STUDY

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Unmanned Aircraft Systems integration into European airspace and operation over populated areas

Final Study

Transport and Tourism

Policy Department for Structural and Cohesion Policies
Directorate-General for Internal Policies
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RESEARCH FOR TRAN COMMITTEE

Unmanned Aircraft Systems integration into European airspace and operation over populated areas

Final Report

Abstract

This study provides research into the operations of Unmanned Aircraft Systems (UAS) within European Airspace and, in particular, over populated areas. It provides an overview of good practices and military and civil UAS integration. This research has been used to inform an assessment of the Drone Strategy 2.0 and the extent to which it addresses the challenges and barriers identified. The study concludes with a set of proposed policy recommendations.

This document was requested by the European Parliament's Committee on Transport and Tourism.

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LIST OF ABBREVIATIONS

ADS-B	Automatic Dependent Surveillance - Broadcast
ACAS	Aerial collision avoidance system
AI	Artificial Intelligence
ANSP	Air Navigation Service Provider
AOM	Aerodrome operating minima
ATC	Air Traffic Control
ATM	Air Traffic Management
BVLOS	Beyond Visual Line of Sight
CAA	Civil Aviation Authority
CNS	Communication navigation and surveillance
COTS	Civilian-Off-The-Shelf
C-UAS	Counter-UAS
DAA	Detect and avoid
DOS	Denial of Service
EASA	European Union Aviation Safety Agency
EDA	European Defence Agency
EUROCAE	European Organisation for Civil Aviation Equipment
EUROCONTROL	European Organisation for the Safety of Air Navigation
eVTOL	Electric Vertical Take Off and Landing
FAA	Federal Aviation Administration
FUA	Flexible Use of Airspace
GDPR	General Data Protection Regulation
GNSS	Global Navigation Satellite System

GPS	Global Positioning System
HALE UAS	High-Altitude, Long Endurance UAS
IAM	Innovative Air Mobility
IAS	Innovative Air Service
ICAO	International Civil Aviation Organization
IFR	Instrumental Flight Rules
ISR	Intelligence, Surveillance, Reconnaissance
IT	Information technology
LIDAR	Light detection and ranging
LoS	Line of Sight
MALE UAS	Medium-Altitude Long Endurance UAS
MIDCAS	Mid-air collision avoidance system
MOTS System	Military off the shelf system
MTOM	Maximum take-off mass
NAA	National Aviation Authority
NATO	North Atlantic Treaty Organisation
NORAD	North American Aerospace Defence Command
NOTAM	Notice to Airmen
PDRA	Predefined Risk Assessment
R&D	Research & Development
R&I	Research & Innovation
RPAS	Remotely Piloted Aircraft Systems
SAFETERM	Safe Autonomous Flight Termination
SESAR JU	Single European Sky ATM Research Joint Undertaking

SORA	Specific Operations Risk Assessment
STS	Standard Templates
TBO	Trajectory Based Operations
TCAS	Traffic Collision Avoidance System
UAS	Unmanned Aircraft Systems
UAV	Unmanned Air Vehicle
USSP	U-space service provider
UTM	Unmanned traffic management
VFR	Visual Flight Rules
VHF	Very High Frequency
VLD	Very large scale demonstration
VLOS	Visual Line of Sight

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1. EXECUTIVE SUMMARY

KEY FINDINGS

- The integration of Unmanned Aircraft Systems (UAS) within airspace will happen in stages. Current operations are in segregated airspace away from manned aircraft. Integration with manned aircraft will require improved technical and operational procedures. These are currently being looked at as part of Research & Innovation (R&I) programmes.
- UAS have similarities and differences with manned aircraft in terms of how they operate. The focus should be on areas in which they differ, such as manoeuvrability, communications, performance and the diversity of their operating environments.
- Operations over populated areas require a specific focus on ground risk. Integration into airspace over these areas needs to account for dynamic changes in population densities as well as safety, privacy, security, noise and social acceptance concerns.
- Good practices have been identified across the areas of user-friendly platforms and information sharing, step-by-step approaches to use cases, engagement with industry and city stakeholders and military and civil synergies.
- There are a number of lessons that can be learned from Military and Civil cooperation on systems, technologies and processes. However, procurement barriers could be eased to support the adoption of civil technologies beyond R&I.
- Incentives for industry are an area in which the EU is arguably slightly lagging behind the US and China, where government programmes are seeking to reduce cost and risk for private sector development in the UAS and electric vertical take off and landing aircraft (eVTOL) markets.
- Drone Strategy 2.0 provides good coverage of the issues currently facing the UAS industry. However, it may underplay some of the difficulty in achieving full integration, which requires further coordination and prioritisation to keep the EU on track to achieve a large-scale drone market in the EU by 2030.

Introduction

Drones have the potential to become an increasingly important part of mobility strategies. The European Drone Strategy 2.0, which was published in November 2022 by the European Commission, provides political direction on the next steps of Unmanned Aircraft Systems (UAS) development within the European market.

However, there remain key technical, procedural, social and regulatory requirements that need to be addressed if UAS are to be safely and commercially integrated within European airspace and wider society. Accordingly, the objective of this study was to assess the challenges and possible solutions of integrating UAS within European airspace and, in particular, over populated areas, to consider military and civil integration, to identify and analyse good practices and to undertake an assessment of the Drone Strategy 2.0.

Integration of UAS within European airspace

The implementation of UAS integration within European airspace is happening in stages, with the most complex aspects due to take place after the simpler issues have been resolved.

While UAS have a lot of similarities to manned aviation, the fact that they are integrated systems, have different flight characteristics and operate without a pilot on board requires many new solutions for airspace integration. As a result, there are some safety issues regarding occurrence under-reporting (meaning a detailed description of a safety issue), collision avoidance and counter-UAS technology where further work is needed.

The economic potential of the UAS market is significant and research and innovation (R&I) into the technical development of UAS for various operational use cases is already underway. However, there remains a need to develop specific programmes to address the adoption of these technologies at scale as well as the operational and regulatory mechanisms required to support them.

Operations over populated areas

Low-altitude UAS operations over populated areas will be essential in a large number of cases. These bring with them a number of associated safety, security and privacy risks not applicable to existing manned aviation operations, which are largely banned in such areas.

Population density analysis is an important consideration in risk assessments applied to drone operations. The methods for identifying densely populated areas are also likely to move from static models, which are more commonly applied to manned aircraft, towards more dynamic approaches.

Social acceptance is a particular area that requires additional strategies to normalise the operation of UAS over populated areas. The provision of information to the public through trials and demonstrations to increase awareness around drone operations and their societal benefits will be important as more use cases become available.

Good practices

The EU is moving ahead with regulation of UAS operations, but there are elements of good practice identified in Member States and third countries that could be applied more widely to the EU as a whole. On a global scale, incentives to industry are an area in which the EU is arguably slightly lagging behind the US and China, where government programmes are seeking to reduce cost and risk for private sector development in the UAS and electric vertical take off and landing aircraft (eVTOL) markets.

Good practices have been identified in the areas of user-available information via accessible applications, publications and training on privacy and weather-related issues. A step-by-step approach to airspace integration has also been identified, adopting low-risk operations first before moving to higher-risk scenarios. This has allowed time to address social acceptance issues relating to wider UAS adoption, with certain countries considering social acceptance roadmaps.

Further good practices have been identified in the use of demonstrators and industry partnerships to increase the support of stakeholders by directly involving them in key decisions regarding UAS operations. Military and civil integration schemes that are already ongoing in third countries have also been identified as good practices.

Military and civil drone integration

Integration of military UAS into mixed airspace will be able to benefit significantly from the decades of experience gained by Air Traffic Management (ATM) in integrating manned equivalents in EU skies.

Mutual agreement with manufacturers and operators concerning responsibilities and procedures, greater UAS familiarity among ATM personnel and an understanding of how to manage the 5% of more complicated UAS operations should all be achievable and present no serious problems for the EU airspace environment. However, as with most aviation subjects, planning should be approached with the understanding that errors and unforeseen issues will arise and hence the efforts should be regarded as a fluid and evolving process.

Although synergies will develop between the civil and military spaces, these are likely to occur naturally as a result of market pressures rather than as an area where direct action can be taken at an EU level. Concurrent technology interests will spur the exchange of concepts, research and systems.

Drone Strategy 2.0

The Drone Strategy 2.0 provides a comprehensive set of flagship actions to support the evolution of the drone ecosystem and promote safe use of drones for a range of aerial operations, as well as, in time, innovative air mobility solutions in urban areas.

We assess that the Strategy correctly captures the need but may downplay the difficulty of scaling operations, both in terms of scope and diversity of operation and particularly in achieving full integration with traditional manned aviation. The Strategy also fails to provide a clear set of actions on how to overcome issues of social acceptance of UAS and issues relating to ground risk.

Conclusions and recommendations

Overall, we conclude that Europe is making good progress in the support elements necessary for UAS adoption, mostly driven by its regulatory frameworks and R&I schemes. The Drone Strategy 2.0 provides an important step in consolidating the required actions needed to achieve the vision for 2030. Achieving complete integration of UAS in airspace will nonetheless require prioritising and careful monitoring of the progress of the flagship actions identified in the Strategy. Scalable technical, commercial and operational solutions will also be required while maintaining the current level of European safety standards, protecting national security interests and encouraging the social acceptance of stakeholders.

Our recommendations are set out below:

- The European Parliament should ensure that large-scale, long-running demonstrators across different environments are supported.
- The EU should prioritise R&I calls and associated funding for the most challenging airspace integration issues.
- The European Parliament should continue to promote the role of citizens in UAS operations and encourage the development of EU-wide social acceptance guidelines.
- The European Parliament should ensure that the European Commission takes a data-led approach to delivering the strategy.
- The European Parliament should promote the sharing of information across private and commercial users of UAS.

- The EU should remain aware of civil and military integration in third countries and consider the adoption of fast-track schemes such as US Agility Prime.
- The European Parliament should ensure that the European Commission has a strategic implementation plan to deliver the strategy.
- The EU should link the technological roadmap identified in the strategy to a wider European industrial plan for the development of UAS and its associated services.
- The European Parliament should promote participation in UAS adoption across the EU.
- The European Parliament should ensure that UAS regulation does not become a prohibitive barrier to adoption and competition within the market while ensuring EU safety standards are upheld.

1. INTRODUCTION

1.1. Background and study objectives

Drones have the potential to become an increasingly important part of mobility strategies. The Commission Communication on '[Sustainable and Smart Mobility Strategy - putting European transport on track for the future](#)', published in 2020, recognises the importance of drones (unmanned aircraft) as a game-changing mobility technology and the need to put in place an enabling framework for innovation. Furthermore, the Commission Communication also underlines the relevance of drones in the area of freight and multimodal logistics within and beyond the urban space. The Sustainable and Smart Mobility Strategy mentions that "the Commission fully supports the deployment of drones and unmanned aircraft and will further develop the relevant rules, including on the U-space, to make it fit for enhancing safe and sustainable mobility" and states that it "will also adopt a 'Drone Strategy 2.0' setting out possible ways to guide the further development of this technology and its regulatory and commercial environment" (European Commission, 2020).

The objective of this study is to assess the challenges and possible solutions of integrating Unmanned Aircraft Systems (UAS) within European airspace and, in particular, over populated areas. The study also considers military and civil integration, good practices, and the assessment of Drone Strategy 2.0. See Annex A1 for a description of the methodology and data sources.

1.2. Definition of a drone

The term UAS (or unmanned aircraft system) is used to refer to a drone, its system, and all the other equipment used to control and operate it. A UAS is therefore made up of three key components:

- An unmanned vehicle that can operate without a pilot on-board;
- A ground control system that allows the pilot to remotely control and/or monitor the operation of the unmanned vehicle;
- A bidirectional link between the unmanned vehicle and the ground control system that provides control, status, and other relevant information.

There are many types and shapes of drones: some are fixed-wing, rotary-wing, or hybrid (rotary and fixed-wing). Power sources include electric sources as well as more conventional aviation power sources (such as jet engines). Capabilities and weight vary greatly from recreational models to large military ones.

1.3. Definition of Innovative Aerial Services (IAS)

Due to the lack of a definition, the European Union Aviation Safety Agency (EASA) has developed the notion of Innovative Aerial Services (IAS). The term 'IAS' refers to a group of operations made possible by new airborne technologies, including aerial operations such as surveillance, inspections, mapping and telecommunication networking as well as transportation of people and/or goods. IAS can be segmented into 'aerial operations' (surveillance, inspection, imaging, etc.), as well as a whole new emerging market focused on passenger transport called Innovative Air Mobility (IAM), which includes international, regional, and urban air mobility. Electric vertical take-off and landing (eVTOL) aircraft are designated as the first UAS planned for passenger transportation as part of IAM.

1.4. European UAS regulatory framework

1.4.1. UAS operating framework

EASA has established a framework for the integration of UAS based on two regulations:

- Delegated Regulation (EU) 945/2019 which defines the airworthiness of UAS and also defines the type of UAS subject to certification;
- Commission Implementation Regulation (EU) 947/2019 which defines requirements for operating UAS: it is risk-based and defines three categories of civil drone operations: The 'Open', 'Specific' and 'Certified' category.

Table 1: EASA categories of UAS operations

Category	Type of operations	Key requirements
Open	For leisure drone activities and low-risk commercial activities: - Flight altitude: <120 m/400 ft.; - Flight range: Visual Line-of-Sight (VLOS) operations.	- UAS under 25kg maximum take-off mass (MTOM) - No flight operational authorisation is required; - Drone operator may need to be registered; - Remote pilot may need to have completed training.
Specific	When a UAS is operated outside of the 'Open' operational limitations, such as: - Flight altitude >120 m/400 ft.; - Beyond Visual Line-of-Sight (BVLOS), when operating a UAS in an urban environment with a MTOM> 4 kg, etc.	- Drone operator needs to be registered in its Member State of residence or principal place of business; - Requires operational authorisation; - Requires drone operator to conduct a risk assessment (under the standard scenarios, Predefined Risk Assessments or Specific Operation Risk Assessment (SORA) for specific operational conditions such as at night, etc.); - May also require obtaining a flight authorisation issued by the authority in charge of a geographical zone, if needed; - Remote pilot has to have completed training dependent on the operation to be conducted.
Certified	UAS operations with the highest level of risk.	- EASA certification of the UAS required (type category and certificate of airworthiness); - Certification of the UAS operator is required; - Licence for the remote pilot is required.

Source: Steer analysis of EASA Civil drones (unmanned aircraft) (n.d.)

Prior to EU regulations being implemented, UAS operators had to rely on national Member State rules for operations and airworthiness. This has now changed:

- The 'Open' category is currently the most mature: since 2023 all UAS 'Open' operations must comply with Regulations (EU) 2019/947 and (EU) 2019/945;

- From 2024 onwards, the EASA framework will replace national regulations for the 'Specific' category. It is less mature than 'Open' but functional for some low-risk operations;
- The 'Certified' category is the least mature, due to a lack of definition for key technical enablers and proportionate guidance material for the certification of drones. This category will include eVTOL.

However, for other aspects, Member States still have to set national regulations concerning, for instance, fines for breaching the regulation, certificate conversions, geographic zones, insurance requirements, minimum age for operation, authorisations of model clubs and associations, etc.

1.4.2. Towards the integration of UAS in shared airspace

U-space is a designated area of airspace in which UAS operations are allowed. U-space may be 'segregated' in that only unmanned aviation would be allowed to operate, or 'integrated' in which case UAS and manned aviation co-exist. U-space may also support 'accommodation' as an early form of integration. Accommodation implies that contingent measures are put in place that may restrict manned aviation during an emergency UAS manoeuvre.

To support the different types of operational categories used in the EASA framework, four levels of U-space services have been defined by the Single European Sky ATM Research Joint Undertaking (SESAR JU) but only the first two are included in the existing U-space Implementing Regulation (EU) 2021/664.

Table 2: U-space services

	Type of UAS Operations	**Description**	**Services as per Regulation (EU) 2021/664**
U1	Open in segregated U-space	Foundation services provide e-registration, e-identification and geofencing[1].	• Network identification • Geo-awareness • Flight clearance service • Traffic information service
U2	Specific in segregated U-space	Initial services to support the management of UAS operations. May include flight planning, flight approval, tracking, airspace dynamic information and procedural interfaces with air traffic control.	• As above • Weather information • Compliance monitoring service
U3	Certified in accommodated U-space	Advanced services to support more complex operations in dense areas and may include capacity management and assistance for conflict detection. Availability of 'detect and avoid' (DAA) functionalities with more reliable means of communication should lead to a significant increase in operations in all environments.	Not yet defined

[1] Geofencing is a drone technology that utilises virtual boundaries to limit the movement of UAS.

	Type of UAS Operations	Description	Services as per Regulation (EU) 2021/664
U4	Certified in integrated U-space	Full services, particularly services offering integrated interfaces with manned aviation. Rely on a very high level of automation, connectivity and digitalisation for both the UAS and the U-space systems.	Not yet defined

Source: Steer analysis of SESAR JU, 2022, Regulation (EU) 2021/664)

Implementing U-space requires Member States to define and designate U-space airspaces, which will be based on a risk assessment conducted by the relevant national authorities.

2. DRONE INTEGRATION WITHIN EUROPEAN AIRSPACE

KEY FINDINGS

- U-space levels 1 and 2 have been validated as part of SESAR JU trials and research, as defined in the EASA regulations, and are being rolled out across Europe. U-space levels 3 and 4 are key to supporting full integration; however, they still need to be developed, validated, and regulated. The current on-going R&I on U-space levels 3 and 4 will support the required development, validation, and implementation.
- UAS will operate differently from manned aviation and require changes to both the rules of the air and technical requirements in order to support their integration into airspace.
- Safety topics such as automated collision avoidance, occurrence reporting, mitigations for weather, and counter-UAS require clear guidelines and processes.
- Security risks are increasing with the advancement of UAS technology. Cybersecurity is a particular concern alongside the weaponsiation of civilian UAS and their use for criminal activity, such as the disruption of critical infrastructure.
- There is significant economic potential for the UAS market due to the different possible applications, but further technical and regulatory measures, such as risk assessments, licencing, insurance, or operations of multiple drones by a single pilot, are required to realise these benefits.
- For the military side, the barriers include procurement and the need to ease the process to allow for dual use and the adoption of civil technology.

2.1. Introduction

The integration of UAS with manned aviation in European airspace requires careful integration with existing air traffic. Currently, operations of UAS occur in separated airspace, with operational, technical, and regulatory measures needed to safely move to integrated operations. This section addresses the challenges involved in integrating drones into European airspace and some of the measures that can be implemented to move towards this objective.

2.2. Technical challenges

2.2.1. Communication, navigation and surveillance (CNS)

A pressing issue for drone integration is communication, navigation and surveillance requirements. CNS used in manned aviation is based on the radio frequency spectrum that was appropriate more than 50 years ago. However, the spectrum and associated technologies are less suited to UAS, and in the case of Very High Frequency (VHF) voice (and data) and Mode S radar frequencies[2], they are physically unable to handle the significant increase in airborne vehicles.

[2] Traditional aviation uses a reserved area of the VHF band for voice communications and 1090/1030 MHz for secondary surveillance radar and ADSB; both bands are reaching saturation and their use cannot be extended for UAS.

In response to this outdated CNS infrastructure, SESAR has developed an integrated CNS (ICNS) concept for new technologies to be integrated into the ATM system and for old technologies to be decommissioned (SESAR, n.d.). This development should also include shorter-range technologies that would better support self-separation in urban environments.

A further issue identified by SESAR is the need for a single reference altitude (SESAR, 2021). Manned aviation uses barometric altitude and requires the pilot and controller to set the same reference pressure, whereas UAS use geometric altitude based on the Global Navigation Satellite System (GNSS). The use of two different systems raises issues around positioning and the possible different altitude readings between the two.

The future connectivity of aviation and the requirement for upgrades have resulted in a joint cooperation initiative between EASA, the Federal Aviation Administration (FAA), Airbus and Boeing (EASA, 2022). 5G, in particular, is an emerging area of consideration for airspace users because of its possible interference with radio frequencies used for aviation systems (IATA, 2022). The spectrum allocated to 5G has been recognised as a safety issue for aircraft due to the competing needs of different users, such as telecommunication providers and aviation. This is an issue currently being faced in the USA and a potential future issue for Europe (EUROCONTROL, 2022). The move away from legacy systems to a modernised CNS is seen as a solution for tackling these issues.

2.2.2. Interaction with manned aircraft

One of the main concerns with airspace integration is how UAS will interact with manned aircraft in uncontrolled (or Class G[3]) airspace. Manned aircraft use 'see and avoid' to self-separate using 'rules of the air' specified by ICAO (2005). These rules have been transposed by the EASA (2023) to ensure harmonised implementation within the EU.

The key issue for UAS is how to implement 'see and avoid' without a human on board. The automation of 'see and avoid' is referred to as 'detect and avoid' (DAA), where detect is the ability to identify other air vehicles and avoid is the ability to manoeuvre to avoid air collisions and, potentially, select a 'crash site' with minimal collateral damage. 'See and avoid' rules are based on mutual visual acquisition of another aircraft by both pilots and based on traditional aircraft flight characteristics and pilot behaviours, whereas 'detect and avoid' needs to work on the assumption that the drone will not be observed by the manned aviation pilot (because, for instance, drones are much smaller than general aviation aircraft). Research is currently being conducted to consider how the 'remain well clear' principle could be used as an alternative (NLR, 2020).

2.2.3. Connecting U-space and Air Traffic Management (ATM)

At the moment, U-space is segregated from manned aircraft. Full integration of U3 and U4 airspace will require UAS to comply with instrumental flight rules (IFR) and the establishment of performance-based standards to have safe de-confliction minima[4] between UAS and manned aircraft. These are the focus of ongoing European research.

The current status of U-space service implementation, ahead of authorisation in January 2023, was summarised by EUROCONTROL (2022): for the U1 foundation services, more than half of Member States have implemented UAS registration, with a rate forecast to reach 76% by 2025. However, the completion rates of geofencing and network identification remain low across Member States, expected

[3] Class A airspace, on the other hand, is highly controlled and requires Air Traffic Control.

[4] A de-confliction minima is the minimum distance between aircraft allowed in a given airspace. The value is dependent on many factors, including the performance of aircraft, the CNS systems in use and a concept of operations.

to reach 55% and 41%, respectively, by 2025. The same study quoted Poland, Croatia and Italy as three of the leaders in U-space implementation.

2.2.4. Air traffic controller involvement

When drones are operating in controlled airspace, they are required to act as any other airspace user, including carrying the required CNS and responding to voice clearances from air traffic controllers (EASA, 2021). This requires a VHF voice link between the controller and the UAS and a link between the drone and its pilot. UAS operations in controlled airspace have been demonstrated in several SESAR projects, which have highlighted the need for controllers to understand the flight characteristics of the UAS under control, as they do for manned flights (SESAR JU, 2020). Current systems and procedures for Air Traffic Control (ATC) have been developed based on the flight characteristics of manned aviation, including cruise and stall speeds, rates of climb and descent, optimal cruise altitudes, etc. However, an important difference with UAS traffic is the diversity of design, flight trajectory changes due to improvements in materials and power sources, the range of operations, as well as their supporting communication systems.

As ATM is modernised, the majority of clearances will be issued by datalink (the digital communication between aircraft and ground systems) and will be valid for a much greater portion of the flight using the trajectory-based operations (TBO) concept (ICAO, n.d.)[5]. This will reduce the need for voice communications and alleviate the need for the remote pilot to be dedicated to a single UAS. Stakeholders interviewed stated that without further automation of air traffic control, UAS operations in controlled airspace would be limited due to the capacity of human controllers. Eventually, a fully automated system based on self-separation is envisaged, with the human controller role limited to complexity management and emergency situations.

2.2.5. Airspace modernisation

The progressive integration of UAS will take place in parallel to the modernisation of ATM in line with the European ATM master plan and its associated airspace architecture study. This modernisation supports an evolution of U-space services and the eventual integration of manned and unmanned aviation. Although this modernisation is very much a European approach, it is also reflected in both ICAO's (2016) and CANSO's (2021) visions of airspace modernisation.

2.3. Safety challenges

2.3.1. Occurrence reporting

An important pillar in safety management is a positive reporting and safety culture that enables the identification of potential risks at the earliest opportunity and allows data collection useful for risk prevention. Occurrence reporting requirements are implemented by Regulation (EU) 2014/376.

An assessment of this regulation has found that it applies to UAS only in the event of an incident involving a manned aircraft or resulting in death or serious injury, according to Konert and Kasprzyk (2021). Changes to occurrence reporting legislation will be required for the inclusion of UAS. According to the same source, there will also be a need to include occurrences impacting people on the ground.

In addition, there is currently no standard UAS occurrence reporting approach, resulting in significant differences in the numbers reported by aviation authorities (Kovacova et al., 2022). Furthermore, most

[5] TBO is an "ATM environment where the flown flight path is as close as possible to the user-preferred flight path" (ICAO, n.d.).

UAS reporting systems are set up on a voluntary basis, which makes them difficult to enforce. A UK Civil Aviation Authority (CAA) (2022) report found that there is significant underreporting of UAS occurrences due to a lack of awareness of reporting channels, which contributes to much lower reporting rates relative to those of general and commercial aviation. The study detailed that the majority of occurrence reports are made by other parties (e.g. ATC) than the operator itself. Occurrence reporting is an area that needs to be considered for future accident prevention and risk mitigation so that the highest level of safety can be ensured both in the air and on the ground.

2.3.2. Collision and accident avoidance

As the number of UAS in European airspace increases, there is a higher risk of hazardous situations such as loss of safe separation between aircraft, leading to a risk of collision. Two key methods can be used to reduce these risks for UAS:

- Procedural: airspace restrictions to manage traffic density, including geofencing and route pre-authorisation; and
- 'Detect and avoid': the digital equivalent of 'see and avoid' which aims to automate conflict detection and resolution.

However, not all obstacles have been overcome: 'Detect and avoid'[6] technologies have been researched as part of U-space capability studies, but there is currently no agreed minimum deconfliction distance between UAS and physical obstacles (Alarcon et al., 2020). We note that establishing adequate separation minima is complex, as too much separation could induce congestion and compromise the UAS route optimisation within the airspace, with a detrimental effect on UAS emission savings.

The unmanned aerial collision avoidance system (ACAS X_U) is an equivalent to the traffic collision avoidance system (TCAS) on board commercial manned aircraft (SESAR JU, 2019). Work on ACAS X_U and sXu minimum operational performance standards is underway, however, it remains absent from ACAS guidance at the European level (EUROCONTROL, 2022). One of the most advanced research projects in the field of unmanned collision avoidance is led by the military as part of the Mid-Air Collision Avoidance System (MIDCAS) project, which has been testing 'detect and avoid' technologies since 2009 (EDA, 2015).

Aviation safety around airports is a key issue due to the high risk posed by UAS when flying within or in the vicinity of an aerodrome where other low-level flight activity is taking place. Geofencing is a popular mitigation method used to reduce the risk of collisions. Most popular UAS control and autopilot systems are able to implement such no-fly zones in their built-in GPS system (Lykou et al., 2020; Kim and Atkins, 2022). However, European airports are keen to support the development of eVTOL activities on site and will therefore not want to prevent all UAS traffic in the vicinity.

Low-level flight of multiple aircraft presents safety risks in the air and, consequently, on the ground. Whilst U-space services and future potential collision avoidance systems should provide the infrastructure to minimise collisions in the air, there is nonetheless a need for UAS emergency landing procedures.

In the first step, safer route planning over sparsely populated areas could be used. From interviews with stakeholders, urban air mobility service providers are considering planning routes over less populated routes such as highways or lakes. Reducing people at risk could also be achieved by signalling or

6 Detect and avoid' is sometimes referred to as 'sense and avoid'.

evacuating the area prior to the landing, or with on-board risk reduction strategies such as equipping UAS with parachutes (Guerin, Delmas and Guiochet, 2021).

The use of sensors and cameras on UAS, valuable to ACAS X_U in the air, could also help with the identification of safe landing sites. Studies by Carney et al. (2019) and Ariante et al. (2022) illustrate how emergency landing systems using light detection and ranging data (LIDAR) could assist with the selection and execution of emergency landings: this technology assesses the nearby landscape and terrain to determine landing zones and assists the UAS and its operator in determining the best control manoeuvres to perform and to maintain stability and minimise impact. For larger military drones, the European Defence Agency (EDA) has trialled machine learning technology to provide contingency procedures for flight termination that calculate and classify different areas of risk when determining potential landing zones (Safe Term, n.d.).

2.3.3. Operations in adverse weather conditions

Rajawat (2021) describes some of the specific challenges for UAS operations that adverse weather conditions may create:

- Cold and windy weather require more power to stabilise the UAS, while particles within the battery are less active.
- Cold temperatures result in higher battery consumption rates, reducing the flight autonomy of the UAS. Stalling due to a lack of power to generate sufficient lift may also happen.
- Adverse weather may also result in the loss of a signal connection between the UAS and its operator.

Moreover, Gao et al. (2021) suggest that most common UAS are not weatherproofed and may malfunction in rainy, foggy or snowy weather with a higher risk of short-circuiting. Without clear regulations and operating guidance stating the worst allowable weather conditions, there is a clear risk to safety created by adverse weather.

Aerodrome operating minima (AOM) used in manned aviation are criteria used by aircrew to determine whether they may land or take off from a runway based on cloud base, visibility and/or runway visual range. The FAA (2022) recommended that pilots set up personal minima in meteorological metrics for when to continue or stop operating their flight. Such an approach could be useful to ensure there is adequate UAS guidance for the operator to mitigate risks. Another weather-related risk for UAS operating in urban environments is that of sudden changes in wind direction and turbulence caused by surrounding buildings (Bauranov and Rakas, 2021). This needs to be considered for low-level small UAS, which could easily be blown off course.

2.4. Security challenges

The fact that the UAS pilot is not on board the aircraft and the future autonomy of drones create potential additional security risks compared to manned aviation, particularly when operating in close proximity to populated areas. The range of personal, commercial and state/military UAS and their respective technological capabilities and communication methods create multiple opportunities for considerate but also potential malicious use.

Table 3: UAS possible uses

Legal		**Malicious**
Civilian	Military	Criminal
Photography and land and infrastructure scans Disaster management, search and rescue Surveillance and security Personal use	Intelligence and surveillance (use of a UAS to collect information) Target acquisition and reconnaissance Combat and strikes Transport of goods or troops	Hostile surveillance Smuggling or contraband delivery Disruption (use of a UAS to interfere, including cyberterrorism) Weaponisation of UAS with arms, explosive, chemical or biological agents to be dropped or through the crash of the UAS

Sources: Steer analysis of Siddiqi et al., 2022, Yaacoub et al., 2020

Whilst most literature focuses on the security threats of UAS, others have considered their benefits to national security activity. Police forces have added drones to their networks, adding a third dimension to their activities while reducing the risk to police officers on the ground (Klauser, 2021). The use of UAS by police forces and other emergency services in Europe is practised in countries such as Belgium, Germany, Italy, Netherlands, Sweden, Norway and Switzerland (Willmer, 2022; Airmour, 2022).

2.4.1. Contraband, weaponisation and disruption concerns

Contraband smuggling is an area of security risk, with the use of drones to deliver prohibited goods or materials into controlled territories (such as schools or prisons) becoming increasingly common. Turkmen and Kuloglu (2018) have found that illegal transportation of drugs and weapons is expanding as UAS become increasingly common and affordable. Such malicious acts are deliberate offences and create complications for law enforcement as it is hard to trace or identify the operator.

Weaponisation of UAS also presents a significant level of risk. Terrorism attacks such as those of 11th September 2001 in the USA clearly demonstrate the vulnerability and damage that could be done by low-altitude flying in densely populated civilian areas. UAS operations over urban areas could provide terrorists with an easy option for disrupting or damaging infrastructure, especially as there is no UAS pilot protection compared to the locked cockpit rules that have been implemented for manned commercial aviation. UAS have already been used for terrorism and military acts, as well as in direct combat or to damage critical infrastructure in conflict zones, such as in the ongoing Russian war on Ukraine (Janes, 2022). For example, a US military drone monitoring the conflict in Ukraine was disabled by the very close flying of a Russian military jet in March 2023, in contradiction to ATC rules (Schmitt and Cooper, 2023).

Individuals or organisations may also take advantage of utilising UAS to cause wide disruptions to public services or civilian operations in energy, telecommunications and transportation infrastructure. A recent example of this type of high-impact disruption was the 2018 drone sightings at London Gatwick airport in the UK, which resulted in the temporary grounding of flights. This has demonstrated how civilian infrastructure has increasingly become a target for drone disruption (Morrow et al., 2020). A stakeholder commented that infrastructure managers, such as airports, are acquiring UAS detection equipment, but some of these systems may only detect the less sophisticated small UAS widely available (and only where the operator has not disabled its identification signal).

2.4.2. Cybersecurity concerns

Cybersecurity is an increasing concern relating to military and increasingly civil UAS operations. UAS technology relies on UAS being controlled wirelessly by a remote pilot or operator, within their line of sight or beyond. While fully autonomous technology is not yet widely available on the market, hostile take-overs of the communication between the ground and the UAS drone pose a potential threat to operations, especially in populated areas.

The weaponisation of drones can cause significant damage, either physical or technological, in populated urban areas should the UAS be compromised either by accessing private information or by interfering with the networks of people or property on the ground (Lykou et al., 2020). This form of criminal manipulation is considered to be the root of many other issues. The unauthorised control of drones can lead to a range of incidents varying in severity, from accidental unintended outcomes for legal users' or operators' aircraft to illegal usage and incidents by malicious operators. One of the more common security risks of this type of UAS activity is privacy intrusion, which is covered in more detail in Section 3.4.

Many UAS are equipped with video and audio recording technology. Flying these types of UAS near military centres and other sensitive civilian locations, such as nuclear power stations, for instance, can create security issues. Spying activities using drones to inspect border facilities and border areas are one of the most high-risk issues to be addressed. There have also been cases in Afghanistan, Russia and Ukraine where military spy drones have flown across borders to observe military operations and gather information (Yaacoub et al., 2020). In the case of Ukraine, this has extended to the use of commercially available drones, which are being used to support military efforts (Ciolponea, 2022).

The most recent ICAO convention on cybersecurity is the 2010 Beijing Convention. As there have been no major updates on international conventions or major regulations since the Beijing Convention in 2010, Pyzynski and Balcerzak (2021) suggest that there is consequently a large gap to fill considering how much technology has evolved since then.

2.4.3. Counter-UAS measures

Counter-UAS measures (C-UAS) are solutions against the safety risks presented by the illegal use of UAS. The FAA recently provided guidance on C-UAS measures (FAA, 2020), whilst the Drone Strategy 2.0 indicates that the Commission will adopt a C-UAS package outlining the EU's future policy in this field.

C-UAS measures often rely on detection, identification, localisation and responding (Chamola et al., 2020). C-UAS systems can take various forms, kinetic or not[7], whether from the ground or the sky, based on the altitude of the UAS (Kang et al., 2020). For low-level operations over populated areas, ground-based systems are the most applicable.

Kinetic C-UAS measures such as physical nets, lasers or aerial systems are proposed in the literature but can sometimes be less relevant in populated areas due to their risk of collateral damage (Lykou et al., 2020; Chamola et al., 2020). There are also military options being considered, such as in France where Thales[8] has been commissioned by the military to test anti-drone systems for temporary events (Thales, 2022).

[7] Kinetic C-UAS involves the physical intervention of the UAS, whilst non-kinetic is a non-physical intervention.

[8] Thales is a French multinational company that designs, develops and manufactures electrical systems in the fields of aerospace, transport, defence and security etc. (Thales, n.d.).

The responsibilities against UAS threats need to be clearly articulated in terms of authority to undertake C-UAS actions. While the identification of non-cooperating drones may well fall within the civil U-space service provider jurisdiction or potentially the infrastructure (nuclear stations, airports, etc.) managers, the competency for addressing the problem, including outright destruction as well as electronic override such as hacking, jamming, spoofing etc., likely does not. This depends on the security approaches of Member States, which all tend to be different. The recent Chinese balloon airspace incursions above North America have perhaps highlighted the European need for increased coordination of cross-border civil, military and security agency activities, as well as the need for more joined-up approaches to national security policies and risk assessments in order to deliver a better coordinated approach at EU level (although we note that it is further complicated by different EU and NATO memberships and relationships). In contrast, the USA coordinated easily with Canada through the North American Aerospace Defence Command (NORAD) (and would likely have done so with Mexico).

2.5. Regulatory challenges

2.5.1. UAS liability

At present, there is no harmonised regime, either in the EU or internationally, for liability for damage to third parties caused by UAS (or by manned aviation). Provisions therefore depend on national law and vary between Member States. As UAS are aircraft, operators are required by Regulation (EC) 785/2004 to have insurance for third-party liability, which as a minimum must be at the levels defined in the regulation. Failing this, their assets would be liquidated to compensate any third-parties.

Assigning liability is complex, even more so in the context of UAS operations and their supporting systems (Emanuilov, 2018). This may include air service operator liability, traffic control liability, product liability or supporting provider (telecommunication provider, maintenance provider etc.) liability (Bassi, 2019). In addition, in the majority of EU Member States, national law defines that the liability regime for Remotely Piloted Aircraft Systems (RPAS) is strict (meaning that they are automatically liable for damage without any need to attribute fault), whereas in others liability is based on tort law.

In order to record accountability, EASA requires registration for UAS over a certain weight or when equipped with sensors or cameras. U-space network identification services can also help to assign accountability (SUSI, 2021), but can easily be disabled where criminal intent is involved. Critics argue that registration schemes were inadequate for preventing malicious activities, citing the Gatwick airport incident in 2018, where remote identification technology was then unsuccessful in identifying the intruder (Shelley, 2019).

Enforcement of UAS regulatory requirements is therefore important but challenging, resulting in a greater risk of illegal or uninsured operations in the UAS sector compared to manned aviation. In the event of an accident involving an uninsured operator, any third party suffering damage will (at most) be able to obtain compensation up to the value of the operator's assets. This raises the issue of whether there needs to be some sort of mechanism to ensure compensation for victims of uninsured operators, as there is, for example, in the motor vehicle sector (Steer, 2014).

2.5.2. Cost sharing

A recent report has estimated that U-space costs could be between EUR 7 and EUR 9 billion (Pivot Regulatory & IPE, 2020). The financing of U-space service providers (USSPs) is an important component of airspace integration for UAS. Commercial users of airspace are concerned that the cost of UAS services will be paid for by manned aviation, given that general aviation is often exempt from air navigation charges, with its cost paid for by commercial aviation operators (IATA, 2020). Multiple independent USSPs may also possibly create competition in the market, potentially challenging Air Navigation Service Providers (ANSPs) on how to provide new services and at what cost.

European ANSPs and civil aviation authorities are currently considering how UAS users should pay for their airspace services. Registration fees are currently required for operators, but a move towards variable user costs was proposed as a preferred method by Merkert et al. (2021), particularly in urban areas that risk becoming congested with excessive drone use in the future. Ideas put forward by the study that could equally be applied to airspace infrastructure include road pricing frameworks, congestion pricing or toll road pricing.

2.6. Research and development

There are many research and development projects taking place across Europe to support the development of UAS technologies and products. The vast majority of these include consortiums of industry and academia that are supported by governments, with or without co-financing by the consortium members.

At the European level, the research and innovation programme Horizon Europe is providing significant amounts of funding to UAS research (and before it, the seventh framework programme). Some of the research grants have been allocated to technology development or demonstration, depending on the technology readiness levels (TRL) (measurements to assess the maturity level of particular drone technologies), whilst some co-funding has been used to validate concepts for specific UAS uses. The Interreg Programme (the interregional cooperation programme, co-funded by the EU) also funds some UAS projects but appears more focused on policy or specific UAS case use.

Research projects on airspace integration include:

- The U-ELCOME project intends to develop, test and demonstrate SESAR U1 and U2 U-space solutions up to TRL, 8 across 15 locations in Spain, Italy and France.
- The CORUS-XUAM project, finished in December 2022, ran a programme of very large-scale demonstrations (VLD) of how U-space services and solutions could support integrated Urban Air Mobility (UAM) flight operations, allowing eVTOLs, UAS and other airspace users (unmanned and manned) to operate safely, securely, sustainably and efficiently in a controlled and fully integrated airspace without undue impact on operations currently managed by ATM.
- The AURA project will identify the requirements for U-space information exchange with ATM, validate a set of selected U-space services, define a novel Collaborative ATM-U-space Concept of Operations for drones in a fully collaborative environment with ATM that goes beyond the existing concepts developed for U-space and validate these new concepts.
- The USEPE project, which finished in December 2022, researched drones' separation methods in highly demanding environments such as cities.
- The BUBBLES project was targeting the formulation and validation of a concept of a U-space advanced (U3) 'separation management service' at TRL3.

The EU-funded BorderUAS project is developing a multi-role lighter-than-air unmanned aerial vehicle with an ultra-high resolution multi-sensor surveillance payload. The technology concepts will be validated in the field by six border police units covering three major illegal migration routes into Europe. The combined solution will provide high coverage, resolution and revisit time with a lower cost than satellites and higher endurance than some drones.

The European Defence Research Programme was launched in 2021 as part of the European Defence Fund. It funds projects SEAWINGS, which will develop a new class of military surveillance UAS to operate in the sea/air interface; HYBRID, which will develop a long-endurance electric hydrogen fuel cell-powered UAS; and ALTISS, which will provide improved intelligence, surveillance and reconnaissance capacity through an affordable, resilient unmanned air vehicle (UAV) swarm. Demonstrations for the adoption of RPAS into civil airspace involving the application and development of MIDCAS have been running since 2009 (EDA, 2015).

There are also some research and innovation programmes funded at the national level, such as in the Netherlands with The BEAST project on autonomous and BVLOS capable drones, operational procedures, risk analysis and mitigations. In France, the CONCERTO project works towards a better consideration of wireless communications in the self-organisation solutions of a swarm of drones to ensure robust connectivity within the swarm and guarantee quality wireless communications among the drones and in end-to-end communications.

Private companies are also conducting research and innovation activities. For instance, Airbus Unmanned Traffic Management (UTM) is developing a proprietary simulation environment called Usim to explore how future airspace will operate. It has already been utilised to validate and develop NASA concepts of operation for Advanced Air Mobility operations in the United States. Airbus UTM has also employed Usim in collaboration with EUROCONTROL to study the safety and performance of future U-space operations in Europe and to demonstrate the role of simulation to support U-space airspace assessment.

On the eVTOL side, manufacturers are partnering with airport operators and authorities to trial their technology. This is the case for Volocopter, in partnership with Groupe Aéroport de Paris and Skyports, which has recently commissioned a fully integrated vertiport terminal for UAM integration, testing and development (Volocopter, 2022). Delivery drone operator Wing, owned by Google's parent company Alphabet, has been working across the EU, USA and Australia to demonstrate last mile delivery by drone operations in partnership with established delivery companies and supermarkets. Wing has also been involved in developing apps for drone operators, regulators and governments to support the safe operation of multiple drones in the same airspace. Its OpenSky app, for example, is currently available to users in Australia and the United States to help operators understand airspace requirements, with a beta version currently available in France (Wing, n.d.).

2.7. Market entry barriers for civil and military

2.7.1. Civil

Initial commercial operations of UAS are expected to be expensive, reducing in cost through economies of scale (cost savings due to increased levels of production). Different Member States are taking different approaches to the adoption of UAS regulations, with some taking a supply approach whilst others are relying on a demand-led requirement (EU Drone Days, 2022). Current EASA regulations prohibit any individual from being a drone operator or pilot for more than one drone at a time. This means that a significant part of operational costs are labour costs. McKinsey (2023) reported that labour costs can represent up to 95% of the total cost of drone delivery. If multiple drones can be operated by one person, this is predicted to lower the overall costs of operations and increase the commercial viability of civil UAS.

Another market entry requirement for civil UAS is the need for operators to obtain affordable third-party liability insurance. This requires brokers and insurers to offer coverage that fulfils the needs of the operators and the regulatory insurance framework. Improvements in the reporting of UAS occurrences and analysis of these occurrences help the development of the insurance offer. In addition, regulatory measures such as pilot training and licencing, drone registration or limitations on UAS uses also support the insurance industry and should, in time, contribute to lower insurance premiums for the users.

UAS operators in the 'Specific' category will be required to employ remote pilots that will often need to be qualified in conformity with pan-European recognised proficiency 'certificates', in order to be able to operate in all EU Member States. However, there is not much time left before standard scenarios are mandatory (in 2024), there are no training or examination guidelines available, and the model documents defined in the EU regulation are neither available nor harmonised. For instance, a common EU question database for the examination of remote pilots in the 'Specific' category (and available in all EU languages) does not exist, which not only risks delays in market entry but also distorts national market entries within the EU (Unmanned Airspace, 2023).

2.7.2. Military

UAS military procurement has traditionally been served by established companies with a strong track record of developing military products and has been further enhanced by the desire of most militaries to maintain specific standards and a preference for tailored products. As a result, there has been little overlap with the civil sector in the area of higher performance, high altitude and complex aircraft.

This has nonetheless changed, with militaries seeking to lower costs and leverage economies of scale available from the use of civil aircraft or design skills. The civilian-off-the-shelf (COTS) approach has become more considered, especially when the emphasis is being put on endurance and efficiency (as per civil aircraft priorities), over speed and performance. As a result, the military UAS space has been open to new entrants. This is particularly true for the smaller UAS, where the required performance matches that of larger civil quadcopters and similar designs available on the open market (JAPCC, 2021).

Military and intelligence agencies have also been monitoring opportunities for procurement of UAS designs from civil or non-traditional sources against current suppliers (NATO, 2021), for complete aircraft, software, communications systems and material development, creating a potential market area for non-traditional military industries to enter dual-use market areas. However, as detailed in Chapter 5, there are also limits to this approach.

2.8. Economic potential for deploying drones in the European airspace

A summary of current market outlook studies for UAS economic contributions across different regions is provided in Table 4. The latest forecasts for Europe show that the expected value of the UAS market in 2030 will be EUR 14.5 billion. In 2016, the size of the market was initially predicted to be 400,000 in 2050; however recent reports suggest it may be closer to this volume by 2030.

Table 4: Economic contribution of UAS

Source	Market	Coverage	Market volume	Market value (EUR)
Droneii (2022)	Commercial and recreational UAS	Europe	N/A	By 2030: EUR 12.6 billion
European Commission (2022)	Commercial UAS	Europe	By 2030: 400,000-800,000 commercial UAS	By 2030: EUR 14.5 billion

Source	Market	Coverage	Market volume	Market value (EUR)
Roland Berger (2020)	Commercial passenger UAM (includes manned)	Global	By 2050: 160,000 passenger UAS	By 2050: EUR 85 billion
Deloitte (2019)	eVTOL (includes manned)	USA	N/A	By 2035: EUR 6.4 billion
NLR (2019)	eVTOL (includes manned)	Global	By 2035: 15,000 eVTOL	By 2035: EUR 20 billion
Deloitte (2018)	All UAS	Global	N/A	By 2025: EUR 1.8 billion
NASA (2018)	Commercial UAS (last mile delivery and UAM)	USA	By 2030: 40,000 UAS for last mile delivery, 23,000 UAM UAS	By 2030: EUR 7.5 billion profit for last mile delivery; EUR 2.6 billion profit for UAM
SESAR (2016)	All UAS	Europe	By 2050: 7 million leisure UAS, 400,000 commercial and government UAS	By 2035: EUR 10 billion By 2050: EUR 15 billion

Source: Steer analysis (EUR/USD conversion at 23/02/2023)

SESAR (2016) suggests that growth will mostly be in the 'Specific' category, with the 'Certified' category accounting for 15,000 operations by 2050. Agriculture and delivery are predicted to be the largest drivers of growth. Deloitte (2018) has similarly named agriculture and logistics as drivers of growth as well as military surveillance and transportation.

The wider eVTOL market is predicted to have a significant global economic impact of EUR 85 billion. Expected customers of these operations are initially expected to have high net worth, with operations starting small with high costs and decreasing over time (Roland Berger, 2020).

2.9. Conclusions

The implementation of UAS integration within European airspace is happening in stages, with the most complex aspects naturally taking place after the simpler obstacles have been removed. It is important not to overlook the more difficult aspects of integration, which require further investment and development, particularly around automation and communication systems.

While UAS have much in common with manned aviation, the fact that they are systems, have different flight characteristics and do not have a pilot on board requires many new solutions for integration. As a result, there are some safety issues regarding occurrence under-reporting, single reference altitudes, collision avoidance and operations in adverse weather conditions where further work is needed.

The rise in UAS operations by different users brings with it increased security concerns regarding malicious use or disturbances by members of the public. Cybersecurity is a particular concern where legislation may need to be updated to account for developments in technology and UAS operators will need to be educated on its implications. Counter-UAS measures are under development. However, the selection of the most appropriate method by type of environment will be important to avoid collateral risk. The responsibility for counter-UAS deployment will also need to be specified.

R&I into the technical proof of concept of UAS is already underway, however, there remains a need to develop specific programmes to address the adoption of these technologies at scale and the operational and regulatory mechanisms that will need to support them.

The economic potential of the UAS market is significant, although, as demonstrated by this chapter, there remain a number of regulatory, technical and market entry barriers that require further work if these targets are to be realised.

3. DRONE OPERATIONS OVER POPULATED AREAS

KEY FINDINGS

- Operations over people require careful consideration of ground risk, such as population density, potential no-fly zones or sheltering factors.
- Static population density information is currently being used to plan for the associated risk of UAS operations and to understand future demand for UAS services. However, more dynamic data may be required to account for temporary assemblies of people on the ground and respond to a changing risk profile.
- The evolving development and range of applications for drones create risks for security and privacy infringements. These range in severity but are largely concerned with cybersecurity and privacy in populated areas. Appropriate mitigation solutions in urban areas include non-kinetic technologies that disrupt communication channels.
- Noise concerns surrounding UAS primarily concern the unfamiliarity of their noise compared to more familiar urban sounds, rather than their actual volume level.
- There has been a growing interest in the subject of social acceptance of UAS. Trends suggest that certain drone operations are preferred over others, with a higher tolerance for manned vs unmanned operations in urban mobility.

3.1. Introduction

With a large share of the European population living in urban or densely populated areas, there is no doubt that there is a demand for UAS operations in these areas. This concerns all types of UAS, from delivery services or emergency services to passenger or air taxi services. Compared to manned aviation, which is often, although not always, prevented from operating above populated areas, UAS operations create a need for specific consideration of the associated flying risks and potential mitigating measures.

This section addresses the challenges involved in operating drones over populated areas and some of the measures that can be implemented to understand and mitigate the associated levels of risk. Two distinct types of risk are involved when operating aircraft: air and ground risk. The previous chapter highlighted the air risks, whilst this chapter focuses on ground risks, particularly in operations over populated areas.

3.2. Safety concerns

Safety concerns relating to the operation of UAS over populated areas have usually been well identified due to the potential catastrophic impact on the public that can be caused by issues or faults resulting from a UAS flight. Operations in airspace over populated areas place additional pressure on existing ATM systems due to the predicted high number of operations within the same proximity, the lower altitude of operation and the varying performance of the different UAS (Bauranov & Raka, 2021), as well as possible telecommunication interferences created by multiple buildings.

Current EU regulations for the 'Open' and 'Specific' categories differentiate between operations over 'involved' and 'uninvolved'[9] people and operations over assemblies of people[10]. Greater operational requirements are advised for the former and a general advisory against the latter: in the 'Open' category operators can only fly over people with a UAS limited to 250g, whereas in the 'specific' category a risk assessment taking into account both ground and air risk needs to be produced. Ground risk and the consideration of population density are currently covered by the existing specific operation risk assessment (SORA) for 'Specific' operations of UAS (EASA, n.d.). We note that risk assessment needs to be done based on expected conditions (with the possibility of flight cancellation if a fundamental assumption is not met on the day of the operation), based on static (how crowded the area should be) and dynamic information where available (how crowded the area really is). For instance, an operator who has planned to fly its UAS in a park assuming it would largely be empty ('Open') should not fly if there happens to be a race in the park. If the intention was to film the race ('Specific'), they should have put in place mitigating measures (such as a crowd line or else).

Drone operators must also be registered to operate drones over people in all categories if the drone weight is over 250g (EASA, 2019). The network identification, geo-awareness and traffic information services of U-space are three services that will also reduce the risk of conflicts in the air and associated ground risk, particularly above busy areas of airspace (European Commission, 2021).

Safety risks arise from multiple sources, including technological, operational and communication issues, as well as simply from human error related to UAS piloting. The risk to third parties on the ground from UAS operations over populated areas today is also enhanced by the lower standards of hardware and software used on-board most UAS compared to what is used in manned aviation, as well as by a higher degree of human error in UAS operations (Lee et al., 2022; Clarke and Moses, 2016). However, we need to acknowledge that this difference in standards may be more of an issue for the smaller UAS than for the largest ones (such as in the 'Certified' category) built for the future transport of passengers, as indeed these UAS need to fulfil the high safety requirements of EASA to obtain their safety certification.

There is currently limited data or information on third-party risks caused by UAS, therefore resulting in most literature on the topic based on prospective modelling instead (Blom et al., 2021; Ren & Cheng, 2020). However, Article 19 of Regulation (EU) 2019/947, which sets out requirements including the exchange of information and reporting of safety occurrences to the relevant authorities, will therefore contribute to an improved collection of UAS safety data. Wider use of UAS will bring an increased risk of safety, security, privacy and social acceptance issues, but it will also bring a better understanding of the scale and nature of these issues.

3.3. Security concerns

Security concerns regarding the operation of UAS within European airspace have been covered in the previous chapter. In terms of counter-UAS measures, in the specific case of populated areas, depending on the precise layout and nature of these areas, the focus may need to be on non-kinetic interventions such as jamming (intentionally blocking the signal of the communication between drone and operator) or spoofing (sending a false GPS location to the drone). Specific mitigating measures for urban environments are set out in Table 5.

9 "An uninvolved person is a person who is not participating in the UAS operation or who is not aware of the instructions and safety precautions given by the UAS (drone) operator" (EASA, n.d.).

10 "If a group of people are so densely packed that their possibility to freely escape or move away from the drone is limited, then it is considered to be an assembly of people" (EASA, n.d.).

Table 5: Communication disruption counter-UAS measures for urban environments, as summarised by Siddiqi et al. (2022)

Counter Measure	Details
Wi-Fi jamming	Wi-Fi-based drone or UAV operates on a 2.4 GHz frequency. A conventional jammer can jam these frequencies within a limited range and can be used for privacy purposes.
Wi-Fi aircrack	Although it is an attacking method, aircrack (a suite of tools for gaining access to WiFi networks) can be used to take control of any illegal or privacy-invading UAV or drone.
Three-way handshake	Although a three-way handshake (establishing a secure connection between a client and server before information is shared) is also an attack method, it can be used to de-authorise or even jam communication between the UAV or drone and the controller.
Denial of service (DoS)	Wi-Fi jammers can be an effective method to jam or de-authenticate an UAV from its controller. However, to conduct a DoS-based attack, some knowledge about the communication channel used is required.
GPS spoofing	Encryption of civilian-based equipment is very costly, making it vulnerable to GPS spoofing attacks.

Source : Siddiqi et al., 2022

3.4. Privacy concerns

Privacy concerns exist for all operations of UAS, from flying over military and civilian facilities, to flying over private property and populated areas. Aerial filming may easily violate General Data Protection Regulation (GDPR) rules regarding people's consent to their faces, locations or recognisable belongings being filmed unknowingly. This is particularly complicated in populated areas, as it is hard to differentiate objects or people that were intended to be filmed from the process. The possibility of accidental or deliberate privacy intrusion due to the range of UAS operational applications makes it difficult to develop overarching regulation for the protection of civil liberties (Finn and Wright, 2012).

Inappropriate use of photography by drones can support criminal activity and direct invasions of privacy. UAS provide an easier means for journalists as well as potential offenders to record their targets from outside of buildings, particularly in high-rises or heavily developed areas, or to conduct preparation by locating valuables and points of break-in through videotaping. Offenders can also use UAS to bypass physical barriers and intrude on private property with a low likelihood of being detected by current anti-burglary device technology (Morrow et al., 2020). Other privacy concerns have been found to include the risk of blackmailing and scamming with the use of drone video footage taken without the victim's knowledge (Yaacoub et al., 2020).

However, alternative views on privacy have rationalised these concerns as being no greater than those posed by mobile phones or recording devices (The Regulatory Horizons Council, 2021). A survey from the USA has further supported the argument that privacy concerns regarding drones are contextual, based on what sphere they are used in (public vs private) and the data they gather (Wang et al., 2016). Another study has suggested that privacy issues with regard to UAS are more closely tied to how people perceive privacy (Bauranov & Rakas, 2021). It may therefore be the case that if UAS are covered by the same privacy regulations as other technologies, it may be enough to mitigate concerns. However, the enforcement of privacy rules in the case of UAS operations is likely to remain complicated.

We note that at the moment, enforcement authorities related to drones are national aviation authorities that are unlikely to be well-versed in or even have the powers to investigate privacy concerns. It is also particularly complex for filmed individuals to identify the UAS and, therefore, to complain to the relevant authorities. Furthermore, UAS offer a significantly lower risk of prosecution for breaches of privacy if the drone is identified or captured (Morrow et al., 2020).

Identifying the intentions of UAS operators, whether malicious or not, was recognised by stakeholders as an issue that remained difficult to tackle. In the USA, the FAA has taken steps to assess and review drone operator and pilot applicants' intentions by conducting background checks prior to authorising their UAS pilot certificate in a bid to minimise the risk of illegal UAS usage (The FAA, n.d.). Whilst operations in the EU 'Certified' category will require the operator to hold a licence similar to a pilot licence today, operations in the 'Specific' and 'Open' categories with lower licencing requirements could still cause significant disruption or harm if operated with malicious intent.

3.5. Noise and pollution concerns

The low emission operations of UAS have made them a strategic mode of transport within the EU's Fit for 55 goals, including the Sustainable and Smart Mobility Strategy (European Commission, 2020).

Noise was identified by NASA as the largest limiting factor for current helicopter operations within urban areas and could have the same barriers to UAS development (NASA, 2018). Noise was also identified as the second largest concern after security by respondents in EASA's (2021) Urban Air Mobility social acceptability study. Findings show that unfamiliar sounds are considered more annoying to people than those that are familiar, with light drones and air taxis perceived to be more annoying than current urban transport sounds despite their equivalent volume (EASA, 2021), as per Table 6. In addition, it is well established that the perception of how much a noise level is disturbing is heavily influenced by the degree of environmental noise: in quieter areas with low road traffic, noise annoyance from the sound of drone hovering was reported up to 6.4 times higher as compared to areas with higher road traffic (Torija & Clark, 2021).

Table 6: Comparative noise of UAS and other urban noises

Noise source	Noise (dBA)
UAS	50-60 dB
Leaf blower	90 dB
Lorry driving at city speed	82 dB
Car driving at city speed	65 dB
Bicycle driving at city speed	57 dB

Sources: EASA, 2021[e]; Cranfield University, 2022

To address UAS noise levels, EASA has recently launched voluntary guidelines on noise levels for drones under 600kg aimed at standardising UAS noise levels in the 'Specific' category across EU Member States (EASA, 2022).

Whilst noise may cause problems in the short term, studies by EASA and Chakravrti et al. (2021) suggest that over the longer term, and with careful introduction, the noise of new urban mobility might become more widely accepted. However, a stakeholder interviewed as part of this study suggested that people may object to the visual pollution of UAS in urban environments as UAS traffic increases, even if the noise level of UAS blends in with the noise level of urban life.

3.6. Population density and criteria to determine drone operation over populated areas

The population under the flight path of UAS operations can determine both the requirement for UAS services and the level of risk that surrounds their operation. As previously discussed, the SORA risk assessment, which includes ground risk, will be required to be undertaken before certain U-space operations. Some academic papers have examined how to measure population density and the considerations that need to be taken into account when operating in urban areas. They found that the determination of the level of risk is based on a number of factors, of which population density is one. Other factors to consider in trying to understand the potential exposure to damage or casualties of a UAS incident include the sheltering factor (level of protection from buildings or trees that may reduce the direct impacts of a UAS), no-fly zones and obstacles, a combination of which could help in understanding the appropriate level of flying permitted over certain areas (Primatesta et al., 2019; Oh & Yoon, 2022; Clothier et al., 2018).

Population density data can be generated from publicly available density statistics and census data on population by unit of land area, however, more dynamic alternative measurements also exist:

- Road traffic congestion data sets (which record levels of road traffic congestion) can provide a suitable vehicle crowding indicator and can be useful for selecting cities that may benefit the most from increased eVTOL systems (as stated in the EASA (2021) social acceptability study).
- The use of mobile phone data allows for real-time crowding information. This data is better at capturing temporary increases in pedestrians in certain areas, which may also need to be accounted for, such as in the case of busy retail areas or large crowd gatherings (including indoors).

The assessment of temporal population density over time with the use of mobile data has been included in recent studies (Bergroth et al., 2022; Jiao et al., 2022; Deville et al., 2014). This method of dynamic population density measurement may be more applicable to a digitally advanced network of UAS, which moves away from the traditional method of assessing populated areas. It may also be applicable for safe flight assessment over central city areas and business areas, which have different levels of population activity throughout the day. This method of assessing ground risk would also work well with the increased involvement of telecoms and big tech companies in the operation of drones, such as Google Wing (a drone delivery company), due to their access to large data sets. It has also been evolving since the COVID-19 pandemic with the application of geotagged big data within apps such as Google Maps to show busy areas (Google, n.d.).

The assessment of population density is also important for industry in determining the level of demand for future UAS drone operations. It is expected that most of the UAS demand will come from densely populated areas in the future (SESAR3 JU, 2016). Doole et al. (2020) estimated an expected demand of 78,000 flights per hour in and above the Paris metropolitan area by 2035. Another study applied a dynamic method of tracking population density and journey trends using mobile data to understand where the need may exist for air taxi services in the USA (Haan et al., 2021).

Changing methods of identification of large populations through more dynamic rather than static approaches need to be taken into account when identifying areas of operation, with time of day taken into account, very similar to the noise restrictions currently in place at airports.

3.7. Social acceptance concerns

The proximity of UAS within populated areas and the success of their commercial adoption will be reliant on the social acceptance of unmanned aircraft in the airspace. Studies of UAS social acceptance have been increasing since 2015 and have largely been undertaken through surveys (Cetin et al., 2022). A summary of the outputs from some of these surveys is captured below.

Broadly, just under 50% of citizens surveyed by EASA (2021), Airbus (2019) and Deloitte (2019) have reported that they perceive UAS to be safe. However, Airbus found that people living in urban environments, whilst likely to be most impacted by urban air mobility, were nonetheless also the most supportive of the technology (Yedavalli & Mooberry, 2019).

EASA's (2021) social acceptability study of Urban Air Mobility in Europe has found that a number of factors were part of the criteria for the social acceptance of urban air mobility, including safety, noise, security, privacy, environmental impact etc. These areas of concern were also identified in a similar study on social acceptance of UAS by Airbus as part of an Urban Air Mobility public perception survey (Yedavalli & Mooberry, 2019).

Studies by Tan et al. (2021) and Chakravarti et al. (2021) both agreed that perception of UAS differs according to the types of proposed operations and is, therefore, sensitive to context. The study by Tan et al. (2021) found that the public was more supportive of government-operated drones compared to commercial and personal users. Search and rescue, disaster management and preserving environments are ranked higher than those used for personal benefit, such as video or photography purposes. The output of these studies also reflects views captured as part of stakeholder engagement. Whilst some city stakeholders are currently trialling a range of different UAS operations, others were clear that they would welcome certain operations, such as emergency service UAS support services before food delivery services, for instance. However, 64% of the respondents surveyed by EASA said that they would rather or very likely use drone delivery services (EASA, 2021, p. 61).

There was also a distinct difference in perception of manned vs unmanned operations of eVTOL with 70% of pedestrians accepting that a *manned* aircraft could fly above their heads compared to 44% who would accept an *unmanned* aircraft operating in the same airspace (EASA, 2021, p. 65). Deloitte (Lineberg & Hussain, 2019) further found that public perception of urban air mobility safety is broadly aligned globally, with public perception of safety highest in Japan (58%) and lowest in China (39%).

The table below presents an overview of possible mitigation measures for social acceptance.

Table 7: Possible mitigations to address concerns

Possible Measures	Concerns They Address
Develop a risk and safety culture in the drone industry with collaboration across the value chain	Concerns of safety and security, competency of operator, economic viability and creation of jobs
Maintain a high level of security measures	Concerns of safety and security, competency of operator, economic viability and creation of jobs, safety
Establish no-fly zones for drones, including over wildlife protection zones	Noise impact, impacts on animals and flora, visual pollution, safety and security concerns, loss of privacy

Possible Measures	Concerns They Address
Encrypt communication signals in the UAM network through both hardware and software encryption as well as geofencing	Concerns of privacy loss, safety and security concerns, competency of operators, economic viability
Ensure industry, government and national body collaboration on airspace architecture	Concerns of safety, competency of operators, creation of jobs, economic viability
Identify a strategic location for vertiports	Safety and security concerns, noise impact, emissions impact, impacts on animals and flora, visual pollution
Limit minimum altitude	Safety concerns, loss of privacy, noise impact, impacts on animals and flora, visual pollution
Avoid/limit hovering drone flights	Concerns of privacy loss, noise impact, impacts on animals and flora, visual pollution
Improve public knowledge about drone technology and operations, including public demonstrations and test flights	Concerns of privacy loss, lack of transparency, competency of operator, economic viability
Promote the use of renewable energy sources to recharge batteries	Safety concerns, emissions impact, recycling, climate change
Ensure proper maintenance processes and controls for batteries to extend their life cycle	Safety concerns, emissions impact, recycling climate change
Work with eco-friendly drones	Emission impact, recycling, climate change, economic viability
Ensure that the cost of drone services is commensurate with the value of the activity	Cost of services, competency, jobs, economics, viability

Sources: Steer analysis based Cetin et al, 2022; Lineberg & Hussain, 2019

A potential approach to public concerns over Urban Air Mobility, as referenced in the literature, includes public familiarity or product demonstrations. The SESAR 3 JU demonstrations have provided a solution to this with the publication of their recent report on the everyday benefits of U-space (SESAR, 2022). They have tested very large-scale demonstration projects, including drone delivery, infrastructure, public safety and air taxis. Testing has been complemented by the actions of manufacturers, who have also been active in presenting their technologies to the public.

Whilst findings from demonstrations and surveys are useful in understanding where social acceptability issues may exist, incidents involving autonomous vehicles are quick to receive media attention, as are those involving manned aviation. Negative media attention to autonomous vehicles has been found to impact social perceptions of those technologies (Othman, 2021). Clothier et al. (2007) suggest that the general public's perceived risk of UAS cannot be quantified easily as it is a function of their understanding and awareness of the technology. The public acceptance of UAS within a wider mobility system may, therefore, not be linear or simple to predict and may change as new information becomes available.

3.8. Conclusions

Low-altitude UAS operations over populated areas are and will be essential in a large number of cases. It brings with it a number of associated risks not applicable to existing manned aviation operations, as most manned aviation operations are banned in such areas.

Population density analysis is an important consideration in risk assessments applied to drone operations, but it is only one of a number of measures that need to be factored in when considering ground risk. The methods of identifying these densely populated areas are also likely to move from a static model, which is more commonly applied to manned aircraft, to more dynamic approaches. However, assessment of ground risk will likely benefit from both static and dynamic population density information, with static used for planning and restricting certain areas (such as airports), and dynamic applied to consider the changing risk environment on the ground. For example, an operation in the 'Open' category may quickly move to the 'Specific' category if the planned area of operation is not as expected and a large crowd of people are present.

The risks to the public from drone operations in urban areas vary by type of operation and are not the same for smaller delivery drones compared to larger unmanned ones destined to carry passengers. The approach, therefore, needs to be proportionate.

Whilst safety, security and privacy are all considerations in the adoption of U-space, social acceptance is a particular area that requires additional strategies to normalise the operation of UAS over populated areas. The provision of information to the public through trials and demonstrations to increase awareness around drone operations and their societal benefits will be important as more use cases come online.

4. GOOD PRACTICES

KEY FINDINGS

- Good practices on UAS integration into airspace and over populated areas have been identified across third countries, and notable EU examples are provided where relevant.
- For UAS users with no aviation background, a number of good practices identified include user tools to support the operation of UAS in different airspace categories and over populated areas, as well as training focusing on the operational risks of weather.
- In addition, privacy management guidance was also found to be a good practice for all user types.
- Other good practices, less focused on the user's needs, include using demonstrators to showcase UAS operations in different environments and secure the buy in of stakeholders, including technological companies and cities in UAS development, or stronger military and civil collaboration (where relevant).

4.1 Introduction

There are some recognised benefits to identifying and sharing good practices, including improving the competence and efficiency of the industry, filling knowledge gaps (where they exist) or reducing the loss of know-how.

Stakeholders interviewed confirmed that Europe appears to be ahead of other regions of the world in terms of its UAS regulatory framework. Nonetheless, for some aspects of airspace integration, operators from diverse parts of the UAS industry and across different geographies share similar requirements and challenges, therefore, it makes sense to consider if good practices exist that may help fulfil some of these tasks in Europe as it seeks to advance its position globally.

With this in mind, we present below an analysis of possible good practices, including those from third countries, in order to integrate drones into the airspace and develop drone operations over populated areas.

4.2 Good practices identified

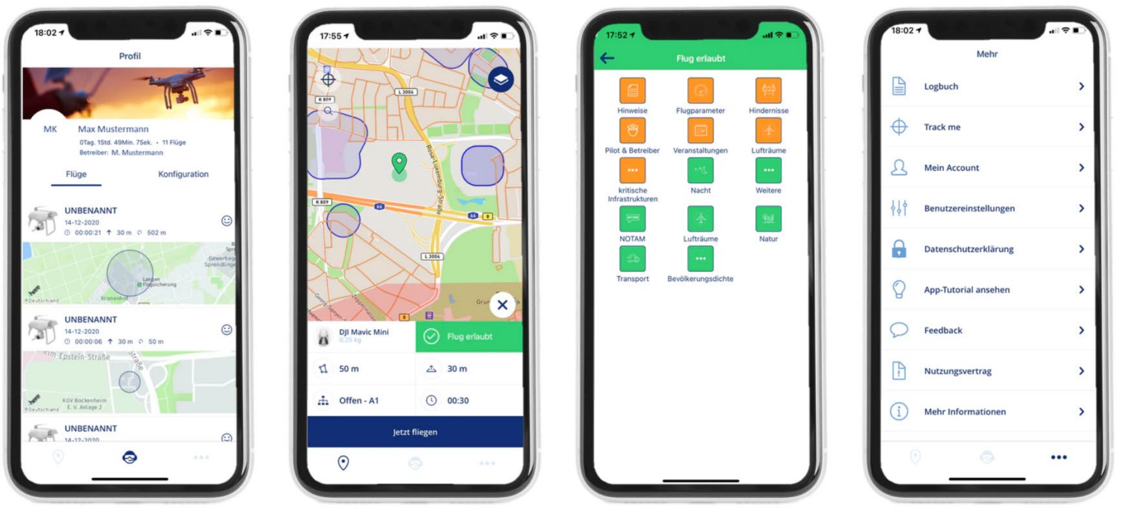
4.2.1 Good practices on user tools

a. Droniq app in Germany

The Droniq app (which is free to download) allows the user to find out where and how they are allowed to fly their UAS in Germany. The app was published so that it is compliant with EU regulation.

The map view of the app displays information on airspaces, airports, Notice to Airmen (NOTAM) and local weather data. Map information has multiple layers that can be shown or hidden according to the settings of the user. The app also allows for the transmission of the take-off location, so that the user's own drone is visible to other airspace participants (in the UTM) and they can also be warned if they use the Droniq app. In addition, the app allows for the registration of the user's drones, supports the pilot as they plan their flights and validates them against relevant EU regulations. The app also provides a logbook of the flights taken.

Figure 1: Droniq app functions



Source: Droniq GmbH

b. B4UFLY app in the United States

Recognising that many UAS operators have no aeronautics familiarity and would not be able to easily read an aeronautical chart map, the FAA has partnered with a private company to develop an FAA mobile application to improve the drone user experience so that users know whether it is safe to fly their drone.

The B4UFLY app (which is free to download) provides situational awareness to recreational flyers and other drone users. The user can input a set of GPS coordinates or just a location and very quickly see on their mobile phone screen whether he or she is "good to go", is in an area with a "warning" or in a "do not fly" area. In the case of "do not fly" areas, the map is covered by an opaque red filter, further reinforcing the point.

The app provides information about controlled airspace, special use airspace, critical infrastructure, airports, national parks, military training routes and temporary flight restrictions. It also comes with a desktop version to facilitate pre-flight planning and research. In addition, it links to other FAA drone resources and regulatory information.

c. Other user apps

Similar applications have been developed in Norway (Ninox Drone), the Netherlands (GoDrone) and the UK (Drone Assist), with app developers generally working with ANSPs and/or civil aviation authorities to make information available to users. These apps take into account privacy, safety, security and environmental concerns when highlighting areas of operation.

Whilst not in app form, Japan has focused on densely populated areas and provided a map for drone operators based on census data that highlights restricted areas based on ground risk (MLIT, n.d.).

d. Good practices on understanding the regulatory framework

In the USA, the Small Unmanned Aircraft Systems (UAS) Regulation (Part 107) is the most important regulation concerning UAS under 25kg (55 lbs). Depending on circumstances (whether the drone is flown for state business, for non-profit activities, for recreational purposes, etc.), there can be different requirements, such as the need for drone operators to be certified, which involves registering and taking a knowledge test (FAA, n.d.).

The FAA recognises that it can be confusing for drone users to know if Part 107 rules apply for their activities or not and has, therefore, developed a simple 'user identification tool' that allows drone users to understand what they must comply with. This tool is an interactive tree where users select responses to standard questions, with the final output being a clear answer as to whether they fall within the scope of Part 107 and a link to the adequate piece of legislation.

4.2.2 Good practice on privacy management

The US National Telecommunications and Information Administration published a set of voluntary best practices (NTIA, 2016) on privacy management. This follows the 2016 launch of regulations in the US for small drone operations. The document focuses on data collected via a UAS, whether operated commercially or not.

Its voluntary best practices cover topics such as informing others of the use of a UAS, showing care when operating a UAS or collecting and storing covered data, limiting the use/sharing of covered data, securing covered data and monitoring and complying with evolving UAS laws. The document also includes appendices for two categories of specific users: news agencies and a simple one-page for neighbourly drone use (i.e. recreational).

Specific industries have also put out guidance on the professional use of UAS and means of protecting privacy. The BBC has published guidance to journalists on the appropriate use of UAS when gathering material for an editorial (BBC, 2022).

4.2.3 Good practice on social acceptance

A recent report produced for Transport Canada by Chakravarti et al. (2021) proposed strategies to improve the social acceptability of drones. The report considers barriers to acceptance (similar to those identified in Chapter 3) and suggests recommendations on the topics of privacy, emerging technologies, safety and security, noise pollution and public outreach. The recommendations include a number of actions that Transport Canada may take on its own as well as a number of action items that can be completed in partnership with industry members, local governments, and the public. The report also suggests an implementation timeframe and a list of actions.

4.2.4 Good practices on flying in urban environments and populated areas

e. Awareness video on effects of wind in urban areas

In Canada, the authorities have been trying to raise awareness that flying in urban areas can be much more complex than flying in an open field. This is especially a risk for UAS operators because of the interactions between the wind and urban structures (tall buildings, etc.).

Transport Canada has developed a 6-minute video aimed at UAS operators to introduce them to key aspects of flight risks in these environments, such as wind speed gradients, venturi effects, leeward and windward effects, shear layers, turbulence intensity and wind vorticities (Government of Canada, 2021). It also includes a brief discussion on UAS icing risks. Note that the video does not cover whether it is legal or not to undertake such a flight in such urban areas.

f. Good practice from Japan

Japan introduced four levels of drone operations in June 2021 through its Civil Aeronautics Act:

- Level 1 is where the UAS remains within visual range of the pilot or operator. These flights are typically for operations like aerial photography and bridge inspections.

- Level 2 flights are automated, with a programmed departure, speed, route and arrival that take place within visual range. They would typically include operations to spray crops or survey land for civil engineering projects.
- Level 3 flights are beyond the visual line of sight (BVLOS) over uninhabited areas. They are permitted in places where humans are not usually present, such as over rivers, the ocean or forests. Some tests are being undertaken by the Japan Post for transport between post offices in remote areas.
- Level 4 refers to automated drone flights over residential and urban areas where the operator cannot see the UAS. The use of these flights could be for package delivery from warehouses to private residences.

The four levels have been permitted since December 2022, so long as the operator obtains permission from the central government for each flight. To pilot or operate a drone under level 4, the pilot or operators must have a first-class drone licence (valid for only 3 years) and take a course at a registered drone school, including a flight test and a physical examination. In addition, approval for each flight is required so that the level 4 flight plan does not overlap with the flight plans of other unmanned aerial vehicles.

However, given that the first exams for first-class licences only began in early 2023, this is still very new (Unmanned Aircraft Remote Pilot Licence Exam, n.d.). In parallel, the Japanese government continues to work with the industry on unmanned aircraft system traffic management (UTM) to help prevent accidents. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has also launched an easy-to-use web platform to support licencing and certification of drones in the level 4 category (MLIT, 2022), which includes links and information on flight approval, flight logbooks, incident reporting and rescue duty in case of injury.

4.2.5 Good practice on civil/military integration

g. Good practice on joint civil/military development program

Through the Agility Prime programme launched in 2020 (AFRL, 2021), the USA has made significant amounts of funding available to support the development of eVTOL aircraft (recognising the possibilities that eVTOL could provide to the military) and the increased development of a US commercial drone industry. By supporting collaboration between the US Air Force and commercial industries and by providing seed support to the burgeoning industry, the programme aims to:

- Lower technical risk through collaborative test and evaluation, utilising US government subject matter experts and test infrastructure;
- Address regulatory risk by encouraging collaboration and government attention on commercial certification paths necessary for civilian operations; and
- Lower financial risk by providing initial government contracts for data, testing, experimentation, use case exploration and early adoption for fielding.

For instance, the programme has fostered collaborative interagency agreements such as those with the US FAA on aircraft certification approaches, flight standards, aircraft configurations, powertrains and levels of autonomy. It has also contributed to the building of relationships with state and local governments to initiate commercial operations, such as the creation of the National Advanced Air Mobility Center of Excellence. The scheme has resulted in 23 contracts awarded to industry, 250 R&D

contracts issued to small and medium-sized enterprises (SMEs) and academia with over 400 test flights conducted (Afwerx, n.d.).

In fiscal year 2022-2023, the US Air Force is planning to spend nearly EUR 70 million (USD 74 million) on Agility Prime research, development, test and evaluation, EUR 3.4 million (USD 3.6 million) on procurement and EUR 8 million (USD 8.5 million) on operations, for a total of more than EUR 81 million (USD 86 million). Overall, in 2020-2021, the Agility Prime partners have raised over EUR 7.1 billion (USD 7.5 billion) (VFS, 2022)[11].

h. Good practice from Israel

Israel offers an advanced example of civil-military integration of airspace: the core focus of this country encompasses the strengthening of national defences against drone (and missile) attacks while increasing its commercial aviation safety and promoting urban drone operations for non-military purposes.

The Israeli police force is, for example, conducting trials with autonomous drone operations in airspace shared with military and civil aircraft in order to test these approaches and identify how they might need to evolve (McNabb, 2023). Although Israel has specific requirements of less concern to the EU, the regulatory arrangements between the civil aviation authority, the Ministry of Defence, airports, airlines and drone operators could be of interest in terms of balancing the needs of all airspace users (gov.Il, 2022).

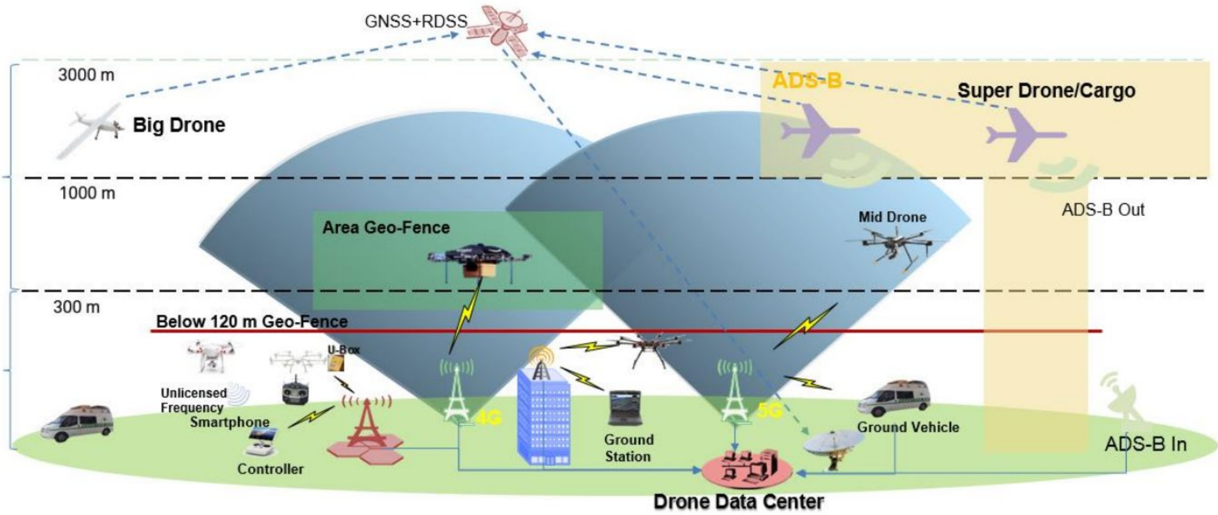
4.2.6 Good practices on supporting technologies

The use of spectrum has been identified as an issue facing the aviation industry and, in particular, mass UAS entry into airspace. Technology and communications company Huawei is working alongside the Chinese Civil Aviation Authority (CAAC) to develop the technology systems needed to safely support UAS integration into different levels of airspace. Huawei's advances with 5G have made them an active player in supporting the development of China's low airspace management structure. This is in contrast with Europe falling behind the US, China, Japan, Australia and Singapore in its 5G adoption (European Court of Auditors, 2022). In the US, tech company Amazon has also produced a position paper on how airspace design should incorporate small UAS operations such as their Prime Air delivery service (Amazon, 2015).

In 2017, in partnership with the Chinese Civil Aviation Authority, Huawei tested low-altitude cellular communication networks required for drones at low altitude, such as over populated areas (CAAC, 2017) and, more recently, it patented a new drone control system using artificial intelligence (Unmanned Airspace, 2021).

[11] USD/EUR exchange rate as of 26.03.2023.

Figure 2: Chinese UAS telecommunication approach



Source: CAAC, 2017

In terms of wider technical practice, China is one of the leading countries for battery development. Its manufacturing capabilities in this area mean that other countries are heavily reliant on China for the supply of lithium batteries for electric vehicles. Whilst battery range remains a common challenge for UAS currently, recent developments in China have involved testing lasers to keep drones in the air by way of remote charging (Evans, 2023).

In Japan, the MLIT has linked their technological requirements to a wider industrial roadmap of UAS applications, which has allowed them to move up their associated operating levels from one to four (Meti, 2018).

4.2.7 Good practice on demonstrators

A number of countries and companies are using demonstrators to conduct research, obtain data and build cases for UAS adoption. In Europe, R&I projects have been listed in Chapter 2 as part of the SESAR JU's very large-scale demonstrations. Demonstrators can be used to build social acceptance and the buy in of city stakeholders. Through interviews with stakeholders, we identified national and European trials, which often involved European cities. At a national level, the Amsterdam drone lab is a public-private organisation, which involves industry and city stakeholders in its demonstrations. It is able to capture public reactions to these trials through its Drone Alert service (Drone Lab, n.d.). Demonstrator projects can also involve cities indirectly. The Horizon 2020 AiRMOUR project on emergency medical drone integration involves replicator cities that can test and validate the outputs of the project and develop their understanding of how UAS can be integrated within their own mobility networks (Airmour, 2022).

In the US, the FAA launched a UAS test site programme in 2012, which has identified seven test sites across the country to verify the safe operation of UAS operations, including areas of certification and air traffic requirements. The scheme has been extended and is currently expected to continue until September 2023 (FAA, 2022).

In China, where eVTOL company Ehang has been building up to its own certification through its 100 air mobility route initiative, key routes have been identified that will connect key Chinese cities, expand testing and allow the operator to build up key operational data. Ehang is different from many of its global competitors in that it plans to skip straight to the certification of unmanned operations, whereas many European and US eVTOL companies are first focusing on the certification of manned operations (Hein, 2022).

4.3 Analysis of good practices

The good practices that we have identified vary considerably in terms of the level of potential they have, their benefits (and for whom), their replicability in a European context, their practicality, their costs and the type of intervention they imply. Hence, they give rise to a range of potential outcomes for users, administrations and the wider industry.

For each of the good practices identified, we analyse below whether and how these could be considered in a European context, using a number of criteria, such as privacy management and social acceptance. We then detail why we have assessed them as such.

Table 8: Replicability of good practice

Good Practice	Benefits	Intervention Type	Implementation Costs	Potential for Use in Europe
User tools	Development of user-friendly ways of communicating relevant information	Technical	Low	High
Privacy management	Improved knowledge of privacy requirements and social acceptance	Information sharing	Low	High
Social acceptance roadmap	Build social acceptability, data and trust by tackling key issues in a structured way	Practical, strategic, social	Low	High
Flying in urban and dense environments	Step-by-step approach to high-risk operations	Practical, regulatory	High	Average
Civil/military integration	Sharing of data and best practices to accelerate integration	R&I, investment	High	Average
Supporting technologies	Improved information sharing and development of enabling technology	Technical	High	Average
Demonstrators	Understanding concepts under 'real world' scenarios and demonstrating benefits to stakeholders	Practical, R&I	High	High

Source: Steer analysis

4.3.1 Good practices that we assess to have higher potential in Europe

i. User tools

Understanding and complying with UAS rules for operations in European airspace is important for ensuring safe operations. As the operators of UAS technology expand to new users, accessible apps and platforms will be important in disseminating this information, such as Germany's Droniq app or the FAA's B4UFLY app.

A similar EASA app could be created for sharing information on U-space services and areas where U-space operation is permitted, particularly for operators wanting to fly UAS in multiple Member States. This would provide an overarching application that follows the implementation of EU regulations rather than a fragmented approach by each Member State.

An app that provides both ground risk and airspace restrictions could be developed to support operations over particularly densely populated areas, similar to the map provided in Japan. However, as identified in Chapter 3, the incorporation of dynamic population density, as is emerging in web mapping platforms, could be more useful for UAS operations to account for the changing level of risk.

j. Privacy management

Privacy guidance, such as that made available by the US, or the specific industry guidance of the BBC, could be disseminated in a usable form to UAS operators. This would further support social acceptability and prevent both private and commercial operators from accidentally infringing on privacy regulations as they increasingly operate in lower airspace.

The main legal privacy framework guiding risk assessments for U-space is the GDPR (EASA, 2022). More guidance could be provided to operators as to how this legal framework applies to UAS operations, particularly in helping them to complete risk assessments.

k. Social acceptance

The step-by-step approach to building social acceptance through targeted actions, as identified in Canada, could be applicable to Europe and could follow the Drone Strategy 2.0 in setting out priorities for the short, medium and long term and the implementation partners that are needed to deliver these actions. This approach could follow the findings of the EASA social acceptability study when identifying priorities.

l. Demonstrators

Different Member States will inevitably develop U-space capabilities at different rates. The promotion of demonstrators to build evidence for the commercial viability of UAS operations whilst gathering performance and social acceptance data will be important in building buy-in across less active Member States that may wait for others to make the first move.

The inclusion of replicator or observer cities in these projects would incorporate a wider stakeholder group and ensure decisions are as informed as possible when planning for future urban mobility. Whilst demonstrators are already ongoing in the EU, the formation of these into a broader, coordinated roadmap with different options for involvement could support a structured approach to incorporating UAS more broadly across Member States and prevent trials from operating in silos.

4.3.2 Good practices that we assess to have lower potential in Europe

m. Flying in urban and dense environments

Similar to the use of demonstrators, the use of UAS in different geographies and for different purposes has supported Japan's path towards level 4 regulatory approval in urban areas.

Licencing requirements in Japan have also followed this step-by-step approach, with different licences provided based on the level of risk. This could help shape the way licences are developed between the 'Specific' and 'Certified' categories in the EU. The focus on low-risk operations could also build up social acceptance and performance data before being applied to more high-risk environments. The challenge of replicability is that different Member States may move at different rates with UAS adoption, which complicates the linear move from U1 to U4 at an EU level.

n. Supporting technologies

Technology companies are increasingly contributing to conversations around future airspace design, with Huawei or Amazon contributing to concepts for low-level flight in China and the USA.

Working groups and the inclusion of industry partners in consultations should be key pillars of delivering the EU's UAS ambitions and collaboration with the SESAR3 JU programme should be continued. At a global level, GUTMA and GSMA have set up a joint collaboration between the aviation and cellular communities as part of the Aerial Connectivity Joint Activity (GUTMA, n.d.). Whilst an industry-driven approach is less applicable to the EU due to its institutionally directed leadership, increased collaboration could help to make progress on technological issues such as spectrum, battery development and 5G and benefit discussions at a global level, including the upcoming World Radio Communication Conference. Similarly, the EU could link its recently announced technological roadmap to a wider industrial strategy for UAS deployment.

o. Civil/military integration

Schemes such as the Agility Prime programme in the US or Israel could also be adopted in some form within the EU to enhance shared technical learning between the two sectors and allow civil SMEs to feed into the military sphere, particularly as a means of overcoming procurement barriers.

While this is assessed as a good practice, it could be more challenging to implement in the EU, as the USA and Israel have involved a significant level of investment and benefit from operating out of one single country. Whilst EDA and SESAR JU could provide overarching guidance for a similar European scheme, it will need to take into consideration the needs and funding of Member States and European authorities.

5. MILITARY AND CIVIL DRONE INTEGRATION

KEY FINDINGS

- In ATM terms, military UAS are in 95% of cases identical to manned military or special mission aircraft and, hence, should not be viewed as a wholly new and difficult concern.
- Dual UAS use between civil and military systems exists and may grow, but it is unlikely to be a core driver of development.
- ATM is increasingly less about direct contact between ground and air crew and more about wider, autonomous management, a process that should allow easier acceptance of UAS introduction.
- This issue is dynamic and will continue to develop, placing emphasis on a flexible and non-rigid approach to the issue and recognising differing structures and responses across different EU Member States. Coordination, the addressing of responsibility and redundancy will be key.
- An EU industrial strategy would need to observe activity in third countries such as the USA and China that have advanced considerably in the encouragement of UAS technology through subsidies for both systems and certification.

5.1 Introduction

Drone use by the military has become increasingly common owing to their lower costs, the absence of direct risk to a human crew and their ability to stay in flight for long periods without fatiguing pilots. Traditionally associated with operations in the Middle East, their increasing ubiquity across NATO forces and the current development of new classes and types suggest they will be seen with greater frequency in EU airspace.

5.1.1 Use of drones by the military

Most current examples of military drone use are for observation missions, also known as Intelligence, Surveillance and Reconnaissance (ISR), providing real-time information to wider military forces. These can carry weapons, but currently such carriage is limited to a minority of missions and, where possible, any ordinance would be removed for transit flights to save weight. Though they can be directly piloted by a remote operator (on the ground or from another aircraft), operators tend to assign flight paths for the UAS to follow and manage rather than control the UAS. As artificial intelligence (AI) development continues, UAS will increasingly select their own flight paths based on mission goals. Though such autonomy may initially appear to be a concern, this computer control, along with on-board systems such as Automatic Dependent Surveillance–Broadcast (ADS-B) and continuous human monitoring, may in fact reduce the potential for confusion or error.

These types of UAS are known as Medium Altitude, Long Endurance (MALE) and usually operate in the 3-12 km altitude band (10,000-40,000 ft or focal length (FL) 100-400), placing them in potential conflict with civil traffic (upper air routes for commercial aircraft are around FL 250-460), and hence represent the priority for EU ATM development of civil military UAS integration.

Increasingly, they are being joined by smaller, 'tactical' types, operating in formations (swarms) at lower altitudes, alongside larger and more powerful UAS capable of high speeds at altitudes above 18 km or 60,000 ft. These new types will become an increasing part of military aviation and demand that EU ATM be flexible and adaptive as the UAS environment evolves.

5.1.2 The operational need to fly undetected

A key operational aspect of military aircraft is the occasional requirement that they not be tracked by civil radar and associated sensors and systems. This means ending transponder/ADS-B activity. With manned aircraft, this has been a choreographed exercise, mitigated by aircrew being able to exercise direct and immediate control of the aircraft, be in continuous voice communication with ATM and undertake VFR operations even where active systems have been disabled.

For UAS, such circumstances will require close coordination between the military operators and civil ATM, which is best handled by strict adherence to agreed flight plans and operating zones through the use of Notices to Airmen (NOTAMs) and similar procedures. Key questions to be resolved are the planning of the flight path or mission and how to ensure that civil ATM adapts rapidly to ensure continued safe and effective airspace management.

A subsidiary issue is that UAS need to gain significant altitude in order to perform their missions. The largest examples, called High Altitude Long-Endurance (HALE), cruise at 18 km or 60,000ft or higher, but owing to their relatively low performance, they require considerable time to reach this altitude. Typically, this process is undertaken over oceans prior to arrival at an area of interest (such as the Middle East, North Africa or Asia) but at times the climbing element may have to be undertaken closer to EU airspace. Though not an entirely new concern for ATM, as other military aircraft have also operated at such heights, this needs to be considered as to where such slow, lengthy transit may be safely managed given the large number of civil aircraft in the 9-12 km (30,000-40,000ft) block.

5.1.3 The dynamic nature of military operations

The dynamic nature of military operations may mean that, over a certain time period, an airspace classification changes and hence a military UAS may remain non-cooperative for the purposes of civil ATM. The current situation in Ukraine is an obvious example and this issue is likely to become more complex as manned and unmanned aircraft collaborate over Eastern EU states. These 'grey areas' of operating in normal EU-controlled airspace but undertaking military operations (falling under the Intelligence, Surveillance and Reconnaissance – ISR – bracket) will vary based on daily circumstances and are a key area in that UAS may wish to disable their ADS-B, transponders and similar systems in order to conceal their presence or specific location. This is a phenomenon that EU air traffic has faced with manned aircraft, but UAS will increasingly be used for such a role and this has to be a core part of planning.

As previously stated, unmanned military aircraft will be operated by a combination – and changing – variety of ground stations, combat aircraft and larger combat support aircraft (such as Airborne Early Warning platforms). This will complicate the ATM function and require that procedures be developed to address this dynamic UAS control approach.

Currently, most of the military UAS that require such a new approach are relatively understood models, such as the US Reaper or the EuroMALE under development. These have a similar performance to general aviation or small commercial aircraft. However, as noted above, the types and performances of UAS will likely rapidly develop and the manner of their control will become more fluid. Many UAS programmes are directed at 'Loyal Wingmen' (an unmanned combat air vehicle) that will operate autonomously alongside high-performance combat aircraft. It is therefore very important to understand the current challenge and how it will develop over the coming decades. This will require an ATM strategy that identifies how the militaries of the EU Member States are currently using their UAS (how, where and what performance levels they have) as well as considering what drones are likely to be operating in military service and what airspace and integration requirements will be in the 2040s. This is likely to become a more complex environment, with new types of eVTOL platforms, large, unmanned cargo aircraft and optionally piloted aircraft, for example, entering EU airspace before then.

5.2 Military and civil UAS solution overlap

A high degree of overlap between military and civil UAS is useful from practical and economic aspects. It also makes best use of ongoing software evolution to avoid using complicated and diverging technological solutions. There has been an increased use of commercial-off-the-shelf (COTS) IT solutions, such as Microsoft or equivalent open-source software used by the military.

However, there is a perceived risk that too much integration of civil technologies into military equipment renders military equipment overly transparent. The Link 16 standardised military data-link communications system will not be made available to civil traffic, but its outputs can be used by military aircraft (manned and unmanned) to assist ATMs via common civil networks. The military aspect is hence protected and flight and location data are shared in a restricted fashion.

A concurrent issue is that military interest in areas such as swarming or machine-learning autonomy currently does not have significant civil market potential and is therefore unlikely to be an area of common interest in the next decade. A key exception to this maybe is the US Air Force Research Laboratory's Agility Prime programme (AFWERX, 2022), in which the US government is helping US civil eVTOL programmes to become certified for commercial flight. This is because the US Air Force wants to use eVTOL aircraft as cargo and soldier supply transport carriers to the front line, which represents a clear overlap with civil UAS interests. As eVTOL certification has been estimated to cost around EUR 1.1 billion (Osinto, 2020), this programme is giving US eVTOL manufacturers a significant advantage in this fast-growing industry, for which there does not appear to be an equivalent in Europe. Goals to facilitate efforts by start-ups are a useful aspect of the efforts to create an EU drone market, and the Horizon 2020 plan identified this area as one for future research (Unmanned Airspace, 2022), but at present no close equivalent to the US programmes exists.

There is also an issue of divergence in objectives where civil and military solutions overlap. The European Parliament has previously expressed its unease about how dual-use UAS technology could be used in the future. According to a 2019 policy document briefing paper (European Parliament, 2019), two areas of concern were data protection issues and privacy for public use of civil UAS. This includes ensuring public support for EU initiatives while building confidence in a drone strategy that addresses the issue of illegal or unsafe drone use and where dual-use characteristics, particularly those of high performance or load-carrying, may present a threat.

A last point that links the ATM industry to industrial elements of the strategy is that key technologies are being transferred to third parties. While core military technology is generally difficult to move or sell illegally, this is not the case for overlapping technologies sitting at the junction of the military and civil sectors. Recent examples of Russian equipment used in Ukraine have shown a considerable presence of commercial EU technology adapted for military use, while similar items have been found in crashed Iranian UAS. The London-based Royal United Services Institute (RUSI) defence think-tank recently highlighted this problem (RUSI, 2023), which has been ongoing but will likely worsen given the steady growth of UAS and the obvious attraction of high-end COTS parts being used by dual-use drone providers. RUSI's conclusion was that "Russia's use of Iranian drones in its war on Ukraine highlights the need for European countries to take stronger action to prevent the transfer of dual-use technologies to Iran" (RUSI, 2023). One of the core elements of this was the availability of European systems purchased online with a high degree of anonymity. Therefore, many of the components are delivered to intermediary countries and then shipped to destinations such as Iran. The use of private organisations limits the transparency and hence the ability of security services to determine or intercept such traffic, as much of this dual-use provision exists in a 'grey', informal area. Such networks in border countries make for great difficulty in the prevention of such smuggling. This will be a key difficulty for the EU strategy and will require further examination.

5.3 Military management of UAS vs manned aircraft

Within the EU ATM industry, there is extensive experience managing military and similar state-owned, high-security aircraft that carry cargo or persons deemed to be at potential risk (which can be considered 'military traffic') along with civil traffic. The approach to integrate both civil and military aircraft has been codified by ICAO under the Flexible Use of Airspace (FUA) approach (EUROCONTROL, n.d.), which identifies the goals outlined by EUROCONTROL and focuses on the relevant points listed below:

- Availability of military training areas;
- Improved real-time civil/military cooperation;
- Reduction in airspace segregation needs;
- Improved efficiency in separation of military and general air traffic;
- Enhanced real-time civil/military coordination at local level and network level; and
- Definition and use of temporary airspace reservation in line with military operational requirements.

None of these points apply in isolation to manned or unmanned military aircraft, which are likely undertaking similar missions and require – for their purposes – similar ATM services. There are three types of scenarios for military usage in airspace:

- UAS may operate in civilian-controlled airspace, where they must follow the rules. This is no different from the current situation with military manned aircraft in airspace, which is discussed below.
- UAS may operate in segregated airspace for training purposes. In this case, there is no issue of airspace integration between civil and military aircraft, as civil aircraft are not allowed in these zones.
- UAS may operate in areas where civil rules do not apply. As said before, there is no issue of airspace integration between civil and military aircraft.

In the case of military UAS operating in civilian airspace, the issue of integration of military UAS on EU ATM is relatively straight-forward in 95% of cases, as issues of unintended and deliberate misuse do not apply to military operations. In addition, military assets are likely to carry a wider sensor package, behave in a more predictable fashion and have trained crews able to alert ATM authorities should any problems occur. The most complicated issue is likely to be that of both professional and ATM staff and wider public concern over aircraft that lack pilots but may possibly be carrying live weapons. A significant part of solving this issue is educating the wider public.

Regarding the civil/military integration in the airspace and the difference between manned and unmanned platforms, one important element is that ATM civil staff understand the technical aspects of military UAS and how these are operated (Unmanned airspace, 2018). As noted above, UAS are less 'flown' but rather 'managed'. Though arguably modern flight crews have a similar approach to both military and civil aircraft, a priority will be the opportunity for continuous communication with the UAS pilot/supervisor (as UAS will increasingly operate autonomously under the accountability of a supervisor). Unlike manned aircraft, it may be less evident as to who is in control (or managing) a UAS at a given moment. Hence, ATM personnel may need to understand the hierarchy of UAS operational control and the interaction between the manned and unmanned military aircraft (where controls may be handled between a ground-based UAS controller and an airborne operator). As UAS design and system carriage will also vary, it is important that ATM understand the on-board sensor array of differing UAS platforms and the manner in which these cope with emergencies or unforeseen circumstances for both civil and military operations. As indicated above, larger UAS will use flight planning and standard IFR operations, so direct voice communication with the operator will be limited except where, due to specific circumstances, it becomes necessary.

In the case of emergency service use of UAS, this will add a further dimension to ATM, as they will likely have performance similar to civil examples but be operated by professionals and over densely populated zones. However, this should be seen more as an element of UAS integration in the wider military and security area rather than a wholly separate category and addressed as part of the low-altitude (below 150m/500ft)/VFR element that covers the military and public UAS elements of airspace integration.

A less critical but developing issue will be the transforming nature of the UAS themselves as militaries invest in larger numbers of 'swarms' of smaller UAS that operate as a single entity but over a diverse physical airspace. At present, this question has not been answered, as these types remain in the basic stages of development but should be considered an issue for the next decade. Clearly, this is a very different prospect from the single or small formations of military aircraft currently in operation.

All of the questions cited above have a degree of overlap with manned aircraft, particularly as the two operate concurrently, but will require new procedures and training as well as flexibility in order to be successfully addressed.

5.4 Challenges and barriers to military UAS integration

A principle of integrating current and evolving military UAS into civil-controlled airspace should be to avoid replication of work that has already been undertaken by different organisations. This should allow for an evolving understanding of how existing concepts such as aircraft-based 'detect-and-avoid' safety protection systems are aligned with ATM practices such as military and civil aircraft separation.

To a degree, the overall framework for military and security UAS should derive in part from similar approaches and guidelines to those of manned aircraft. There is a significant overlap in terms of all military aircraft – manned or unmanned – using different flight paths, data sharing and the necessity to end normal position location/transmission during 'grey areas' of operations. It should be noted that the last point would be of issue only during critical elements of a mission, and is hence unlikely to be frequent during operation in EU airspace. Nevertheless, training for ATM staff and the establishment of clear procedures will reduce the inevitable human reaction where ATM personnel feel concern over managing unfamiliar and unmanned aircraft. The inability to speak directly with an on-board crew will require a new approach and acceptance of more 'remote' ATM operations. Though the reality of UAS in mixed airspace should not be an actual ATM concern, this understandable 'fear of the unknown' must be acknowledged and addressed in training and preparation. Given that direct voice communication is becoming a more limited part of ATM, this is not itself an issue but more one of building confidence among ATM personnel via familiarity.

Similarly, planning must be made for the inevitable and likely negative public reaction. Popular media and reporting have tended to cultivate a deep suspicion of military UAS, which represents a challenge. Popular protests, leading to hasty political intervention, must be expected and hence addressed. A programme of confidence-building will therefore be essential from the start, alongside technical and professional aspects of the strategy.

An issue that the EU will have to address is that of core and common EU Member States militaries and organisations versus non-EU operators. The majority of these will be NATO or NATO-aligned examples and hence have a general understanding of the issues involved. Nevertheless, specific UAS operating procedures need to be clearly established, particularly what the military classifies as 'second degree concepts', such as liability in case of errors or emergency procedures. For instance, a UAS military operator based in the US could be managing an unmanned platform in European airspace but be less aware of European airspace procedures versus those in US airspace within which he or she normally operates.

A further technical challenge is consideration of scalability, meaning an understanding and planning of how to accommodate the rise of next-generation military UAS and their widening activities. Such new UAS and operations include new-generation fighters with semi-autonomous 'loyal wingman' (a pilotless aircraft with enough flight performance to accompany fighter aircraft), networked 'swarms' of small UAS and machine-learning autonomous systems that are given a wide mission remit by their operators. These will all need to be addressed and accommodated in the EU's limited airspace. This will require the flexibility of new ATM concepts to better address this extremely complex and evolving new aerospace picture as it develops. We note that extensions to Advanced Flexible Use of Airspace are already planned to allow for more dynamic airspace allocation, including bigger military training areas.

A core requirement, derived from the above, is the need for a clear delineation between developing common operational standards for UAS ATM and the recognition of work that has been undertaken, in some cases by individual member states, in this area and where difficulties have already been identified.

An example of this is that of low-altitude operations (below 500 ft, where small, tactical military UAS operate). There is an unresolved issue of how to ensure that smaller aircraft can be safely flown in the same airspace as these tactical UAS. At present, such aviation covers most of low-level EU airspace and is not closely controlled by sophisticated ATM. Instead, it relies primarily on VFR (Visual Flight Rules) together with 'sense and avoid' aircraft systems. It is vital for the adequate integration of civil and military aircraft that the operation of these smaller UAS and procedures for ATM are harmonised in all EU states, otherwise, there is a danger that an aircraft on-board protection system will tell the UAS to manoeuvre in one direction to avoid a collision while the ATM will command the UAS/operator to fly in a different direction in order to avoid a collision. While this issue also exists at higher altitudes and with larger aircraft, the relatively basic ATM at low levels, the shorter line-of-site and the less sophisticated aircraft sensors all suggest that this will present a problem. National or local variations, though nominally no longer authorised, could exacerbate potential dangers in this crowded and less controllable environment. Though such variations should not exist, small differences can occur and this needs to be taken into account, not least of which is the potential for confusion where the UAS itself and operator are not from the EU and hence may have slightly different procedures. This is an issue for general military traffic and not simply UAS. Even within militaries, such errors do occur. Several studies of interest exist from bodies such as ICAO, EDA, the Mid-Air Collision Avoidance Programme (MIDCAS), SAFETERM and previous UAS EU papers.

In the same manner, concerns will likely exist from the military regarding ATMs losing situational awareness in such circumstances, particularly during hand-over between controllers in different regions. Hence, it will be necessary to follow instructions from ATM operators that are using local data rather than policies, procedures, rules and standards that may have been in effect, for instance, in the UAS point of origin outside the EU.

5.5 Conclusions

Integration of military and equivalent UAS into mixed airspace will benefit enormously from the experience gained by ATM through decades of manned equivalents using EU skies. Mutual agreement with manufacturers and operators concerning responsibilities and procedures, greater UAS familiarity among ATM personnel and an understanding of how to manage the 5% of UAS operations that are more complicated should all be achievable and present no serious problems for the EU airspace environment. Using the work that has gone before and addressing the concerns of specific groups on key issues – such as data sharing or the necessity of 'transponder-off' operations – will require careful thought but is eminently achievable. As a basis for planning, however, as with most aviation subjects, it should be approached with the understanding that errors and unforeseen issues will arise and hence the efforts should be regarded as a fluid and evolving study.

The use of EU airspace by non-local operators and platforms does raise other issues concerning the potential for incidents as well as a wider point over EU sovereignty. The need to prescribe EU airspace regulations rather than having them imposed from outside is clearly a core part of developing a strategy. Concurrent with this is the offering of incentives to industry. This latter point is an area in which the EU is arguably training the US and China, where government programmes are seeking to reduce cost and risk for private sector development in the UAS and eVTOL markets. This needs to be addressed to avoid the EU becoming uncompetitive as a technology development region.

Although synergies will develop between the civil and military spaces, these are likely to prove organic rather than an area where direct action can be taken at an EU level. Concurrent technology interests will spur the exchange of concepts, research and systems and platforms, but these are likely to be influenced more by wider market forces than specific planning or directives from the EU as an entity.

6. DRONE STRATEGY 2.0

KEY FINDINGS

- The Drone Strategy 2.0 is the next step in achieving UAS integration within the EU. It sets out the ambition for UAS and their required ecosystems to be an accepted part of EU life.
- The strategy provides good coverage of the issues facing UAS airspace integration. However, it may slightly underplay the difficulty in achieving full integration with manned aircraft and regulation of the 'Certified' category and unmanned Urban Air Mobility.
- Social acceptance and ground risk for operations over populated areas do not receive much coverage in the Drone Strategy 2.0.
- The strategy does not provide an industrialisation roadmap. While the strategy identifies measures to complete the regulatory framework, provide R&I and support industry coordination, more work is required on how certain concepts will be operationalised and the data that will be required to inform decisions.
- Current measures are not scalable, with more work needed for both traditional and non-traditional aviation operators of UAS.
- Accountability and prioritisation of the 19 flagship actions would better support the European Commission in moving towards its 2030 goals.

The publication of the Drone Strategy 2.0 in November 2022 is the next step in achieving UAS integration within the EU. It brings together the regulatory, funding and coordination actions required by the Commission and EU institutions to support the growth of the drone ecosystem as an enabler of a green and digital Europe. It also sets out 19 flagship actions against two key objectives, namely building a union drone service market and strengthening European civil, security and defence industry capabilities and synergies (Drone Strategy 2.0, 2022).

6.1 Overview of the Drone Strategy 2.0

The strategy sets out a vision for the further development of the European drone market, which was formulated as:

- By 2030, drones and their required ecosystem will have become an accepted part of the lives of EU citizens.
- Drones will be used to provide numerous services to the benefit of diversified civilian and defence end-users, including EU citizens, organisations, Member States and industry. Drones' aerial operations will include emergency services, inspections and surveillance using drones to gather data, as well as the delivery of goods.
- An increased spectrum of distinct types of drones and use cases will coexist.
- Innovative Air Mobility (IAM) services will start providing regular transport services for passengers, initially using aircraft with a pilot on board but with the ultimate aim of fully automating their operations. UAM will become a part of the future urban multimodal intelligent mobility ecosystem and the ground and air infrastructures enabling these transport services will be widely deployed and integrated.

- The current U-space regulatory framework will have been completely rolled out in the EU. The integration between manned and unmanned traffic in the same airspace will be initiated, inside and outside U-space airspace.
- The EU drone industry will have become viable and accessible to EU citizens and businesses with the active participation of actors of all sizes, including a variety of diversified SMEs.
- Civil-defence industry synergies will be systematically identified and exploited to benefit both sectors, improve the competitiveness of European industry and strengthen Europe's strategic autonomy.
- The drone ecosystem will provide jobs, promote and protect European technological know-how and allow for growth opportunities for the EU economy as a whole.

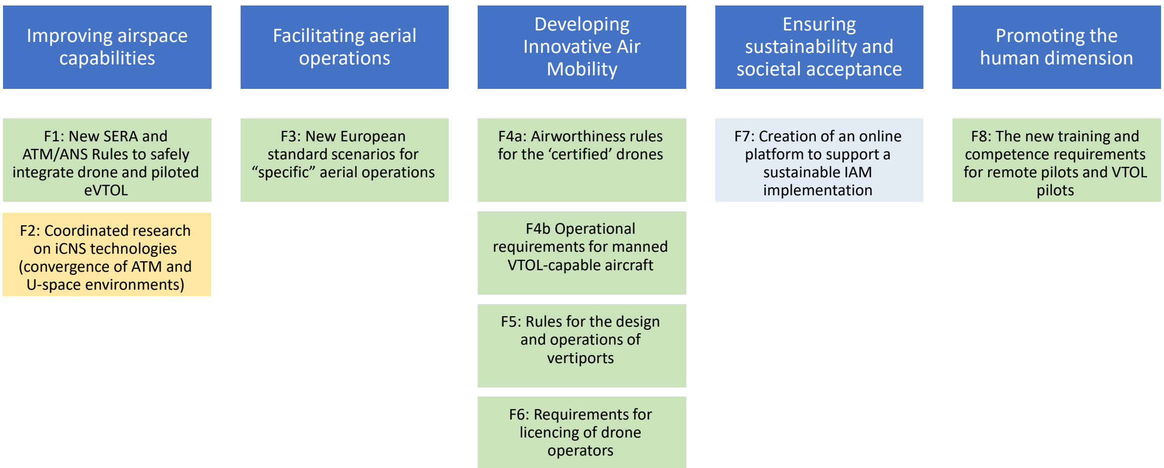
The strategy was developed from a multitude of sources, including a large programme of stakeholder engagement, a report from the Drone Leaders Group [EC 2022] as well as inputs from the informal Drone Experts Group.

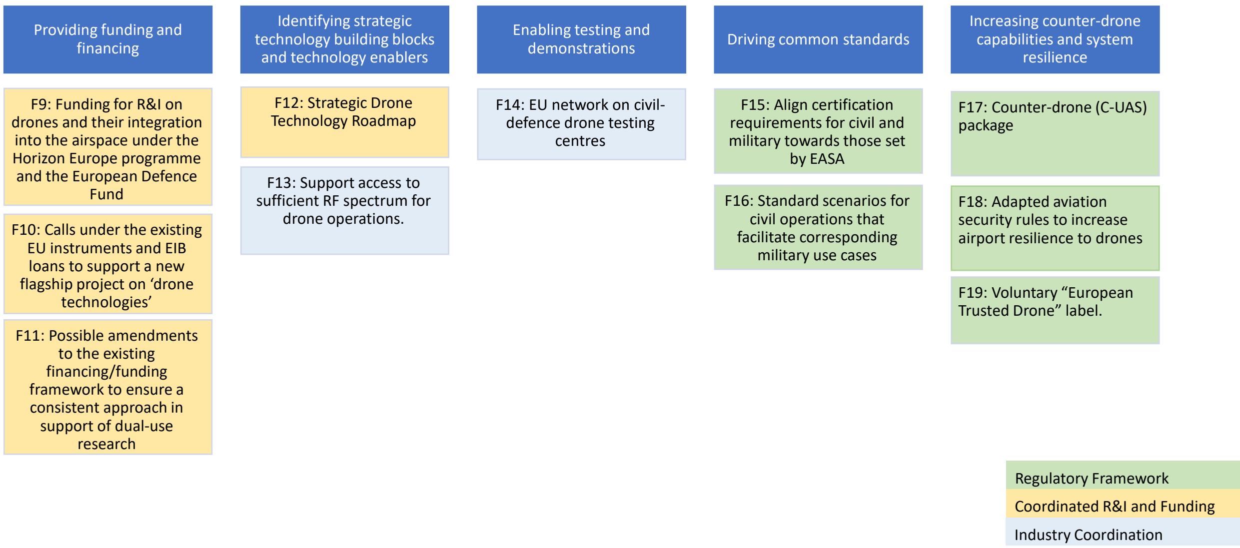
To achieve its vision, the strategy sets out 19 operational, technical, and financial flagship actions to build the right regulatory and commercial environment for tomorrow's drone air space and market.

As highlighted in the figure below, the strategy suggests different types of actions:

- Completing the regulatory framework for drones and Urban Air Mobility;
- Supporting coordinated R&I, including provision of public funding; and
- Supporting industry coordination on three key themes: the role of UAM as part of the wider mobility required in urban areas (flagship action 7), support access radio frequency spectrum for drone operations (flagship action 13) and a network of civil-military drone testing centres (flagship action 14).

Figure 3: Flagship actions of the Drone Strategy 2.0





Source: Steer analysis of the Drone Strategy 2.0

6.2 Assessment of the Drone Strategy 2.0

6.2.1 Stakeholder views

The stakeholder engagement programme for this study was based on ten interviews carried out between January and March 2023 with a mix of institutional and business stakeholders from organisations active in airspace management, drone operating and manufacturing, UAS R&I, defence and traditional aviation activities as well as city authorities. Interviewees mentioned that the drone community welcomed the strategy. There was broad consensus that the strategy provided important and necessary political direction for UAS integration within Europe and addressed the right topics and largely took into account the input from the Drone Leaders Group.

Whilst most stakeholders interviewed agreed that existing and future UAS regulations were both important and necessary, industry representatives stressed the importance of ensuring that regulation does not slow down or limit progress. Stakeholders also acknowledged the funding mechanisms identified in the strategy but were concerned as to the extent to which they would adequately support some of the more complex system requirements for scalable UAS adoption. We also recorded strong interest from both institutional and business stakeholders for wider industry involvement. Industry representatives were keen to see more accessible funding made available to support a competitive operating environment within the EU.

Interviews with city representatives demonstrated the different levels of engagement and preparedness for UAS adoption at Member State level, with some cities leading the way and others waiting to learn from the first movers. Regardless of their involvement, stakeholders interviewed broadly agreed that the strategy covered most of the issues currently facing UAS integration. They stated, however, that a clearer roadmap would be beneficial to understand who is responsible for each flagship action and what flagship actions should be prioritised. The complexity of implementing some of the flagship actions relating to the 'Certified' category, rules of the air and airspace integration was also highlighted as was the need to make current procedures scalable. However, stakeholders appeared to differ over the extent to which UAS specifications could build on existing manned aviation operations and standards or whether they would require a new approach and change in paradigm due to their specific technical differences.

Some additional issues or gaps were also highlighted through our review work. Below, we list them in groups according to themes.

6.2.2 Integration of UAS within the European airspace

The strategy rightly focuses on the integration of UAS (that is, where UAS have full access to airspace shared with other users) as the long-term goal. For UAS to offer commercially viable and scaled-up services, it will be necessary to allow integrated services requiring both 'detect and avoid' (DAA) avionics and U-space levels 3 and 4, which are not yet validated or standardised. The fact that UAS cannot conform to standard rules of the air, particularly regarding 'see and avoid' will require legislative amendments as identified in flagship 1. However, these changes will likely take time and require coordination at a global level.

The pathway to integration will need to be supported by R&I and large-scale demonstrations of the technology and operations required. Multiple flagship actions reference R&I (including flagship actions 9, 10, 11, 12 and 14). We note that it will be important to ensure that these developments can be implemented and funded across Member States and that the supporting technical systems advance at the same rate.

We also note that the difficulty of stepping from accommodated to integrated operations may have been somewhat underplayed in the strategy. The development of innovative air mobility, particularly those intended to carry people and dangerous goods, will require these operations to take place in the 'Certified' category, which requires further work as has been identified in flagship 4. However, the necessary regulations and standards are not sufficiently mature and early adopters are likely to need to use segregated airspace and rules for operations and airworthiness largely based on the existing rules for manned aviation. We make a number of remarks:

- The airworthiness certification of eVTOL uses the same certification specifications as manned aircraft. It will therefore be necessary to develop drone-specific material based on the data gathered during the development process. This is because eVTOLs have a different flight envelope than existing aircraft (in terms of operating speeds and altitudes) and will therefore require a completely different form of traffic management. This will particularly be the case if multiple eVTOLs are able to operate from the same vertiport, as the business case for UAM seems to suggest. This may mean that EU funding for flagships 9, 10 and 11 needs to focus on high volume operational concepts and supporting technologies.
- The strategy rightly considers IAM (urban, regional and international air mobility) and not just UAM. We would assess that completion of the regulatory framework is sufficient for regional air mobility when operating fixed wing UAMs out of existing airfields (as opposed to rotary wing drone operations at vertiports, as will be the case for urban air mobility). However, the international dimension seems to be missing from the strategy.
- There also does not appear to be consideration for other innovative air vehicles such as High Altitude Platforms or High Altitude Long Endurance aircraft, which are manned or unmanned aircraft positioned above 20 km altitude in the stratosphere in order to compose a telecommunications network or perform remote sensing for civilian or military applications. New types of supersonic aircraft operating in higher airspace may also need to be considered in the strategy so that all forms of innovative unmanned aviation are included.
- Ensuring that communications, navigation and surveillance systems (CNS) deployed for UAS are able to operate in urban areas is critical (flagship 2), noting that traditional CNS may not be appropriate due to propagation models based on line of sight. Flagship action 2 focuses on

integrated CNS, including U-space and Innovative Air Mobility, and it would be ideal to ensure that this specific urban issue is included in its scope.

6.2.3 Safety

A method for developing performance-based standards based on data collection will be required to ensure the safe integration of UAS within European airspace, particularly to support deconfliction minima in integrated airspace. The collection of this information will be important to scalable operations for all sizes of UAS. In the 'Certified' category, performance data will likely start first with manned passenger carrying eVTOL before being applied to unmanned operations.

Approaches to UAS safety within European airspace are also likely to require a more dynamic approach than that currently applied to manned aircraft. UAS operations could quickly move from the 'Open' category to 'Specific' during flights, based on a changing ground risk. Similarly, more advanced methods of assessing population density could enhance the level of assurance provided in risk assessments. The ability for UAS operations to adapt to these circumstances and respond to emergency situations, which may require the grounding of aircraft, needs to be considered, as do the possible difficulties involved when communications are no longer directly with a pilot on board.

The specific focus on ground risk appears to be missing from the strategy. Whilst this risk is covered by the SORA for the 'Specific' category and will be tackled through certification of more high-risk UAS, cities and urban areas will need to remain informed on how they can safely incorporate a higher number of these low-level operations within their wider infrastructure and transport networks and future urban planning decisions. The strategy focuses on the issues of social acceptance and sustainability, but not on how cities can help support the high level of safety standards in aviation today. Neither does it cover how they will be involved when taking account of operations in lower-level airspace, particularly in the shaping of new lower air routes and the positioning of alternative landing sites.

Proportionality will be key when dealing with the safety issues of incorporating UAS into European airspace. Flagship action 3 calls for more standard scenarios for low- and medium-risk aerial operations. This seems sensible, however, it is crucial that Standard Templates (STS) are not used for medium- and high-risk operations, in particular, pre-authorisation should not be used for operations that include flying over assemblies of people. Certification and licencing should be used in these cases.

Flagship actions 6 and 8 identify licencing and training requirements, which will be important to improve the safety and accountability of drone operators. There could be some work to be done on how best to deliver this and implement compliance for both traditional aviation and non-aviation UAS operators, particularly at scale given the number of UAS operations that are forecast to enter the market.

6.2.4 Security

The counter-UAS package (flagship actions 17 and 18) is critical for improving safety, security and social acceptance. This is one area where the different methods of kinetic and non-kinetic counter-UAS should be considered, particularly when finding the most appropriate method near high-risk areas such as over populated areas and airports where there is a collateral risk. The liability issues associated with counter-UAS must also be considered as part of this package, along with identifying who is responsible for these measures near critical infrastructure such as airports.

Further steps, which do not appear to be currently included in the strategy, are the required measures that will be taken if operators act outside the remits of their licence (either intentionally or accidentally):

For instance, there could be some consideration for possible penalties for infringements (without being too limiting so as to restrict the development of the market, particularly for individual or SME operators). The provision of information to UAS operators to prevent accidental security infringements will be important, as will a system that can quickly assess the intention of the UAS infringement. The inclusion of national security bodies should be included in the development of flagship 17.

A common approach to radio frequencies for drone operations will be an important means of improving security and preventing interference with communications. Work is needed to strengthen these communication channels against interference technologies identified in the literature review. Working with the telecoms and other digital industry stakeholders through forums such as the Aerial Connectivity Joint Activity should be prioritised as part of the industry engagement referenced in the strategy.

With a large number of UAS and systems being procured from non-EU suppliers, particularly China, some form of common EU standard, such as the EU Drone Label, would mitigate against a diverse range of capabilities and the absence of commonality. Though it should be recognised that international trade will result in non-local products in circulation, the use of UAS by any form of government agency must be strongly policed and a UAS with capabilities exceeding certain parameters should also be included in strict regulation. Though not currently a threat, the dependence on a variety of communication and control systems from a mass of providers represents a danger to the control of UAS and the potential for malicious action by third parties that may be able to override direct command for their own purposes.

6.2.5 Military and civil integration

Common technology standards between civil and military stakeholders are beneficial to all. While they are recognised in the strategy as a key part (flagship action 15), there also needs to be recognition that other major participants in the military area (such as NATO members) have separate programmes that will also require a degree of commonality, such as with the US Agile Prime initiative. Nonetheless, commonality across Member States and drone types and purposes will be a key element of deploying the Drone Strategy. EU Civil and Defence drone testing centres have already begun via various initiatives and joint centres for testing and exchange of data and concepts – with the concurrent declining barriers between COTS and MOTS usage – will be of high importance, especially to reduce military barriers for further COTS and MOTS (modified or modifiable off-the-shelf, or military off-the-shelf products are typically COTS products whose source code can be modified) use.

However, the Drone Strategy places perhaps too much focus on the potential for finding synergies between civil and military dual-use technologies. This was more of a credible potential idea in the past, but the pathways of technology development for civil and military operators have begun to diverge owing to concerns that military UAS with commercial components can now be easily tracked by hostile sensors (as very recently observed in Ukraine). Hence, militaries now require more (cyber) resilient communication systems and standards for command-and-control, video downlink, telemetry and similar.

6.2.6 The role of stakeholders and social acceptance

We note that while the strategy mentions the roles of the EASA, EDA, EUROCAE and SESAR JU, there is less mention of the wider stakeholder community and no mention of the role of EUROCONTROL, which, however, plays a central role in the coordination of stakeholders in support of safe drone operations (EUROCONTROL, n.d.). The organisation has developed a network of U-space users pulling together the resources of civilian U-space centres and, on the basis of flagship 14, is already working with EDA to include military test centres.

The development in the use of UAS and particularly eVTOL means that stakeholders new to the aviation environment, such as city authorities, will need to play a role. Flagship action 7 rightly addresses the need for an online platform to support a sustainable IAM implementation by authorities, communities, municipalities, industry and stakeholders which will likely include information and guidance on infrastructure and technical capabilities. However, in spite of acknowledging that social acceptance is key to their successful development, beyond this online platform, there is little coverage on how social acceptance will be ensured.

For social acceptance, it might be necessary to consider small drones and IAM separately:

- When small drones are discussed in the public media, it is often for the nuisance they can cause when operated inconsiderately or illegally (for example, halting sporting events or runway operations). The detailed rules for the 'Open' and 'Specific' categories are designed to reduce this nuisance. Another issue with small drones is privacy, particularly where they are fitted with cameras. Drone operators are required to comply with privacy and data protection laws; the requirements are normally expressed in a national 'code of conduct', for example, in the UK (CAA, 2023). This is perhaps another area where the sharing of information among UAS operators could be enhanced.
- For IAM, which will initially be manned and then unmanned and will have a similar mass to current helicopters operating in urban areas and routes flying over people, this will cause a range of concerns within society related to safety, noise and visual impact. Virtual reality simulation may be a tool to enable people to understand the potential visual and noise impacts of drones. As described in Chapter 3, work in this area is, however, in its infancy and is therefore not explicitly addressed by the Drone Strategy 2.0. Completion of the regulatory framework and, in particular, regulations that require certification of UAS and operations near people will support general acceptance, including the flagship 19 on a 'European Trusted Drone' label. A coordinated approach similar to that proposed in Canada could close the gap on social acceptance issues with a clear pathway setting out the required actions.

6.2.7 Coherence and integration with other European policy strategies

Adoption of drones within the wider European economy will be dependent on the extent to which they support the wider green and digital EU ambitions identified in the Digital and Sustainable and Smart Mobility Strategy.

A number of the flagship actions identified by the strategy identify the requirements for regulations, standards, research and infrastructure needed to support greener air mobility, whilst the need for security, particularly cyber security, automation and smart cities will interlink with Europe's digital priorities. The strategy, however, is not explicit on how it will join up synergies between the different overarching EU work streams, particularly on the digital side, to advance the technology required to support UAS adoption. Similarly, the technology roadmap proposed in flagship 12 could be attached to a wider industry roadmap, similar to that in Japan, which sets out the types of UAS operations it could support and how this interlinks with the different stages of U-space.

6.3 Conclusions

The Drone Strategy 2.0 provides a comprehensive set of flagship actions to support the evolution of the drone ecosystem and promote safe use of drones for a range of aerial operations and, in time, innovative air mobility solutions in urban areas. The main areas of focus are completing the regulatory framework, stakeholder coordination and the provision of R&I and funding.

We assess that the strategy correctly captures the need but may downplay the difficulty of scaling operations, both in terms of scope and diversity of operation, and particularly in achieving full integration with traditional manned aviation to a certain extent. Whilst it identifies the key need for technological advancements, standards and rules of the air, it does not assign dependencies, with many of these flagship actions dependent on each other for the successful integration of UAS within airspace. Prioritisation via a clear implementation plan would enable the strategy to move from U1 and U2 U-space towards more complex U3 and U4 operations without the risk of leaving these more complex elements until last. The strategy also does not explicitly provide a clear set of actions for operations over populated areas or ground risk in particular, or how issues of social acceptance should be tackled or approached in these environments.

7. CONCLUSIONS AND POLICY RECOMMENDATIONS

KEY FINDINGS

- Further development is required to complete the regulatory framework for UAS operations and support the development of advanced systems and procedures.
- Airspace integration should focus on U-space levels 3 & 4 which are yet to be developed, with R&I focused on scalable operations both in terms of technical capability and accessibility to the market.
- Operations over people involve increased risk and additional mitigation measures. These risks will require a step-by-step approach to safety and social acceptance.
- Military and civil integration are already ongoing and supported by the strategy. Awareness of actions taken in third countries will be important as well as contingency measures, which cover both military and civil UAS operations.
- The delivery of Drone Strategy 2.0 will require coordination, accountability and prioritisation of flagship actions.
- Incentives to industry is an area in which the EU is arguably lagging behind the US and China, where government programmes are seeking to reduce cost and risk for private sector development in the UAS and eVTOL markets.
- Policy recommendations have been proposed on the supportive measures that can be taken to deliver the flagships within the strategy, including promoting demonstrators, information sharing, prioritising funding and data gathering. They also provide practical suggestions on how the strategy can be delivered in its entirety.

7.1 Conclusions

The report has considered the use and integration of UAS for aerial operations and innovative mobility within European airspace to understand obstacles and solutions. The use of UAS for aerial operations is becoming commonplace, but is so far largely limited to operations of small drones within line of sight (on the civil side). To achieve the economic promise and support for green mobility offered by UAS, further development is required to complete the regulatory framework and support the development of advanced systems and procedures to scale up operations.

7.1.1 Airspace integration

The key to supporting airspace integration in EU airspace is the continued development of U-space services. U-space levels 1 and 2 have been validated, defined in EASA Regulations and are being rolled out across Europe by the first U-space service providers (although with varying degrees across Member States). This will enable aerial operations and parcel delivery in a wide range of environments, but does not cover operations over people or mass mobility. For that, U-space levels 3 and 4 will need to be developed, validated, and regulated. The current focus of research on U-space levels 3 and 4 will support the required development, validation and implementation.

R&I has been focused largely on the proof of technology. The focus now needs to be on the support systems for scalable commercial operations, particularly the integration of more high-risk UAS operations in urban areas. The move from a less efficient segregated airspace model towards UAS integration requires technical operating concepts underpinned by evidence. This is particularly the case for technologies that will allow for safe operating minima between manned and unmanned aircraft, the link between U-space and ATM and CNS requirements, including communication channels between the UAS, its operator and air traffic controllers. Many of these developments will be dependent on greater automation, which will require changes to the legal framework for airspace users and ATM. This will necessitate changes to the rules of the air, which are currently built on a long history of traditional manned aviation.

Safety issues regarding standardised reporting, a single reference altitude and collision avoidance systems such as detect and avoid and operating in adverse weather conditions are all factors that need to be addressed when integrating UAS within airspace. The range of security risks and their possible countermeasures will also need to be considered. Scalable licencing of operators will be important due to the predicted size of the market, as will a greater understanding of the liability and accountability of counter-UAS measures. To support scalable UAS adoption, a revenue framework will also be required that allows ANSPs and USSPs to provide services to new airspace users.

Based on the above, we propose the following recommendations:

- The European Parliament should promote information sharing across private and commercial users of UAS, including the legal requirements of UAS operations, post-occurrence safety reporting and the use of dynamic population density information as part of UAS risk assessments over populated areas. The benefits of an EU-wide app should be considered as a platform on which airspace information could be shared with UAS operators.
- The EU should prioritise R&I calls and associated funding on the most challenging airspace integration issues that may require the greatest coordination at the Member State and international level, such as the enabling of automation technologies to allow for entry to integrated airspace, amendments to the rules of the air and requirements for the 'Certified' category.
- The European Parliament should continue to ensure that UAS regulations do not become a prohibitive barrier to adoption and competition within the market whilst ensuring EU safety standards are maintained.
- The European Parliament should support large-scale, long-running demonstrators across different environments in the EU, as they are important to the collection of data, informing evidence-based decisions, and supporting wider public acceptance.

7.1.2 Operations over people

There is still an undefined risk in allowing drones to operate over people; as evidence is gained from the real-life operations currently being deployed, it will become possible to authorise drone operations over people with sufficient mitigations to lower the risk to acceptable levels.

Operations over people may include beyond line of sight (BVLOS) operations of small drones in the 'specific' category, with another very important goal being urban air mobility based on U-space levels 3 and 4. The integration of UAS within airspace over populated areas requires a multi-step approach that takes into account proportionate risk mitigation, learning through the collection of safety data and strengthening responsibility and liability for UAS operations. Communication and response strategies will also be required so that public confidence is not lost in the event of an incident and the safety reputation of EU regulators is maintained.

Social acceptance will also be an important component of UAS operations over people and to meet the Commission's vision of UAS becoming an accepted part of life for EU citizens by 2030. As well as safety, the security, privacy, noise and visual aspects of eVTOL operating over populations will need to be considered– even where routes are designed to reduce risk. Whilst the Drone Strategy 2.0 covers a number of these issues indirectly, the safe adoption of UAS as part of air mobility or for other services will require the coordination of a number of flagship actions.

We propose the below recommendation:

- The European Parliament should continue to promote the role of citizens when considering UAS operations. The development of EU-wide social acceptance guidelines for Member States, regional or local authorities and commercial UAS operators should be encouraged. Guidelines should provide information on how best to engage with the public and build their trust on security, privacy, noise and visual pollution issues.

7.1.3 Military accommodation

Military UAS can be treated largely as identical to manned military aircraft, meaning existing ATM practices should be used wherever possible. The sharing of best practices and learning between the military and civil UAS industries is well covered by Drone Strategy 2.0 and will deliver a range of benefits. This is supported by the range of data and level of understanding held by the military on UAS. A particular area of synergy that has been identified is counter-UAS. However, the accountability of C-UAS will need to be considered in terms of who may be responsible between the military, security and civil authorities depending on the level of threat. Contingency measures for UAS operations, both civil and military, will also be important and ATM will need to be able to respond accordingly to changing operational environments.

In terms of technology, US and China government programmes are seeking to reduce cost and risk for private sector development in the UAS and eVTOL markets. This gap needs to be addressed in Europe to avoid the EU becoming uncompetitive as a technology development region.

The exchange of concepts has been promoted through Drone Strategy 2.0, however, procurement barriers have been identified as currently preventing the adoption of civil UAS technologies within the military.

We propose the following recommendation:

- The EU should remain aware of civil and military integration in third countries and consider the adoption of fast-track schemes such as the US Agility Prime to advance the civil/military procurement processes of UAS technology. A similar scheme can support certified civil SME suppliers beyond the development of shared technology.

7.1.4 Good practices

The EU is moving ahead with regulation of UAS operations, but there are elements of good practice identified in Member States and third countries that could be applied more widely to the EU as a whole.

Good practices have been identified in the areas of user-available information via accessible applications and the publication and training on privacy and weather-related issues. They have also been identified via step-by-step approaches to airspace integration, both in a practical sense by adopting low-risk operations first before moving to higher-risk scenarios and by strategically addressing social acceptance issues relating to wider UAS adoption.

Further good practices have been identified in the use of demonstrators and industry partnerships to increase the support of stakeholders by directly involving them in key decisions regarding UAS operations. Military and civil integration schemes that are already ongoing in third countries have also been identified as good practice.

7.1.5 Delivering the strategy

The Drone Strategy 2.0 provides flagship actions designed to support the growth of the European drone ecosystem that are comprehensive in terms of coverage of the key issues and actions required by the various parties. However, the strategy does not provide an industrialisation roadmap identifying how the flagship actions support underlying actions by the industry, such as receiving feedback when challenges are resolved and new ones appear. It is also necessary to ensure that non-EU institutions that support aviation in Europe, such as EUROCONTROL or EUROCAE, are included in the future development of the UAS market.

To ensure the EU works towards its 2030 targets, flagship actions would need to be coordinated and prioritised so that the most difficult challenges are not left until last. Accountability through ownership of flagship actions and review dates would help keep the strategy implementation on track.

Future operators of UAS are also likely to extend beyond the existing traditional aviation industry. Cities and urban areas will also become increasingly involved in plans for Urban Air Mobility and will need to remain informed on how they can incorporate new transport modes safely within their Sustainable Urban Mobility Plans. It will therefore be important to involve new industries in discussions around UAS operations and ensure information is disseminated in an understandable and easy-to-use manner.

To address the conclusions above, we propose the following recommendations:

- The European Parliament should ensure that the European Commission has a strategic implementation plan to deliver the strategy. This should ideally prioritise flagship actions, assign specific accountability for actions and set review dates for progress.

- The EU should link the technological roadmap identified in the strategy to a wider European industrial plan for the development of UAS and its associated services.

- The European Parliament should ensure that the European Commission takes a data-led approach to delivering the strategy, including the setup of a central database of UAS safety and performance information from trials, demonstrators and live U-space environments from which to build specific use cases and operating requirements that will help shape level 3 and 4 U-space operations.

- The European Parliament should promote participation in UAS adoption across the EU: different levels of stakeholder involvement should be made available in trials and demonstrators, supporting the role of replicator cities who may want to learn from others before adopting their own Urban Mobility Plan (opportunities for involvement in UAS trials could be made available via the strategy's flagship action 7’s proposed online information sharing platform).

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ANNEXES

A1 Research method

The analysis in this report is based on the following methodology:

p. Literature Review

A literature review has been carried out on the integration of UAS into European airspace and on UAS operations over populated areas.

The literature review has been based on openly available journal articles, literature and reports from industry, academia and government sources. To start with, the selection has been based on the relevance to this report identified using key words within the Terms of Reference. Selection was also made in terms of geographical coverage, type of operations, and reliability of the source, prioritising sources that had received peer review.

Sources were identified using literature known to the authors, through search engines and as referenced by other credible academic, industry or institutional sources. The literature review was conducted in different languages other than English, notably Italian and Mandarin. Where possible, literature within the past 5-10 years was used to keep the content relevant to the current operational and technological environment. The list of sources is available in Chapter 8.

Whilst efforts have been made to ensure the literature review covers a broad range of recent sources, the authors are aware that this is a rapidly evolving and fast-moving topic and that there is a large body of literature that continues to be published on the subjects covered by this report.

q. Stakeholder engagement

A programme of stakeholder engagement with ten targeted organisations was carried out between January 2023 and March 2023 (see table 9). The engagement of stakeholders involved:

- Identifying key stakeholders based on the research topics;
- Checking their availability and interest in the study;
- Identifying how best to engage stakeholders: the research team devised a list of relevant questions to ask depending on the stakeholder's areas of expertise and research topics;
- Assessing the involvement or influence of the stakeholder on Drone Strategy 2.0 and the topics within it.

Interviews were with senior EU and global stakeholders representing organisations across airspace, R&I, manufacturers, defence, traditional aviation and city authorities. A number of stakeholders were directly involved in the development of Drone Strategy 2.0, with some more involved in its implementation than others, whereas others were more likely to be recipients of its flagship actions.

Questions asked to stakeholders focused on:

- Identifying technical, regulatory, financial, safety and social acceptance issues of UAS integration with airspace;
- Identifying best practices;
- Their actions taken to facilitate UAS integration where relevant;
- Assessment of Drone Strategy 2.0.

Table 9: Stakeholders interviewed

Category	Organisation
Air Traffic Management organisations	EUROCONTROL (Senior Manager, ATM/UTM) CANSO (Manager, European ATM Coordination and Safety)
Research and innovation	SESAR 3 JU (Senior External Affairs Officer)
Military stakeholders	European Defence Agency (Senior member of Single European Sky Unit) Janes (Former Editor)
UAS industry	GUTMA (Secretary General) Volocopter (Senior member of Global Policy and Regulatory Affairs team)
Airport operators	ACI-Europe (Senior member of Airport Capacity and Operations team)
City or metropolitan authorities	BKK Budapest (Center for Budapest Transport) (Senior Officer) City of Amsterdam (Programme Manager)

r. Military and Civil integration

The overview of military and civil UAS integration synergies and challenges has been provided based on the expertise of the author, supplemented through desktop research (as documented in Chapter 8) and both formal and informal conversations with stakeholders within the author's network to understand the latest industry position.

s. Identification and analysis of a selection of good practices

An identification and analysis of a selection of good practices has been carried out by the research team, with a focus on third countries such as the USA, Japan, China and others, including Member States where relevant. All stakeholders consulted were asked about potential best practices. In addition, the research team also identified good practices through the literature review and analysis of the most important and relevant topics.

t. Assessment of Drone Strategy 2.0

The assessment of Drone Strategy 2.0 was made based on the key issues raised through the literature review and interviews with stakeholders. It also aimed to address the research questions identified at the beginning of this research project as part of the planned methodology. In addition to consulting stakeholders on their views of the strategy (considering whether or not they had played a role through consultation with the European Commission or other means), the research team also assessed the strategy against its research findings in terms of gaps and further potential areas of work. Good practice identified in third countries was used to inform suggestions for further work or possible solutions that could be applied in an EU context. The recommendations of the research team provide suggestions for how the EU may deliver Drone Strategy 2.0, tackle the key issues of UAS airspace integration and ensure the ambitions of the strategy are met.

This study provides research into the operations of Unmanned Aircraft Systems (UAS) within European Airspace and in particular over populated areas. It provides an overview of good practices and military and civil UAS integration. This research has been used to inform an assessment of the Drone Strategy 2.0 and the extent to which it addresses the challenges and barriers identified. The study concludes with a set of proposed policy recommendations.

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