BLUEPRINT

FOR THE SKY

The roadmap for the safe integration of autonomous aircraft

AIRBUS

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About Airbus

Airbus is an international pioneer in the aerospace industry. The company is a leader in designing, manufacturing, and delivering aerospace products, services, and solutions to customers on a global scale. Airbus aims for a better-connected, safer, and more prosperous world.

About Altiscope

Altiscope plays a vital role in developing the architecture and systems to enable autonomous aircraft to fly safely and efficiently. Altiscope is the UTM initiative of A³, the innovation outpost of Airbus.

Contact **hello@utmblueprint.com** or visit **utmblueprint.com** for more information.

Welcome

We stand at a thrilling point in the history of aviation. The skies are busier than ever, and Airbus is one of the world's largest manufacturers of commercial aircraft, helicopters, military jets, rockets, drones, and space-craft, among others. Our industry's prospects for the future are exciting, with current air traffic—that is, commercial and cargo flights and helicopters—having quadrupled in the last 30 years, and set to double in the next 15[1]. Soon there will be an estimated 25,000 human-piloted flights in the air at any given moment[2]. Nobody would have imagined that future a century ago.

But there is another change on the horizon. An entirely new category of airspace user is on the rise, with self- and remotely-piloted aircraft developing rapidly. Soon, autonomous aircraft will be transporting people and goods all around the world.

Airbus welcomes this revolution. The shift is exciting, and enables all manner of new opportunities. It also brings risks that need to be addressed now. Safety is not an afterthought in aerospace; it is a fundamental rule that cannot be compromised.

We have always been on the forefront of innovation in the skies, from our origins among Europe's aerospace pioneers, through jet age creations including the Concorde, to megascale airliners such as the Airbus A380. We know bold ideas, new technologies, and thoughtful strategies are how to navigate and conquer such risks.

So how do you marry the promise of innovation with the culture of safety developed over aviation's many decades? How do you create opportunities to collaborate and build an airspace that works for everyone?

That's what this Blueprint is. It is a roadmap for collaboration and cooperation that puts safety on an equal footing with technological advancement. It supports policies and rulemaking that can regulate autonomous operations to ensure that air transport remains as safe tomorrow as it is today. And, because Airbus cares about the skies—not just building drones—it anticipates how an integrated airspace will impact everybody, developing fresh models of air traffic management that will enable new kinds of operations to flourish.

The airspace of tomorrow can only deliver on its promise through collaboration—regulators, manufacturers, service providers, investors, and consumers, all working together with a common understanding. We are excited to share this with you, and to see the future we can make fly together.

Tom

Tom Enders
Airbus Chief Executive Officer

Look up!

Human flight has captivated our imaginations for thousands of years. It was only when the Wright Brothers first took to the air in 1903, however, that our collective dream became real. Since then, aviation has scaled at an unbelievable pace, from those pioneering days, to the jet age of the 1950s, to now. In 2017, more than 3.5 billion passengers traveled by air[3]. That is a 10-fold increase in 30 years. Now, at any given moment, there are over 1 million people airborne around the world[2]—more than the populations of San Francisco or Stockholm. And it is only growing.

The biggest surprise, though, is that we're still just at the beginning of this revolution. Change is happening faster than anyone imagined, and the digital age is speeding innovation up even more.

Recent developments—in battery capacity, autonomy, and on-board technology—make new kinds of aircraft possible. These vehicles have new shapes, capabilities, and operations, which our current airspace system was not designed to handle. Smaller cargo drones can move packages faster and more efficiently to hospitals, offices, and homes. An emerging class of electric vertical take-off and landing (eVTOL) aircraft can transport people around congested cities in minutes instead of hours. These new vehicles can fly higher—and lower—than ever before. And because prices will fall to a fraction of today's air operations, they create the potential for massive, wide-scale use.

The digital age of aviation will change our skies. The number of flights will grow by orders of magnitude[4]. The airports of tomorrow will be all around us—in our homes and our workplaces, on the roofs of buildings, on top of delivery vans and fire trucks.

Such dramatic expansion is not straightforward, however. How can these aircraft be introduced safely? How can they co-exist with each other—and with future uses that have not even been invented yet? And how can we make sure that we manage that change? The answers require redesigning airspace in a way that enables innovation while also prioritizing high assurance.

We have already seen the benefits that one flexible architecture—the Internet—made possible in the online world. And today, there are multiple proposals for modernizing airspace using digital systems. NASA's UAS Traffic Management[5] (NASA UTM) creates a framework for safely managing growing use of low-altitude airspace.

In Europe, the SESAR Joint Undertaking is developing U-space[6], which is endorsed by the European Commissioner for Transport, Violeta Bulc, and opens the continental market for lower altitude drone services and aircraft. RPAS are governed by a separate and parallel framework with rules similar to manned aircraft.

Both plans paint a picture of a decentralized, coordinated network of services that safely open airspace to new and exciting uses. But NASA UTM and SESAR U-space also leave open the implementation details. For ease of reading, the term UTM is used throughout this document to refer to the various proposals and systems around the world.

Here is our contribution to moving aviation forward. This document lays out the information and the specifications needed to implement an action plan. It is an outline of how we can transform airspace faster for the next generation of aircraft. This is a Blueprint for the skies that will enable a new revolution in aviation—safely, efficiently, and fairly.

eVTOL: Vehicles that can take off and land like a helicopter, but use electric or hybrid power. They may or may not use wings for cruise.

NASA UTM: NASA's UAS Traffic Management program started in 2014 in collaboration with the FAA and other federal agencies[7].

SESAR Joint Undertaking: The technological pillar of Europe's Single European Sky initiative, coordinating and concentrating all EU research and development activities.

What is UTM?

Today, aircraft are guided around the skies by air traffic controllers. Each controller is responsible for a sector, keeping aircraft safe by talking directly with pilots using radio communications. Estimates show that the growth of commercial air traffic is already exceeding the capacity of a human-centered system[8]—and that is only for human-piloted flights. The expected growth of unmanned and self-piloted operations will increase traffic by several orders of magnitude.

To handle this dramatic growth, air traffic management must shift to a more scalable model: a digital system that can monitor and manage this increased activity. That system is what we call Unmanned Traffic Management, or UTM.

UTM is not a single, central system that mandates one way of operating for everything. Instead, it is a framework. It is a networked collection of services that join together and understand each other, based on common rules.

UTM is built to enable future applications. The challenge is designing a system that can remain relevant as technology progresses and market needs mature without knowing what that future will look like. Rather than relying on centralized control, UTM frameworks around the world use the principle of distributed authority[9]. This opens up the system to more service providers, who can adapt as the market evolves and needs change. Decentralization privatizes the cost of serving and adapting to market needs, while government regulators remain key for ensuring that safety, access, and equity are maintained.

In practice, this means aircraft are no longer forced to talk only to a single entity, such as an assigned air traffic controller. Instead, aircraft can communicate freely with their service suppliers of choice, who are held to relevant safety, security, and performance standards by the authorities and coordinate with the rest of the network to make efficient decisions based on specific flight objectives.

Human air traffic controllers, meanwhile, will become airspace managers, focused on oversight, safety, and security.

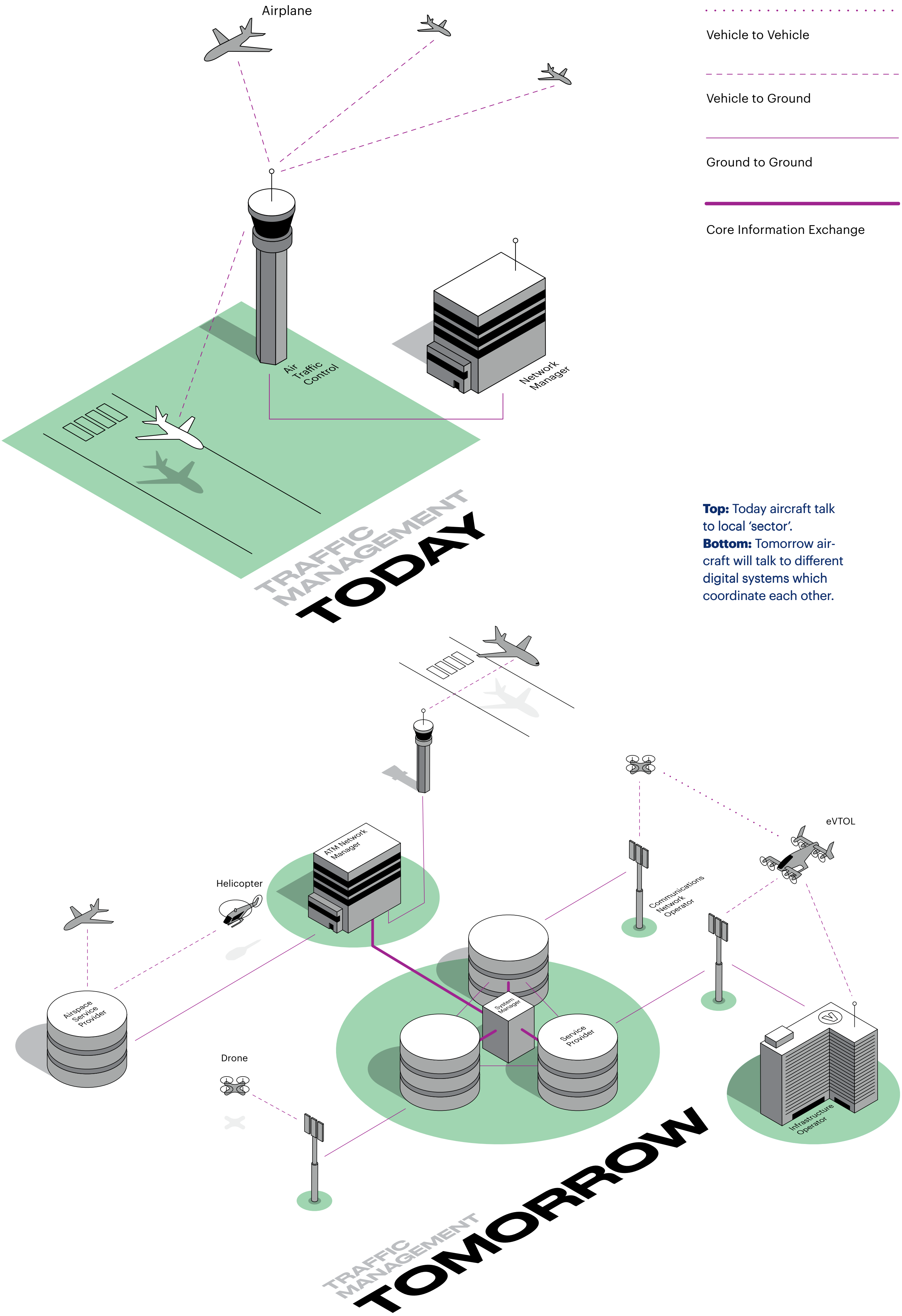
UTM allows the same foundation to serve different needs in different geographies at different times. Regulators can adapt requirements to match their local needs, and operators can select the providers they need to complete their missions. Providers can create, update and deploy their own services quickly. One operator can choose to build, certify and supply its own services, while another may find the same services in a marketplace. Providers will be responsible for coordinating with each other[10].

For unmanned applications to thrive, many stakeholders must come together to advance their respective domains. Advances can be accomplished in phases, with each phase dependent on the previous ones. As UTM shows positive results, there may be technology sharing or increased integration with traditional ATM. Pages 26 and 27 outline the blueprint for stakeholders.

Several countries and trans-national bodies have already adopted this overall approach as the foundation for their own UTM implementations (see pages 8-9). Each government has a slightly different view on how authority should be distributed.

UTM: UTM is the autonomous corollary to ATM, the existing Air Traffic Management systems that are used to handle movement in aispace. The acronym 'UTM' is widely used to describe a traffic management system that will support self-piloting aircraft.

Distributed Authority: A system in which any individual actor is able to make decisions and take action based on information and a set of agreed rules, rather than refer to a central authority for permission.



Top: Today aircraft talk to local 'sector'.
Bottom: Tomorrow aircraft will talk to different digital systems which coordinate each other.

Different Countries, Similar Approaches

The underlying principles and approaches of UTM schemes in development around the world are very similar, even though each region uses slightly different terminology and organization. Each one consists of systems run by regulatory authorities, independent service providers, data providers, operators, and aircraft.

UNITED STATES- UTM (NASA)

In NASA's model[10], private **Unmanned Aircraft Systems Service Suppliers (USS)** are certified by the Federal Aviation Administration (FAA). Each one takes responsibility for exchanging data and coordinating with the others. Data needed for coordination with the ATM system passes through an information exchange called **System Wide Information Management (SWIM)**, which is run by the FAA and stores information such as flight plans. At the same time the FAA also runs the **Flight Information Management System (FIMS)** that coordinates between USS providers, traditional air traffic management, and the national airspace system.

Status: The first USS have already been approved to provide Low Altitude Authorization and Notification Capabilities (LAANC) to operators who wish to fly unmanned missions following Part 107 rules in controlled airspace near airports. Expanded capabilities will extend the airspace available to unmanned vehicles and permit greater autonomy.

- Coordination Manager: FIMS
- Core Info Exchange: SWIM
- Service Provider: USS
- Drone: Aircraft

EUROPE – U-SPACE (SESAR)

Key functions are provided by **U-space Service Providers (USP)** which may be required to exchange certain information and coordinate through a **SWIM** system. They may also communicate with a **U-space system manager**—similar to the Single European Sky's current network manager. This acts as a centralized coordinator in a manner much like NASA's FIMS, as well as manages traffic. Other providers are responsible for non–safety–critical services, as well as data on weather and terrain.

Status: U-space is scheduled for a gradual rollout in four stages, called U1-U4. U1 services are expected to be in full use in 2019, when pre-operational demonstrations of U2 will also take place. The first results of U3-U4 research will be complete in 2019. Demonstrations and rollouts are planned for the early 2020s[6], with exact timelines driven by individual countries.

- Coordination Manager: System Manager
- Core Info Exchange: SWIM
- Service Provider: USP (U-space Service Provider)
- Drone: Aircraft

CHINA – (UOMS)

The China CAAC has specified the use of a civil UAS Operation Management System (UOMS)[11], with several **Unmanned Aircraft Cloud System (UACS)** providers responsible for the final link to the operator. These supply alerts, geofencing, registration, and vehicle location services.

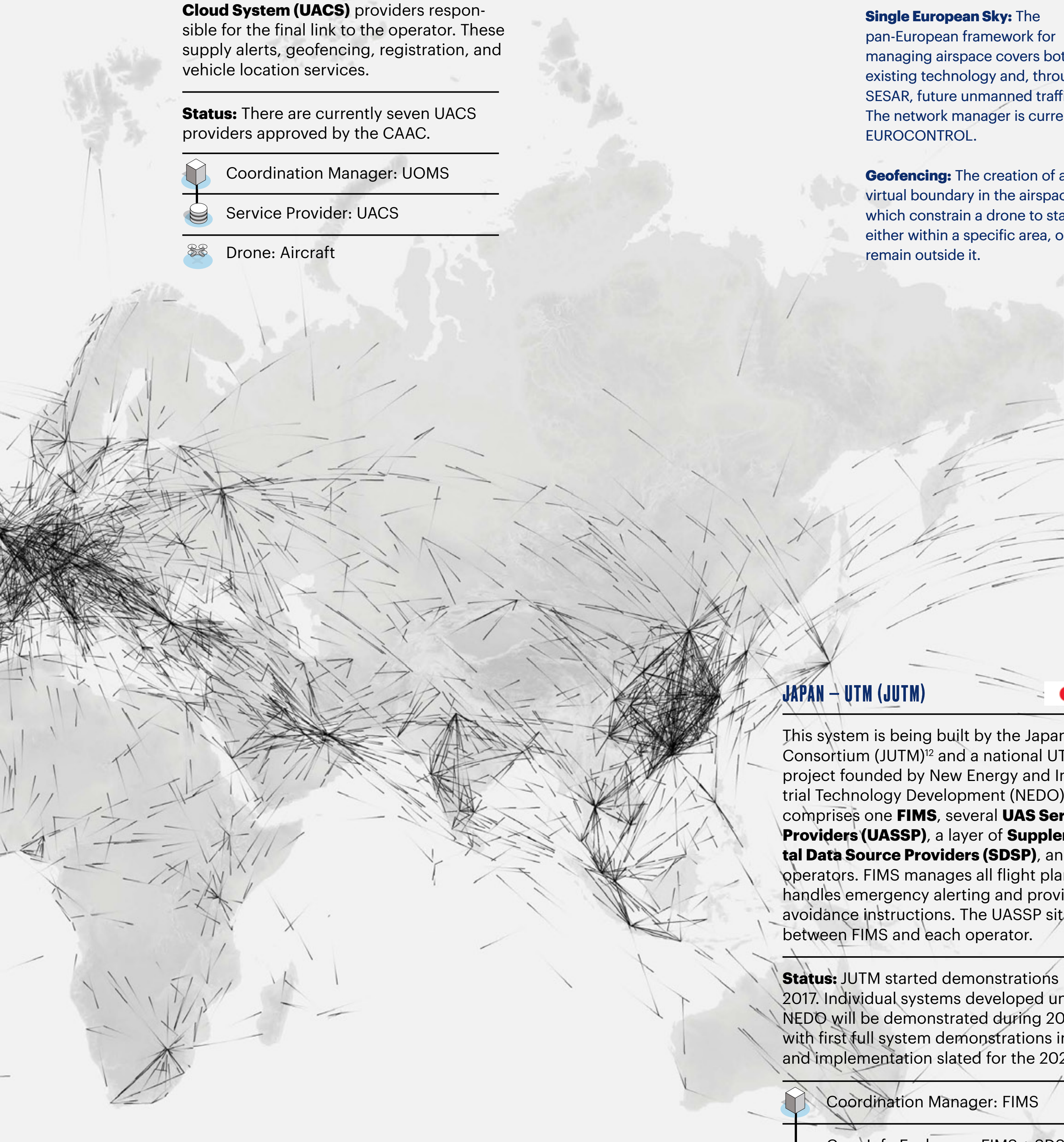
Status: There are currently seven UACS providers approved by the CAAC.

- Coordination Manager: UOMS
- Service Provider: UACS
- Drone: Aircraft

FIMS: Flight Information Management Systems coordinate between the central authority responsible for enforcing airspace regulations—like the United States FAA—and the unmanned services happening in its region.

Single European Sky: The pan-European framework for managing airspace covers both existing technology and, through SESAR, future unmanned traffic. The network manager is currently EUROCONTROL.

Geofencing: The creation of a virtual boundary in the airspace, which constrain a drone to stay either within a specific area, or remain outside it.



JAPAN – UTM (JUTM)

This system is being built by the Japan UTM Consortium (JUTM)[12] and a national UTM project founded by New Energy and Industrial Technology Development (NEDO). It comprises one **FIMS**, several **UAS Service Providers (UASSP)**, a layer of **Supplemental Data Source Providers (SDSP)**, and operators. FIMS manages all flight plans, handles emergency alerting and provides avoidance instructions. The UASSP sits between FIMS and each operator.

Status: JUTM started demonstrations in 2017. Individual systems developed under NEDO will be demonstrated during 2018, with first full system demonstrations in 2019 and implementation slated for the 2020s.

- Coordination Manager: FIMS
- Core Info Exchange: FIMS + SDSP
- Service Provider: UASSP
- Drone: Aircraft

How Airspace Will Expand

The primary users of airspace today are commercial jets and general aviation. As technological advances take hold, we need to open the skies—and our imaginations—to many more possibilities.

HOBBY DRONES

More than 3 million consumer hobby drones were sold worldwide in 2017. Users fly for fun, and most flights are remotely controlled, while some newer drones can automatically follow the user or fly pre-programmed patterns. Hobby pilots are required to stay below 400 feet above ground level in most areas, but this is currently difficult to enforce. Most users are untrained, relying on education from pamphlets or programs like the FAA's Know Before You Fly[13].

IMAGING AND ANALYTICS

Drones can perform inspections and capture imagery faster, more often, and more safely than people. This data can be used for everything from construction and agriculture to insurance and disaster relief. Flights can cover a region on a regular schedule, or be ordered on demand. These missions can be local or cover long distances.

DELIVERIES

Four billion parcels were ordered online for home delivery in Europe in 2017, up 28% on the previous year[14]. Tomorrow, everything from retail parcels to urgent medical deliveries will be moved by air—from small drones to larger eVTOL transports. Delivering only 1% of parcels this way will create more than 14,000 drone flights every daylight hour across Europe alone, requiring significant airspace management to ensure safety.

TRANSPORT

Today, light planes and helicopters connect air taxi operators and passengers through platforms like Airbus' Voom and Blade. Air Mobility (UAM) aircraft will take off and land vertically from airports and "vertiports" all over towns and cities for passengers and emergency transport. As the technology becomes more affordable, air traffic will increase hundreds of times over. If just 1% of the 2.2M people in central Paris commute by UAM each day, there will be more than 11,000 flights per hour over the city during peak times.

HELICOPTERS

Helicopters excel when endurance or capacity are important—such as in emergencies, search and rescue, commercial transport, and maintenance of infrastructure. Today's helicopters predominantly use visual flight rules, but are increasingly adopting digital systems for navigation and air traffic coordination.

GENERAL AVIATION

Private, non-commercial flight covers everything from high-performance business jets and medical transports to gliders and flight trainers. Pilots require flexibility in when and where they fly, generally depart without filing a flight plan, and may seldom talk to air traffic controllers, depending on where they fly.
In general, the community is cost-conscious, against new equipage mandates, and concerned about privacy, so should only be required to participate in the air traffic system when it is a safety issue. Several groups hold considerable sway, particularly when it comes to imposing taxes or usage fees.

GOVERNMENT AND MILITARY

National and regional governments regularly use airspace for law enforcement and emergency management. They use light aircraft, helicopters, and drones. Military training and operations, meanwhile, use aircraft and drones extensively. It is important that government and military operators receive priority access to airspace when necessary.
They should also be able to enact airspace restrictions, define training routes, and mandate other airspace constructs that are essential to public safety and national security missions.

COMMERCIAL AVIATION

Airspace will get busier and more complicated as unmanned operations expand and global air traffic doubles by 2036.
With up to 25,000 commercial flights[15] in the air during peak times, demand for pilots will triple current numbers and greater ATM automation will be necessary to handle the increased volume.

HIGH ALTITUDE

Drones, both self- and remotely-piloted, can operate far above normal commercial altitudes for long periods. They will deliver services including sub-satellite imaging and provision of internet access.

HIGH ALTITUDE

Operators: Airbus Zephyr, Google Loon

COMMERCIAL AIRCRAFT

Manufacturers: Airbus, Boeing

GOVERNMENT AND MILITARY

Operators/Organizations: National militaries, Police and Fire departments, EMS

GENERAL AVIATION

Manufacturers: Cirrus, Diamond, Cessna
Organizations: EAA, AOPA, GAMA, NBAA

HELICOPTERS

Manufacturers: Bell, Sikorsky, Robinson, Airbus, Leonardo, MD Helicopters

TRANSPORT

Services: Uber Elevate, Blade, Airbus Voom
Aircraft: Kitty Hawk Cora, Airbus Vahana, CityAirbus, Aurora eVTOL, Joby S4

DELIVERIES

Operators: Airbus Skyways, Google Wing, Amazon Prime Air, Zipline, SF Express

IMAGING AND ANALYTICS

Operators: Airbus Aerial, Airware, DroneDeploy, PrecisionHawk, DJI

HOBBY DRONES

Manufacturers: DJI, Yuneec

UAM: UAM covers passenger and cargo flights operated in densely populated areas, including air taxis, delivery drones, remotely piloted and autonomous operations.

PinS: Point in Space approaches use instrumentation as well as visual maneuvering—enabling helicopters to deal with inclement conditions or difficult terrain more easily.

Classes: E is general controlled airspace, G is uncontrolled airspace—both areas outside highly-controlled zones like airports, air corridors, and radar control zones.

The New Principles of Airspace

Future airspace will be full of drones, commercial aircraft, helicopters, and more. It must be structured and managed to ensure safety, equitable access, efficiency, and compatibility with future technology.

Here are the operating principles that will be needed in order to thrive.

1

Safety and Security are Paramount

Air traffic management systems are responsible for safely guiding physical objects through airspace which carry both people and cargo over populated areas and sensitive sites. That means the consequences of a dropped packet are far more severe in aviation than on the Internet. Services like tracking, identification, and registration must be established rapidly. However, the airspace will also become more dense. That means these services must be quickly followed by those that provide active risk management, deconfliction, emergency alerts, and other critical functions. Provisions must exist for emergency and security response vehicles to rapidly access the airspace. Operators must be incentivized to invest in safety through airspace, process, and service design. Safety, security, and the integrity of the airspace against careless, clueless, and criminal actors must always be the top priority and considered at every step of design, testing, certification, and operation.

2

Airspace Must be Shared

Unmanned aircraft will share airspace with manned counterparts. A piloted passenger jet will share airspace, runways, and taxiways with an unmanned cargo jet. Self-piloted air taxis will share airspace with helicopters. High altitude drones will share airspace with supersonic military jets. Airspace must be configured so that these can coexist—and it is vital that it is properly integrated.Access to airspace must be dependent on equipage and performance, not mission. Airspace reserved only for a single kind of user is more complex, less flexible, and restricts what is possible in the future. For example, small drones will not routinely fly in the same areas as commercial aircraft. Commercial aircraft may sometimes make emergency maneuvers through areas dense with drone operations. Drones will need to adapt their flight paths accordingly.

3

Drones Must be Allowed to Self Pilot

The commercial viability of drone and air taxi operations depends on achieving economies of scale. Requiring a human to serve as an onboard or remote pilot significantly limits economic feasibility of drone businesses. This means that drones must be able to react to changing conditions. Not all drones will be self-piloting, and self-piloting drones will sometimes need human control. But they must be capable of adapting their flight paths to ensure they can safely coexist.

4

Fleets Must be Able to Self-Manage

To achieve scale and efficiency, operators want to manage their own fleets. This includes flight planning, vehicle assignment, vehicle management, flight dispatching, and fleet coordination. Examples include coordinated formation flying, hovering near warehouses, and fleet balancing.

5

Airspace Must be Harmonized Worldwide

Systems, vehicles, and technology built for one region will need to be interoperable with other regions. Incompatible regulations, inconsistent procedures, spectrum licensing, or vendor restrictions all force manufacturers and operators to adapt their products and services for each region. This can have significant costs, and will reduce both the speed of innovation and the adoption of proven safety technology worldwide. Standardized rules and procedures encourage innovation, maximize market potential, and speed up the adoption of autonomous systems. Countries that choose to adopt rules that are very different from elsewhere may see their market underserved—or not served at all.

6

Airspace Must be Accessible

The rules for access to airspace must be impartial, clear, and openly available. Two identically-licensed operators should have equitable access. Equitable does not mean equal; it means that both operators are evaluated by the same set of rules without bias. Clear rules incentivize and enable operators to either invest in added safety or select less risky mission profiles, depending on their business model and market. Exceptions can be granted for government or military, but a level playing field is necessary for the market to support new entrants. The objective is to create the greatest possible market opportunity through opening the airspace to new players. Restrictions on airspace use, such as no-fly zones based on aircraft risk or capability, or air traffic management decisions such as routing changes, must be impartial to the operator or aircraft. They may, however, favor or disfavor based on aircraft capabilities or characteristics in the interest of ensuring safety or meeting societal desires such as vehicle noise limits.

7

Airspace Must be Futureproof

When the Internet was first created, a supercomputer in everyone's pocket was science fiction. But the decentralized and layered design of the Internet made it possible to create new and wildly different uses of the technology without ever requiring the core architecture to be radically upgraded. Today Air Traffic Management is largely centralized and will not be able to support the volume and scope of operations we know are coming, let alone the ones that have not been invented yet. If we are going to design airspace management to be useful and relevant as the future is still developing, we need well-defined interfaces between decentralized systems so they work together.

Governments and ANSPs will need oversight and audit mechanisms for these distributed services and their providers.

Blueprints

If autonomous aviation systems are going to reach their full potential, then the rules under which aircraft fly, the way airspace is configured, and the services that manage airspace must also adapt to incorporate autonomy.

The current approach, where one person is required to directly operate each aircraft while traffic management is funneled through central points of control, makes it difficult to introduce new applications.

Here are our blueprints—an adaptable model that provides guidance—for evolving roles, rules, configuration, and management in the airspace of the future.

- **Blueprint for Airspace**
- **Blueprint for Systems**
- **Blueprint for Regulation**
- **Blueprint for Stakeholders**

Blueprint for Airspace

The current air traffic system focuses primarily on flights between airports, with airspace classes and procedures in place to guide fixed-wing pilots in making control decisions. Most aircraft climb away from the ground as quickly as possible, and only descend toward the ground on approach to a runway.

Helicopters have very different operations and the volume of flights is relatively low, so they operate in a unique space.

Drones

Existing flight rules and airspace services limit or prevent drone flights. Drone traffic has a greater diversity of landing locations: not just airports, but vertiports and delivery platforms that could be on buildings, in backyards, and even on vehicles. These landing locations are spread throughout a region rather than concentrated at an airport—indeed, every home could be a potential landing site. The current system of approach and departure routes needs adapting for drones and helicopters.

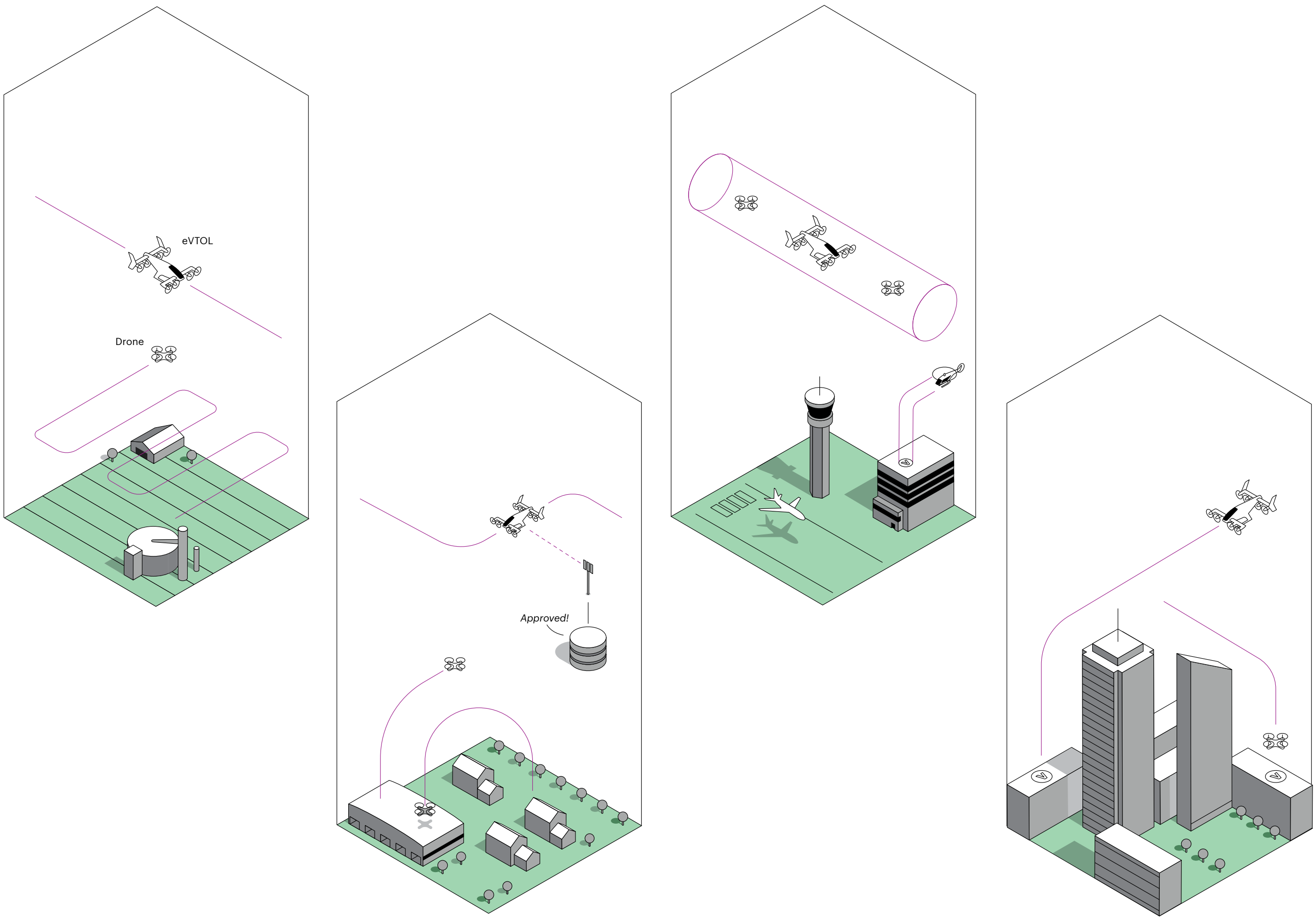
The in-flight phase can vary widely, too. Infrastructure inspection and emergency response can involve hovering near a ground location at a low altitude point. Agricultural missions involve low-altitude flights back and forth over a plot of land to measure soil or plant conditions. New kinds of missions require new kinds of traffic management.

Safety

The current air navigation system is largely organized around paths that travel between waypoints, increasingly defined ad-hoc in 3-D by satellites[16]. Drone flights performing missions in lower density airspace could use free routing, with fixed routes, corridors, or other constructs to avoid conflicts, obstacles, or areas too dense for safe operation. In high-traffic areas like urban centers, airspace structure, infrastructure, and procedures may be required to enable safe operations. A delivery warehouse, for example, has many drones approaching and departing, requiring coordination to operate safely. Procedures can define a safe route through an otherwise sensitive space, such as crossing over an airport. Other procedures can organize safe routes between buildings in an urban core, with special navigation aids to ensure high-precision guidance in complex environments.

Routing

As traffic over a region increases, airspace will become more disordered if it is not managed. Simulations run by Altiscope[17] show that increasing disorder leads to lower safety levels, including a loss of separation and increased collision rates. Ensuring safe operations means employing routing strategies to keep the airspace ordered. Several routing strategies exist, each with their own tradeoffs between freedom for the individual aircraft and amount of ordering it provides to the airspace. The most appropriate choice will depend on the exact local criteria.



BASIC FLIGHT

Aircraft under basic flight are responsible for self-separation. Aircraft must maintain separation with other vehicles through automated or manual means. Basic flight is the simplest routing scheme and is the most straightforward to implement. However, when everyone is allowed to take the most direct route without coordination, conflicts are bound to occur as the number of aircraft increases. Simulations show this happens even at low traffic volumes[18].

FREE ROUTE

Free routing is when aircraft can fly any path, so long as their planned path is coordinated with and deconflicted from the paths of other aircraft by a traffic manager and approved based on calculated risk. Free routing is being introduced worldwide, such as free route airspace in Europe[19]. This allows commercial flights to freely plan their route through participating sectors during cruise. There is less freedom for an aircraft in this situation than in basic flight, since its request may be rejected.

CORRIDORS

Corridors are defined volumes in space, useful for managing airspace in high demand or to manage traffic flow and separation. Coordination is necessary to ensure safety in this airspace. A corridor may take on many different shapes. Aircraft are often guided inside corridors using predetermined routes analogous to approach procedures used worldwide today.

FIXED ROUTE

Fixed flight routes are used to ensure safety when there is high traffic density or in any location where structure is required to ensure safe operations. This could include locations such as airports or warehouses. These routes could be constructed or modified dynamically based on calculated risk. The most restrictive version is a predetermined path, where the only variable is when an aircraft is at a specific point in the path.

VFR: Pilots flying under visual flight rules are required to see and avoid other aircraft.

IFR: Pilots flying under instrument flight rules are tracked by air traffic control and given instructions to avoid other aircraft.

Detect and avoid: A system that allows aircraft to spot obstacles or dangers and take action to avoid collision without human intervention. This happens either through sensors on other aircraft or the ground, which send an alert to the endangered aircraft, or takes place when the autonomous vehicle itself senses a problem and takes action on its own.

Procedural separation: A method by which air traffic control mitigates the risk of aircraft collisions by separating them in time on predetermined routes.

Corridors: Corridors are volumes in space that aircraft must stay inside. They can take on any shape necessary to safely and efficiently separate traffic—such as cones, cylinders, tubes, or multiple connected tubes.

Flight Rules

Aircraft today use Visual Flight Rules (VFR) or Instrument Flight Rules (IFR). These are essential for maintaining safe separation distances between aircraft to prevent collisions.

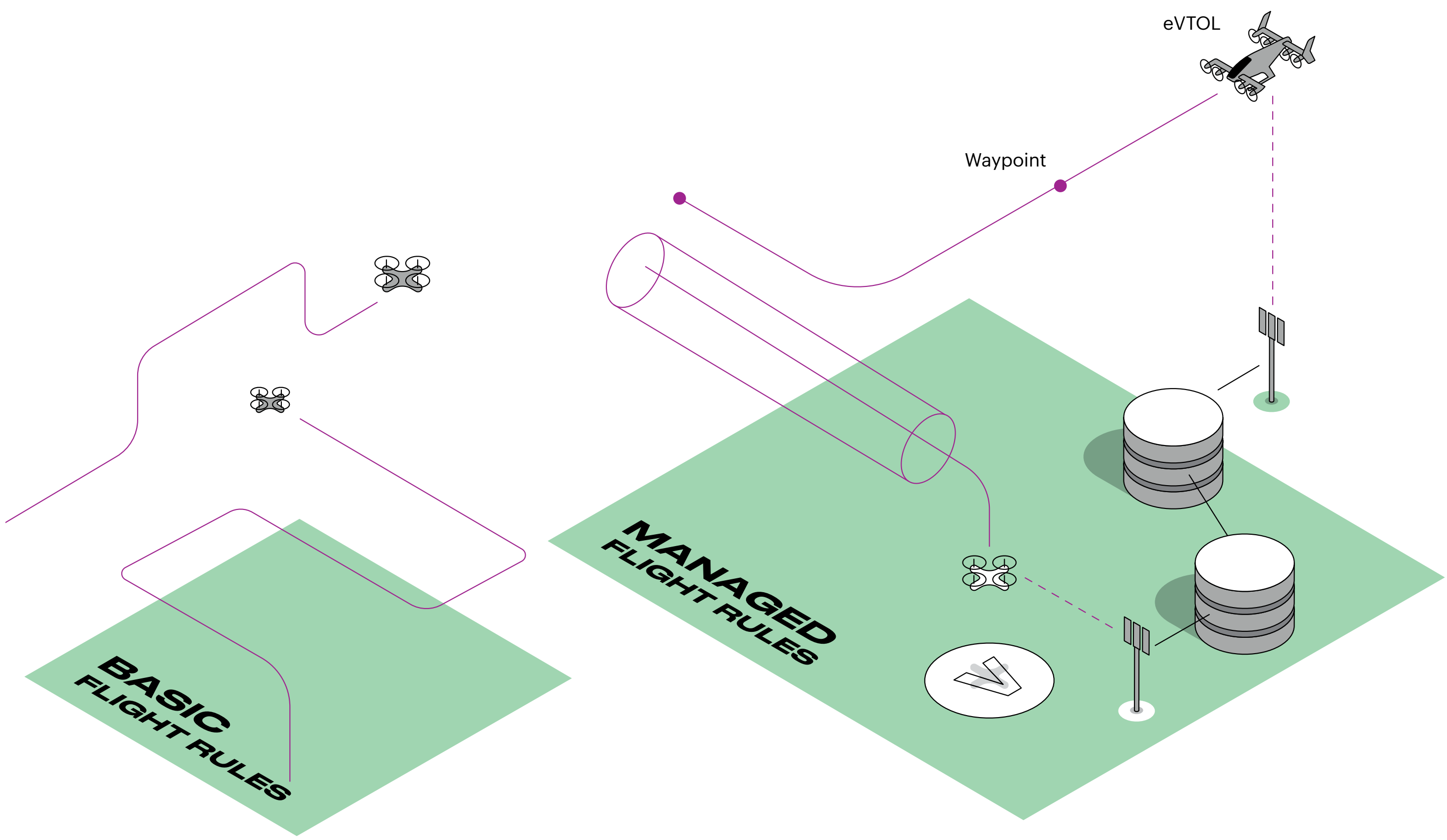
Complying with these rules limits operations for drones and helicopters, and does not allow for the introduction of new capabilities like automation in a safe and extensible way.

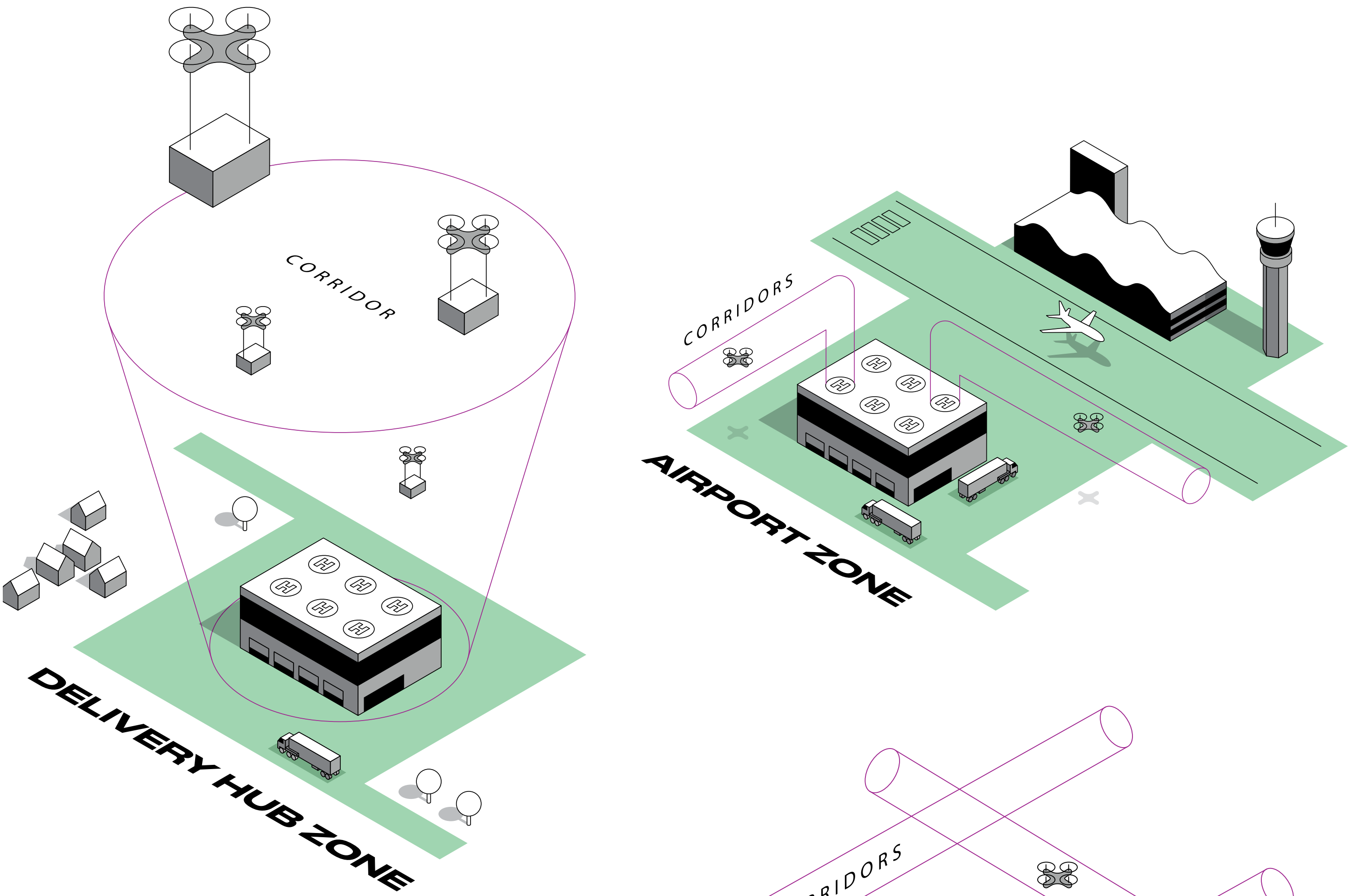
To accommodate unmanned flight, new flight rules need to be established—for example, Basic Flight Rules (BFR) and Managed Flight Rules (MFR).

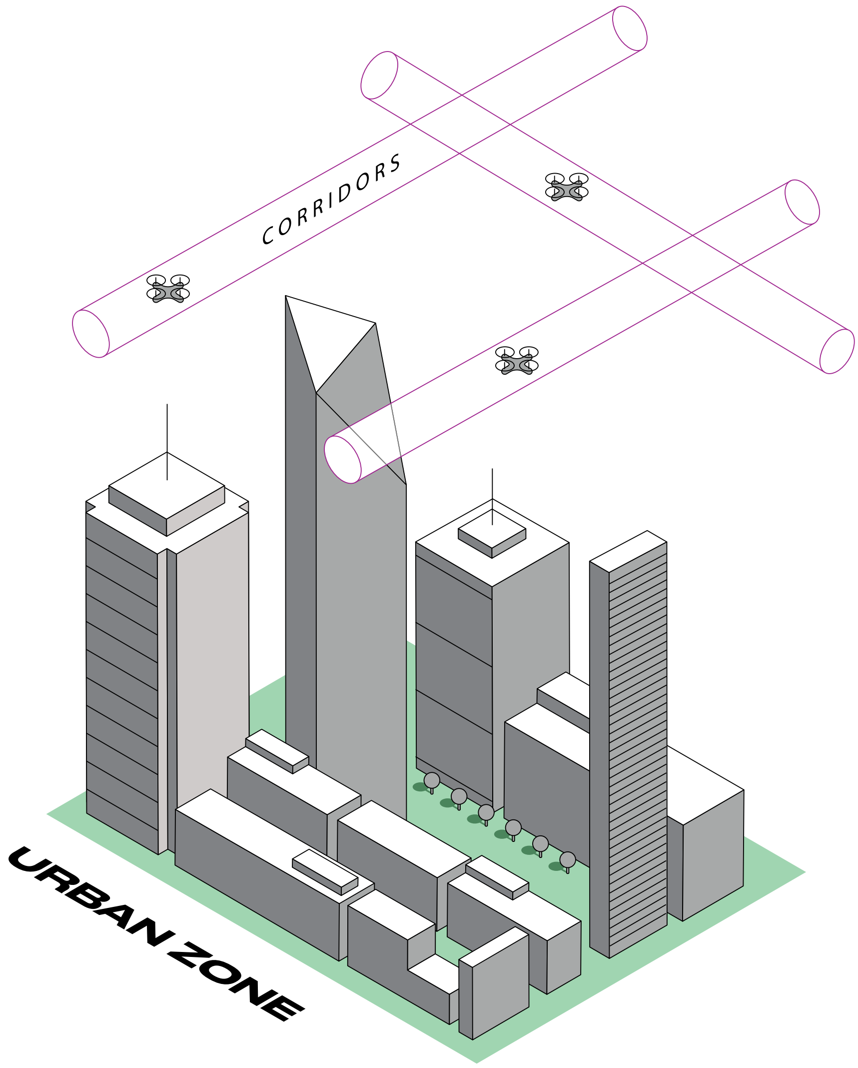
BFR would cover flights that operate independently. They take full responsibility for their safety, routing, and separation from other air traffic. MFR will apply to flights that coordinate their trajectory with a traffic management service and follow its guidance to maintain separation.

Traffic management services direct flights using MFR and monitor changes in the airspace, such as temporary restrictions or weather conditions. Flights receive control instructions to keep operations within acceptable risk tolerance thresholds. Real-time two-way communications report position and status so that traffic managers can coordinate with their aircraft. Around airports, ATM and UTM services work together. For example, they coordinate the direction of local traffic flows between fixed wing aircraft and unmanned drones at local airports based on weather conditions.

Traffic management services provide basic information to pilots and autopilots about conditions in the airspace, regulation, and nearby traffic. Managed aircraft use this information as input for tactical self-separation and collision avoidance. The same general traffic information is useful to any pilot to improve their flight planning and in-flight situational awareness.







Corridors

A corridor can be implemented in areas of high demand or wherever a special procedure or routing is needed to manage traffic flow and separation.

Each corridor has a control service that governs and coordinates its use. A drone must get clearance from the corridor's control service to enter.

Corridors may have specific procedures or rules to mitigate risk. An urban corridor may require a specialized navigation sensor, because GPS signals can be degraded by nearby buildings and multipath reflections. Similarly, there may be groundspeed and endurance requirements, limiting the types and capabilities of the aircraft which can enter. Other corridors may be implemented for aircraft with lesser equippage to traverse an otherwise complex region.
Corridors are flexible enough that they could take on the shape necessary to safely and efficiently separate traffic—such as cones, cylinders, tubes, or multiple connected tubes.

Over time, corridors may be replaced by new constructs or eliminated entirely with more sophisticated, high assurance technology.

Blueprint for Systems

Architecture

Today's Air Traffic Management systems are complex and consist of many different functions. They are provided in a one-to-many fashion, through a central entity such as a control center, and the services are deployed en masse as a monolithic system. Functions include the acceptance and approval or rejection of flight plans, tracking of aircraft, providing guidance and separation services to pilots, and handling emergency situations. This approach works well for existing aviation needs, which are well defined and grow predictably.

New traffic management systems will perform many similar functions. However, the way these are delivered will need to be different because of the radical increase in traffic density and the changes in vehicle performance, onboard automation, and sensing technology.

For example, while most commercial flights are planned in advance and follow regular schedules, air taxi and cargo missions can be requested just minutes before takeoff. In urban environments, traffic densities will be far higher, with vehicles much closer to each other, and to obstacles[20]. The diversity of operations means the traffic management system must be able to cope with aircraft that have radically different characteristics sharing the same airspace.

Microservices

In order to meet these needs, NASA UTM, SESAR U-space, and Japan UTM all rely on a networked, microservice-oriented system architecture where services are built and provided by multiple players.

A microservice is a piece of software built to conduct a single function. Microservices have well-defined interface and performance requirements, which allow them to be added, removed, or upgraded quickly. New microservices can be created and deployed as new requirements are uncovered. These services may be certified against a reference standard by regulatory bodies and ANSPs depending on function. Customers can select the ones that best meet their needs.

There may be multiple providers for any given microservice. For example, there may be several traffic management service providers, each performing real time tracking and deconfliction. A cargo company with a large fleet may operate a service that only manages their flights. Other services would be available for anyone to use as part of a marketplace. The authority would certify services, ensure interoperability, and perform audits.

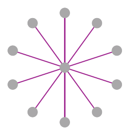
A microservices approach does not mean that all functions will be served by multiple players. Governments may operate a services directory to ensure that only microservices which meet applicable certification requirements are able to operate. Others may operate a service to ensure that all parties have an identical, real-time view of traffic.

The microservices approach is extremely powerful because of its flexibility. Regulators can adapt requirements to meet local needs. Operators can select the exact service providers that best serve their missions. And service providers can quickly create, update, and deploy microservices, subject to certification, where business opportunity arises.

Services in this architecture must meet the key principles outlined earlier—safe, automated, harmonized, accessible, futureproof. The level of safety and security must be equivalent to or better than the current air transport system. It must also incentivize innovation and safety.

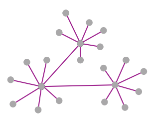
CENTRALIZED

Single entity provides for all vehicles in an airspace.



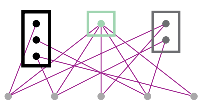
HUB AND SPOKE

Multiple entities exist in an airspace, but each vehicle gets services from single entity.



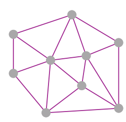
FEDERATED

Multiple providers exist for most services, each aircraft can choose between entities.



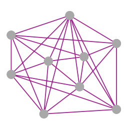
PEER TO PEER / CLOSEST PEER

No entity provides services, aircraft communicate locally with nearest neighbors.



DISTRIBUTED

No entity provides services, vehicles communicate globally and directly, relative to flight plan.



Communication

Participating in controlled airspace requires two-way, real-time communications on board all aircraft. The communications must be performant and secure. High bandwidth and low latency is necessary to quickly and safely respond to threats. Performance-based requirements allow operators to equip the best available technology and it incentivizes market innovation.

Aircraft will also need to meet navigation performance standards. Navigation may be assisted by GPS, ground-based beacons, or other technology. Aircraft may need to maintain precise navigation in areas like urban canyons, where multipath effects degrade traditional navigation accuracy.

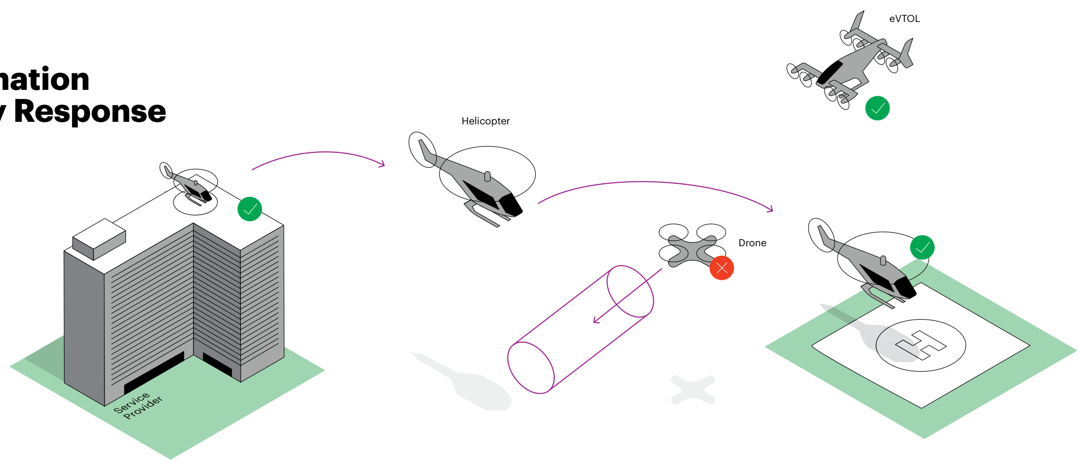
With traffic management services maintaining separation for managed drones, detect and avoid (DAA) is a backup. Simulations show that it works well in low-density regions, while strategic and tactical management work better at higher densities[17]. When there are more than a few drones in a 2 square kilometer area traveling at 100 knots, DAA creates follow-on conflicts caused by the resolution of the first conflict. The safest solution is a hybrid between management and DAA. If dangerous conditions can be anticipated, strategic airspace management adapts well. Tactical airspace management, meanwhile, is effective at avoiding near-term threats and keeping density lower. DAA is then a secondary option, avoiding follow-on effects.

Communications channels must be designed with security in mind to limit vulnerabilities such as spoofing of flight plans. Without this, malicious actors could potentially interrupt communication between an aircraft and management so that a flight cannot be tracked, or compromise systems to give the aircraft false instructions. Communication providers must also protect against message deletion through deliberate signal jamming or unintentional interference. This may lead to unexpected or even unsafe congestion or misallocation of resources. Protocols which ensure data integrity must be used to guard against deletion or injection attacks that modify messages. GPS spoofing or overshadowing could be defended against with redundancy or cross-validation. Regulators will be responsible for setting data privacy requirements, as this will affect the solutions used to guard against eavesdropping attacks.

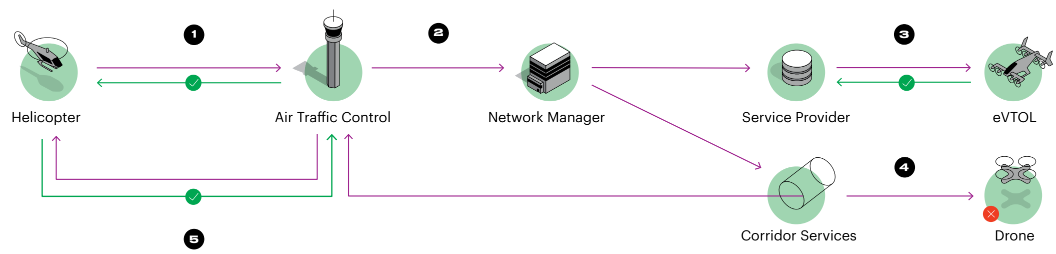
GPS Spoofing and overshadowing: Spoofing attempts to fool a GPS receiver by broadcasting incorrect GPS signals. In the case of an overshadow attack, the false signal is boosted to such levels it drowns out the accurate data.

ATM-UTM Coordination during Emergency Response

One critical area for new communications will be in emergency response. Rapidly creating new flight plans in emergencies will become more complex as the number of actors in the airspace increases. Today, an EMS aircraft receives an urgent call and communicates directly with a control facility, and ATC gives it priority clearance to fly. Tomorrow, the request from the aircraft will need to be pushed throughout the entire network so that is can safely cross existing corridors or flight paths without conflict. The system will also be robust enough to cope if communications fail, remaining safe and allowing emergency operations to continue.



1. Helicopter requests emergency takeoff clearance, clearance approved.
2. ATC notifies network manager, which notifies UTM service providers and corridor control services.
3. UTM service provider computes new flight plan, advises new trajectory, and eVTOL aircraft confirms.
4. Corridor service instructs affected drones to expedite transit through corridor. Drone fails to respond.
5. Corridor service informs ATM of drone non-compliance in flight path, ATC assigns helicopter a vector for traffic. Helicopter confirms.



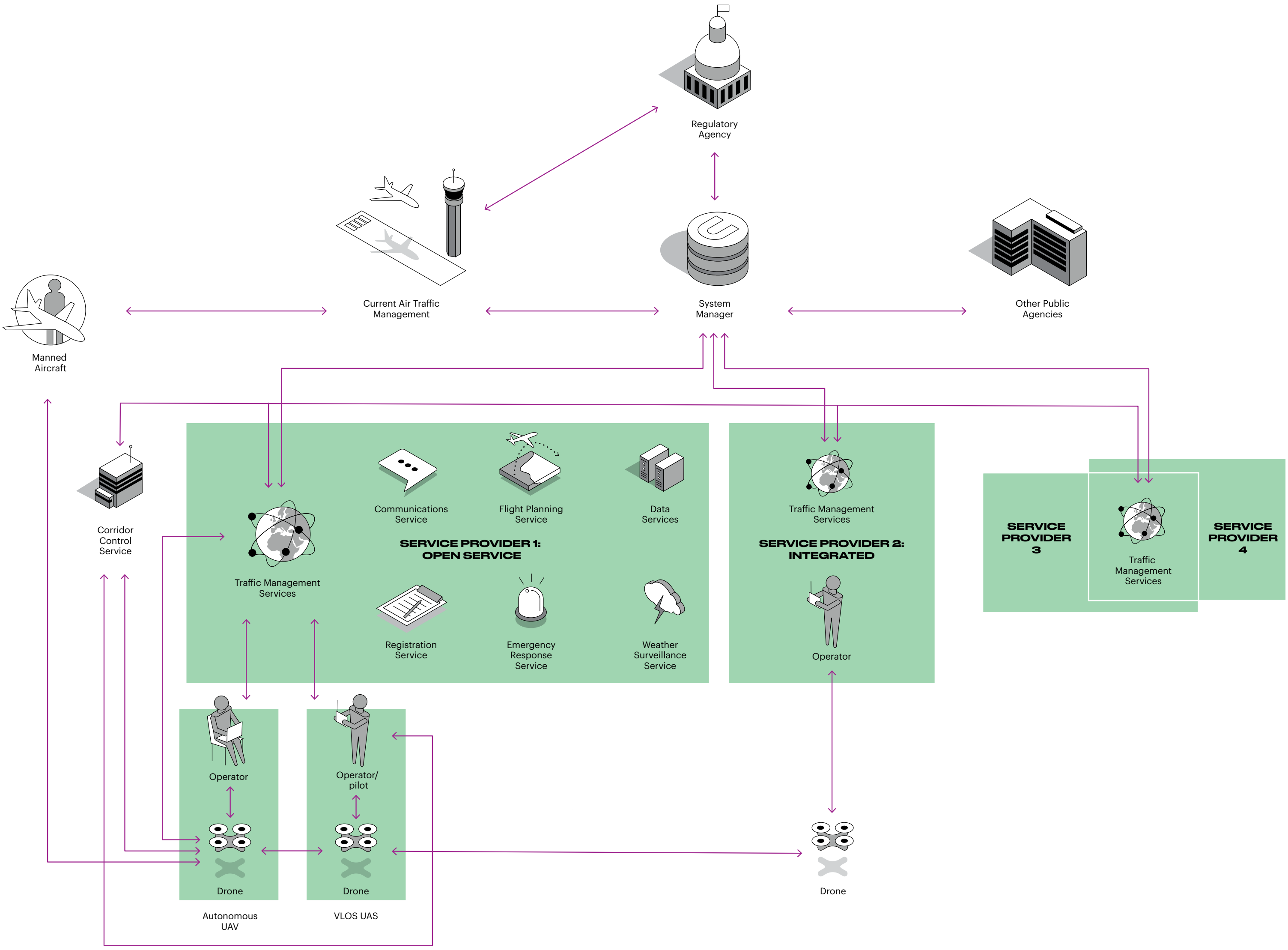
A UTM Service Stack

The system manager provides a single, authoritative system to coordinate digital traffic services. This is implemented and operated under the auspices of government regulatory agencies. Scope will vary between countries.

Digital traffic management services manage the flights of aircraft in broader airspace. The services coordinate with each other to ensure safety at all stages to ensure that flight plans are deconflicted, aircraft maneuvers are coordinated, and emergency response is deconflicted rapidly. These are complemented by corridor control services that provide guidance for drones taking off, landing, or traversing specific airspace corridors.

All the other services support traffic management and corridor control services. These include: weather information, surveillance, information, registration, and more. Each one should inform the others of their decisions, to assist each other in making the best possible decision.

A service provider may utilize their own certified traffic management service, or contract with other providers that offer a certified service. This allows for the flexible composition of service providers that may specialize in a particular set of use cases, services, functionality, or regions.



Blueprint for Regulation

Aviation has a safety culture of continuous learning and improvement. Pilots, controllers, and maintenance personnel are all part of the foundation of safe operations. Expanding these principles to unmanned operations is fundamental to future airspace safety.

Safety Culture: Many decades of experience have led the aviation industry to focus intensely on safety as a priority. A conservative approach to operations, from task checklists to open communications, has led to air travel becoming the safest form of global transport.

ETOPS: Extended Operations rules allow aircraft on longer flights to fly further from the nearest airport—for example ETOPS-180 certification means that an aircraft must always be within 180 minute range of a suitable airport in case of engine failure. Altiscope proposes similar rules about how long an aircraft can fly that are checked during flight planning and submission.

SORA from JARUS: The Specific Operations Risk Assessment is a methodology for establishing confidence that a particular flight operation can be conducted safely. JARUS, the Joint Authorities for Rulemaking on Unmanned Systems, is a group of regulatory experts from 54 countries.

Risk Assessment

Using all available data about potential threats to calculate risk is critical to safe operations. Comprehensive Safety Management Systems (SMS) identify, analyze, and mitigate a wide range of these risks. Threats include failures in avionics, navigation, and communication. They can also include bad weather, or pushing an aircraft beyond its capabilities. Depending on the capabilities of the aircraft, its path, and the other aircraft in the area, the flight will have a different risk assessment. Flying over a city center has more potential harm to people on the ground than a flight over a river, for example.

Traditional risk assessment approaches are problematic when applied to high-volume, highly automated unmanned operations. Their conclusions rely largely on qualitative aspects, and different people assessing the same risks will often reach different conclusions. Creating a quantitative risk assessment workflow is a vital step to enabling high-volume automated flight plan processing while maintaining safety.

When it comes to risk, authorities can set the thresholds or policies for safe flight under different conditions, and design airspace structure, procedures, equipage, and other requirements to keep harm rates within acceptable limits. Those conditions are enforced when a flight plan is submitted for approval (such as permission to access certain airspace, corridors, or routes), and in pilot ratings and system certifications (similar to VFR and IFR flight). Risk assessments must use a common methodology so that they are directly comparable between services, and to the thresholds set by authorities. Altiscope and JARUS[21] are developing open risk assessment frameworks. Both are being collaboratively developed with regulators and industry. The SORA from JARUS is qualitative in how it categorizes threats and resultant risk classes. By contrast, Altiscope is using statistical modeling and relevant data to construct a quantitative model with a variety of outputs.

Security

Air traffic control systems rely on redundant dedicated links to securely exchange data. External users have limited points of entry to these networks, which often function like one-way streets. ANSPs also use dedicated fiber to connect radar antennas and remote communication outlets with controllers. All of this limits the attack surface. Each component in the ATM network is certified to high-reliability standards for uptime and latency, including backup power and fallback systems, and is routinely subject to penetration testing.

Distributed UTM systems introduce a number of new challenges in ensuring security. Each connection between two service providers introduces two new attack surfaces. A region with multiple providers will easily have many more attack surfaces than today's ATM network.

Regulators have several tools to ensure security. Many of the strategies used to keep ATC systems safe, including dedicated and one-way links, limited physical access to network equipment, and redundant power and backup systems can be employed. Requiring operators to register to receive encryption keys can limit access to only known users, and regular audits (announced and unannounced) of system providers can ensure compliance with certification requirements.

Certification and Licensing

Certification and licensing—currently required for aircraft, avionics, operators, traffic management service providers, and pilots—will follow substantially the same form as today.

Under current FAA/EASA regulations, performance and training requirements for each certification or license parallels the level of safety required. Recreational and private drone pilots do not operate for hire, may be restricted from flying in certain airspace classes, and have different training requirements from commercial pilots. Recreational operators do not need a certificate, whereas commercial operators must have an operating certificate that ensures they have the personnel, training, and systems in place to protect the safety of their employees, customers, and the general public. Similarly, manufacturers and avionics suppliers must certify their equipment to performance specifications.

Services that provide safety or security-critical services will require accreditation and licensing. This list is kept to a minimum. Regulatory agencies are responsible for the licensing and a periodic review and renewal. Agencies make performance results of licensed services publicly available.

A licensing and certification regime provides regulatory authorities with an enforcement mechanism: a pilot's license can be suspended, an operating certificate can be revoked, while airworthiness directives are used to correct unsafe conditions in a product.

Standards

Standards are necessary for interoperability between suppliers, while allowing each product to innovate in their own way. Standards are required for:

- Air traffic management and digital traffic management suppliers, including notification of threats, conflict resolution, and emergency procedures.

- Between traffic management service suppliers, including flight plan exchange, conflict detection, and agreement on conflict resolution.

- Between system management service and traffic management services, including discovery of service suppliers, flight plan data, and auditing.

- Between traffic management services and corridor control services, for flight planning (sequencing, flow control) and in-flight safety and capacity management (tactical deconfliction from corridor control service).

- Aircraft performance metrics, for traffic management services to accurately plan, assess, and guide aircraft safely and within capabilities.

Other standards will speed the development of necessary technologies. Communication standards open the field for multiple providers of aircraft and ground communications. Navigation standards focus research and development organizations to meet performance targets with for a well-defined market.

Most likely, the required standards will evolve out of consensus-based industry working groups, using comparable levels of reliability, latency and interoperability specifications for similar conventional ATM systems, with an aim of ensuring overall equivalent levels of safety and performance are maintained.

Blueprint for Stakeholders

For unmanned applications to thrive, many stakeholders must come together to advance their respective domains. Advances can be accomplished in phases, with each phase dependent on the previous ones. This model was first proposed for autonomous vehicles and mirrors SAE J3016A[22].

hint: the next page is sideways

	LEVEL 0: NO AUTOMATION	LEVEL 1: HUMAN ASSISTANCE	LEVEL 2: PARTIAL AUTOMATION	LEVEL 3: CONDITIONAL AUTOMATION	LEVEL 4: HIGH AUTOMATION	LEVEL 5: FULL AUTOMATION
	Human pilots are responsible for the safe operation of all aircraft. Conventional aircraft avoid each other with well-defined airspace constructs, pilot vigilance, and onboard collision avoidance systems. Drones are legally limited to flying within sight of the pilot.	Computer systems assist human pilots by reducing workload and providing safety protections. Automation is introduced in the form of autopilots, while navigation assistance for the pilot becomes widespread with GPS and navigation aids. Drones can be used commercially, but with very limited access to airspace.	For routine flight, onboard automation systems now control the majority of activities. Pilots supervise the systems and take control only when necessary. Aircraft and drones can coordinate using their ground-based systems to co-exist at low densities.	Automation systems perform the entirety of flight operations, falling back to pilot control when performance-based conditions cannot be met. Through well-defined procedures, flight rules, and communication channels, aircraft and drones can operate in proximity to each other, such as near airports.	Supervisors monitor fleets as they coordinate amongst themselves, rather than requiring pilots for individual aircraft. Drones can fly in larger automated fleets, and commercial aircraft are capable of single-pilot operation. Automation systems actively assess risk and provide advance notice to human supervisors when their attention will be necessary.	Autonomous systems are proven and certified for use in all conditions and during all phases of flight. Drones safely co-exist with helicopters, general aviation, and commercial aviation in dense, complex urban areas. Performance of onboard systems combined with their service providers' capabilities determines when and how airspace can be used.
OPERATIONS ENABLED	**Visual line of sight (VLOS), commercial drone operations**	**Improves safety for VLOS commercial drone operations and Beyond Visual Line of Sight (BVLOS) operations**	**Autonomous BVLOS operations in low-density airspace**	**Safe integration of BVLOS in controlled airspace**	**Fleet operations at moderate scale**	**On-demand autonomous operations in dynamic, high-density airspace.**
POLICY MAKERS AND REGULATORS	• VLOS Flight Rules (eg. US Part 107, NZ 101/102)	• Waiver program • VLOS pilot licensing	• Authorization policy • Registration • ID equipment requirements • Emergency and priority access	• Basic & Managed Flight Rules • Pilot/System rating • Flights over people • Equitable access provisions	• Autonomous certification • Detect and Avoid certification • Fleet operating certification • Risk-based approval	• Third-party accreditation for certification services
TECHNICAL PROVIDERS AND STANDARDS BODIES	• Wireless command and control	• Basic sense and avoid (ex. ACAS-X) • Basic surveillance (ex. ADS-B)	• Vehicle-to-infrastructure comms • Security requirements • ID surveillance equipment	• Navigation and DAA performance requirements • Traffic Manager accreditation • Risk assessment	• Service-to-service coordination • Corridor control accreditation	• Vehicle-to-vehicle information sharing • Multi-modal transport coordination
AIRSPACE OPERATORS (ANSPS AND REGULATORS)	• Published aeronautical charts • No fly zones • Altitude restrictions	• PinS Procedures • VFR corridors • Altitude restrictions • Automated geofencing and altitude limits	• UAS tracking • Expanded Instrument Procedures • Automated approvals	• Unmanned procedures • Corridor configuration	• High-density controlled airspace established	• Dynamic and performance-based rules for access to airspace
AIRSPACE AND UNMANNED SERVICE PROVIDERS	• Flight plan filing • Aircraft and pilot registry	• SWIM	• Network Manager • Operator flight planning • Unmanned Aeronautical Information Service	• Digital Traffic Managers • ATM-UTM coordination • Info Service Providers • High assurance IT infrastructure • Service provider marketplace	• Corridor control services • Specialized traffic management	• ATM integration • Congestion avoidance

TODAY

Stakeholder Responsibilities In Levels of Automation

What Comes Next?

This is the underlying reality of a future with autonomous aircraft. Not only is airspace integration possible or even preferable, it is entirely achievable. Some parts of this Blueprint are complex and technical; others are intended to be illustrative. All of it, however, is meant to be inspirational. This is a future we can build together.

But Blueprints like this are only one element in achieving change. Crafting an airspace where traditional aviation and unmanned aircraft can thrive requires a combination of pragmatism, cooperation, and action.

It also requires adapting to new developments, only a fraction of which we understand today. Some of these developments are things we can predict and plan for. Others have yet to be invented, or even conceived. We can say for certain, though, that as the era of autonomy arrives, new technologies, new products, and new ideas will emerge. These will add to the uses of our airspace, while also improving it. New systems will reduce risks or improve communications.

Fresh developments will increase safety levels. Progress can—and will—happen on all levels, on all tracks.

These developments are why it is so important today to build in an appreciation for aviation cultures: the cultures of safety, of security, of access. Ensuring that these foundational elements remain in focus is a duty held by every participant. We must be careful and apply forethought.

Evolution in air traffic happens slowly, but it happens, and it is lasting. Take the introduction of radar services at individual airports with TRACON in 1981; by the 2000s, it had morphed into consolidated operations that could serve dozens of airports from a single facility. The choices we make now will affect the world for generations to come.

Building the best possible version of the future requires imagination. Doing it properly demands collaboration. So we ask you—whether you are a policy maker, a participant, or a stakeholder—to join our community defining these developments, and shape how tomorrow's airspace will operate. The blueprint for a safe, efficient, and fair sky must be developed together.

www.utmblueprint.com

Glossary

A

Aircraft*: A device that is used or capable of controlled flight.

Air traffic management, ATM: The existing system for managing or controlling manned aircraft; includes Air Traffic Control (ATC) services.

Autopilot*: An automated system that directly operates an aircraft.

B

Basic flight: A category of flights (or segment of a flight) that operates independently of traffic management services, taking full responsibility for safety and routing.

Beyond Visual Line of Sight, BVLOS: Operation of a drone beyond the visual line of sight of a remote pilot or observer. Compare VLOS (Visual Line of Sight).

C

Corridor control service*: A digital traffic management service that that has authority for a specific corridor to safely manage the flow in, out, or through the corridor.

D

Detect and avoid: A system which allows aircraft to spot obstacles or dangers and take action to avoid collision without human intervention. This can happen through sensors on other aircraft or on the ground, which send an alert to the endangered aircraft. Or it may occur when the autonomous vehicle itself senses a problem and takes action on its own.

Distributed authority: A system in which any individual actor is able to make decisions and take action based on information and a set of agreed rules, rather than refer to a central authority for permission.

Drone: An aircraft without a human pilot on board; includes unmanned aerial vehicle (UAV) and remotely-piloted aircraft (RPA).

Digital traffic management services*, or traffic manager: A service for assisting, organizing, and governing aircraft using digital means in the airspace. The service is responsible for preventing collisions and maintaining orderly flow. Compare with the ICAO term Air Traffic Services[24].

E

eVTOL*: Electric or hybrid-electric vertical takeoff and landing aircraft; they can be winged or wingless, manned or unmanned, and have any number of applications from packages and cargo to air taxi.

F

Fleet supervisor: A person or automated system that manages flight plans, aircraft assignments, and performs business optimizations. The fleet supervisor dispatches aircraft with a flight plan that is followed by an pilot, autopilot, or supervisor.

Flight plan: A record of the intended route in time and space that an aircraft expects to follow while in flight.

G

Geofence, geofencing: The creation of virtual boundaries in the airspace which constrain a drone, either to stay within its limits, or remain outside them.

GPS spoofing: An attempt to fool a GPS receiver by broadcasting incorrect GPS signals.

L

Local authority: A government or equivalent organization that has authority to set policy and restrictions on land and airspace usage within a local area.

M

Managed aircraft*: An aircraft flying a managed flight under the guidance of a digital traffic management service.

Managed flight: A category of flights (or segment of a flight) where the path is controlled by a traffic management service which also provides separation services.

N

NASA UTM: NASA's UAS Traffic Management program started in 2015 in collaboration with the FAA and other federal agencies.

O

Operator*: The person or organization that sets a mission for a drone, provides oversight of the drone in flight, and takes responsibility for the effects of the drone's flight.

Overshadowing: An attack on computer systems in which a false signal is boosted to such levels it drowns out the accurate data.

Owner: The person or organization that owns the aircraft and is responsible for maintaining its airworthiness.

P

Pilot: A human operator of an aircraft (onboard or from the ground).

R

Regulator, regulatory agency: The singular organization that has legal authority to regulate air traffic in a location, along with that organization's delegates (such as an ANSP).

S

Safety culture: The aviation industry focuses intensely on safety as a priority, including a conservative approach to operations, from task checklists to open communications.

Self-piloted aircraft*: An aircraft whose flight path is managed exclusively by an autopilot without the need for a pilot.

Separation: The minimum safe distance required between aircraft, set by standards or regulation.

Service: The abstract provision of a function related to drone flight, provided to one or more stakeholders. For self-piloted or managed services, much but not all of the function is provided digitally.

Service provider: An organization that offers a collection of services that manage aircraft in flight, including drones and self-piloted aircraft. Compare to the ICAO term Air Traffic Services[24].

SESAR Joint Undertaking: The technological pillar of Europe's Single European Sky initiative, coordinating and concentrating all EU research and development activities.

Supervisor*: A person (onboard or on the ground) who relies on an autopilot to operate an aircraft in normal conditions. The supervisor is available to intercede and provide a new plan to the autopilot or directly/remotely operate the aircraft. There may be a many-to-one relationship where one supervisor oversees multiple aircraft.

System Wide Information Management, SWIM: The FAA's System Wide Information Management Program to implement a set of Information Technology principles and provide users with relevant and commonly understandable information.

System manager*: A single, authoritative service to coordinate digital traffic services. This is implemented and operated under the auspices of government regulatory agencies. Scope will vary between countries.

U

UAS Traffic Management: A networked collection of services that work together to safely direct self-piloted air traffic based on common rules.

Unmanned aerial system, UAS: A system that comprises the flying vehicle, communications link and any ground infrastructure, such as a handheld remote control unit or a computer that sends commands to the vehicle.

V

Visual Line of Sight, VLOS: Operation of a drone within visual line of sight of a remote pilot or observer. The remote pilot must be able to see the drone sufficiently well to have continuous awareness of its location, heading, and status, as well as the drone's environment in order to avoid other aircraft, structures, and terrain.

Terms marked with * require a license or certification to operate.

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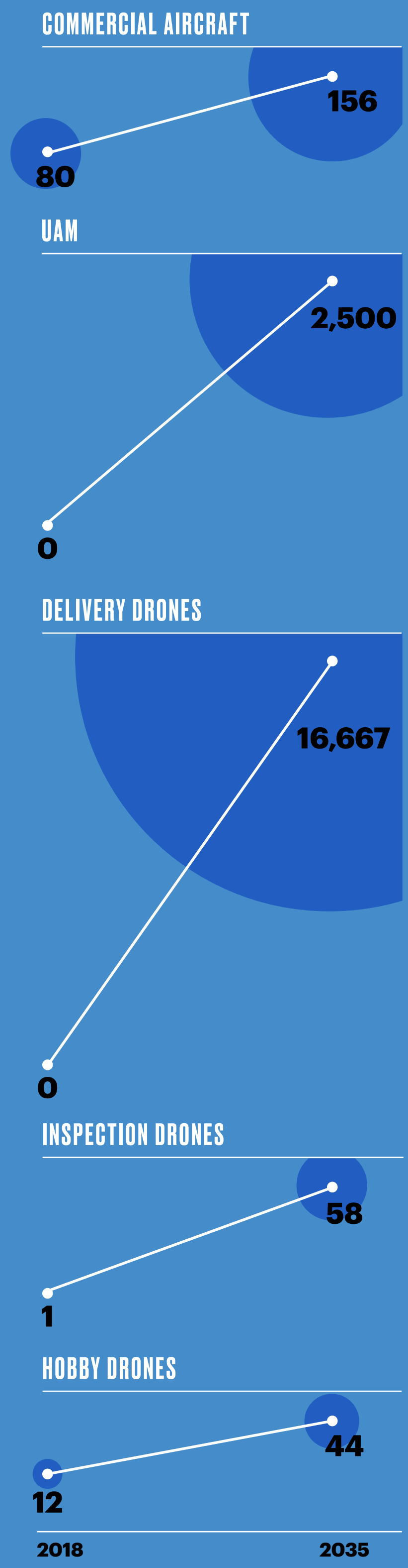
How air traffic in Paris will increase by 2035

Average number of flights per hour.



Source: Based on Altiscope drone volume model[23].