created Working Group 112 to begin work on technical standards and a concept of operations for eVTOLs. First work results will appear in the coming years (note that D3 is a full member of EUROCAE).

In the US, the FAA has recently published a first version of a Concept of Operations for UAM [13]. This concept proposes UAM “corridors” to separate UAM traffic from other types of air traffic across different types of airspace categories.
First reactions from industry indicate that this first version falls short of a viable solution for the predicted levels of UAM traffic. The corridor concept seems to be merely a workaround to minimize impact on current ATC operations.

What we believe

We believe that a future urban air traffic environment at scale needs to:

- **Be highly automated:** No human operator monitoring every single air vehicle (increased safety and capacity, lower cost)
- **Allow for regional competition:** no single service provider for an entire country, but connected and interoperable service providers (note that this is also promoted by policy makers and regulatory bodies)
- **Integrate small work drones and passenger-carrying drones in the same low-altitude airspace**: this point is not fully addressed by regulatory authorities at this point.

The challenge is to manage and monitor UAS and passenger drones with diverse performance characteristics safely and together with other airspace users (e.g., helicopters, non-scheduled aircraft, gliders) in a future joint airspace.

We believe that deterministic planning of flight routes (vs. so-called “autonomy in which vehicles decide on routings independently*) **is an indispensable component for a secure and scalable urban air traffic management system.***

The current ATC system architecture (in any country) does not support high-density, low-altitude operations in a UAM environment:

- it is not scalable to meet the predicted rapidly increasing demand
- voice communication methods in use today are not suited for UAM traffic density
- surveillance and navigation infrastructure are not suited for the emerging types of air traffic and they need to be significantly enhanced
- pilots and air vehicles may have widely varying performance capabilities and cannot be managed by today’s systems
- predicted UAM traffic volumes and density will exceed pilots’ see-and-avoid capacity, and it needs to be complemented by a certified electronic sense-and-avoid system.

Traditional air traffic management systems, including communication, navigation, and surveillance systems, are built for managing 100s or 1000s of nautical miles air travel. UAM traffic travels 10s(??) up to about 100 nautical miles per flight. The D3 system design tenets take into account the following beliefs:

- **Only deterministic systems can be certified.** Certification for an urban air traffic management system is mandatory, as the same rules and safety requirements as for current air traffic control systems will apply.
- **Layered safety mechanisms will be required.** In order to achieve overall safety levels, air vehicles will have to be equipped with the ability to perform harmonized escape or recovery maneuvers in the event of primary system failures or outages. Such a secondary system essentially replaces the highly intelligent but volume-limited tactical deconfliction, following the “rules of the air”. Current deconfliction procedures enable pilots and controllers to maintain minimum aircraft separation and to “remain well clear” of obstacles.

- **Systems built for managing non-passenger-carrying UTM cannot be "upgraded" to reach the safety level required for regulatory certification.** System-wide failure rates of 10^{-9}/hour per person using an air vehicle need to be achieved. Regulatory requirements for certification of ATC systems ([16], [17], [18], [19]) and airborne systems ([20], [21], [22], [23]) need to be integrated in the development lifecycle from the beginning. The retroactive addition of processes, phases and products that were not carried out as part of the development, the "certify later" approach, is not feasible and/or prohibitively expensive.
- The lower the Design Assurance Level (DAL, ranging from A, highest level, to E, lowest level), the lower the development cost and effort. Therefore, D3 aims to opt for the lowest DAL possible. The DAL for the D3 system is being determined during the product development as part of the system architecture and system specification phases.

D3 technical solution concept

System rationale

We are pursuing the – in our opinion – only viable approach to making urban air transport an ultimately safe proposition: deterministic route planning with dissimilar and redundant safety layers. ***Only an approach that includes these criteria will satisfy the requirements for public safety.***

Our approach follows the fundamental realization that any aviation product needs to be inherently fail-safe in order to obtain certification. This means that several safety levels need to be added on top of each other in order to form a safety net in case errors occur in a preceding level.

The fundamental logic of D3's technical solution is as follows:

<u>Planning Level</u>

A suitable algorithm determines collision-free routes satisfying all known (and predicted) traffic and collective routing requirements (other vehicles). It takes into consideration all known factors that impose constraints on an ideal "free routing" (direct line from A to B).
These factors are derived from an "Air Situation Image" (ASI) that represents all known and relevant factors (this image is similar to a "Digital Twin" of the air situation relevant to a specific geographical area). It includes static and dynamic factors such as topography, buildings, obstacles, closed and restricted airspaces, already confirmed and cleared routings of other vehicles, political and safety considerations (no-fly zones, capacity limitations, noise abatement), weather and more.
Essentially, an aircraft adhering to this route will have a safe and accident-free flight. This statement should be true in 99,9…9% of all flight operations.
D3 calls the determination of collision-free routes to the participating vehicles the Deterministic Planning Function (DPF, patent pending). Routes will be negotiated and contracted with air vehicles via appropriate negotiation functions according to data resident in the ASI. Flight routes will be provided (transmitted, negotiated, contracted and cleared) to air vehicles via a Communication Backbone that ensures AV-AV and AV-ground communications.

<u>Tactical Level</u>

Using the above numbers, if more than 1,…0,000 flights are performed in a given time period this would lead to 1 statistical fatality in this time period, which is be unacceptable in aviation safety terms.

Moreover, there are two additional elements of risk:
(1) the probability that an AV actually adheres to the planned and cleared route, and
(2) whether the ASI actually has obtained knowledge of all relevant factors in due time.

D3 addresses this challenge with two added safety layers.
(1) The Flight Guarding Function (FGF, patent pending) integrated with the avionics on board of all participating vehicles. It translates the routing

requirements agreed with the vehicle into actionable commands that either limit a pilot's ability to make errors via a dedicated Human-Machine Interface (HMI), or can be fed into the AV's flight control computer directly. This ensures that agreed routings are adhered to strictly and limits the risks associated with risk factor 1 (see above). At the same time, it allows for a seamless transition of piloted air vehicles to automated air vehicles.

(2) It is conceivable that an AV encounters situations that do not correspond to the assumptions that were made while planning the AV's route.
Among other factors, this could be due to (among others):
   a. certified information suppliers (to the ASI) provided erroneous data
   b. official data are erroneous or outdated
   c. third parties did not comply with reporting requirements (e.g. building cranes were not removed when agreed)
   d. there is uncooperative traffic (e.g. AVs use the airspace without being registered and part of the planning process)

These factors will be registered by an on-board sensor suite in each vehicle (Sense-and-Avoid, SAA). Contradicting factors will be fed back to the D3 AVCS. In all likelihood the deviating factors will be reported by several vehicles and will be compared to each other by the D3 system. A most plausible correction of the ASI will be determined, and the image (ASI) will be updated. The previously determined routings will be recalculated for all affected vehicles and the vehicles will be provided with amended routings in almost-real time. In the case of uncooperative vehicles being the cause for the deviation, appropriate protocols will be triggered.

<u>**Contingency Level**</u>

In the highly unlikely event that one or more air vehicles are not able to communicate their findings (deviation from assumptions used for planning) to the D3 AVCS for immediate re-planning (due to communication outages or active interference), they need to be equipped with a rule-set that allows for evasive maneuvers or contingency actions. D3 calls this the Reversionary Flight Planning Function (RPF, patent pending) as a part of the FGF. This rule-set, codified in appropriate algorithms, needs to be implemented homogenously across all vehicles in a system. This ensures that the evasive or reversionary actions are predictable and can be designed such that propagation of disruptions across the system can be minimized and will abate within the distance of a few vehicles. The area of disruption is a function of traffic density. This consideration is a key reason why ***D3 is convinced that homogeneous reversionary algorithms across a given operations area are key to achieving the traffic density*** required for efficient passenger-carrying operations.

System scope

The D3 AVCS offers a hierarchy of automated functions to provide the safety level required for passenger-carrying eVTOLs, including:

1. A deterministic planning function to provide safe and optimized routes
2. An airborne function integrated in the air vehicle to monitor adherence to the planned route and to support the pilot

3. Airborne Air Situation Image updates triggered in case of changes in the environment (weather, airspace availability, airspace capacity) or triggered by on-board sensors in case of obstacles detected
4. Contingency procedures

D3 is evaluating a dedicated 4G, later 5G, network as an initial solution for continuous and reliable communications.

Stakeholder interaction

Vehicle manufacturers:

D3 is considering partnerships with air vehicle manufacturers in the development stage. D3 has to offer a service that already supports early test flights. The loss of communication from the ground to the air vehicles has been described as a main pain point by air vehicle manufacturers. Among the main stakeholders, vehicle manufacturers are the most hardware driven. Therefore, fixed system designs are difficult and costly to change after certain design freezes. So vehicle manufacturers need to be addressed at a very early stage, before vehicle designs are frozen for production at scale.

Regulatory bodies:

The D3 development roadmap takes into account a software system development lifecycle in conformance with all relevant regulatory standards to demonstrate the level of confidence in system integrity necessary for certification.
Civil Aviation Authorities: oversee the approval and regulation of civil aviation in each country.

European Organization for Civil Aviation Equipment (EUROCAE): deals exclusively with aviation standardization, for both airborne and ground systems. Members are aviation stakeholders made up of regulators, manufacturers, services providers, users (such as airlines and airports) and academia. EUROCAE documents are widely referenced by the International Civil Aviation Organization (ICAO) as Guidance Material and by the European Aviation Safety Agency (EASA) as means of compliance to European Technical Standard Orders (ETSOs) and other regulatory documents.

Eurocontrol: is the European Organization for the Safety of Air Navigation. Eurocontrol Safety Regulatory Requirement (ESARRs) are the basis requirements for certification of air traffic management systems in the EU.

European Union Aviation Safety Agency (EASA): EASA has taken over the responsibilities of the former Joint Aviation Authorities (JAA) system. EASA promotes common standards of safety and environmental protection in civil aviation. EASA relies on expert working groups at EUROCAE for the development of standards for UAS (WG 105), VTOL (WG 112) and the corresponding air traffic management systems.

Service providers:

Integrating D3 services with other service providers will allow for a seamless customer experience and increase the universality of the D3 solution. Relevant service providers are:

Aeronautical Information Services (AIS): each country has its own AIS. In Europe, the European Aeronautical Database, operated by Eurocontrol, is the world's largest aeronautical information management (AIM) system.

Air navigation service providers (ANSP): for flights crossing, entering or leaving controlled airspace, coordination with air traffic control will be a necessity. We assume that a central gateway similar to the Flight Information Management System (FIMS) for UTM will be defined to enable coordination.

Airport operators: Collaborative Decision Making (CDM) between airport operators and D3 will allow for optimized flight operations.

Ground transportation services: enabling multi-modal transportation services such as a taxi service etc.

Meteorological data services (MET): current and forecast weather data

UAS Service Suppliers (USS): we expect USS to continue providing their services for smaller work drones while D3 focuses on an integrated service for passenger-carrying drones and work drones. Integration of USS and D3 services in the same airspace depends on future airspace concepts.

VTOL port operators: we expect new VTOL ports to appear in metropolitan areas around the world. Similar to existing airport operators, D3 enables data sharing and CDM with VTOL operators.

Other: such as topographical map providers for very low-level drone flights.

Enabling user autonomy and public benefit

The D3 deterministic planning approach differs from the mainstream in the industry with regard to overall system capabilities and system architecture.

The D3 solution integrates an airborne and a ground segment (dedicated in-air vehicle and on-the-ground hard-/software units), it automates communication between the two segments, provides safe, collision-free routings and back-up on-board intelligence (algorithms) for contingency/escape maneuvers and thus allows for continuous use of airspace and capacity optimization.

In *D3's view, other current initiatives in the EU and the US will most likely not deliver a viable solution for an urban air mobility scenario with high-density and high-complexity traffic*.

The D3 Air Vehicle Control System aims to optimize the following factors:

- flexibility for operators (choice of time, duration and routing)
- convenience of interaction with system
- cost of operations
- interaction with other transport modes
- disruption of present aviation activity

The D3 operations model will provide:

- Authority to exercise control of airspace by appropriate authorities (maximize public benefit)
- Equitable and unbiased access to airspace for transport providers
- Simply integrated avionics assuring ATC compatibility for vehicle manufacturers
- Safe and efficient transport options for end users (passengers)

In the resulting product strategy, D3 has determined that product value can be demonstrated at the earliest through adoption by vehicle manufacturers (OEMs). While the most value will eventually be provided to operators (fleet operators, transportation providers) and cities for traffic management, the tangible benefits for these entities are downstream from vehicle manufacturers' possible benefits.

As mentioned above, D3 research has shown that there is a definite requirement for uninterrupted data transmission from vehicle to ground for flight test purposes. Since the corresponding technology is part of the D3 technology stack, it makes sense to offer this service at an early point. The hardware installed in vehicles will be a placeholder for evolving hardware and will be expanded with additional capabilities over time.

It is highly likely that OEMs will choose to remain with the D3 soft-/hardware solution once they have adopted it and can be convinced that the expanding capabilities suit their requirements and those of their customers.

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Abbreviations

AAM	Advanced Air Mobility
ANSP	Air Navigation Service Provider
ASI	Air Situation Image
ATC	Air Traffic Control
ATM	Air Traffic Management
AV	Air Vehicle
AVCS	D3 Air Vehicle Control System
CDM	Collaborative Decision Making
DAL	Design Assurance Level
DPF	Deterministic Planning Function
EASA	European Union Aviation Safety Agency
EUROCAE	European Organzation for Civil Aviation Equipment
EVTOL	Electric Vertical Take-Off and Landing
FAA	Federal Aviation Administration
FGF	Flight Guarding Function
HMI	Human-Machine Interface
IFR	Instrument Flight Rules
JAA	Joint Aviation Authorities
MET	Meteorological Data
OEM	Original Equipment Manufacturer
SAA	Sense and Avoid
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UOMS	Civil UAS Operation Management System in China
USS	UTM Service Supplier
UTM	UAS Traffic Management
VFR	Visual Flight Rules

Glossary

Advanced Air Mobility	The more inclusive term “advanced air mobility” encompasses a wider range of transformational applications enabled by electrification and automation, whether performed by eVTOL aircraft, electric conventional take-off and landing (eCTOL) aircraft, or small drones. These might include cargo transportation or aerial work operations, in addition to the large-scale air taxi operations that have become synonymous with “urban air mobility.”
Air Vehicle	A passenger-carrying vertical take-off and landing capable Air Vehicle.
Air Vehicle Control System	The D3 Air Vehicle Control System is defined as the combination of the D3 Airborne Segment (located in Air Vehicles) and the D3 Ground Segment which allows to perform flights with Air Vehicles along predefined Air Tracks.
Airborne Segment	The Airborne Segment of the D3 Air Vehicle Control System consists of Air Vehicles which are managed by the D3 Air Vehicle Control System.
Data Link	The Data Link is used for flight critical data transmission (e.g. navigation data update, flight plan, AV status, telemetric data, voice communication) between the D3 Airborne Segment and the Ground Segment.
Flight Plan	The internal representation of the Flight Request. The Flight Plan contains all Flight Route information.
Flight Route	The Flight Route is defined as the 3D path from a Departure (Port, Pad) to a Destination (Port, Pad). The Flight Route consists of Route Segments and Route Points.
Port	A Port is a landing and take-off location with one or more Pads. The Port may support multiple Air Vehicles.
Safety Pilot	A licensed pilot on board, able to assume manual control of the air vehicle.
Urban Air Mobility	A system that enables on-demand, highly automated, passenger- or cargo-carrying air transportation services in a metropolitan area, involving new vehicle designs and system technologies, developing new airspace management constructs and operational procedures, and embracing the sharing and services economy to enable a new transport service network.

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