

European ATM Master Plan:

Roadmap for the safe integration of drones into all classes of airspace



founding members



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Foreword

Drones will be part of our future. Rapid changes in drone technology hold enormous promise for the future use of airspace and aviation at large as the digital transformation expands skyward. This requires a step-change in the way airspace is managed. Essentially, there will be a move from several thousand conventional aircraft in the sky every day to potentially hundreds of thousands of highly connected and automated aerial vehicles, offering advanced data-driven services and operating everywhere, including in cities.

Transforming infrastructure to support such operations will be critical to harnessing the potential of the sector, unlocking market growth, jobs and services to EU citizens. SESAR's mission is to develop an advanced aviation environment that supports the traffic growth for both manned and unmanned aviation. Bringing together established aviation stakeholders and new players to rethink airspace and scale up technologies is one of SESAR's key challenges in preparation for this exciting new era. Adaptation of our ways of working will not be sufficient, we also need to introduce a new approach and this is where U-Space plays will play a central role in the future transformation of our skies.

This proposed contribution to the update of the European ATM Master Plan is an important milestone on that path. It provides a bold vision for the safe integration of drones into all classes of airspace and an ambitious rollout plan, ensuring that the energy of our community is channelled towards clear priorities.

The drone race is on; let's make it happen together.

Florian Guillermet

Executive Director
SESAR Joint Undertaking

Introduction: The window of opportunity for Europe is now

It is estimated that the European drone market will represent EUR 10 billion annually by 2035 and over EUR 15 billion annually by 2050¹.

Unmanned aviation technological developments are currently moving at a much faster pace than for manned aviation. This rapid growth in use of drones (both civil and military) has increased the demand for access to non-segregated airspace. In particular, there is a strong pressure on very low level (VLL) operations where the market is driven by new business opportunities (e.g. data services and mobility).

For VLL operations, many procedural and technological areas require further development, and this lies behind the U-space concept (see box). Given the need to develop a new framework to enable safe and efficient operations of highly automated drone, especially at low altitudes in urban areas, there is a window of opportunity to take advantage of the latest developments related to technological areas, such as artificial intelligence, the Internet-of-Things (IOT), 5G networks while taking into account the need to address appropriate cybersecurity requirements and specific procedures for emergency situations and management of failures. Areas for research, in addition to those listed below for larger drones, include identification and geofencing. Safety, security, privacy and environmental concerns must be addressed irrespective of the technology selected.

Operations in and around airports are expected to grow. However, airports are a critical infrastructure for air traffic and they are particularly vulnerable to intruders. Drone operations in and around airports and other critical infrastructures must therefore comply with strict safety and security requirements. Furthermore, the national military airspace defence systems should be capable of reacting to any drone-related situations deemed critical to national security.

Drones operating between 500ft and 60,000ft will have to be integrated into conventional air traffic management using instrument flight rules (IFR). Standards and Recommended Practices (SARPs) are under development for such operations by the International Civil Aviation Organization (ICAO) with adoption foreseen in 2020 leading to operations as from 2023.

Finally, suborbital unmanned flights, and for extended periods in the order of months, are also expected to grow. Particular attention needs to be given to entry and exit points, and the interaction with lower airspace volumes.

What is U-space?

U-space is a set of new services relying on a high level of digitalisation and automation of functions and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones. As such, U-space is an enabling framework designed to facilitate any kind of routine mission, in all classes of airspace and all types of environment - even the most congested - while addressing an appropriate interface with manned aviation and air traffic control / ATC

Drones, UAS, RPAS?

In line with the Drones Outlook Study and the U-space blueprint document, this document uses the term "drones" as a generic term to cover all types of unmanned aircraft systems (UAS), be they remotely piloted (RPAS - remotely piloted aircraft system) or automated. By exception, the term RPAS may be used when a specific aspect of such vehicles (the fact that it is operated by a pilot instead of being automated) is addressed.

¹SESAR Drones Outlook Study, 2016

http://www.sesarju.eu/sites/default/files/documents/reports/European_Drones_Outlook_Study_2016.pdf

Establishing the right infrastructure to support drone operations and traffic growth for both manned and unmanned aviation will be critical to harnessing the potential of the sector. Bringing together established aviation stakeholders and new players to rethink airspace and scale up technologies is one of SESAR's key challenges.

This *“Roadmap for the safe integration of drones into all classes of airspace”* outlines which drone related-research and development (R&D) activities should be prioritised in order to support the expansion of the drone market and achieve the smooth, safe and fair integration of these new aircraft systems into the European airspace. It also provides an ambitious rollout plan for these technological developments.

It will be integrated in the 2018 Edition of the European ATM Master Plan as part of the update campaign, paying particular attention to the refinement of the regulatory roadmap in the light of the recent Helsinki declaration.

When integrated into the Master Plan, this roadmap will support the allocation of resources for the development and the deployment of drone operations in all kinds of operational environments.

Vision for the safe integration of drones

The vision for drone integration is that drones (civil and military) will be completely and seamlessly integrated into all environments and classes of airspace, operating safely and efficiently alongside manned aircraft.

The vision is enabled by the establishment of a new framework, the U-space which, by design, relies on high levels of automation and connectivity. U-space will support the management of safe and efficient drone operations and address the proper interface with manned aviation and ATC. U-space will take advantage of emerging technologies and will include automated functions in view of enabling routine operations of large number of drones even in complex and dense areas, such as cities. Over the time, automation and artificial intelligence (AI) will lead to the optimisation of drone operations.

The vision also builds on the evolution of ATM towards the integration of large remotely-piloted aircraft systems (RPAS) that will operate safely using ATM services: manned and unmanned will be able to use the same airport infrastructure; they will both communicate with ATC using datalink; rules and procedures will be applied to both with some adaptations for drones as the pilot is on the ground.

Drone operations using U-space services will include leisure, commercial, and governmental purposes, and will account for a majority of all drone flying hours. Operations using larger drones, currently dominated by State and military operators, will expand including cargo and other civil operations. These types of operations will imply changes to the relevant ICAO SARPS and will be harmonised globally.

While large drones using ATM services are expected to be piloted remotely in a one to one relationship, drones using U-space services will be highly automated and supervised. In U-space, the flow of data is crucial and therefore depends on greater levels of connectivity.

By 2035, our skies will be at least ten times busier with a major part of flying hours performed by drones operating beyond line of sight (BVLOS) in all environments using U-space to deliver a large variety of services: inspection of critical infrastructure, deliveries, cargo freight, transport of people / air urban mobility, precision agriculture, etc.

Airports operations will also evolve with an increased number of drones performing visual line of sight (VLOS) platform inspections, flying in and out amongst single pilot aircraft or flying in the vicinity of the airport, to transiting via pre-defined tracks or tactically managed route. Even in case of mixed manned-unmanned operations, the drone and the manned aircraft is managed by either the U-space traffic manager or conventional ATC.

Manned and unmanned traffic will operate safely and in harmony, including in non-controlled airspace, especially rural environments thanks to established common rules ensuring fair access to airspace. General aviation will fly jointly with drones in portions of airspace where they will provide services for precision agriculture, deliver packages in remote areas, carry out search and rescue missions, or execute preventive inspections of forest, high voltage lines and railways. The environment will be mainly cooperative with an enhanced information-sharing system to allow situation awareness at both strategic and tactical levels.

The high demand of access to airspace in urban areas will require the establishment of specific requirements and procedures to ensure safety in the air but also protect people on the ground and limit the impact of drone traffic on environment (emissions, noise, visual pollution). These operations will rely on secure and robust communication systems which can cope with large number of simultaneous operations as well as interference issues caused by large buildings. Drones operating in urban areas will have to comply with reinforced requirements and abilities, including navigation accuracy, management of failure and detect and avoid (DAA) capabilities. Drone operations will be fully integrated with the concept of smart cities using innovative technologies and connectivity. In these complex and dense areas, U-space will play a major role in managing the drone traffic and ensuring the interface with all the actors involved in the broader drone ecosystem. As an example, U-space will provide conflict-free trajectories to prevent an excessive reliance on on-board DAA. On the other hand, operations of manned aviation will be safeguarded in these urban areas, in particular for its high priority missions such as ambulance or security missions.

Flights above FL660 will also be integrated with entry and exit procedures through segregated or non-segregated airspace. For example, high-altitude pseudo-satellites (HAPS) will be able to transit and then fly at high altitudes to provide high-speed broadband communications.

At the same time, military will be fully integrated in the wider traffic situation except where mission requirements demand otherwise. The integration of military medium-altitude long-endurance (MALE) RPAS, will have paved the way for civil large RPAS operations in non-segregated airspace.

Work towards this vision will give an unprecedented impetus to the digitalisation, and automation of the European ATM network. These are integral enablers to the SESAR vision to allow the efficient and safe operation of both manned and unmanned systems in a shared airspace. In doing so, the performance ambition of the European ATM Master Plan, in line with the Single European Sky High-Level Goals, will not only be reached but may even be exceeded through the successful implementation of disruptive technologies.

The evolution toward this target vision will be achieved through two complementary threads:

- An evolutionary thread, addressing the accommodation and integration of large certified² remotely-piloted drones with manned aviation. These RPAS will interact with ATM in the same way as manned aircraft, with special provisions designed to compensate for the fact that the pilot is not on board the aircraft.
- An innovative thread, requiring the development of new U-space services and procedures to provide airspace access to large numbers of typically smaller drones (mainly specific²), supported by automation and connectivity.

Progress on both threads will be made in parallel, each benefiting from the results of research and development (R&D) conducted on common areas of interest such as DAA, command and control datalink or cybersecurity. This evolution will be supported by developments in standardisation and regulation.

² See EASA typology: <https://www.easa.europa.eu/easa-and-you/civil-drones-rpas>

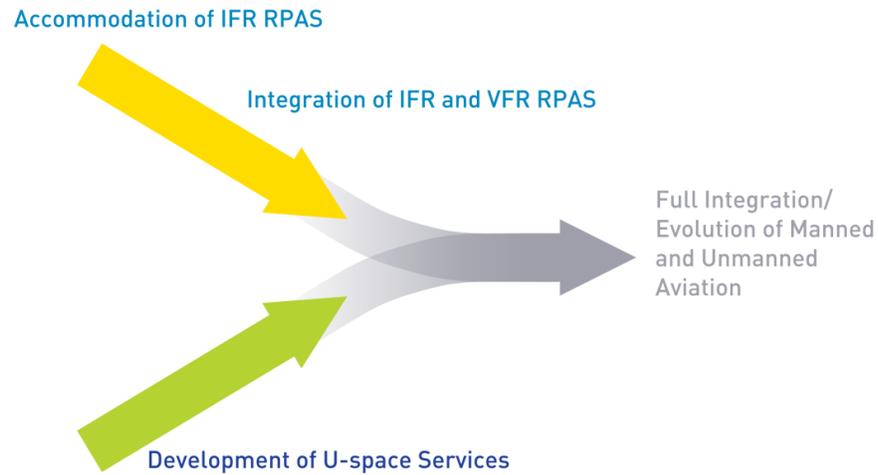


Figure 1: the evolution of the target vision

Achieving the integration of drones will be an iterative process: as more services are deployed and operations are enabled, drones will be progressively integrated into all classes of airspace until reaching a point where full integration is achieved. Throughout this process, manned and unmanned aviation will develop, with each sector benefitting from the technologies and evolutions of the other.

Operational and deployment view

Large drones are expected to be remotely piloted with an identified operator and fly under instrument flight rules (IFR) and an equivalent to visual flight rules (VFR)³ in the same manner as manned aircraft.

The integration of hundreds of thousands of smaller leisure, commercial, or governmental drones requires the creation of a new aviation concept: U-space.

These two threads that will evolve towards the full integration of all vehicles into the airspace; technologies and procedures need to be developed accordingly.

3.1 Achieving RPAS integration with manned aviation

RPAS should be able to operate safely alongside manned aviation, respecting ICAO's key principles⁴:

- In order to integrate seamlessly into the airspace, RPAS must, as far as possible, comply with the operational procedures that exist for manned aircraft. Flight operations must not present an undue hazard or burden to persons, property or other aircraft.
- RPAS operations must not degrade the current level of aviation safety or impair manned aviation safety or efficiency. This applies equally to all operators and all drones.
- RPAS should conform to manned aircraft standards to the greatest extent possible. When these principles are not achievable (due to unique RPAS designs or flight characteristics), and no alternative means of compliance are identified, the operation of such RPAS may be subject to safety risk mitigations, such as restricting operations to remain within segregated airspace.

In order to achieve integration with manned aviation, a phased approach is envisaged:

- **Phase 1:** IFR RPAS in classes A-C: RPAS will be able to operate in airspace classes A-C under IFR, with a DAA system that provides collision avoidance and situational awareness in relation to cooperative traffic. RPAS will be able to communicate with ATC. Navigation and surveillance equipage will be commensurate with the airspace in which the drone is operating. Special provisions will be needed for ground operations at most airports. Procedures and technology for dealing with contingency situations will be in place.
- **Phase 2:** IFR RPAS in classes A-G: RPAS flying under IFR will have a DAA capability, enabling them to integrate with IFR and VFR traffic, both cooperative and non-cooperative, in airspace classes A-G. Communications with ATC will use an appropriate architecture, addressing integrity and security requirements.
- **Phase 3:** RPAS in classes A-G (IFR and VFR): RPAS will be able to operate in controlled/uncontrolled airspace, both under IFR or VFR, and safely integrate with cooperative and non-cooperative traffic. Increased use of datalink for ATC communications is

³ It is expected that technology will evolve and provide drones with capabilities allowing them to operate in a way similar to VFR.

⁴ ICAO RPAS CONOPS (March 2017)

likely. Work on broadening the range of drone types and mission continues, and the ATM environment starts to evolve as routine operations diversify.

Phases 1 and 2 correspond to the ICAO “accommodation” period, while Phase 3 equates to the ICAO “integration” period. “Accommodation” refers to the condition when RPAS can operate along with some level of adaptation or support that compensates for its inability to comply within existing operational constructs. This may be necessary during normal operations, abnormal or problem scenarios, and when emergency situations arise. “Integration” refers to a future when RPAS may be expected to enter the airspace routinely without requiring special provisions.

Suitably-equipped RPAS can therefore “integrate” as soon as the aircraft and the supporting ATM environment allow such integration. The “Integration” phase foresees a time when all European ATM environments can support routine RPAS operations, but this does not prevent early adopters from operating.

State RPAS will be integrated, operating as their civil counterparts except where operationally necessary. Military requirements⁵ will be incorporated in the technical, operational and regulatory domains. This will be enabled through the development of dual-use technology and the adoption of common standards and procedures. Where State agencies have an operational need, they will be given a level of priority commensurate with the operational need, as is now the case for manned assets. Specific training needs will be met, where necessary, through airspace reservation, executed under the provisions of advanced flexible use of airspace (AFUA).

3.2 Securing the development of U-space services

U-space is defined in the U-space blueprint document⁶ as a set of services designed to support safe, efficient and secure access to airspace for large numbers of drones. These services rely on a high level of digitalisation and automation of functions, whether they are airborne or part of the ground-based environment. U-space provides an enabling framework to support routine drone operations, as well as a clear and effective interface with manned aviation, ATM/ANS service providers and authorities. U-space is therefore not a defined volume of airspace, segregated and designated for the sole use of drones. Nonetheless, at early stages, there could be portions of reserved airspace to allow for an earlier and incremental deployment of BVLOS operations, fostering the development of safe and efficient traffic management for drones.

U-space will ensure the smooth operation of large numbers of small drones (mainly open or specific²) in all operating environments, including in urban areas, and in all classes of airspace. It will support all types of missions and concern all drone users⁷.

U-space architecture will be based on a federation of U-space service providers that can cooperatively manage drone traffic in the same or/and adjacent geographical region, under a regulatory framework ensuring the overall performance level and in particular its safety. U-space

⁵ *In particular military Medium-Altitude Long-Endurance (MALE) RPAS will be integrated in non-segregated airspace through an accommodation phase (2020-2025) and integration as IFR RPAS in classes A-C as from 2025.*

⁶ <https://www.sesarju.eu/u-space-blueprint>

⁷ *Including commercial and leisure users as well as State (including military) and public entities with appropriate prioritisation for special missions.*

service providers will exchange information and coordinate themselves using interoperable standards allowing for automated drone traffic management. It is expected that they will have a certain level of qualification and appropriate oversight according to the criticality of the services they do provide.

The progressive deployment of U-space is foreseen in an incremental manner: each new phase will propose a new set of services while including an upgraded version of the services already existing from the previous phase. The roll-out of each new phase should be seen as a high-level sequence for EU-wide harmonisation, however implementations can be fast-tracked in parallel at local level and for certain type of operations of lower risk and complexity. Over time, U-space services will evolve and scale up as the level of automation of the drone increases, and advanced forms of interaction with the environment are enabled (including manned and unmanned aircraft) mainly through digital information exchanges.

U1 provides foundation services (e-registration, e-identification and pre-tactical geo-fencing) . The main objectives of these services are to identify drones and operators and to inform operators about known restricted areas. With the deployment of the U1 foundation services more drone operations are enabled, especially in areas where the density of manned traffic is very low. The administrative procedures for permission to fly and the authorisations for some specific missions will be facilitated. The range of VLOS routine operations will be extended and will support extended VLOS flights, including VLOS operations in an urban environment. BVLOS operations will still be constrained but will become more and more possible.

U2 refers to an initial set of services that support the safe management of drone operations and a first level of interface and connection with ATM/ATC and manned aviation. Where appropriate, U2 will make use of existing infrastructure from ATM, but new opportunities for drones operations will be enabled through the exploitation of technologies from other sectors (e.g. long-term evolution - LTE - for data communication). The range of operations at low levels will be increased, including some operations in controlled airspace. Drone flights will no longer be necessarily considered on a case-by-case basis, and some examples of BVLOS operations will become routine (albeit with some constraints).

U3 will build on the experience gained in U2 and will unlock new and enhanced applications and mission types in high density and high complexity areas. New technologies, automated DAA functionalities and more reliable means of communication will enable a significant increase of operations in all environments and will reinforce interfaces with ATM/ATC and manned aviation. This is where the most significant growth of drone operations is expected to occur, especially in urban areas, with the initiation of new types of operations, such as air urban mobility.

U4 focuses on services offering integrated interfaces with ATM/ATC and manned aviation and supports the full operational capability of U-space based on a very high level of automation. It is expected that the need for new services will arise during the roll-out of U3.

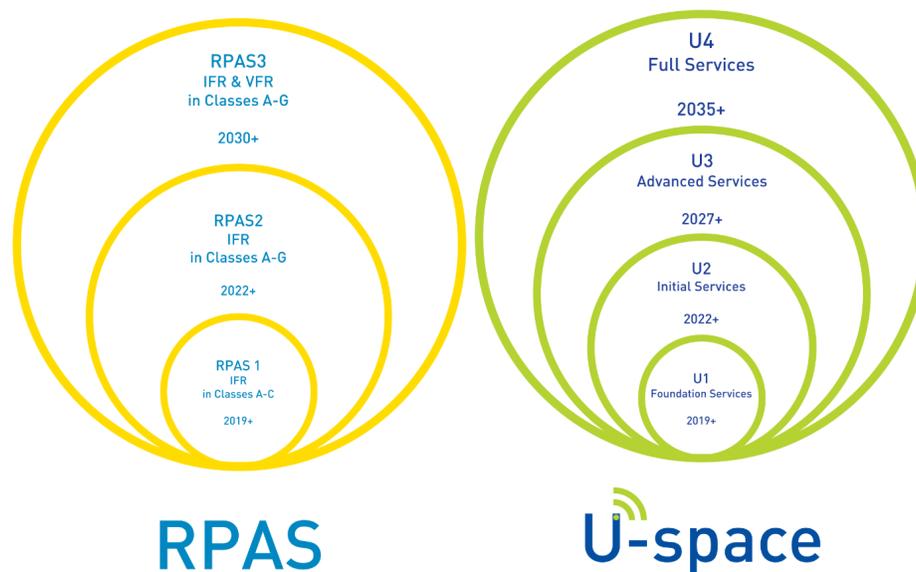


Figure 2: Initial operating capability (IOC) dates for the integration of RPAS with manned aviation and development of U-space services at scale

3.3 Ensuring cybersecurity

The current ATM system consists of many bespoke systems and networks, often utilising national and proprietary standards. It is clear that the future ATM system and U-space will rely on an increase in interconnected systems based on novel technologies. Interoperability will be key in order to deliver operational improvements through a shared view of all aeronautical information.

Two key concerns that threaten these benefits have been identified:

- Increased interconnectivity and integration creates new vulnerabilities to cyber-attacks, for example through third-party access to ATM networks and systems.
- Interoperability implies an increased use of commercial-off-the-shelf (COTS) components and, without careful planning, a corresponding loss of diversity. This increases the likelihood of introducing common vulnerabilities into the system even if, by using open standards, there is also a larger body of users who are actively finding and fixing vulnerabilities.

Not only should cybersecurity architecture be established at an early stage of U-space development, number of guiding principles should also be defined for the organisational and technical measures that are needed to strengthen cyber resilience, building on current cybersecurity best practices in the information technology domain.

3.4 Ensuring optimal use and protection of aviation spectrum

To provide a safe and efficient global ATM system, internationally harmonised protected spectrum is allocated to aviation. However, aeronautical spectrum allocations are and will continue to be under

significant pressure from other sectors and additional protected spectrum bandwidth for use by aviation is unlikely to be made available. It is therefore imperative to ensure an optimal use and protection of the spectrum currently available for communications, surveillance and navigation systems, and also to take advantage of the development of non-aviation-specific telecommunication systems and infrastructure, such as 5G mobile networks and satellite communication where they meet the needs.

3.5 Addressing safety and regulatory needs

Drones should be integrated into the aviation system in a safe and proportionate manner and this integration should foster an innovative and competitive European drone industry, creating jobs and growth, in particular for small and medium enterprises.

The regulatory framework, whose development has started under the auspices of EASA⁸, will set a level of safety and of environmental protection, security and privacy that is acceptable to society. It will offer enough flexibility for the drone industry to evolve, innovate and mature. The regulatory framework will not simply transpose the system put in place for manned aviation, but will be proportionate, progressive and risk-based. The rules must express objectives that will be complemented by industry standards.

The further development of drones and their integration into non-segregated airspace will pose new challenges for which a significant amount of further research needs to be performed.

As already identified by EASA⁹, the safety risks considered must take into account:

- Mid-air collision with manned aircraft;
- Harm to people;
- Damage to property in particular critical and sensitive infrastructure.

To reach these safety objectives, it is important to adopt an operation centric approach that includes the aircraft, mission and operating environment¹⁰. Appropriate combinations of requirements linked to these three parameters should ensure reaching the requested level of safety.

One particular area of regulatory focus will be to review safety assessment and certification requirements considering the change of the role of human in the overall system.

The future system will rely on a very high level of automation. Considering the wide disparity of drone performance and reliability (ranging from toys to fully-certified platforms), it is extremely important to ensure that aircraft operating in safety-critical environment incorporate appropriate objective-based design requirements that contribute to the mitigation of the abovementioned risks.

Objective-based design requirements are closely linked to the operational environment and procedures; e.g. the operation close to crowds could be acceptable when the drone has some

⁸ <https://www.easa.europa.eu/easa-and-you/civil-drones-rpas>

⁹ Stated in EASA's Opinion: <https://www.easa.europa.eu/document-library/opinions/opinion-technical-nature>

¹⁰ This term includes also the airspace in which the drones flies and the overflow area

additional functionality (e.g. automatic loss of link procedures), and the competencies of the remote pilot and the operational procedures are adequate. Industry standards will be needed to facilitate demonstrating compliance to the objective-based design requirements.

In an era of rapidly changing technology, there is a need to be innovative and embrace new regulatory tools inspired by other industries aiming at similar levels of automation, and create conditions for Europe to develop strong testing/demonstration platforms and a showcase of EU leadership on unmanned aviation.

Figure 2 depicts the regulatory approach, as well as the major regulatory activities that need to be considered in order to ensure the safe, secure and environmentally-friendly integration of drones. The principle of this approach is to implement an incremental regulatory baseline that is synchronised with the deployment milestones and offers the possibility to learn from experience, and adapt the regulatory tools taking advantage of the experience gained. The package numbering in the figure is for illustration purposes only.

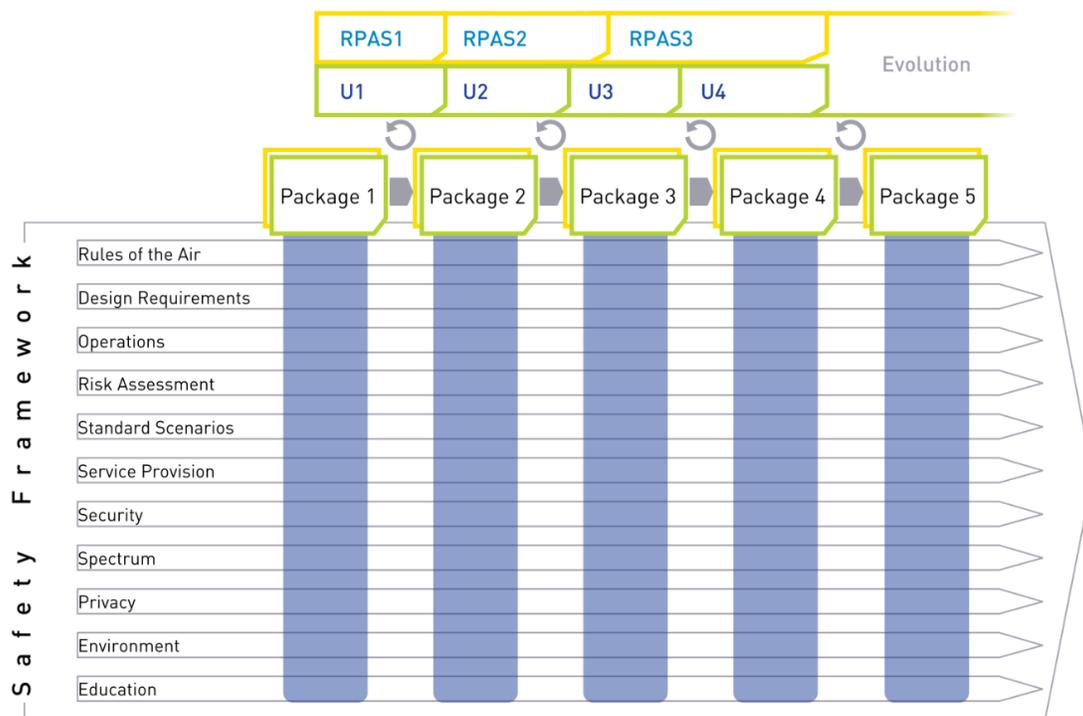


Figure 3: High-level regulatory cycle

Standardisation

Beyond the regulatory context, adequate standards will be critical to support the harmonised implementation of concepts and technologies arising directly from industry.

The drone family represent a wide range of aircraft. It includes very large aircraft, which resemble manned aircraft in size and complexity, but also very small consumer-electronics aircraft. All of these categories are used in the same airspace as commercial air transport, general aviation, aerial work and specific rotorcraft and military activities. Therefore, it is very important to ensure standards are fit for purpose and are designed in a way that is commensurate with the type of drone, the type of operation and the environment in which it will operate.

The bodies involved in the planning and development of drone-related standards have recently agreed collectively to establish the European UAS Standards Coordination Group (EUSCG). The EUSCG is a joint coordination and advisory group established to coordinate the UAS-related standardisation activities across Europe, essentially stemming from EU regulations and EASA rulemaking initiatives. The EUSCG provides a bridge between European activities in this domain and those at international level. The main task of the EUSCG is to develop, monitor and maintain an overarching European UAS standardisation rolling development plan, based on inputs from the EUSCG members¹¹, while addressing the needs identified in the European ATM Master Plan. In that meaning EUSCG will coordinate with EASCG in view of supporting a harmonised approach.

Figure 4 below represents the major standardisation activities that are required to enable the safe integration of drones, some of which are already ongoing. For a matter of graphical representation, the figure associates the EASA “certified” drone category to the conventional IFR/VFR domain covered by RPAS, it also associates the “open” and “specific” categories with the relative U-Space domain. This does not prevent certified drones to operate under U-Space.

It should be noted that, to allow the market to expand, only those standards that are acknowledged as absolutely necessary to secure safety and efficiency of drone operations and their insertion into the airspace should be developed. Any other standards that may be needed to support market growth will largely be developed by the industry itself, pioneers steering the developments of industry-led standards without waiting for “hard regulation”. This will be likely to allow the market to flourish faster and deliver benefits earlier. In addition, it may also be possible to adapt and use existing standards from other relevant industries such as telecoms or autonomous land vehicles. Basically, all possible efforts will be made to keep the standardisation cycle to its minimum, whilst of course protecting safety and security.

¹¹ The plenary membership of the EUSCG is composed of ASD, ASD-STAN, ASTM, DMAE, DAE, EASA, EUROCAE, EUROCONTROL, The European Commission, EDA, CEN, CENELEC, ETSI, GUTMA, ISO, JARUS, SAE, SESAR JU, UVSI.



Figure 4: Standardisation needs

Operational and deployment roadmap

The European ATM Master Plan provides the high-level roadmap for the development and deployment of capabilities and services supporting drone operations in a harmonised way across Europe. Dates provided on the roadmap are aspirational and reflect the latest points in time at which critical activities should be completed at a European scale. It is also clear that to harness the full power of digital technologies for the sector, speed and a trial-and-error mind-set are needed. These dates will therefore be regularly updated to reflect latest industry advancements as part of the maintenance of the European ATM Master Plan.

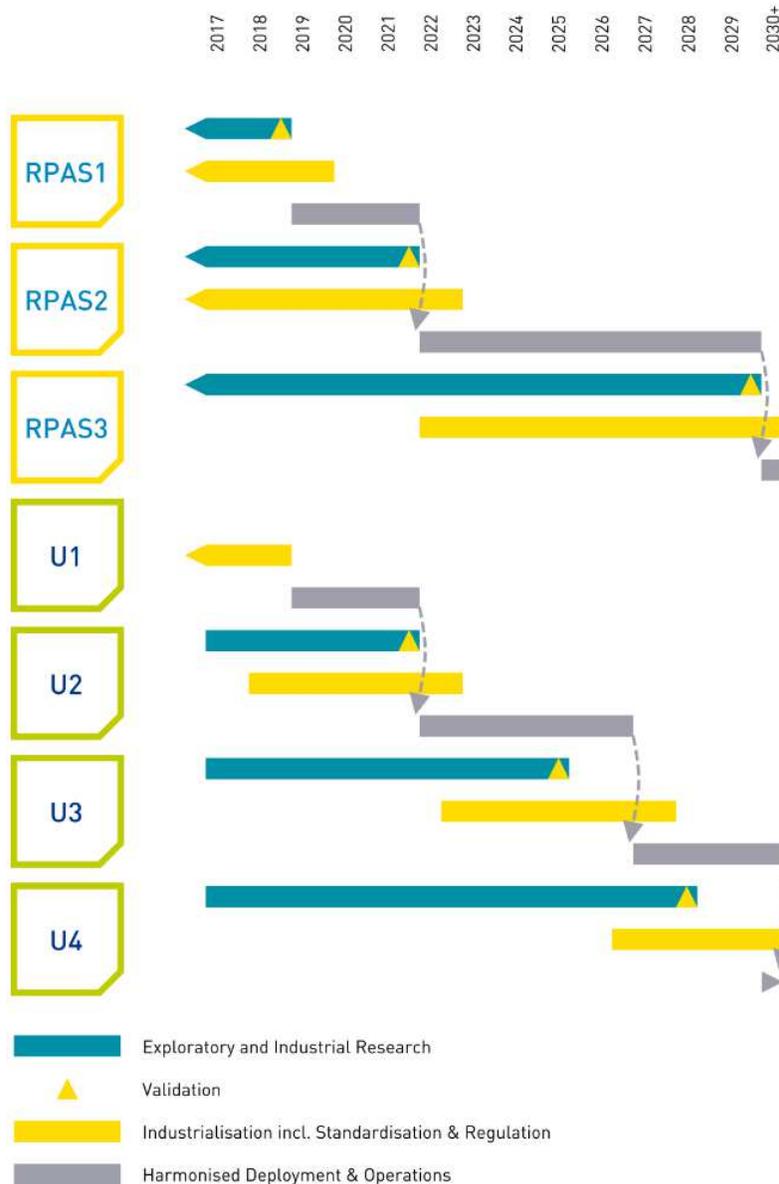


Figure 5: The Deployment View

Global Harmonisation

The European vision of the safe and seamless integration of drones is carried out not in isolation but in a global context. European efforts and initiatives to collaborate and coordinate at worldwide level promote convergence of approaches, sharing of experiences and ultimately target global interoperability for the integration of drones.

Cooperation between Europe and the US is achieved through the Memorandum of Cooperation on civil aviation research and development, which includes a specific cooperation plan on UAS. In this framework, the SESAR JU, the FAA and NASA aim to deliver a joint vision for safe integration of drones in all classes of airspace, including U-space and UTM. This cooperation framework also allows an exchange of views concerning common operational and deployment challenges, including the standardisation and regulatory roadmaps.

At worldwide level, Europe is deeply involved in ICAO work on RPAS integration and the definition of a common framework for UTM. The ICAO RPAS Panel has developed an RPAS CONOPS and work is ongoing to identify the required updates to SARPs to allow IFR RPAS integration. In addition to this, Europe also actively contributes to the ICAO UAS advisory group on UTM to ensure global harmonisation.

Business view

This Section provides an estimate of the investments required to support the safe and efficient deployment of drones in Europe, in addition to the foreseen benefits arising from this future drone ecosystem. Both benefits and investment levels are covered in detail, with the benefits drawn largely from the previously released 2016 Drone Outlook Study¹², and the investment needs determined through a high-level assessment, consolidating inputs from stakeholder groups, including: ANSPs, innovative actors and start-ups, airspace users, drone operators, telecommunications and satellite communications manufacturers, airport operators and the military.

The following should be noted regarding the assessments:

- The calculations are based on the initial roadmap of how ATM will develop to allow for the safe deployment of drones, as defined by SESAR and refined throughout this exercise. They are intended to act as a starting point for reflection by European decision makers.
- Throughout the document, the inputs have largely been developed through inputs from stakeholders and SESAR hypotheses; as this field continues to evolve rapidly, it is possible that the end-state may differ from the stance taken within this document
- Only investments associated with ATM, covering both RPAS integration and U-space implementation, are considered and reported; benefits include all of those indicated in the 2016 Drone Outlook Study and the impact of urban air mobility
- This work will be leveraged to support further developments for a more concrete and holistic view in the future.

4.1 Overview of benefits and investment levels

European demand within the drone marketplace is valued at in excess of EUR 10 billion annually¹³, in nominal terms, leading to a cumulative benefit of over EUR 140 billion by 2035¹⁴. Civil missions for government purposes and commercial businesses are expected to generate the majority of this value on the basis of multi-billion product and service industries. Defence and leisure industries will continue to contribute to this marketplace and remain a source of high value in the near-term, representing together nearly EUR 2 billion in annual product-related turnover for the industry over the long term.¹⁵

The minimum infrastructure investment required to ensure safety and unlock the value at stake for Europe is attainable through relatively low investments, leveraging existing infrastructure and scaling-up through investments in automated and smart systems. The assessment has identified key investments by stakeholders amounting to nearly EUR 4.5 billion by 2035 (Figure 6).

¹² The 2016 Drone Outlook Study can be found on the [SESAR website](#)

¹³ 2016 Drone Outlook Study, Section 4.2 of this document (covering urban air mobility addition)

¹⁴ Composed of commercial, governmental, and leisure drones (excluding defence)

¹⁵ Although the 2016 Drone Outlook Study assessed the economic impact for defence, as noted above, these figures have been excluded from the overall benefits illustrated throughout this document, as limited data was available on the investment needs and therefore illustrating full benefits without full anticipated investments was deemed misleading to represent.

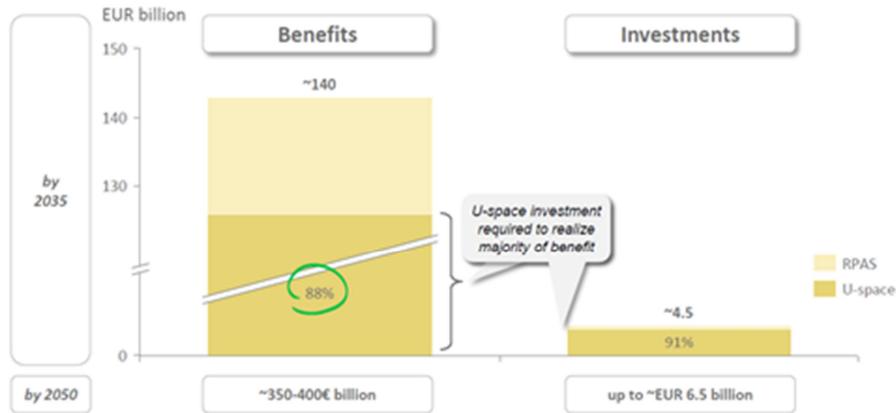


Figure 6: Overview of investment associated to the safe integration of drones and benefit levels¹⁶

The investment in U-space should be viewed as critical to unlocking the future potential benefits from the drone ecosystem, accounting for >85% of the anticipated benefit by 2035.

4.2 Review of the economic and societal benefits identified in the 2016 Drone Outlook Study

An economic impact analysis of the entire value chain for each demand area revealed the yearly potential for a European market would exceed EUR 10 billion by 2035 and would further grow to approximately EUR 15 billion by 2050. A market of this size will also drive new job creation throughout all Member States, as each will need localised operations, pilots, maintenance contractors and insurers among other specific occupations. In short, over 100 000 direct jobs are expected to be generated by this significant market¹⁷, in addition to many other indirect benefits.

In addition to the aforementioned benefits, the business assessment also takes into account benefits stemming from the growth and adoption of urban air mobility¹⁸. It is envisaged that this form of mobility will result in market value of at least EUR 2 billion annually by 2031 with a market take-off in 2027¹⁹. The value is calculated by estimating adoption across the following three use cases:

1. City to airport travel – based on actual airport passengers and price sensitivity analysis;
2. Taxi use – based on actual origin-destination figures, focusing on long-distance trunk routes;
3. Commuting – typically high volume routes.

Volumes were determined by considering 25-30 European cities among an initial assessment based on the 130 largest cities worldwide.

The annual economic value across the indicated landscapes has been summarised in Figure 7.

¹⁶ Source: 2016 Drone Outlook Study; SESAR and stakeholder assessments. Investments cover only changes related to the safe integration of drones. In order to realise the benefits, additional investments that are not safety-related will have to be made by stakeholders but are not accounted for here (e.g. investments related to commercial service delivery).

¹⁷ Based on data by the Organisation for Economic Cooperation and Development (OECD)

¹⁸ Urban Air Mobility refers to an envisaged future state where people and/or goods can be transported around densely populated urban areas within very short timeframes, leveraging airspace to do this.

¹⁹ Urban Air Mobility figures based on an assessment performed by BCG in collaboration with Airbus. This assessment was completed with a view through 2032. To extend the work through 2050, traffic volumes and benefits were assumed constant after 2032. Although additional growth is likely, further assessment was outside the scope of this business review and not completed given time and resource constraints.

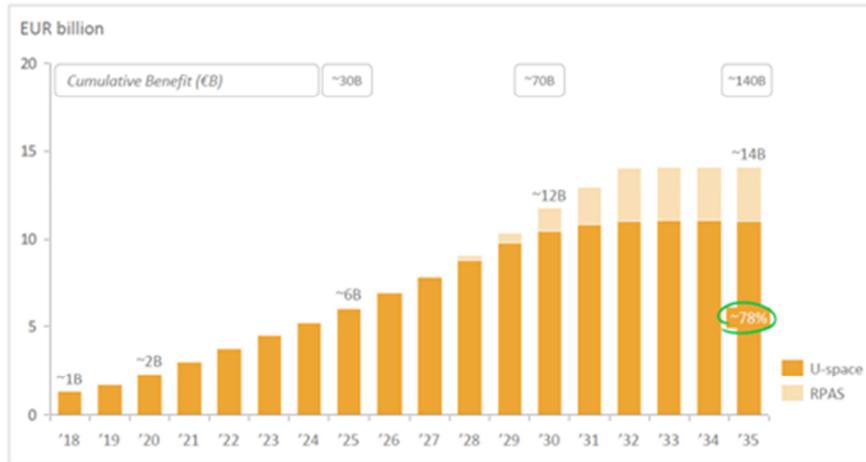


Figure 7: Economic benefits of drone deployment in Europe (undiscounted)20

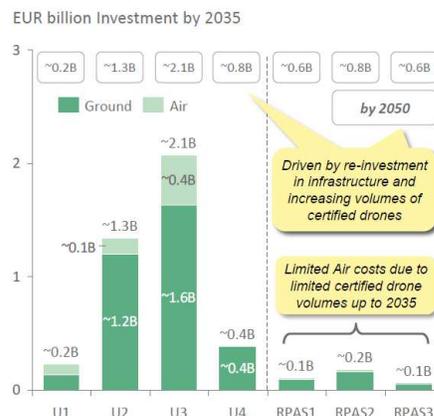
4.3 Investment level assessment

This assessment aims to identify the required investments related to ATM for the safe and efficient integration of drones into European airspace. These are based on a number of assumptions that carry significant uncertainty. As a result, the overall investment figures should be interpreted in terms of their order of magnitude only. In order to increase the validity of assumptions used in calculating the investment levels, stakeholder bilateral meetings were conducted with experts, in addition to an investment survey. The assessment does not represent any specific organisation or stakeholder, but rather represents a consolidation of available industry input, including that of SESAR. This work serves as a reference to build upon and further substantiate in the future. A list of key underlying investment assumptions are provided in Annex 3.

The anticipated investments have been structured into three categories: Infrastructure and services, airborne investments and human resources. Investment levels associated to each category and sub-category are provided below, in addition to a deployment view showing investments over time.

Investment Category & Sub-category	Investment (2035)
Infrastructure & Services	~€ 3.4B
ATC Interface & airport adaptations	~€ 1.2B
Drone traffic management	~€ 0.9B
Protection of airports & sensitive sites	~€ 0.3B
Telecom & Satcom	~€ 0.6B
Geo-fencing database	~€ 0.1B
Enhanced data provision & info sharing	~€ 0.1B
Drone traffic management oversight	~€ 0.1B
e-registration & identification	~€ 0.1B
Systems Hardware & Software	~€ 0.7B
Drone systems	~€ 0.6B
On other aircraft	~€ 0.1B
Human resources	~€ 0.4B
Procedure development	~€ 0.3B
ATC personnel training	~€ 0.1B
Total	~€ 4.5B

~6.5B by 2050



²⁰ Source: 2016 Drone Outlook Study; Urban Air Mobility input from external BCG project in collaboration with Airbus

Figure 8: Breakdown of investment level by category and associated with each phase²¹

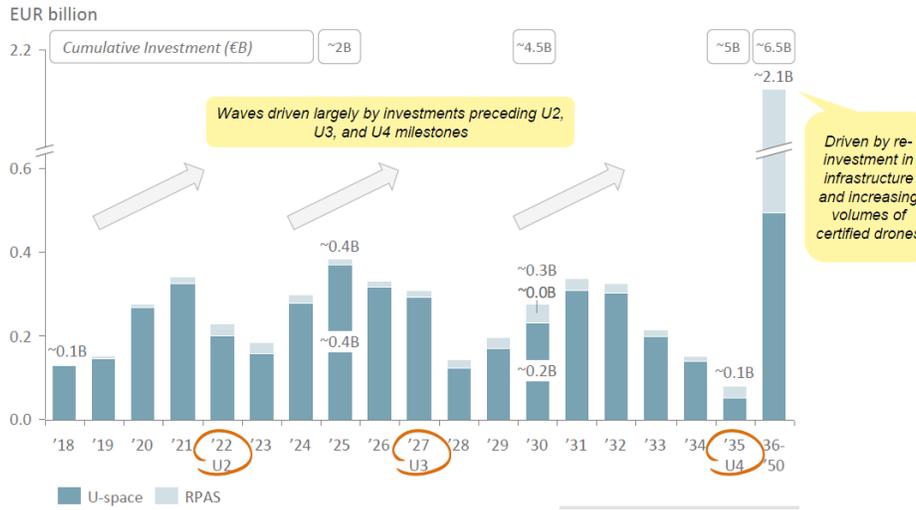


Figure 9: Investment needs of drone deployment in Europe (undiscounted)

For each identified investment sub-category, a high-level assessment and assumption base were developed to provide a view on the potential investment level for stakeholders. The split between the assessment and associated stakeholder is expected to evolve as the drone ecosystem maturity level increases. To facilitate this exercise, primary, secondary, and tertiary stakeholders were identified for each investment category and high-level assumptions drove a percentage split across the stakeholders. This assessment should not be interpreted as exhaustive or final, but rather as a directional view to be further refined.

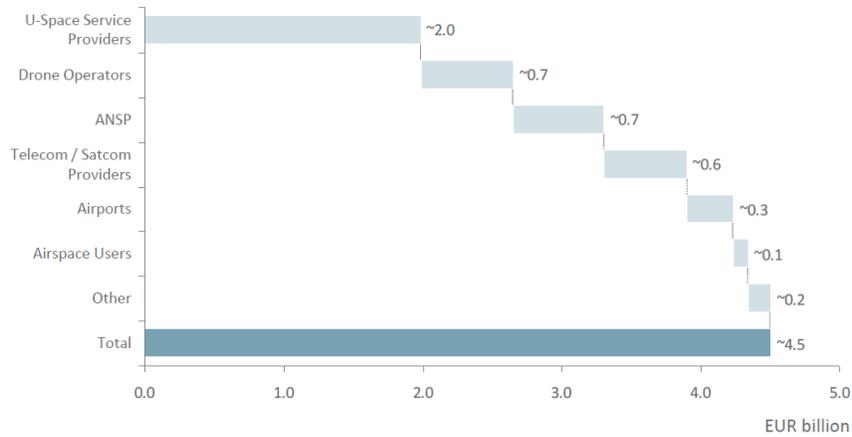


Figure 10: Preliminary stakeholder investment breakdown

U-space service providers and drone operators are expected to invest the most across stakeholder groups. For U-space service providers, this is driven by the investments required to support new

²¹ Investment associated to a particular phase, regardless of the point in time the investment occurs (e.g. investment to support all U3 services, regardless of whether investment started in U2)

services in the ecosystem, while large investments for drone operators are required to ensure the drones are appropriately equipped to enable the required services. The scale of operations and growth in drones are expected to grow substantially, making the associated investment meaningful (the specific category fleet size will evolve from under 10 000 drones in 2015 to nearly 400 000 drones in 2050²²). The Military is not listed per se since this stakeholder is not integrated into the various roles, i.e. airspace user, ANSP, airport operator and drone operator. Stakeholder inputs on required military investments (air and ground) were not fully available at the time of publication. A standalone assessment of available military data indicates that partial investment levels are in the order of EUR ~400 million.²³

4.4 The ATM business model and the need for incentivisation

Given the dependency of drone deployment on new technologies, new interfaces, new sets of services and new service providers, business models with limited presence in current ATM are likely to emerge to support this ecosystem, particularly for U-space. It is not the role of the Master Plan to define these business models, but it is clear that viable models must be developed in order to support the investments and realise future benefits. Other industries provide a glimpse into the potential models available, such as fee-based or software as a service (SaaS) models, where drone operators may receive basic services free of charge, but require higher investment for more advanced needs, scaled operations or higher service levels.

As development of the landscape is still at an early stage, both from technological readiness and operational perspectives, substantial risk exist for first movers and early investors. Industry must ensure that the commercialisation can be realised and scaled up; industry must recognise this risk and take measures to ensure the necessary resources are available to make these critical investments – without them, the pace of evolution will slow and the vast value at stake will not fully materialise. In addition, given the dependencies described above, coordination at European level should help ensure that investment levels are kept as low as possible and that benefits are fully realised. More broadly, a robust incentivisation strategy will de-risk the deployment, maximising the opportunity for benefits across all stakeholders.

²² A summary of drone fleet size evolution can be found in the Appendix

²³ Unit level airborne investment for certified drones were used as a proxy and applied to the anticipated military drone fleet. Ground investments for airport adaptations and ATC interface requirements, were applied to 10 military air bases in Europe. Additional investments may be required and this assessment will be updated as more data becomes available.

Risk management

This Section addresses the most significant risks associated with the realisation of the vision for the safe integration of drones. Determining risks does not imply that they will actually materialise, rather that these risks have been identified and are adequately managed so that they do not impact the delivery of the Master Plan.

By necessity, risk management is an ongoing process in which regular monitoring is required of the status of ongoing mitigation actions.

Table 1 - Identified high-priority risks

Risk description	Impact/Consequences	Mitigation actions
The necessary investments for R&D activities related to the safe integration of drones are not secured	<ul style="list-style-type: none"> • Delay in the development of critical solutions and standards • Limited development of the drone EU market. 	By: EC, SJU <ul style="list-style-type: none"> • Ensure that SESAR work programme covers necessary R&D. • Secure participation from innovative players, new entrants • Secure adequate funding for next multiannual financial framework (MFF)
Global harmonisation of the regulatory framework for drone operations is not ensured	<ul style="list-style-type: none"> • Re-alignment with international regulation will cause delays in deployment and increase costs. 	By: EC, EASA, SJU <ul style="list-style-type: none"> • Ensure EU presence in global fora dealing with drones. • EU collaboration with other regions (e.g. US, Asia).
Standardisation and regulatory needs are not sufficiently addressed and delivered on time, resulting in delays in U-space deployment	<ul style="list-style-type: none"> • Economic and societal benefits not realised at the expected level. 	By: EC, SJU, EASA, standardisation bodies <ul style="list-style-type: none"> • Strengthen cooperation with standardisation bodies to ensure alignment of their respective work programmes with the needs identified in the Master Plan. • Strengthen engagement of the regulatory authorities in the development phase to prepare for deployment.
Incidents and/or accidents involving drones and manned aviation	<ul style="list-style-type: none"> • While serious incidents or accidents are likely to be very infrequent, they may have very serious consequences; even a trickle of low impact incidents will erode trust in the safety of drone operations and could delay their integration and the associated benefits. 	By: EASA and Member States Regulator/NAA: <ul style="list-style-type: none"> • To accelerate the development of rules and means of compliance (incl. harmonised U-space services) • To establish a timely set of rules around minimum training requirements.
Requirements linked to societal expectations such as environment,	<ul style="list-style-type: none"> • Delay in the deployment of U-space services resulting in lost business opportunities 	By: EC, SJU <ul style="list-style-type: none"> • Ensure participation of relevant European Commission

**privacy and security
are not properly
addressed in
developing U-Space**

and negative impacts on EU
citizens

Directorate Generals (e.g. DG
HOME) when developing U-
space

Annex 1: U-space services

U-space is a set of new services which will be deployed in an incremental manner: each new step will propose a new set of services while including an enhanced version of the services already existing.

This annex proposes an indicative description of services, for which the detailed definition and the applicable environments are the subject of ongoing research and development.

U1 – U-space foundation services

E-registration

The service enables the registration of the operator, drone and pilot with the appropriate information according to Regulation. A level of security of the service will be defined.

E-identification

The service allows the identification of a drone operator from a drone in operation (in line with the global scope of registry (ICAO) & eIDAS - Regulation (EU) No 910/2014). The identification provides access to the information stored in the registry based on an identifier emitted electronically by the drone. The identification service includes the localisation of the drones (position and time stamp).

Pre-tactical geofencing

The service provides the operator with geo-information about predefined restricted areas (prisons, etc.) and available aeronautical information (NOTAM, AIRAC cycle) used during the flight preparation.

This service requires the identification of accredited sources and the availability of qualified geo-information related to restricted areas.

This service provides information that allows the drone operator to make use of the geofencing capability of the drone.

U2 – U-space initial services

Tactical geofencing

Compared to U1 pre-tactical geofencing, tactical geofencing brings the possibility to update the operator with geofencing information even during the flight.

Tracking

This refers to the service provider using cooperative and non-cooperative surveillance data to maintain track-identity of individual drones. The capability includes ground and air surveillance systems, as well as surveillance data processing systems.

The performance requirements of the capability will vary in accordance with the specific requirements of each application.

Flight planning management

This service covers the receipt of a flight notification or a flight plan and provides the appropriate answer according to the characteristics of the mission and applicable regulations

This service will be available for any drone operator/user with different levels of requirements.

Weather information

The service provides drone operators with forecast and actual weather information either before or during the flight; it can also collect and make available weather information from different stakeholders.

Different levels of service provision could be considered; for example:

- MET information for missions in a rural environment (based on existing aeronautical information);
- Enhanced weather information for missions in urban areas;
- Micro-weather information for urban areas (urban canyoning/ autonomous vehicles)

Drone aeronautical information management.

This service provides the operator with relevant aeronautical information for drone operations. It will connect to the Aeronautical information service (AIS) to guarantee coherent information provision for manned and unmanned operators.

Procedural interface with ATC

The service is a set of defined procedures for some mission types where there may be an impact on ATC; for example crossing certain types of controlled airspace under prescribed conditions. The procedures ensure clear and unambiguous drone operation, and provide an appropriate flow of information between the drone operators and ATC. Such procedures will allow drones to fly in controlled airspace and near airports with more flexibility and procedural approval/rejection based on agreed rules.

Emergency management

The service receives emergency alerts from operators (e.g. loss of control), and informs relevant actors of the ecosystem. These may include drone operators operating drones nearby, ANSPs, police, airport authorities. The service also provides the drone/operator with assistance information to manage the emergency situation (e.g. location of landing pads).

Strategic deconfliction

The service provides deconfliction assistance to a drone operator at strategic level (when the flight plan is submitted, it is compared to other known flight plans and a deconfliction in time or route could be proposed). This service could be mandatory or optional according to the operating environment.

Monitoring

Subject to appropriate data-quality requirements, this service retrieves data from the tracking service and fuses it with information related to non-cooperative obstacles and vehicles in order to create air situation for authorities, service providers, and operators. This service may include conformance monitoring.

Traffic information

This service provides the drone operator with traffic information coming from any kind of monitoring services.

U3 – U-space advanced services

Dynamic geofencing

Compared to tactical geofencing in U2, the dynamic geofencing targets the drone itself and then this service requires data-link connectivity to a geofencing system that allows the data to be updated during the flight.

Collaborative interface with ATC

The service provides a mechanism to ensure proper effective coordination when drone operations using U-space services impact ATC. It encompasses shared situational awareness and procedures to enable a two-way dialogue supporting the safe and flexible operation of drones in airspace where ANS are provided.

Tactical deconfliction

This service provides information to the operators or the drones to ensure separation management when flying. The differences with the strategic deconfliction described in U2 are twofold: the drone may receive the information and this deconfliction is set for the in-flight phase. It will be necessary to appropriately define the boundaries with the use of Detect & Avoid capabilities.

Dynamic capacity management

Upon the definition of drone density thresholds (that can be dynamically modified), the service monitors demand for airspace, and manages access to that airspace as new flight notifications are received. This service may be coupled with the flight planning management service. There should be appropriate set of rules and priorities for slot allocation when a portion of airspace is expected to reach its capacity limits. Apart from the demand and capacity balancing, the service could manage capacity due to non-nominal occurrences, such as weather hazards or emergency situations.

U4 – U-space full services

U4 offers the full integration with manned aviation and air traffic services and supports the full operational capability of U-space based on a very high level of automation. It is expected that the need for new services will arise during the roll-out of U3. In addition, it is envisaged that manned aircraft could be equipped to take advantage of U-space services.

Annex 2 below describes the capabilities that will be needed to support the implementation of U-space services. The 'Phase' column describes the initial U-space deployment phase where each capability will be required. As new phases are entered, and new and more advanced U-space services become available, the specification of many capabilities will become more demanding. Moreover, the specification of the capability requirements may change with the mission environment (Urban, sub-urban, rural).

Annex 2: Drone capabilities for U-space

As the range of mission types expands, and U-space services are deployed and enhanced, drones of all types, and the supporting ground infrastructure, will need to have capabilities that evolve accordingly. Table 2 below show the capabilities expected to enable U-space services.

Capability	Actor	Description	Phase
e-Identification	Drone, drone operator, service provider	Ability to identify the drone and its operator in the U-space system	U1
Geofencing	Drone, drone operator, service provider	Ability to comply with geographical, altitude and time restrictions defined by the geofencing service. This capability covers the technology, processing and any required communication links, as well as management and use of geofencing information used in the provision of this service.	U1
Security	Drone, drone operator, service provider	Ability to protect vehicle and data (interaction with other vehicles and infrastructure) against attacks on information technology and communications systems.	U1
Telemetry	Drone	Ability to transmit measurement data from the drone-to-drone operator and/or service provider to meet the demands of relevant services.	U1
Tracking	Drone, drone operator, service provider	Ability of the drone to provide flight parameters including at least its position and height.	U1/U2
Vehicle to Vehicle communication (V2V)	Drone	Ability for drones to communicate information to each other. The nature of the information exchanged, and its performance requirements, will depend on the application.	U3
Vehicle to Infrastructure communication (V2I)	Drone, drone operator, service provider	Ability for drones to share information with infrastructure components.	U3
Communication, Navigation and Surveillance	Drone, drone operator, service provider	Ability for drones to meet the communication, navigation and surveillance performance requirements for the specific environment in which they will operate. This capability involves the combination of on-board sensors and equipment (e.g. data link, voice radio relay, transponder, laser, GNSS, cellular etc.) as means of achieving the required performance.	U1
Detect and Avoid	Drone	Ability for drones to detect cooperative and non-cooperative conflicting traffic, or other hazards, and take the appropriate action to comply with the applicable rules of flight. This includes the collision avoidance, situational awareness and “remain well clear” functionalities, as well as the other hazards described in chapter 10.2.3 of the ICAO RPAS Manual: terrain and obstacles, hazardous meteorological conditions, ground operations and other airborne hazards.	U3
Emergency Recovery	Drone	Ability of drones to take account of failure modes, such as command and control (C2) link failure, and take measures to ensure the safety of the vehicle, other vehicles and people and property on the ground. This includes identification of possible problems (auto-diagnostic) and all equipment required to manage solutions.	U1/U2
Command and control	Drone, drone operator	Ability of drones to communicate with their ground control station to manage the conduct of the flight, normally via a specific data link.	U1
Operations management	Drone operator, service provider	Ability to plan and manage drone missions. This includes access to and use of all aeronautical, meteorological and other relevant information to plan, notify and operate a mission.	U1

Table 2: Drone capabilities for U-space

Annex 3: Business view

Table 3: Primary investment requirements

Category	Sub-category	Description and/or example
Ground infrastructure	ATC interface and airport adaptations	This includes both enhancements for current ATM/ATC systems to ensure processing the necessary data and adaptations for U-space infrastructure to support this interface. A potential requirement may be for investments in adaptations (e.g. a more robust set network of sensors) to ensure surface procedures operate efficiently.
	Drone traffic management (DTM)	The DTM system encompasses the functionalities and services attached to the safe and efficient management of drone flights (e.g. flight planning management, assistance for deconfliction, as well as requirements linked to the cybersecurity and the communication with other actors in the ecosystem). This may require investments related to ground and/or cloud-based servers, computers, software, and facilities.
	Protection sensitive sites	Critical infrastructures (e.g. airports, government buildings, power plants), may need hardware (e.g. radar, counter drones) to protect from intrusion of non-cooperative drones.
	Telecommunications & satellite communications	Enhancements, reconfiguration to existing telecom networks and deployment of shared low earth orbite (LEO) satellite constellation to support full-scale deployment
	Geo-fencing database	A continuously updated repository of airspace restrictions must be fully developed and accessible to ensure no-fly zones and other restrictions are respected.
	Enhanced data provision and information sharing	The term "enhanced data provision and information sharing" refers to three topics: (1) the provision of drone-specific aeronautical information (2) enhanced weather capabilities (to provide more specific meteorological), (3) real-time information sharing between all actors of the ecosystem.
	Drone traffic management oversight	DTM oversight at the EU level would leverage access to an overarching view of traffic and activity of the different certified DTM service providers to, among other tasks, support capacity management and assist in service provider coordination.
	e-registration and e-identification	Drones will be required to register, and accordingly, this information needs to be stored and managed in a secure way. In addition, drones are expected to broadcast their identifier so that they can be identified by accredited entities.
Airborne infrastructure	On-drone capabilities	To enable the services associated with the various stages of U-space & RPAS, hardware and software capabilities will be required. This investment sub-category covers the incremental requirement of equipping the drone with this hardware and software to enable each

		service.
	On other aircraft capabilities	Although expected to be minimal, hardware and software may be required on the current and future civil fleets.
Human resources	Procedure development	Procedures will need to be developed in order to support the interfaces and services across U-space and ATM.
	ATC personnel training	Training will be required for personnel in order to adapt to new processes, procedures, and interfaces accommodating the increasing number of drones mixed with manned aviation that will use the traditional ATC services.

Table 4: Consolidated assumptions driving stakeholders' share of investment

Stakeholder	Key assumptions
U-space service providers	<ul style="list-style-type: none"> • 100 % investment in DTM, DTM oversight, geo-fencing, enhanced data provision and information sharing, and e-registration/e-identification infrastructure requirements noted within this assessment. In some cases for e-registration/e-identification there may be national government involvement, which is not accounted for in this early assessment. • 50 % investment in infrastructure requirements related to the Interface with ATC, shared with ANSP stakeholders; • ~50 % investment in procedure development investment; the percentage of investment level for procedure development is split across U-space service providers, drone operators, and ANSPs, based on the stakeholder split of investment required for ground and air infrastructure.
Drone operators	<ul style="list-style-type: none"> • 100 % in drone investment requirements and ~35 % in procedure development investment levels; the percentage of investment level for procedure development is split across U-space service providers, drone operators, and ANSPs, based on the stakeholder split of investment required for ground and air infrastructure.
ANSPs	<ul style="list-style-type: none"> • 50 % investment related to ATC interfacing, shared with U-space service providers; • 100 % investment for ATC personnel training and ~15 % of procedure development investments; the percentage of investment level for procedure development is split across U-space service providers, drone operators, and ANSPs, based on the stakeholder split of investment required for ground and air infrastructure..
Telecom & Satcom provider	<ul style="list-style-type: none"> • 100% of required infrastructure investment to support telecom/ satellite communications enhancements
Others	<ul style="list-style-type: none"> • Investments will be required by public and private entities to support protection of sensitive sites (e.g. government buildings, power supply, transportation systems, etc.)
Airport operators	<ul style="list-style-type: none"> • 100% investment in airport adaptation investments, including protecting these airports as sensitive sites
Airspace users	<ul style="list-style-type: none"> • 100% of required investment for equipage on non-drone aircraft.

Table 5: Summary of drone & conventional air fleet volumes

Summary – Drone & Conventional Fleet Sizes (000s) ²⁴									
	2015	2018	2020	2025	2030	2035	2040	2045	2050
Open category	1,000	5,000	6,000	7,000	7,000	7,000	7,000	7,000	7,000
Certified category (excl. Military)	-	-	-	-	-	-	2	6	13
Specific category	9	45	86	200	373	386	384	390	396
Military	1	1	1	1	1	2	2	2	3
Urban air mobility	-	-	-	-	2	4	4	4	4
Scheduled airline fleet	11	12	13	15	17	20	22	25	25
Business aviation fleet	7	7	8	8	8	9	8	7	4
Rotorcraft fleet	2	2	2	3	3	3	3	2	1
VFR	59	61	63	67	71	75	79	83	87
IFR	13	14	15	17	20	22	25	27	29

Key underlying investment assumptions supporting Section 4.3²⁵

- The focus of effort was to determine the minimum ATM-related infrastructure investment required to support a safe drone ecosystem in Europe. In scope investments include: ground and airborne infrastructure investments and select human resources directly related to deployment and safety. Out of scope elements include, but are not limited to: operating costs, investments to develop and establish U-space services, drone design and certification investment, and insurance related costs.
- The timeframe for the business view is 2018-2050, with most figures and tables depicting the timeframe to 2035, by which time the majority of investment (~70%) is anticipated to have been spent. Figures referring to 2035 (or any other annual figure) investments include those required for future phases, while figures referring to a phase (e.g. U3) include all investments associated to that phase, regardless of timing.
- Other relevant sectors (e.g. connected cars, advanced metering infrastructure, etc.) are assumed to allow for meaningful comparisons to the drone landscape in particular areas. Where appropriate, they are leveraged as proxies to support assumptions.
- Drone volumes materialise as foreseen in the Drone Outlook Study, with all inherent assumptions.
- Open, specific, and certified drone categories, as defined in the Drone Outlook Study, are within scope; It is assumed that open category drones are impacted by e-registration, e-identification, and tracking requirements only on the basis of likely safety regulations.
- A combination of published V2V module investment decline data and drone price evolution input were used to determine an experience curve, applied to decrease on-drone investments over time.
- Investments start in 2018 for U1 and are made either in the preparation of a new phase or when a new step starts depending on the operational and technical needs.
- For this assessment, it is assumed that the U-space will follow a federated model in Europe given the necessity for highly automated systems to handle the anticipated scale of

²⁴ Source: 2016 Drone Outlook Study model

²⁵ Based on SJU & working group input

operations; a volume of 15 certified drone traffic management (DTM) providers is assumed for Europe.

- Existing communication infrastructure will be leveraged and no dedicated communication layer is required; similarly, a new satellite constellation that would be shared both with non-European users and for non-drone applications (e.g. connected trains) is envisaged.
- Airborne investment requirements for urban air mobility are included, but due to lack of available data at time of publishing, airport modification and landing pad investments to accommodate this are not included.
- It is assumed that ground infrastructure solutions include facility, build-out, and necessary hardware and software to serve the indicated function; the actual end-state solution could also be cloud-based or hybrid, however, this is not accounted for in this assessment.
- The evolution of the drone ecosystem will materialise with minimal impact on civil aviation fleets; however, it is foreseen some equipment for general aviation may be needed to accommodate the safe operation of drones in uncontrolled airspace.

Figure 11: Ground investment levels over time

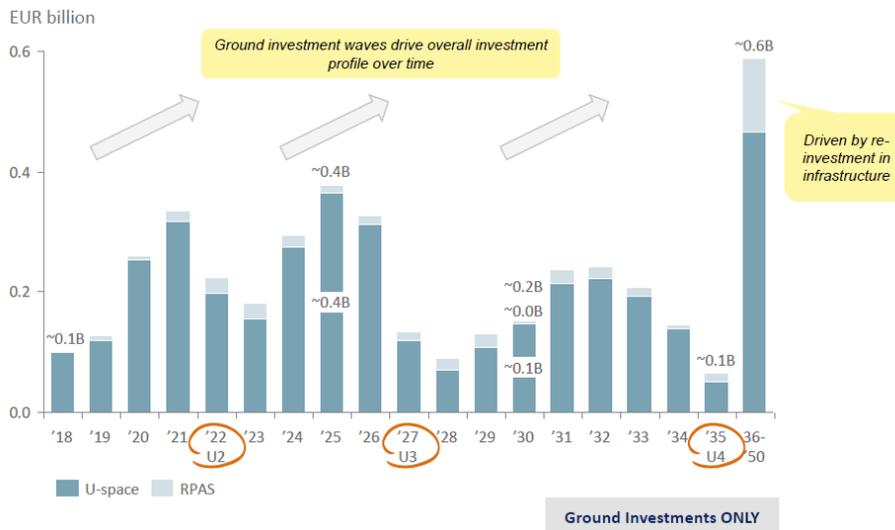


Figure 12: Airborne investment levels over time

